2006 Annual Report of the GEM Project

2006 PROGRAM ACCOMPLISHMENTS AND HIGHLIGHTS

Germplasm releases and development:

- Two Crop Science manuscripts were published in 2006 for 29 germplasm lines developed in Raleigh, NC. See Balint-Kurti, et al., and Carson, et al.
- A manuscript was submitted to Crop Science by Campbell et al. for registration of GEMS-0067. GEMS-0067 is an amylomaize VII (70% amylose) source of germplasm derived from the GEM 50% tropical breeding cross, GUAT209:S13.
- Ten GEM lines from the Ames program are recommended for release to GEM Cooperators for 2007 planting year. The derivation of six of the lines trace from accessions that have had no prior GEM releases - two from AR13026 (Cristalino Colorado), three from BR51721 (Dente Amarelo), and one from CASH (US Corn Belt-Ohio).
- The most promising germplasm sources for yield in 2007 were lines derived from breeding crosses containing GUAT209 (PI 498583). GUAT209 is a member of the Tusón race.

Pathology/Entomology:

Pathology and entomology research collaborations from the private and public sectors included extensive screening of GEM lines and breeding crosses for anthracnose, Northern Leaf Blight races 1 and 2, Southern Leaf Blight, Stewart's Wilt, Goss's Wilt, Gray Leafspot, common and southern rust, Fusarium ear rot, Diplodia ear rot, Aspergillus, European Corn Borer, Corn ear worm, and corn root worm. Public Cooperator Reports of these results are available at this meeting. Special recognition and thanks are extended for the extensive efforts of private GEM Cooperators Pioneer Hi-Bred International, and Professional Seed Research.

Highlights of important accomplishments in 2006 include:

- Completion of a brochure designed to promote awareness of the GEM Project's mission, objectives, and operations, and to highlight the germplasm and their component traits released from the Ames and Raleigh programs. The brochures were made available at the ASA-CSSA-SSSA meetings in Indianapolis, November 13-16, and distributed at the GEM Cooperator Meeting held in conjunction with the ASTA meeting in December 5-7.
- Implementation of 2D bar codes in Ames to facilitate accuracy, inventory management, and expedite data collection in the field.
- Entry of lab data to our PRISM data base; significant progress was made. Efforts have begun to enter all disease screening data.
- Use of the new twin plot TR88 combine; this expedited plot harvest (9 seconds/plot) enabling completion by mid October - approximately 2 weeks earlier than previous years.
- Completion of a photoperiod experiment (Ames). The shading treatments reduced flowering time by15-23 days in 100% tropical accessions and breeding crosses. Seven different sources comprising six races were used in the study. The experiment compared non-treated plants with those covered with a trash can for 6 weeks (suggestion from Marty Sachs), or an improvised A-frame, using pipe and black shadecloth as a cover.

Quality Traits:

- Two GEM lines were developed by Mark Campbell that consistently has 70% amylose content: AR16035:S02-615, and DKXL370:N11a20-31. Among the highest yielding partially converted amylose lines, 2011-01 SE32_S17 (crossed to CH05015:N15-3-1), was the highest yielding line.
- Recommended lines for 2007 include CUBA117:S1542-057-002, which has 15.7% protein, and 5.0% oil content (2-year data). This line is also resistant to Stewart's Wilt.
- GEM lines derived from 50% Brazilian tropical breeding crosses (DKXL212, XL370, XL380), have above average amino acid content and are recommended for intermating and further selection to enhance their amino acid index (see Scott report).

Ames Location Highlights:

- Eighty-eight top cross hybrids exceeded the mean yield of the check hybrids in Midwest trials in 2006. This was a significant improvement of performance over last year, when70 yielded above the check mean.
- Forty six GEM breeding crosses were evaluated for phenotypic traits and adaptability in Ames, IA, Mt.Vernon, IN (Mycogen), Memphis, TN (RBS), and Newark, DE (UDEL).
- Approximately 11,340 plots (1,949 entries) were managed or coordinated through Ames.
- Approximately 7,600 nursery rows and 1,400 isolation rows were managed by Ames.
- Five new GEM Cooperators joined GEM in 2006. Three US private companies include Brodbeck Seeds, PRIME Farm Seeds Inc, and MBS Genetics LLC. One private international cooperator from France, APEX-Agri, is our first European cooperator. Dr. Xinzhi Ni, an Entomologist from the Crop Genetics and Breeding Research Unit, USDA-ARS in Tifton, GA, is a new public cooperator.

GEM Line Recommendations for Midwest for 2007 Release:

Ten GEM lines are recommended for 2007 based on 2-years of favorable data for yield and/or Y/M, lodging resistance, resistance to Stewart's Wilt, or protein and oil content. The derivation of six of the lines trace from accessions that have had no prior GEM releases- Two from AR13026 (PI 492746), two from BR51721 (PI 583914), and two from CASH (PI 278710). Details of agronomic traits, disease, NIR, and yield can be found in the handout 'GEM recommended lines for 2007 release,' and on the CD.

Table 1. Recommended Ames GEM Lines for 2007 Release

Pedigree	Race	Type
AR13026:N08b15-016	Argentina (Cristalino Colorado)	25% Temperate
AR13026:N08b15-086	Argentina (Cristalino Colorado)	25% Temperate
BR51721:N2012-098-002	Brazil (Dente Amarelo)	25% Tropical
BR51721:N2012-164-002	Brazil (Dente Amarelo)	25% Tropical
BR51721:N2012-397-001	Brazil (Dente Amarelo)	25% Tropical
CASH:N1410-018-001	USA (Corn Belt Dent)	25% Temperate
CUBA117:S1542-037-002	Cuba (Argentino)	25% Tropical
CUBA117:S1542-057-001	Cuba (Argentino)	25% Tropical
CUBA117:S1542-057-002	Cuba (Argentino)	25% Tropical
CUBA164:S2012-456-001	Cuba (Mixed Creole)	25% Tropical

Raleigh, NC Location Highlights (from Dr. Major Goodman):
This report summarizes the research conducted under specific cooperative agreements between the ARS and N.C. State University. Additional details will be available in handouts at the December, 2006, cooperators meeting and the December, 2006, TSG meeting. This subproject is concerned with ten aspects of the overall GEM effort. (1) The development of GEM families from breeding crosses. (2) Making topcross seed of the families. (3) Setting up appropriate experiments to compare the topcross families with commercial and experimental checks. (4) Providing seed for these experiments to 14 additional GEM collaborators. (5) Growing the experiments ourselves at several locations. (6) Analyzing and summarizing our own and our collaborators data. (7) Selecting the better materials for subsequent-year trials. (8) Increasing seed of better families, providing it to Ames and other GEM cooperators and to the NCRPIS. (9) Deriving and testing inbred lines from the better GEM families. (10) Sampling allelic diversity from representative races not encompassed by GEM yield-trial efforts.

