

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

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**Introduction:** The corn-breeding program at NDSU has been developing early maturing (65-95RM) corn since 1933. We have created 'EarlyGEM', a continuous effort to incorporate GEM germplasm into the northern U.S. Corn Belt. Our program is one of the few public programs that can still offer a strong emphasis on germplasm improvement, inbred line development, and training of applied plant breeders. The EarlyGEM project has the unique capability for adapting late temperate and tropical genetic materials to the northern U.S. Corn Belt and to increase the number of competitive products utilizing useful genetic diversity. 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. North Central Region.

**Justification:** The purpose of this research is to develop early maturing high quality GEM lines for utilization in the northern U.S. Corn Belt. North Dakota (ND) corn producers planted a record 2.6 million acres in 2007 (and for the first time the crop with highest production in the state of ND) due in part to renewable fuel demand. However, this corn-ethanol relationship will only be possible in ND if high yielding early maturing corn quality products are available. Our hypothesis is that early maturing recovered versions of GEM lines can be obtained retaining grain yield and quality maintaining useful genetic diversity.

**General Objective:** Develop short-season (90RM) high quality 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 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. 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 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 including the early generation test presented in this report.

### **Inbred Line Development**

The nine source populations consist of three Stiff Stalk (SSS) and six non Stiff Stalk (NSS) populations. Monies for 2007 funded mostly our breeding activities advancing over 3,000 adapted lines and test-crossing for first and second year early generation testing. Stiff Stalk donors (CUBA117:S1520-388-1-B, CHIS775:S1911b-B-B, and AR16026:S17-66-1-B or GEM21 in our list) 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 to the S3 generation. Only GEM 21 lines were crossed to industry testers for the data showed in this report (Table 1). GEM S1 selections were planted across three locations (Fargo, Prosper, and Casselton, ND) 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. S1 selections were advanced to S2 and crossed to LH and Iodent Bt industry testers. First year trials were conducted across six ND locations in 2007 and top S2 lines are being advanced to the S3 generation for both inbreeding and more extensive testing in winter nursery. In addition, winter nursery testing of hybrids under drought tolerance will be conducted. Field days were held to communicate the use of GEM genetic materials to broaden the germplasm base for the northern Corn Belt at across several ND locations.

### **Evaluation of 2007 Experiments**

#### ***Materials and Methods***

Five hundred BC1:S1 lines derived from (AR16026:S17-66-1-B x ND2000) x ND2000 were advanced one generation of inbreeding and top ones (visually) were crossed to industry testers. A range of progeny BC1:S1s was used as male and two ranges of industry testers were used as females so that self-pollination could be done at the same time as cross-pollination. The seed produced on female ranges was bulked and used for yield trials. Experiments including 64 and 81 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. Data were collected for grain yield, grain moisture at harvest, root lodging, stalk lodging, test weight, and emergence percentage across ND environments. A sub-sample of 500 g of kernels was

collected from every plot in all environments and used to measure the grain quality of all genotypes. Grain quality screening will be conducted with on-site cooperation from Iowa State University and equipment committed provided by Monsanto during Jan and Feb 2008.

### Statistical Analyses

Analyses of variance were performed for all traits within and among environments. Homogeneity of variances was evaluated for each location. Genotypes were considered as fixed effects while environments and replications within each environment were considered as random effects. Analyses of variance for each location were performed using the PROC LATTICE procedure from SAS. Means adjusted by incomplete blocks were used when the relative efficiency of lattices was higher than 105% compared with a randomized complete block design (RCBD); otherwise, unadjusted means were used for the combined analyses. In the same way, the effective error (average of the variance) instead of RCBD error mean square was used as a denominator in the *F*-test when relative efficiency of lattice designs was greater than 105% compared with RCBD. Adjusted or unadjusted means (depending on efficiencies) from each location were used to perform a combined analysis of variance using the PROC GLM procedure from SAS. The data set was analyzed as a RCBD where locations were considered as the replications. The pooled error mean square was calculated as the average of the sum of squares of the residual variances from each location divided by the total degrees of freedom and the number of replications within each location. Components of variance and broad-sense heritability were calculated in order to determine the proportion of variation due to genetic effects. Estimates were obtained based on the expected mean squares for this design. Fisher protected least significant differences (FLSD) were used to compare among genotype means at  $P \leq 0.05$ .

