QUANTITATIVE GENETICS AND MAIZE BREEDING
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Final Report: *Hybrid Development and Testing for Yield, Stress Tolerance, and Aflatoxin Resistance*

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Executive Summary

We thank the Texas Corn Producers Board for supporting this project. This support has been critical for genetic improvement of corn that will benefit growers of the State of Texas, general corn research under Texas conditions, and training future generations of corn researchers. Overall this was an outstanding year in irrigated trials and nurseries due to cooler conditions than last year and timely rainfall which has allowed critical determinations to be made on the yield potential and usefulness of TAMU material as well as to increase seed for next year's testing. While we only had one successful dryland location this year (more will be used in future years), the data was very useful. Seasonal conditions were not favorable to aflatoxin production; this was a blessing for growers but did not allow us to make any useful determinations this year in aflatoxin resistance. High southern rust disease pressure allowed us to screen for this disease and TAMU material was much more resistant than commercial checks. Taken together we have now identified a small number of inbreds and hybrid combinations which we will pursue towards commercialization and we were able to produce enough seed for meaningful larger scale testing in the following year for many of these hybrids. The work and graduate students partially supported with TCPB funds resulted in 3 peer reviewed publications accepted or published this year, another 6 peer reviewed publications submitted, 4 peer review publications (including germplasm/ line releases) are in preparation, 12 presentations were made at national meetings and 2 corn program students received their MS degrees.

Objective 1: *Test more than 200 new hybrids from crosses between our best TAMU inbreds and relevant commercial inbred lines (mostly traited) to find winning combinations for yield, stress and aflatoxin; work with industry to develop a path towards rapid commercialization.*

A total of 743 different hybrids were tested this year under this project (+ ~1000 more under other USDA projects which will not be discussed here) in multi-environmental multi-replicate tests. The majority of these hybrids were new combinations between proven TAMU lines with the most recent relevant commercial tester inbreds. Because these testers are ones that industry is currently using, this will allow the most outstanding hybrids to be most quickly made available for growers.

All data from all locations was fit into a single model for easy presentation and analysis (Table 1). The Best Linear Unbiased Predictor (BLUP) gives an estimate of how much greater yield is predicted over the experimental average. Hybrids and testers were coded because of disclosure agreements; many are present although randomized in Table 2.

College Station - Over 2401 plots were planted early in College Station for yield measurements only, additionally 653 plots were planted late to evaluate yield under late season stress and were inoculated for aflatoxin evaluation. This was an outstanding year for yield trials averaging ~171 bu/ac in the early planting and 160 bu/ac in the late planting. In the early planting 68 out of 537 hybrids beat one or more commercial checks. In the late planting 61 out of 325 hybrids beat one or more commercial checks. Aflatoxin levels were tested on a proportion of plots and found to be mostly below 50ppb, therefore rigorous testing for aflatoxin was not performed.

Weslaco – Over 1240 plots were planted early in Weslaco for yield measurements only, additionally 494 plots were planted late to evaluate yield under late season stress and were inoculated for aflatoxin evaluation. An above average year for yield trials, the tests averaged ~124 bu/ac in the early planting and 143 bu/ac in the late planting. In the early planting 37 out of 389 hybrids beat one or more commercial checks. In the late planting 3 out of 86 hybrids beat one or more commercial checks. Aflatoxin levels were mostly below 50ppb so only minimal testing was performed.

Ganado – 210 plots were planted and resulted in slightly below average but very informative dryland yield trials averaging ~98 bu/ac. In the early planting 16 out of 105 hybrids beat one or more commercial checks and one hybrid beat the best check by 8 bu/ac. No samples were collected for aflatoxin to be run. Measurements were taken on southern rust and most all TAMU material had far superior resistance to commercially available checks – likely due to the strong tropical background. On a scale of 0 (no rust) to 10 (top leaf covered in orange pustules) TAMU hybrids averaged 3.6 (range 0.5 to 7) for this disease while the checks averaged 6 (range 4 to 8). We thank the owners and staff of BH genetics for in-kind support and assistance in conducting this test.

Corpus Christi – Over 330 plots were planted late at Corpus Christi to induce stress but given the extremely hot and dry conditions at this site at flowering, it was a complete loss.

Halfway – Over 150 plots were planted at Halfway to evaluate yield. Data collection has finished but was not sorted out in time to include in this report.