56 entries (out of 720 tested) have been advanced from first year to second year trials in 2006, and 58 entries (out of 134 tested) advanced from second year to third year testing. In 2006, 16,747 yield trial plots (Tables 1 and 2) were coordinated through Raleigh (9,309 planted at NC State locations). An additional 1,458 plots were grown solely for GLS evaluations at three NC State locations; thus a total of 18,205 evaluation plots were coordinated through Raleigh.

Over 1,500 nursery rows and 1,550 isolation block rows were planted in 2006 at Raleigh. Nursery work involves 4 new breeding crosses and 3 additional breeding crosses derived from tropical inbred lines. In 2006, 19 GEM families were recommended to GEM Cooperators and provided from stocks furnished to Ames; five additional families were recommended and provided directly from Raleigh.

We have continued routine screening of available tropical lines, as so little data are available to choose among them for use in GEM or other research. A summary of some of that work has been published in the Duvick issue of *Maydica*; a reprint is included as an Appendix to this report. Summaries of ongoing work are presented in Tables 3, 4, and 5.

In 2005, the effort to evaluate GEM breeding crosses for yield *per se* was continued as part of an overall effort to evaluate new material. Data from that study revealed a great spread in yield potential and heavily influenced our choices for 2006 nursery work. While substantial variation occurs in GEM F2 populations, it unlikely to be sufficient to alleviate a difference of several standard deviations between Breeding Cross F1s and the mean of the lowest yielding adapted check. Direct tests of Breeding Cross F1s were continued in 2006, and useful data was obtained for 3 locations. The following crosses look reasonably promising:

PEDIGREE	Bu/A.	H2O	%E.P.	PEDIGREE	Bu/A.	H2O	%E.P.
FS8B(T):N11a	132	19.4	91	BR106:T33a20	116	17.0	92
BR106:T33axLH132	125	19.1	95	BR105:N16	115	19.5	87
CHIS775:S19	123	19.5	85	PE11(51501):S11a	115	18.4	89
FS8B(T):N18	118	18.8	90	BG70404:D27xLH51	115	18.1	89
BR106:G39	117	19.2	93	FS8A(T):N18	113	19.0	89
BR106:LH132	117	19.7	99	SE32(52051):N11c	113	18.2	95
PE27(51675):D27	116	21.0	91	BVIR155:S18	112	19.7	88
FS8B(S):S03	116	17.7	94	DKB830:S19	112	19.3	90

While BG070404:D27 with corresponding values of 114, 21.1, and 75 looks reasonable except for lodging.

In contrast, the following Breeding Cross F1s look as though they should be avoided:

PEDIGREE	Bu/A.	H2O	%E.P.
DK888:S08a	91	21.0	94
CUBA164:T26aS41	86	18.1	94
MDI022:LH132	69	20.1	88

Check performance and CVs are listed below:

PEDIGREE	Bu/A.	H2O	%E.P.
Pioneer 32D99	148	18.7	97
Pioneer 31G98	145	16.8	98
Pioneer 32K22	144	17.8	98
DeKalb 697	139	19.0	97
LH200 x LH262	139	17.0	98
Garst 8288	136	17.6	99
LH132 x LH51	117	16.8	99
LSD .05	16	1.1	11
C.V. %	9	3	7

In addition, a group of Breeding Cross F2s were tested. While testing F2s is a more questionable endeavor, nevertheless,

PEDIGREE	Bu/A.	H2O	%E.P.
ANTIG01:N16F2	111	19.0	78
DREP269:S06F2	102	17.0	96*
DKXL380:N11aF2	94	18.8	90
DKB844:S16F2	89	19.0	83*
CML287:S18F2	86	19.4	94*

* Also good in 2005.

look like keepers (although two do lodge), while

PEDIGREE	Bu/A.	H2O	%E.P.
SANM126:LH132F2	71	19.8	88
CHIS462:N08aF2	52	20.3	86

do not look very promising.

Table 6 presents summary data for the better GEM families that have been tested for more than one year and the status of seed availability. Most of these families are from DK888 N11; one each is from DK212T N11 and Chis 740 S14. One (from SCR Gp3 N14) is recommended on the basis of its performance on a second tester (LH132.LH195; it was originally recommended on the basis of crosses with FR992.FR1064).

Tables 7 through 12 report the ANOVAs and LS Means summaries of 2nd and 3rd year data for families tested in a third year, while Tables 13 to 16 report the 2nd year summaries for families tested for a second year.

Table 17 presents the summary for the breeding cross trial. Tables 18 to 21 present summaries of inbred trials based upon elite GEM families across NC environments.

After working with 50%-tropical GEM allelic diversity lines a second summer, it was apparent that survival to homozygosity of such materials was problematic in North Carolina. The likelihood of any surviving lines being used for phenotyping in the Midwest would clearly be very low. In addition, two of the PVP lines used initially, LH39 and MBNA, were not very widely adapted. A third, LH132, would probably do well in crosses to early and medium maturity accessions, but it is now considered a fairly late line in the Midwest. As a result, we recommended the use of a single, earlier-maturing PVP line, PHB47, but others felt that two PVPs were needed. At this point, the best reasonably-early non-SS PVP that appears to have wide adaptation is PHZ51, so we recommended that. Two other PVPs merit mention: HBA1 appears to be one of the best non-SSs in Raleigh, but, like LH132, it is late. MDF-13D would be the second choice for a non-SS. Both it and PHB47 did well in hurricane-battered Florida in 2005.