### Results

Table 1 shows data generated from hybrids between GEM-derived materials and a Holden Foundation Seed tester. Table 2 shows data generated from hybrids between GEM-derived materials and a Syngenta Iodent-derived Bt tester. It is important to note that there are not many choices for early maturing industry testers.

Table 1. Means combined over six North Dakota environments of six traits for 81 entries sorted by yield for GEM-derived maize hybrids.

GEM Pedigree	Hybrid	Grain Yield bu/A	Grain Moisture %	Root Ldg %	Stalk Ldg %	Test Weight lb/bu	Emergence %
	TR3621Bt X TR1017Bt	<b>173.86</b>	19.17	0.00	3.37	<b>59.24</b>	0.64
	LH176 X ND2002	<b>165.74</b>	19.72	<b>0.88</b>	3.79	56.62	0.70
[(GEM21xND2000)XND2000]-9	LH176XND07-209	<b>164.98</b>	20.34	0.00	0.92	55.77	0.65
[(GEM21xND2000)XND2000]-60	LH176XND07-260	<b>162.19</b>	19.92	<b>0.74</b>	1.86	56.88	0.65
[(GEM21xND2000)XND2000]-28	LH176XND07-228	<b>159.49</b>	20.00	0.00	1.49	56.86	<b>0.75</b>
[(GEM21xND2000)XND2000]-26	ND07-226XLH176	<b>159.33</b>	20.17	0.00	<b>7.28</b>	<b>58.03</b>	0.61
[(GEM21xND2000)XND2000]-7	LH176XND07-207	<b>155.73</b>	20.67	0.00	1.78	55.88	0.63
[(GEM21xND2000)XND2000]-52	LH176XND07-252	<b>155.72</b>	<b>23.80</b>	0.00	<b>5.47</b>	<b>53.59</b>	0.64
[(GEM21xND2000)XND2000]-7	ND07-207XLH176	<b>152.06</b>	<b>21.00</b>	<b>1.63</b>	<b>5.80</b>	55.18	0.65