Objective 2: *Produce new and additional hybrid seed for testing in crosses between TAMU inbreds and relevant commercial inbred lines (mostly traited).*

College Station summer nursery - This year over 288 Texas A&M inbred lines (which have been previously proven in past trials with a single tester) were put into the crossing block with 14 commercial inbred lines, many with traits, planted in three delay plantings. This crossing was performed before results of this year's yield trials were obtained so crosses were made based on heterotic grouping and compatible flowering time only. 707 different crosses were made and nearly all 288 lines had at least one cross and many have two or three. The summer conditions for the crossing block were outstanding and seed from most crosses was clean and abundant. Across all breeding nurseries over 5000 envelopes of seed have been shelled and saved.

Weslaco fall nursery – Weslaco winter nursery was successfully planted with two delays – August 3rd, 7th, and 14th and harvested December 10-12. A total of 2925 plots were planted in the Weslaco winter nursery for this project and others supported by the USDA or Texas Monocot Improvement Projects. Specifically under this project a crossing block containing 6 plots for each of the 25 top irrigated TAMU inbred lines were planted along with 10 commercial or ex-PVP tester lines (150 plots total) for crossing. These combinations were selected based on top yield performance in this years irrigated trials. Insect pressure was high but most crosses made were successful and harvest was plentiful. We will begin shelling this material in early January.

Objective 3: *Train students and participate in cooperative tests. All objectives will concurrently train graduate students and expose undergraduate student workers to agronomy and corn breeding.*

This summer, five graduate students, four undergraduate and two high school workers have worked in the TAMU corn breeding program. Two graduate students from the corn program received their MS degrees: Gerald De La Fuente is now working on a PhD at Iowa State University with Dr. Thomas Lubberstedt in corn doubled haploid systems; Adam Mahan is now working on a PhD on genetic determination of corn recombination with Dr. Murray. Additionally three other graduate students employed by other crops were trained for a day or more. Multiple cooperative tests were planted, mostly in College Station, Weslaco and Halfway.

Publications relevant to the project published and accepted (plus 6 more submitted)

Contributing, or communicating author designated with *, students contributions are *highlighted in italics:*

De La Fuente, G.N, S.C. Murray*, T.Isakeit, Y.-S. Park, Y. Yan, M. Warburton and M.V. Kolomiets. 2012. Characterization of genetic diversity and linkage disequilibrium of ZmLOX4 and ZmLOX5 Loci in Maize. PLoS One. (accepted)

Henry, W.B.*, D.E. Rowe, G.L. Windham, M.H. Blanco, S.C. Murray, and W.P. Williams. 2012. Diallel analysis of diverse maize germplasm lines for resistance to aflatoxin accumulation. Crop Science. doi: 10.2135/cropsci2012.04.0240

Meeks M., S.C. Murray*, S. Hague, D. Hays, and A. Ibrahim. 2012. Genetic variation for maize epicuticular wax response to drought stress at flowering. Journal of Agronomy and Crop Science. 198:161–244.

Presentations relevant to the project:

De La Fuente, G., S.C. Murray*, M. Kolomiets, T. Isakeit and I. Barrero. 2012. Genetic diversity in members of the *Z. mays* lipoxygenase gene family and its utility in association mapping for drought tolerance and aflatoxin resistance. PAG. (talk)

Henry, B.*, G.Windham, D. Rowe, M. Blanco, S. Murray and W.P. Williams. 2012. Diallel Analysis of Diverse Maize Germplasm Lines for Agronomic Characteristics and Resistance to Aflatoxin Accumulation. ASA-CSSA-SSA Meeting. 10/21-10/24/2012

Kanchi, R.*, S.C. Murray, N. Lauter and R.J. Wisser. 2012. Numerical optimization of a marker-assisted backcrossing scheme for introgression library construction. Maize Genetics Meeting. (poster)

*Mahan A.L.**, Murray S.C. 2012. Diallel Mating to Determine Combining Ability for Important Economic, Agronomic, and Compositional Traits in a Diverse Set of Colored (Red, Blue, Purple) Maize [Z. Mays]. ASA-CSSA-SSA Meeting. 10/21-10/24/2012

Murray, S.C.* 2012. Schemes for efficient realization of effective recombination events to enhance breeding progress. Illinois Maize Breeders School. 3/5-6/2012 Champaign, IL. (invited talk)