PRISM database enhancements (SCA- Kendall Lamkey, Iowa State University)
The SCA for PRISM database was terminated with many enhancements made. Some of the more important enhancements included:

- Implementation of 2D barcode feature
- Capability to store images and scanned documents
- Alias name option for pedigree management
- Fine-tune modifications to improve functionality and user-friendliness

Thanks to Jode Edwards for the insight and leadership he provided in serving as a communication link between the various corn research groups that use the PRISM database in Ames, and Greg Van Holland, the developer of PRISM.

Highlights from Other Research Projects Funded by Specific Cooperative Agreements:

Eight university projects were funded in 2006 for a total of $182,000.

Table 2. Public Cooperators Supported In 2006

Name	Institute	Amount
Martin Bohn	U. of Illinois	13,000
Mark Campbell	Truman State	10,000
Jay-lin Jane	Iowa State	23,000
Jim Coors	U. of Wisconsin	16,000
Major Goodman	N.C. State U.	65,000
Jim Hawk	U. of Delaware	23,000
Margaret Smith	Cornell	13,000
Wenwei Xu	Texas A&M	20,000
	Total	**$183,000**

A short summary of key highlights from each SCA report is included below. There was significant progress made this year in all SCA projects. Space does not allow extensive discussion of methods, germplasm development, and results in the summaries below. Please see the **full report** submitted by each cooperator on the CD, or website for topics of interest.

Martin Bohn, University of Illinois: Evaluation of GEM germplasm for multiple insect resistance and fumonisin concentration.

This project is a continuation of the study begun in 2003 with the objective to develop and evaluate germplasm, and study the genetic basis of resistance to Western Corn Rootworm (WCR), European Corn Borer (ECB), and the association of insect resistance to fumonisin concentration, a mycotoxin produced by Fusarium sp. Two experiments were conducted to evaluate experimental hybrids made from crosses of GEM lines having promising level of WCR, and a repeat of a diallel experiment to investigate the genetics of WCR resistance. Test cross hybrids and *per se* lines led to the identification of ten inbreds with improved WCR and agronomic traits. Hybrid combinations containing AR17056:N2025 select # 5 had low root lodging and reduced Fusarium ear rot. For ECB, stalk damage ratings for second brood were not significantly different for several GEM hybrids relative to the resistant Bt check for ECB. Hybrid combinations involving various selections of AR17056:N2025 (used as males), had very good yield and resistance to WCR, ECB, and Fusarium ear rot when crossed to females derived from DKXL212:N11a01. A multivariate analysis of the data grouped the hybrids into four clusters. Cluster 2 hybrids were the most promising with excellent yield, and good resistance to WCR induced root lodging. Hybrids in clusters 1 and 3 showed significantly lower ECB stalk damage, but less yield than cluster 2 hybrids. Since these are within heterotic group crosses of NSS x NSS, the best combinations will be used to develop new breeding crosses.

Mark Campbell, Truman State University: Development and utilization of GEM based amylomaize hybrids and the identification of amylose modifying genes through QTL analysis

Two recent advances have increased interest in amylose starch. These include thermoplastic starch based biodegradable plastics, and resistant starch (RS). Resistant starch has received significant interest in human nutrition since it lowers glycemic index benefiting patients with diabetes or obesity. The objectives of this research includes the development of high amylose (>70%) germplasm, and mapping the high amylose modifiers (HAM) that were identified in the Guatemalan breeding cross from the GEM Project, GUAT209:S13. Progress in 2006 includes the submission of GEMS-0067 for registration in Crop Science. GEMS-0067 is an S4 source of GUAT209:S13 x (H99ae x OH43ae) having amylose levels of 70%, and RS levels between 40-45%. In an effort to develop public sources of high amylose germplasm, GEMS-0067 was crossed to numerous GEM lines representing stiff stalk (SS), and non-stiff stalk (NSS). The segregating progeny are selected for amylose levels above 70%, and starch content. An improved method for starch isolation includes the protease method which is showing promise for removing contaminating protein for accurate measurement of amylose, and starch content. Two converted GEM lines (F4 stage) which most consistently have 70% amylose are AR16035:S02-615 (SS), and DKXL370:N11a20-31 (NSS). Yield trials in 2006 include top crosses involving GEM x GEM lines that were converted or partially converted to high amylose. Twenty GEM x GEM hybrids out performed the high amylose commercial check in 2006. Among the highest yielding converted GEM lines, 2011-01 SE32_S17 x CH05015:N15-3-1 had the highest yield in Ames

(170 bu/ac vs check at 129 bu/ac). Efforts are underway to fix amylose modifiers to consistently have 70% amylose content. The mapping experiment includes segregating progeny of GEMS-0067 x H99ae, and 46 polymorphic markers were identified out of 384 screened so far.

Jim Coors, University of Wisconsin: Development of inbreds, hybrids, and enhanced GEM breeding populations with superior silage yield and nutritional value.

In 2006, we continued to evaluate silage yield and nutritional value of GEM topcrosses. The trials included materials designated from three classifications. Table 1 included "GEMNEW" pedigrees which were selected from 2005 grain trial data. The GEMNEW material was very promising with 15 of the 23 new top crosses exceeding the check mean (4 commercial hybrids) of 9.92 tons/acre. The most noteworthy included GUAT209:S1308a-084-001xLH287 and W605SxLH244-both pedigrees with forage yield greater than 11 tons/acre. W605S was released in 2004 and developed from the GEM breeding cross AR17026:N1019. Table 2 included breeding material from the GEM Quality Synthetic (GQS) developed from three GEM Cuban populations (CUBA164:S1517, CUBA164:S15, and CUBA117:S1520. The tester used for this study (W604S) may be poorly suited and additional testers will be used in the future. Table 3 included three advanced GEM inbred lines crossed to three testers each (LH227, LH244, and LH332). Several derived from St. Croix germplasm SCRO1:N1310-398 exceeded 11 tons/acre with 39% dry matter. Inbreds derived from the Chilean material CH05015:N15-8-1 had very good lodging resistance under windstorm conditions. Nutritional evaluations are not yet completed but will be available in early 2007 on the website www.silagebreeding.agronomy.wisc.edu for neutral detergent fiber (NDF), in vitro true digestibility (IVD), in vitro NDF digestibility (IVNDFD), crude protein (CP), and starch.