	<b>TR3026 Bt X TR1957</b>	<b>151.77</b>	20.88	0.00	0.82	57.30	0.70
[(GEM21xND2000)XND2000]-10	<b>ND07-210XLH176</b>	<b>151.66</b>	19.73	<b>0.48</b>	3.78	55.84	0.68
[(GEM21xND2000)XND2000]-55	LH176XND07-255	149.89	19.21	<b>2.61</b>	2.02	56.65	0.64
[(GEM21xND2000)XND2000]-44	LH176XND07-244	149.52	<b>21.46</b>	<b>1.19</b>	0.48	<b>54.53</b>	0.62
[(GEM21xND2000)XND2000]-49	LH176XND07-249	149.32	19.95	0.00	2.77	56.46	0.64
[(GEM21xND2000)XND2000]-5	LH176XND07-205	148.99	19.81	0.00	<b>4.65</b>	55.70	0.63
[(GEM21xND2000)XND2000]-36	LH176XND07-236	148.22	19.83	0.00	3.47	56.41	0.61
[(GEM21xND2000)XND2000]-41	LH176XND07-241	147.97	<b>21.12</b>	0.00	<b>5.11</b>	55.55	0.65
	<b>Pioneer 39D82</b>	146.81	<b>18.14</b>	0.00	2.21	56.12	<b>0.56</b>
[(GEM21xND2000)XND2000]-56	LH176XND07-256	146.65	<b>19.06</b>	0.00	<b>6.53</b>	<b>57.99</b>	0.67
[(GEM21xND2000)XND2000]-18	LH176XND07-218	146.55	20.40	0.00	3.28	56.56	0.62
[(GEM21xND2000)XND2000]-57	LH176XND07-257	146.50	19.62	0.00	4.34	55.21	0.65
[(GEM21xND2000)XND2000]-10	LH176XND07-210	146.09	<b>21.67</b>	0.00	2.81	56.39	0.65
	<b>TR3621Bt X TR3273</b>	145.11	20.84	0.00	2.44	<b>58.21</b>	0.65
[(GEM21xND2000)XND2000]-54	LH176XND07-254	144.21	19.39	<b>1.19</b>	3.36	57.06	0.65
[(GEM21xND2000)XND2000]-35	LH176XND07-235	143.90	20.79	0.00	3.35	57.10	0.68
[(GEM21xND2000)XND2000]-34	LH176XND07-234	143.88	20.80	<b>2.63</b>	4.04	55.75	0.70
[(GEM21xND2000)XND2000]-45	LH176XND07-245	142.99	19.37	0.00	<b>6.72</b>	57.49	0.61
[(GEM21xND2000)XND2000]-50	LH176XND07-250	142.64	19.19	<b>2.38</b>	<b>5.81</b>	56.35	0.63
[(GEM21xND2000)XND2000]-48	LH176XND07-248	142.50	20.35	<b>0.36</b>	0.49	55.34	0.64
[(GEM21xND2000)XND2000]-43	LH176XND07-243	142.41	<b>21.02</b>	0.00	3.62	56.28	0.60
[(GEM21xND2000)XND2000]-45	ND07-245XLH176	141.95	19.46	<b>1.91</b>	<b>6.97</b>	57.50	0.62
[(GEM21xND2000)XND2000]-17	LH176XND07-217	141.68	<b>18.97</b>	0.00	<b>8.19</b>	57.37	0.66
[(GEM21xND2000)XND2000]-16	LH176XND07-216	141.64	20.48	<b>0.45</b>	1.84	55.97	<b>0.57</b>
[(GEM21xND2000)XND2000]-26	LH176XND07-226	141.63	20.32	0.00	2.95	56.23	0.64
[(GEM21xND2000)XND2000]-46	LH176XND07-246	140.84	19.61	<b>0.48</b>	3.70	55.62	0.68
[(GEM21xND2000)XND2000]-22	LH176XND07-222	140.56	19.40	0.00	<b>5.09</b>	56.36	0.62
[(GEM21xND2000)XND2000]-58	LH176XND07-258	140.46	20.72	0.00	<b>4.96</b>	56.50	0.61
[(GEM21xND2000)XND2000]-29	LH176XND07-229	140.36	<b>21.78</b>	0.00	2.27	<b>53.93</b>	0.59
[(GEM21xND2000)XND2000]-4	LH176XND07-204	139.80	<b>22.08</b>	<b>1.67</b>	<b>5.35</b>	55.10	0.63
[(GEM21xND2000)XND2000]-39	LH176XND07-239	138.43	19.82	0.00	<b>5.46</b>	55.27	0.67
	<b>TR2040 X TR1957</b>	138.30	<b>18.68</b>	0.00	3.32	57.48	0.65
	<b>LH176 x ND2000</b>	138.29	<b>18.67</b>	0.00	1.34	57.09	0.62
[(GEM21xND2000)XND2000]-20	LH176XND07-220	138.24	19.45	0.00	2.77	55.52	0.67
[(GEM21xND2000)XND2000]-59	LH176XND07-259	136.99	20.13	0.00	<b>4.88</b>	56.11	0.70
[(GEM21xND2000)XND2000]-48	ND07-248XLH176	136.56	20.77	0.00	2.25	55.95	0.67
[(GEM21xND2000)XND2000]-33	LH176XND07-233	136.54	20.21	0.00	4.15	56.35	0.59
[(GEM21xND2000)XND2000]-47	LH176XND07-247	136.39	20.12	0.00	3.68	55.84	0.64
[(GEM21xND2000)XND2000]-8	LH176XND07-208	136.33	19.88	0.00	<b>6.36</b>	55.83	0.59
[(GEM21xND2000)XND2000]-40	<b>LH176XND07-240</b>	134.55	19.42	<b>0.54</b>	<b>5.17</b>	56.33	0.62
[(GEM21xND2000)XND2000]-1	LH176XND07-201	134.33	19.70	0.00	<b>5.22</b>	56.00	<b>0.58</b>
[(GEM21xND2000)XND2000]-47	ND07-247XLH176	134.04	20.05	0.00	2.45	56.42	0.68
[(GEM21xND2000)XND2000]-32	LH176XND07-232	132.92	19.60	0.00	0.97	56.44	<b>0.58</b>
[(GEM21xND2000)XND2000]-15	LH176XND07-215	132.58	19.71	0.00	3.94	56.26	0.67
[(GEM21xND2000)XND2000]-21	LH176XND07-221	132.19	20.36	<b>0.44</b>	2.14	56.18	0.67
[(GEM21xND2000)XND2000]-14	LH176XND07-214	132.17	19.64	0.00	<b>6.21</b>	56.64	0.68
	LH176XND07-203	132.13	19.53	0.00	1.99	56.19	0.63
[(GEM21xND2000)XND2000]-27	ND07-227XLH176	131.06	<b>19.05</b>	0.00	<b>7.83</b>	55.91	<b>0.52</b>
[(GEM21xND2000)XND2000]-37	LH176XND07-237	130.39	19.29	0.00	3.54	<b>57.88</b>	0.65
[(GEM21xND2000)XND2000]-16	ND07-216XLH176	130.30	19.67	0.00	2.00	55.99	0.66