Murray, S.C.* , M. Kolomeits, T. Isakeit, *G. De La Fuente*, *I. Barerro*. 2012. Improving maize against aflatoxin and drought: translational plant breeding, education, and extension. USDA Awardees Meeting – Plant and Animal Genome Conference. 1/13/2012 (invited talk)

Murray, S.C.*, M. Kolomiets, T. Isakeit, and *G. De La Fuente.* 2011. Improving drought tolerance and aflatoxin resistance in maize; education, extension, and translational breeding via altered lipid metabolism. USDA awardees meeting - Plant and Animal Genome Conference. (invited poster)

Murray, S.C.*, *G.N. De La Fuente*, *I.D. Barrero-Farfan*, M.L. Warburton, W. P.l Williams, G.L. Windham, Y.-S. Park, Y. Yan, T.Isakeit, M.V. Kolomiets. 2012. Genetic diversity in maize aflatoxin resistance and drought tolerance: Translation plant breeding, education and extension. NAPB Annual Meeting; Indianapolis, IN 8/6-8/8/2012 (poster)

Teixeira, J., T. Weldekidan, Y. Veturi, K. Rogers, J. Reiner, N. Kumar, R. Kanchi, L. Peddicord, M. Lopez, N. de Leon, S. Flint-Garcia, J. Holland, N. Lauter, S.C. Murray, W. Xu and R.J. Wisser*. 2012, The maize ATLAS project: implementation of an experimental framework for studying adaptation. PAG (poster)

Wisser, R.J.*, N. De Leon, S. Flint-Garcia, J. Holland, N. Lauter, S.C. Murray, W. Xu, T. Weldekidan, J. Teixeira, Y. Veturi, N. Kumar, K. Rogers, *R. Kanchi*, L. Peddicord, M. Lopez and S. Sood. 2012. The Maize ATLAS Project: Implementation of An Experimental Framework for Studying Adaptation. ASA-CSSA-SSA Meeting. 10/21-10/24/2012

Wisser R.J.*, Teixeira, J., T. Weldekidan, Y. Veturi, K. Rogers, J. Reiner, N. Kumar, R. Kanchi, L. Peddicord, M. Lopez, N. de Leon, S. Flint-Garcia, J. Holland, N. Lauter, S.C. Murray and W. Xu. 2012. The Maize ATLAS project: implementation of an experimental framework for studying adaptation. Maize Genetics Conference (Poster)

Xu, W. T. Gaus, T. Marek, S. Murray, P. Williams, and G. Odvody. 2012. Exploring Native Resistance Genes to Develop Aflatoxin Resistant Corn. Corn Utilization and Technology Conference in Indianapolis 6/ 4-6/6/2012