Major Goodman, North Carolina State University: Conducting, coordinating, and developing inbreds from the Southern GEM trials using 50%-tropical maize germplasm.

See full report under Raleigh, NC highlights. Additional yield trial data is available on the GEM CD distributed at December 2006 Cooperator Meeting and on the GEM website.

Jim Hawk, University of Delaware: Inbred line development and hybrid evaluation in GEM breeding crosses.

The objective of the research at UDEL is to release lines derived from GEM breeding crosses having value-added traits (VAT), and/or resistance to abiotic stress. A second objective is to evaluate breeding methods for effective use of exotic germplasm. In 2006, 46 GEM breeding crosses were evaluated for phenotypic adaptability. Results of this study will be compiled jointly at the December TSG GEM meeting with data from GEM in Ames, Mycogen Seeds in Mt. Vernon, IN, and the RBS Corn Research location in Memphis, TN. Inbreeding was initiated in four new stiff stalk (SS) breeding crosses, and two non-stiff (NSS) stalk breeding crosses. Yield trials were conducted for 330 GEM SS x LH287, and 171 GEM NSS x Pioneer SS tester. Entries derived from DKXL212:S0943b were particularly interesting for having high yield, and high yield/moisture ratio. Collaborative research with the USDA-ARS in Ames is continuing for the third year comparing three breeding methods- modified single seed descent (SSD), mass selection, and the standard protocol (modified pedigree breeding method). In addition, amino acid analysis for the *per se* line DKXL212:N11a-139, and hybrid combinations made with this line is in the third year of study in collaboration with Dr. Paul Scott, USDA-ARS in Ames. This

line has shown promise as a NSS source with favorable amino acid index (lysine + methionine + tryptophan).

Jay-lin Jane, Iowa State University: Value added utilization of GEM normal and high amylose line starch.

The objective of this project is to characterize starches from GEM germplasm with value-added utilization. High amylose maize is the source used for studies with resistant starch (RS), and normal maize germplasm for our studies for starch high digestibility (baby chick feed applications, etc.). Understanding the molecular structure of maize starch is important for selection of future germplasm having utility for industrial applications for the end-user (such as RS sources that can be processed economically, etc.) The source of RS germplasm used in this study included three F4 selections derived from GEMS-0067 provided by Mark Campbell at Truman State University. GEMS-0067 was derived from GUAT209:S13 *ae* having amylose content of 70%, and RS content ranging from 39.4%-43.2% (vs 11.5%-19.1% for four public amylose inbred sources (H99ae, OH43ae, B89ae, and B84ae). Further studies in our lab identified other molecular features of GEMS-0067 not found in the public *ae* sources. The new GEM line high amylose maize starches consisted of amylopectin with shorter branch chains, with intermediate components have longer branch chains than the four public *ae* sources tested. The GEM lines displayed large enthalpy changes in melting amylose – lipid complex which suggested that the intermediate components have a greater facility to form helical complexes with lipids. When viewed under a light microscope it was found that the RS of the GEM lines was located at the periphery of the starch granule and retained partial birefringence. The structure of the large molecules from GEM line starch is being further investigated. Studies for highly digestible starch for the two GEM lines and their F1 grown in 2006 (AR17056:N2025-574, and DKB844:S1601-289, with the F1 made of the two lines) is now in progress.

Paul Scott, USDA-ARS, Ames, IA: Evaluation of amino acid content of GEM germplasm. (Volunteered report from Public GEM Cooperator)

Amino acid content of GEM samples has been analyzed in Dr. Scott's lab for the past four years. The three amino acids analyzed include methionine, tryptophan, and lysine using a high-throughput microbial screening method described by Scott et al., Maydica 49: 303-311. Two experiments were conducted in 2006. The first experiment included screening of germplasm lines which had amino acid levels similar to high methionine and lysine checks over 2-3 year's of previous data. The second experiment involved hybrids made with lines having above average amino acid index. Grain samples were obtained from self pollinated seed, shelled in bulk, and analyzed for protein, oil, and starch by Sue Duvick using NIR spectroscopy. Grain samples were then ground to a fine powder for amino acid analysis in the Scott lab. Results in 2006 included four years of analysis and identified some lines that were marginally better than conventional germplasm. A trend is emerging in which GEM lines derived from 50% tropical breeding crosses involving Brazilian hybrids developed in the Goodman program (XL370, XL380, XL212) are among the best for amino acid levels. In four year of evaluations, DkXL212:N11a-139 (from Jim Hawk's program at U of Delaware) had the highest quality index of GEM lines overall due to good methionine and lysine content.

Margaret Smith, Cornell University: Anthracnose stalk rot resistance from exotic maize germplasm.

Anthracnose stalk rot (ASR) is caused by *Colletotrichum graminicola* (Ces.) G.W. Wils., and is one of the most important pathogens contributing to stalk lodging in the US. A multi-year inbred development effort at Cornell is designed to identify and release lines from GEM breeding crosses having high levels of resistance to stalk rot and good yield potential. The objectives of the project for 2006 include (1) increasing seed of the superior GEM families with descriptive data for release, (2) generate new families by creating a synthetic made from the superior families, and (3) initiate selection from two new GEM populations for ASR. For the first objective, four lines were increased in 2006 by sib pollination for potential release. The pedigrees of the germplasm for release include CH04030:S0906-195, AR01150:N0406-266, FS8B(T):N1802-212, and FS8B(T):N1802-215. Yield data and ASR of the four lines and their top crosses can be found in the Public Cooperator Report. For the second objective, new families were created by making all possible F1 crosses among the best non-stiff stalk lines obtained from objective 1. The second generation of random mating was completed in summer 2006, and the resulting population was planted in winter nursery to generate S1 families to initiate further selection and evaluation in 2007. For the third objective, S1 families from two new GEM populations (CH05015:N1204 and UR10001:N1702) were evaluated in summer 2006 by splitting stalks and rating for ASR. These same families were top crossed to B37 (susceptible to ASR), and LH198 for evaluating ASR, and yield potential in 2007.