[(GEM21xND2000)XND2000]-14	ND07-214XLH176	130.28	20.30	0.00	2.78	<b>54.93</b>	0.69
[(GEM21xND2000)XND2000]-38	LH176XND07-238	129.65	19.80	0.00	3.93	57.09	0.63
[(GEM21xND2000)XND2000]-6	LH176XND07-206	129.36	20.08	0.00	3.14	56.31	0.69
[(GEM21xND2000)XND2000]-24	LH176XND07-224	128.95	19.33	<b>0.43</b>	<b>4.56</b>	56.65	0.68
[(GEM21xND2000)XND2000]-20	ND07-220XLH176	128.54	20.52	0.00	<b>7.73</b>	55.67	<b>0.58</b>
[(GEM21xND2000)XND2000]-2	LH176XND07-202	128.44	20.92	0.00	0.82	55.36	0.60
[(GEM21xND2000)XND2000]-19	ND07-219XLH176	127.36	20.67	0.00	3.28	55.92	0.60
[(GEM21xND2000)XND2000]-34	ND07-234XLH176	126.28	<b>21.35</b>	<b>0.57</b>	4.24	55.05	0.67
[(GEM21xND2000)XND2000]-31	LH176XND07-231	126.23	<b>19.08</b>	0.00	4.17	<b>57.80</b>	0.67
[(GEM21xND2000)XND2000]-30	LH176XND07-230	125.75	<b>21.59</b>	0.00	<b>4.65</b>	55.96	0.61
[(GEM21xND2000)XND2000]-19	LH176XND07-219	125.12	19.90	0.00	1.13	55.88	0.66
[(GEM21xND2000)XND2000]-53	LH176XND07-253	124.74	<b>18.93</b>	0.00	<b>4.66</b>	56.78	0.68
[(GEM21xND2000)XND2000]-42	LH176XND07-242	123.93	<b>18.98</b>	0.00	<b>6.20</b>	56.67	0.65
[(GEM21xND2000)XND2000]-25	LH176XND07-225	123.20	<b>21.14</b>	0.00	2.46	56.45	0.65
[(GEM21xND2000)XND2000]-12	LH176XND07-212	121.69	<b>19.03</b>	0.00	2.99	57.25	0.68
[(GEM21xND2000)XND2000]-13	LH176XND07-213	121.67	<b>18.93</b>	0.00	1.38	56.66	0.65
[(GEM21xND2000)XND2000]-17	ND07-217XLH176	119.34	19.79	0.00	2.60	56.41	0.60
[(GEM21xND2000)XND2000]-51	LH176XND07-251	119.28	20.93	<b>0.48</b>	3.43	<b>51.97</b>	0.67
[(GEM21xND2000)XND2000]-11	LH176XND07-211	117.88	20.85	0.00	<b>7.20</b>	56.78	0.64
[(GEM21xND2000)XND2000]-23	LH176XND07-223	117.27	<b>18.80</b>	<b>2.78</b>	3.15	56.19	0.68
	<b>LH176 X ND278</b>	110.67	<b>18.89</b>	0.00	1.88	55.15	<b>0.57</b>
	<b>ND2000 X LH298</b>	93.88	20.36	0.00	<b>9.97</b>	57.04	0.66
<b>Experiment</b>	<b>Mean</b>	138.12	20.05	0.29	3.79	56.25	0.64
	<b>CV (%)</b>	10.79	4.89	359.79	83.28	2.18	9.28
	<b>LSD(0.05)</b>	22.21	3.34	1.27	5.19	1.39	0.11
<b>Check (Top Five)</b>	<b>Mean</b>	153.96	19.31	0.18	3.03	57.53	0.64