Table 1: Top 60 Hybrids across all locations

Hybrids [1]	BLUP Bu/Acre above mean [2]	Std. Error	P [3]	Hybrid [4]
((LAMA2002-23-3-B/LAMA2002-58-4-B)-B-B-2-3-B-B-B) ***X SS2***	**51.5**	± 11.3	****	Y1
(Red Hybrid Ear-B-1-2-2-1/Red Ear 5-2-4-1-4-2)-B-B-1 ***X SS5***	**49**	± 16.8	**	
Commercial Hybrid #09	**46.8**	± 5.4	****	
Commercial Hybrid #08	**46.2**	± 13.7	***	
Commercial Hybrid #02	**45.1**	± 4.8	****	
Tx114 X (Tx120) (Tx114 (B73w)-B x CML343/Tx110 x Pop24)-B-B-B-4-B-B-B-B-B	**44**	± 14.5	**	
Commercial Hybrid #04	**43.3**	± 6.7	****	
Commercial Hybrid #05	**42.3**	± 13.7	**	
NSS1 X (CML442-B/CML343-B-B-B-B-B-B)-B-B-1-1-B	**40.7**	± 11.3	***	W1
(LAMA2002-58-3-B-B-B-B-B-B) ***X NSS2***	**38.1**	± 8.9	****	
SS1 X (CML450-B/Tx110)-B-3-B-1-B-B-B7	**37.5**	± 9.6	***	W2
Commercial Hybrid #01	**37.2**	± 6.1	****	
(LAMA2002-23-3-B/LAMA2002-58-4-B)-B-B-2-3-B-B-B ***X NSS2***	**37.1**	± 9.6	***	Y1
(LAMA2002-35-2-B-B-B-B/CG44)-1-3-B-1 ***X NSS2***	**37**	± 14.5	*	Y3
SS1 X Ethiopia12-B-3-3-B-B2-B1-2-B-B-B	**36**	± 14.6	*	
Commercial Hybrid #11	**35.9**	± 6.3	****	
(CML442-B/CML343-B-B-B-B-B-B)-B-B-1-1-B ***X SS4***	**35.5**	± 10.2	***	W1
GT602/ Tx303	**35.4**	± 14.4	*	
(LAMA2002-23-1-B-B/LAMA2002-11-1-B-B)-B-B-B-B-B-1 ***X WXLBRED1***	**34.7**	± 14.6	*	Y21
((CML288/NC300)-B-9-B1-B-B-B-B-B-B-B-B) ***X SS5***	**34.7**	± 11.3	**	
(CML450-B/Tx110)-B-3-B-1-B-B-1 ***X SS5***	**34.6**	± 8.9	***	W2
(LAMA2002-2-5-B/(CML285/B104)-B-4-B-B-B-B)-B-B2-2-3-B ***X NSS1***	**33.3**	± 9.6	***	Y22
Red Ear 2-2-2-1-1-2-B-B ***X WX-LBRED2***	**33.3**	± 14.6	*	
(LAMA2002-10-1-B/(CML288/NC300)-B-9-B1-B-B-B)-B-B-1-3-B-1 ***X SS1***	**33**	± 9.6	***	Y2
((LAMA2002-2-5-B/(CML285/B104)-B-4-B-B-B-B)-B-B2-2-1-B) ***X NSS1***	**32.6**	± 11.3	**	Y22
(CML442-B/CML343-B-B-B-B-B-B)-B-B-1-1-B ***X NSS1***	**32.5**	± 14.5	*	W1
((CML 373/FR825)/(CML269/Tx110)-1-B-B-B-B/CML269/TX114-B-B-B-1-1-B-B-B-B-B)-B-1-B-1-B ***X SS2***	**32.4**	± 16.8	NS	
NSS5 ExPVP X (CML442-B/CML343-B-B-B-B-B-B)-B-B-1-1-B	**32.2**	± 11.3	**	W1
TX740 (TAMU aflatoxin released line) X SS3	***31.9***	**± 8.9**	***	