Wenwei Xu, Texas A&M University: Characterization and utilization of GEM breeding crosses, top crosses, and advanced lines for drought tolerance, grain mold, and corn ear worm resistance.

The objectives of this project include (1) conducting field trials for drought tolerance, Corn Ear Worm (CEW) resistance, grain mold, and yield under drought stressed and well watered conditions, (2) assay aflatoxin levels among 10 GEM top crosses, and (3) perform second year field evaluation of 25 GEM breeding crosses for drought, grain mold resistance, CEW resistance, and *per se* yield. Evaluation trials were conducted under drought stress by managing water by controlled irrigation at multiple testing regions in TX, and locations in MS where aflatoxin experiments were conducted. Favorable lines were identified from two 50% exotic Cuban breeding crosses: CUBA117:S15, and CUBA164:S20. Lines derived from this material had good stalks, had low grain mold, and combined with lines from stiff stalk (SS), and non-stiff stalk (NSS) groups. CUBA117:S15)-1A-1 x Tx205 averaged 1,855 ppb aflatoxin compared to a mean of 3,805 ppb for four commercial checks in the same experiment. Testcrosses to LH200 with lines derived from the breeding crosses DK888:N11, DKXL370:N11a20, BR52051:N04, and PE001:N16 were found to have good stay green, and low grain mold under drought stress. These top crosses were medium-late maturity, and very robust plants with potential for grain or silage production. Argentine and Chilean GEM lines were early-medium maturity in the TX environments. The most promising material was derived from the Argentine breeding cross, AR03056:N0902. Top crosses derived from this breeding cross were very resistant to drought conditions and yielded well under well irrigated conditions. Chilean lines derived from CH05015:N15, and CH05015:N12 lacked drought stress resistance under TX environments, and are not promising sources of germplasm. Lines having good tolerance to heat include selections from FS8A(T):N1801, and FS8B(T):N11a. Among the breeding crosses being evaluated for the

second year, hybrids having good yield, stay green, and low grain mold and smut, include BR105:N99d, BR106:T33a99a, SANM126:N1299b, and UR11002:S14.

TSG Meeting and Some Important Highlights:
The TSG held their meeting at the University of Delaware on August 17-18, hosted by Dr. Jim Hawk. An important item included acquiring new germplasm to supplement breeding crosses made with LAMP accessions, and other germplasm presently in the program (CIMMYT, Thailand, and breeding crosses made by international GEM Cooperators). A germplasm sub-team was started and led by Walter Trevisan. An effort is an underway to obtain germplasm from various tropical regions with known elite sources. The TSG also suggested that a greater effort be made to promote awareness of the GEM Project, its relevance and accomplishments, through presentations and distribution of brochures, germplasm information and availability, and regular newsletters via our web site. As a follow up to this recommendation, a brochure was prepared along with germplasm and trait descriptions. We plan to post newsletters on our web site in the near future.

PERSONNEL UPDATE:

Ames: ***USDA-ARS Plant Introduction Unit***

Dr. Mike Blanco, GEM Coordinator and Geneticist
Mack Shen, IT Specialist
Sue Duvick, Quality Traits Lab Manager
Andrew Smelser, GEM Technician
Fred Engstrom, GEM Technician
Dr. Candice Gardner, Research Leader

Raleigh: ***USDA-ARS Plant Science Research Unit***

Dale Dowden, Agricultural Research Technician
Dr. Jim Holland, Maize Research Geneticist, GEM Collaborator.
Dr. Peter Balint-Kurti, Research Geneticist, GEM Collaborator
Vickie Brewster, Research Support Scientist.
Dr. David Marshall, Research Leader and Fund holder.

NC State University
Dr. Major Goodman, William Neal Reynolds Distinguished Professor

IN KIND SUPPORT MIDWEST GEM PROJECT IN 2006:

Table 3. Private In-Kind Nursery Support – Summer 2006

Company	Breeding Cross
AgReliant Genetics	Advance to S2's GUAT209:N1934
BASF Plant Science	Make S1's in AR17056:N2021
	Make S1's in UR11003:S17e45
Beck's Superior Hybrids	Top cross S2's GUAD05:N3215
	Advance to S2's BR105:S1612
	Make new breeding crosses
Brodbeck	Make S1's in MBRC10:S1741
FFR Cooperative	Make S1's in BR51403:N1611c
Hoegemeyer Enterprises	Make S1's in NEI9004:S2817b
Hyland (Canada)	Advance to S3's AR13026:N08c06
	Top cross S2's in AR13026:N08c06
	Make new breeding cross
Identity Seed & Grain	Amylose increases
Illinois Foundation Seed	Advance to S2's BR105:N1641
MBS Genetics	Top cross S2's of re-test lines
Monsanto Company	Advance to S2's AR13026:S1523
	Advance to S2's DKXL370:N11a14
	Advance to S2's AR17026:N1012
	Advance to S2's BR51039:S1528
Mycogen Seeds	Advance to S2's CUBA164:S2008dF44
	Breeding cross evaluation and observations
	Make new breeding crosses
National Starch and Chem	Backcross wx into advanced GEM lines
PANNAR Genetics	Top cross S2's in AR03056:N1630b
	Top cross S2's GUAT209:S1318
Pioneer Hi-Bred Int.	Make S1's in BR51039:S1520
	Advance to S2's UR13010:N0614
	Disease and insect evaluations of lines & breeding crosses
PRIME Farm Seed	Advance to S2's GOQUEEN:N1612
	Make new breeding crosses
Professional Seed Research	Multi-disease evaluations of lines and breeding crosses
RBS Corn Research	Make new breeding crosses
	Breeding cross evaluation and observations
Schillinger Seeds	Make S1's in DKXL370:S08c17a
Sursem	Top cross S2's of CUBA110:N1712
	Make new breeding crosses
Syngenta Seeds	Support GEM Raleigh, NC
	Make S1's in AR17056:S1221
	Make S1's in GUAT209:N11c41
Wyffels Hybrids	Make S1's in CH05015:N3215