The average plant population for both trials was 82300 plant ha<sup>-1</sup>. Preliminary data showed several experimental GEM-Derived (25%, 50% Originally Exotic) with 75% ND2000 had better grain yield performance than popular industry hybrids at similar grain moisture at harvest. Average yield of these early generation experiments was even similar to average of state performance trials. At least 15 GEM-derived lines showed over 101% of check mean yield and test weight and will be advanced to second year testing. This is not new. Inbred lines with 25 to 50% non-Corn Belt germplasm had combining abilities for grain yield greater than the 100% Corn Belt inbred lines (Griffing and Lindstrom, 1956). Also, exotic populations carry more genetic diversity (Goodman, 1965). Table 1 included one irrigated location.

Table 2. Means combined over six North Dakota environments of five traits for 64 entries sorted by yield for GEM-derived maize hybrids.

GEM Pedigree	Hybrid	Grain Yield bu/A	Grain Moisture %	Root Ldg %	Stalk Ldg %	Test Weight lb/bu
	<b>NP2123BtXND2000</b>	<b>136.34</b>	<b>11.96</b>	29.62	0.00	61.18
[(GEM21xND2000)XND2000]-43	NP2123BtXND07-243	<b>129.42</b>	<b>16.09</b>	14.41	<b>3.14</b>	60.68
	<b>Pioneer 39D82</b>	<b>124.25</b>	<b>12.66</b>	<b>3.12</b>	0.00	<b>58.47</b>
[(GEM21xND2000)XND2000]-41	<b>NP2123BtXND07-241</b>	<b>123.19</b>	<b>16.21</b>	21.17	0.74	60.09
[(GEM21xND2000)XND2000]-9	<b>NP2123BtXND07-209</b>	<b>117.12</b>	<b>13.11</b>	16.17	0.00	61.35
[(GEM21xND2000)XND2000]-3	<b>NP2123BtXND07-203</b>	<b>116.68</b>	15.18	21.79	0.44	61.60