(LAMA2002-22-1-B-B-B-B/LAMA2002-10-1-B-B-B-B)-2-2-B ***X SS1***	**31.7**	± 12.3	*	Y23
(LAMA2002-35-2-B-B-B-B/CG44)-1-3-B-B14 ***X SS1***	**31.2**	± 9.4	***	Y3
((LAMA2002-12-1-B/(CML 325/B104)-B-1-B-B-B-B)-B-B2-3-2-B-B-B) ***X SS3***	**31**	± 11.3	**	Y13
((Tx745-B-B/CML161)-B-B-1-B-B) ***X SS1***	**30.9**	± 16.8	NS	
Tx811 (TAMU QPM released line) X SS4	***29.9***	***± 16.7***	***NS***	
SS1 X Red Hybrid Ear-B-1-2-2-1-B-B	**29.7**	± 14.6	*	
(CML450-B/(Tx106-Tx714)-1-1-714-1-1-1-B-B-B-B-B)-B-2-B-3-B-1 ***X NSS2***	**29.4**	± 9.6	**	
SS1 X NC258	**29.4**	± 12.4	*	
((LAMA2002-12-1-B/(CML 325/B104)-B-1-B-B-B-B)-B-B2-3-2-B-B-B) ***X NSS2***	**29.1**	± 11.3	*	Y13
(LAMA2002-35-2-B-B-B-B/CG44)-1-3-B-B14 ***X SS5***	**29.1**	± 9	**	Y3
((B104-1 x Tx714-B-B)-23-1-B-B-B-B/(CML288/NC300)-B-9-B1-B-B-B)-B-B-1-1-B-B-B-B ***X SS2***	**29**	± 12.4	*	
(LAMA2002-23-1-B-B/LAMA2002-11-1-B-B)-B-B-B-B-B-1 ***X WXLBRED2***	**28.9**	± 14.6	*	Y21
CML78xCML270-B-B-B-B-3-B-B-B-B ***X SS4***	**28.6**	± 11.3	*	
CML176xCML343-B-B-B-B-2-B-B-B-B-1 ***X SS1***	**28.6**	± 11.4	*	
(LAMA2002-10-1-B/(CML288/NC300)-B-9-B1-B-B-B)-B-B-1-3-B-B-B-B-1 ***X SS1***	**27.5**	± 12.4	*	Y2
(LAMA2002-23-1-BB/LAMA2002-11-1-B-B)-B-B-B-B-B-1 ***X SS1***	**27.5**	± 14.4	NS	Y21
SS2 X (LAMA2002-22-1-B-B-B-B/LAMA2002-1-5-B-B-B-B)-2-1-B-1-1	**27.2**	± 12.4	*	Y5
(CML379/CML311-B-1-B-B-B-B/Tx110)-B-1-B-2-B-B-1 ***X SS1***	**26.9**	± 16.7	NS	
(((B104-1 x Tx714-B/B110 x FR2128-B)-2-2-B-B-B-B/SCR86-B)-B-B-3-1-B) ***X Tx110***	**26.9**	± 16.8	NS	
SS1 X Red Ear 2-2-2-1-1-2-B-B	**26.8**	± 14.6	NS	
Commercial Hybrid #06	**26.5**	± 6.4	****	
SS1 X (LAMA2002-23-1-B-B/LAMA2002-11-1-B-B)-B-B-B-B-B-1	**26.5**	± 14.6	NS	Y21
SS6 X (LAMA2002-22-1-B-B-B-B/LAMA2002-1-5-B-B-B-B)-2-1-B-1-1	**26.5**	± 9.4	**	Y5
NSS2 X (LAMA2002-23-3-B/LAMA2002-2-5-B)-B-B-1-2-B-B-B	**26.2**	± 10.9	*	
((Tx741); LAMA2002-42-B-B-B-B-B) ***X SS5***	**26**	± 14.5	NS	
(AR16021:S08a02 Derived line (energy dense)-B-B-B-1-B-B-B-B-B/CL-RCY031=CL02410*CML287)B-9-1-1-2-B-B-B)-B-4-B-B1 White Cob-2 ***X SS6***	**26**	± 12.4	*	
Commercial Hybrid #10	**25.6**	± 13.7	NS	
(LAMA2002-22-3-B-B1-B-B/LAMA2002-10-1-B-B-B-B)-2-3-B-2-1 **X SS2**	**25.4**	± 12.4	*	Y23
Commercial Hybrid #07	**24.9**	± 13.7	NS	

Commercial Hybrid #03	**17.1**	± 14.6	NS
TX740 (TAMU aflatoxin released line) ***X NSS2***	***12.6***	*± 16.8*	NS
Commercial Hybrid #03	**12.6**	± 5.6	*

Footnotes
1) Commercial checks coded and centered in italics
Commercial tester lines coded in bold italics (e.g. ***SS1*** = Stiff stalk tester #1 ; ***NSS3*** = Non-stiff stalk tester #3)
2) All 2012 data was put in a single model and the Best Linear Unbiased Prediction (BLUP) was made
3) Level of significant difference from test mean **** p <0.0001; *** p <0.001; ** p <0.01; * p <0.05
4) TAMU lines with success on multiple testers; If blank only one tester was used and/or made it into the top 60 hybrids.

Table 2: Some commercial hybrids and testers used in 2012 (order does not correspond to coding in Table 1)**.**

Commercial hybrids included	**Stiff stalk (SS) inbred testers**	**Non-stiff stalk (NSS) inbred testers**	**Other testers**
BH8895VT3	TR8453	TR8944	CML269
BH8910RR/HX	TR8145RR2	TR7582	GT602
BH8928VT3	TR7169RR2	TR7322RR2	LH82
BH9014VT3	TR7169GT	TR6331	Mp313E
BH9051RR	TR6282RR2	SGI847	Mp715
DK697	SGI890	SGI079	PHR36
DKC64-69	LH195RR2	LH61	PHV63
DKC68-05	LH132	LH51	PHW17
GA26V21	FR7905	LH287RR2	PHW52
GA28V81	FR3311	LH123HT	Tx772W
P31P41	FR1064	GT603	TZAR101