Table 4. Private In-Kind Support – Winter 2006-2007

Company	Breeding Cross
AgReliant Genetics	Make top cross to GEM breeding crosses for evaluation
	Top cross S2's of GUAT209:N1934
Agrotuniche (Chile)	Make S1's in BR106:S99e99j
BASF Plant Science	Top cross S1's of UR11003:S17e45
	SSD advance of AR17056:N2021-B
Beck's Superior Hybrids	Top cross S2's of BR105:S1612
Hyland (Canada)	Top cross S2's of AR13026:N08c06
Illinois Foundation Seed	Top cross S2's of BR105:N1641
Monsanto Company	Top cross S2's of AR16021:S0908a
	Top cross S2's of BR105:S1640
Mycogen Seeds	Top cross S2's of AR16021:S0908c
	Top cross S2's of CUBA164:S2008dF44
National Starch and Chem	Top cross waxy converted GEM lines to waxy tester
	Advance selected waxy GEM lines
PANNAR Genetics	Top cross S2's of CUBA117:S1516
	Top cross S2's of PRICGP3:N1218
Pioneer Hi-Bred Int.	Make new crosses for allelic diversity
	Self pollinate allelic diversity families
Syngenta	Top cross S2's of CUBA110:N1711c
	Top cross S2's of DKB830:N11b20
	Make new crosses for allelic diversity

Table 5. Yield Trials 2006

Experiment	Cooperator Making Topcross*	% Exotic	Tester	Zone of Germplasm	Number of Entries	Number of Reps
06121	GEM	50%	nSS	Tropical	115	6
06122	GEM	50%	nSS	Tropical	125	6
06123	GEM	50%	SS	Tropical	20	6
06131	GEM	25%	SS	Tropical	45	6
06132	GEM	25%	SS	Tropical	60	6
06133	GEM	25%	nSS	Tropical	75	6
06134	GEM	25%	nSS	Tropical	70	6
06135	GEM	25%	nSS	Tropical	48	6
06136	Syngenta	25%	SS	Tropical	98	6
06137	Mycogen	25%	SS	Tropical	50	6
06138	BASF	25%	nSS	Tropical	60	6
06139	Pioneer	25%	nSS	Tropical	55	4
061310	Pioneer	25%	nSS	Tropical	55	4
061311	Pioneer	25%	nSS	Tropical	55	4
061312	Pioneer	25%	nSS	Tropical	56	4
061313	Pioneer	25%	nSS	Tropical	56	4
06521	GEM	50%	SS	Temperate	48	6
06522	GEM	50%	SS	Temperate	65	6
06523	GEM	50%	SS	Temperate	48	6
06524	GEM	50%	SS	Temperate	50	6
06525	GEM	50%	nSS	Temperate	40	6
06526	GEM	50%	nSS	Temperate	25	6
06527	GEM	50%	nSS	Temperate	20	6
06531	GEM	25%	SS	Temperate	60	6
06532	GEM	25%	SS	Temperate	45	6
06533	GEM	25%	nSS	Temperate	65	6
06534	GEM	25%	nSS	Temperate	45	6
06535	GEM	25%	SS	Temperate	55	6
06536	Mycogen	25%	nSS	Temperate	50	6
06601	GEM	25%	nSS	Trop/Temp	30	8
06602	GEM	25%	SS	Trop/Temp	40	8
06603	GEM	25,50%	nSS	Trop/Temp	30	8
06641	GEM	25%	SS	Trop/Temp	45	6
06642	GEM	25,50%	nSS	Trop/Temp	45	6
06643	GEM	25%	nSS	Trop/Temp	15	6
06644	GEM	GEM x GEM		Trop/Temp	40	6
06645	GEM	GEM x GEM		Trop/Temp	45	6
Total					**1949**	

PUBLICITY:

Balint-Kurti, P., M. Blanco, M. Millard, S. Duvick, J. Holland, M. Clements, R. Holley, M.L. Carson, M. Goodman. 2006. Registration of 20 GEM maize breeding germplasm lines adapted to the southern USA. Crop Sci. 46: 996-998.

Blanco, M., C. Gardner, W. Salhuana, N. Shen. 2006. Maize races and traits identified from the GEM Project. ASA-CSSA-SSSA Annual Meeting Abstract: 1621a. Indianapolis, IN. Nov 12-16, 2006.

Campbell, M.R., J. Jane, L.M. Pollak, M. Blanco, and A. O'Brien. Registration of maize germplasm line GEMS-0067. Crop Sci. (Submitted).

Carson, M.L., P.J. Balint-Kurti, M. Blanco, M. Millard, S. Duvick, R. Holley, J. Hudyncia, and M.M. Goodman. 2006. Registration of nine high-yielding tropical by temperate maize germplasm lines adapted for the southern USA. Crop Sci. 46:1825-1826.

Duvick, S., and L. M. Pollak. 2006. Quality trait characterization of expired plant variety protected corn lines. Corn Utilization and Technology Conference, June 5-7, Dallas, TX.

Goodman, M.M. 2005. Broadening the U.S. maize germplasm base. Maydica 50:203-214.

Lenihan, E., L.M. Pollak, and P.J. White. Thermal properties of starch from exotic by adapted corn (Zea mays L.) lines grown in four environments. 2005. Cereal Chem. 82(6):683-689.

Li, L., M. Blanco, and J. Jane. Physicochemical properties of endosperm and pericarp starches during maize development. Carbohdr. Polym. In press.

Li, L., H. Jang, M. Campbell, and J. Jane. Characterization of starch from maize amylose-extender mutants. American Association of Cereal Chemists Annual Meeting, San Francisco, CA. Sept. 17-20, 2006. (The poster received Outstanding Poster Award)

Li, L., M.Blanco, and J.Jane. 2006. Development of maize starch granules. The IV Brazilian meeting in chemistry of food and beverages. Sao Jose do Rio preto, Brazil, Nov. 30-Dec. 3, 2006.

Nelson, P.T., M.P. Jines, and M.M. Goodman. 2006. Selecting among available, elite tropical maize inbreds for use in long-term temperate breeding. Maydica 51:255-262.

Pollak, L.M., and M.P. Scott. 2005. Breeding for grain quality traits. Maydica 50:247-257.

Pollak, L.M., S. Duvick, and P.J. White. 2006. Variation in fatty acid content in a wide breeding cross. 97th American Oil Chemists Society Annual Meeting & Expo, April 30-May 3, St. Louis, MO.

Pollak, L. M., K. Montgomery, S. Duvick, and Jesse Niggemann. 2006. Breeding for grain quality by using synthetic populations. Corn Utilization and Technology Conference, June 5-7, Dallas, TX.

Salhuana, W., and L.M. Pollak. 2006. Latin American Maize Project (LAMP) and Germplasm Enhancement of Maize (GEM) Project: Generating useful breeding germplasm. Maydica 51: 339-355.

Taboada-Gaytan, O.R., L.M. Pollak, L. Johnson, S. Fox, S. Duvick, and K. Montgomery. 2006. Wet milling efficiency of hybrids from exotic by adapted inbred lines in corn. Corn Utilization and Technology Conference, June 5-7, Dallas, TX.

Taboada-Gaytan, O. R., L. M. Pollak, L. Johnson, S. Fox, S. Duvick, and K. Montgomery. 2006. Wet milling efficiency of the F1 and F2 generations of hybrids from exotic by adapted inbred lines in corn. International Plant Breeding Symp., August 20-25, Mexico City, D.F.

Taboada-Gaytan, O.R., L.M. Pollak, L. Johnson, S. Fox, and S. Duvick. 2006. Effects of pollination method on the wet milling efficiency of hybrids from exotic by adapted lines in corn. ASA-CSSA-SSA annual meetings, Nov. 12-16, Indianapolis, IN.

Williams, W.P. 2006. Breeding for resistance to aflatoxin accumulation in maize. Mycotoxin Research 22: 27-32.

Wu, X., R. Zhao, D. Wang, S.R. Bean, P.A. Seib, M.R. Tuinstra, M. Campbell, and A. O'Brien. 2006. Effects of amylose, corn protein, and corn fiber contents on production of ethanol from starch-rich media. Cereal Chem. 83(5):569-575.

Iowa Field Day, Laura Krause Farm, Mt. Vernon, Iowa. August 6, 2006. Presentation by Linda Pollak on a participatory plant breeding project using a GEM synthetic.

Iowa Field Day, Ron and Farm, Cresco, IA. September 12, 2006 Practical Farmers of Iowa Field Day. Presentation by Linda Pollak, John Golden, and Walter Goldstein on hybrids/varieties, some of GEM origin, tested for yield and grain quality.

Iowa Field Day, GEM Project Field Day held at North Central Regional Plant Introduction Station, Ames, IA. September 21, 2006.

GEM Project Brochure was completed in November (combined efforts of Mack Shen, Mike Blanco, and Candice Gardner) to promote the GEM Project mission, objectives, and operations, and to highlight the germplasm and component traits released from the Ames and Raleigh programs.

LAB REPORT:

Whole grain composition data for protein, oil, and starch content was generated by Sue Duvick, GEM Lab Manager. The data was generated using an NIR Infratech 1241 with a sample transport module and whole grain calibration from Iowa State Grain Quality Lab. All lab data is

reported on a dry matter basis and available on the CD, and will be posted on the GEM web site in early 2007. Samples are obtained from a bulk of 8 ears from self pollinated rows. NIR data includes S4 lines ("advanced") grown in 2006, the recommended lines new for 2007 (2 year data), recommended lines from 2006 (discussed at 2005 GEM Cooperator Meeting), breeding crosses under evaluation (open pollinated ear source), lines and hybrids in the amino acid experiment, and recommended lines from Raleigh, NC.

Starch functional properties are studied by differential scanning calorimetry (DSC). DSC data was collected on selected GEM lines recommended for release, and on lines with known starch properties from previous GEM research. Since starch properties vary among years data are collected over a period of 2-3 years. We expect to have summarized DSC data on our web site in early 2007.

A laboratory dry grind hammer mill was purchased in 2006 to evaluate germplasm for ethanol potential. Fred Engstrom constructed a vacuum suction apparatus that will facilitate clean-out and speed up sample analysis. Our objective is to simulate the kind of samples used for dry grind in the ethanol industry and develop a calibration to accurately estimate ethanol content. Ethanol yield is not highly correlated to percent starch content, or extractable starch obtained by wet milling. Evaluating germplasm for dry-grind ethanol potential is a new developing technology and we look forward to explore it with GEM germplasm.

Data for protein, oil, and starch content for 2007 recommended lines from Ames, IA and recommended lines from Raleigh, NC are below. Data from Ames are 2 year averages (2005 and 2006), and Raleigh one year (2006). Some lines from Raleigh are not included due to late maturity and insufficient seed in Ames.

Two year NIR summary (2005-2006) self pollinated bulk seed. 2007 Recommendations-Ames

Recommended Lines for 2007 Ames						
Pedigree	Race	Country	Protein	Oil	Starch	Density
B73 (check)	-	-	12.1	4.2	69.5	1.268
AR13026:N08b15-016	Cristalino Colorado	Argentina	12.6	3.7	69.6	1.313
AR13026:N08b15-086	Cristalino Colorado	Argentina	11.3	4.0	70.3	1.251
BR51721:N2012-098-002	Dente Amarelo	Brazil	10.3	3.5	72.6	1.314
BR51721:N2012-164-002	Dente Amarelo	Brazil	10.6	4.0	71.3	1.294
BR51721:N2012-397-001	Dente Amarelo	Brazil	10.0	3.5	71.7	1.286
CASH:N1410-018-001	Corn Belt Dent	USA	12.1	3.5	70.0	1.285
CUBA117:S1542-037-002	Argentino	Cuba	13.8	3.8	67.4	1.290
CUBA117:S1542-057-001	Argentino	Cuba	14.3	4.8	67.1	1.332
CUBA117:S1542-057-002	Argentino	Cuba	15.7	5.0	65.0	1.331
CUBA164:S2012-456-001	Mixed (Creole)	Cuba	12.5	4.4	68.2	1.231

NC GEM Project Lines					
2006 (from self pollinated seed in Ames, IA)					
Code	**Pedigrees**	**Protein**	**Oil**	**Starch**	**Density**
GEMS-0119	(1311-01/97_CHS775N19F1S3_1721-42)-B-B-B	14.3	4.6	66.0	1.315
GEMS-0122	(7384-02/96_CHS775N19F1S3_3587-43)-B-B	11.5	5.0	69.3	1.311
GEMS-0125	(1415-01/97_DK888S11F2S3_7461-29)-B	12.8	4.8	68.6	1.344
GEMS-0126	(1415-06/97_DK888S11F2S3_7461-29)-B	11.5	4.2	70.1	1.334
GEMS-0127	(9353-01/97_DK888N11F2S3_7451-17)-B-B	11.2	4.1	70.8	1.342
GEMS-0130	(1883-001/98_DKXL370AN11F2S3_7521-05)-B-B	13.8	4.2	68.3	1.329
GEMS-0129	(1881-006/98_DKXL370AN11F2S3_7521-05)-B	13.5	4.7	67.6	1.304
GEMS-0132	(1886-003/98_DKXL370AN11F2S3_7521-05)-B	14.2	5.0	67.0	1.322
GEMS-0135	(9531-02/97_DKXL380N11F2S3_7541-7)-B	12.0	5.2	68.5	1.311
GEMS-0136	(9532-02/97_DKXL380N11F2S4_7541-7)-B	12.4	5.0	69.0	1.338
GEMS-0119	CHIS 775 N19 F1S7_1721-42-12-3-B-B-B-B-B	12.6	4.4	68.6	1.312
	DK212T N11 F2S5_7431-16-5-B-B-B-B	10.9	4.8	70.0	1.303
	DKXL380 N11 F2S6_7541-7-32-1-B-B-B-B-B	11.9	4.3	69.6	1.331
GEMS-0007	DK212T:S11 F2S4 2089-01)-Sib-B-B	14.4	3.7	68.7	1.332
GEMS-0019	(DK888:S11 F2S4 2146-01)-Sib-B	12.9	4.8	69.0	1.318
GEMS-0137	(2410-003/99_SCRGp3N14F2S3_7258-3)-B-B	12.4	3.5	70.6	1.287
GEMS-0006	(2088-01_DK212T_S11_F2S4_9157-Blk29/00-sib)-B-B-B	13.1	4.1	69.2	1.312
GEMS-0016	(2132-03_DK888_S11_F2S4_9187-Blk22/00-sib)-B-B-B	12.1	4.7	69.2	1.316
GEMS-0030	(2258-03_XL380_S11_F2S4_71/97_Bulk/98-sib)-B-B-B	12.0	3.7	70.5	1.330
GEMS-0124	(1507-001/98_DK212TN11F2S3_7431-03)-B-B	12.0	5.0	69.0	1.320
GEMS-0131	(1883-002/98_DKXL370AN11F2S3_7521-05)-B-B	12.3	4.9	68.6	1.309
GEMS-0133	(1895-001/98_DKXL370AN11F2S3_7521-29)-B-B	13.3	4.5	68.1	1.297
GEMS-0003	SE32(BR52 051):S17 F2S4 2011-01)-Sib-B-B-B	12.8	5.5	67.6	1.334
GEMS-0006	(2088-01_DK212T_S11_F2S4_9157-Blk29/00-sib)-B-B-B	13.0	4.2	68.8	1.332
GEMS-0009	(2111-01_DK212T_S11_F2S4_9166-Blk31/00-sib)-B-B	12.0	3.7	70.4	1.277
GEMS-0010	(2112-02_DK212T_S11_F2S4_9169-Blk20/00-sib)-B-B	13.6	3.8	68.3	1.319
GEMS-0014	DK888:S11 F2S4 2127-01)-Sib-B-B	13.2	4.0	68.7	1.306
GEMS-0016	(2132-03_DK888_S11_F2S4_9187-Blk22/00-sib)-B-B-B	11.9	4.8	69.2	1.324
GEMS-0018	(2143-02_DK888_S11_F2S4_9193-Blk19/00-sib)-B-B	12.8	3.8	69.8	1.316
GEMS-0029	(2253-01_XL370A_S11_F2S4_9220-Blk24/00-sib)-B-B	13.1	4.5	67.7	1.320
GEMS-0030	(2258-03_XL380_S11_F2S4_71/97_Bulk/98-sib)-B-B	12.6	3.9	69.7	1.333
GEMS-0031	DKXL380:S11 F2S4 2282-01)-Sib-B-B-B-B	14.0	3.6	68.0	1.291
GEMS-0134	(2423-017/99_DKXL380N11F2S3_7541-10)-B-B	13.4	3.8	68.6	1.331
GEMS-0039	PE001n16F2S2-239-B-B-B-B	14.1	3.7	67.6	1.329
GEMS-0027	XL370A:S11 F2S4 2250-01)-Sib-B-B	13.3	3.4	69.3	1.315
	min	10.9	3.4	66.0	1.277
	max	14.4	5.5	70.8	1.344
	avg	12.8	4.3	68.8	1.318
	std dev	0.9	0.6	1.1	0.016