[(GEM21xND2000)XND2000]-20	<b>NP2123BtXND07-220</b>	<b>115.55</b>	<b>13.60</b>	23.49	0.00	<b>59.59</b>
[(GEM21xND2000)XND2000]-14	NP2123BtXND07-214	114.81	14.66	15.05	<b>1.74</b>	60.51
[(GEM21xND2000)XND2000]-19	NP2123BtXND07-219	114.27	15.42	28.70	0.00	60.44
[(GEM21xND2000)XND2000]-60	<b>NP2123BtXND07-260</b>	114.25	<b>15.93</b>	22.14	0.00	60.47
[(GEM21xND2000)XND2000]-24	NP2123BtXND07-224	113.80	14.20	19.76	0.00	60.97
[(GEM21xND2000)XND2000]-17	NP2123BtXND07-217	113.69	<b>15.98</b>	22.01	0.00	61.64
[(GEM21xND2000)XND2000]-12	NP2123BtXND07-212	113.68	13.71	18.16	<b>2.53</b>	<b>61.92</b>
	<b>ND278 X NP2123Bt</b>	112.99	<b>15.83</b>	24.98	<b>2.08</b>	60.58
[(GEM21xND2000)XND2000]-25	NP2123BtXND07-225	112.09	15.52	<b>6.09</b>	0.00	61.28
[(GEM21xND2000)XND2000]-28	NP2123BtXND07-228	111.94	<b>13.25</b>	14.45	0.33	61.35
[(GEM21xND2000)XND2000]-13	NP2123BtXND07-213	110.34	<b>16.23</b>	15.32	0.00	60.90
[(GEM21xND2000)XND2000]-7	NP2123BtXND07-207	109.17	14.91	25.76	0.00	59.98
[(GEM21xND2000)XND2000]-55	NP2123BtXND07-255	108.35	15.06	18.10	<b>1.96</b>	61.14
[(GEM21xND2000)XND2000]-22	NP2123BtXND07-222	108.33	<b>13.55</b>	27.04	0.00	61.46
[(GEM21xND2000)XND2000]-38	NP2123BtXND07-238	108.12	14.50	<b>9.76</b>	0.00	61.00
[(GEM21xND2000)XND2000]-52	NP2123BtXND07-252	107.57	<b>15.80</b>	29.37	0.95	60.37
[(GEM21xND2000)XND2000]-46	NP2123BtXND07-246	107.45	15.58	25.00	0.00	61.46
[(GEM21xND2000)XND2000]-11	NP2123BtXND07-211	107.25	14.20	31.56	<b>2.18</b>	61.49
[(GEM21xND2000)XND2000]-26	NP2123BtXND07-226	107.12	<b>13.61</b>	16.02	0.00	<b>62.27</b>
[(GEM21xND2000)XND2000]-4	<b>NP2123BtXND07-204</b>	106.56	15.14	20.48	<b>1.67</b>	59.77
[(GEM21xND2000)XND2000]-39	NP2123BtXND07-239	106.45	<b>13.61</b>	16.57	0.00	61.00
[(GEM21xND2000)XND2000]-10	NP2123BtXND07-210	106.44	14.78	26.38	0.00	60.47
[(GEM21xND2000)XND2000]-8	NP2123BtXND07-208	105.50	14.03	19.73	0.00	60.68
[(GEM21xND2000)XND2000]-44	NP2123BtXND07-244	105.28	<b>18.31</b>	18.44	1.39	60.30
[(GEM21xND2000)XND2000]-18	NP2123BtXND07-218	105.14	15.59	21.98	0.64	60.97
[(GEM21xND2000)XND2000]-33	NP2123BtXND07-233	104.67	15.09	23.51	0.45	61.07
[(GEM21xND2000)XND2000]-59	NP2123BtXND07-259	104.14	14.33	26.17	<b>2.36</b>	60.83
[(GEM21xND2000)XND2000]-40	NP2123BtXND07-240	103.89	13.93	23.95	0.00	60.58
[(GEM21xND2000)XND2000]-15	NP2123BtXND07-215	103.74	<b>13.34</b>	23.04	0.79	61.25
[(GEM21xND2000)XND2000]-29	NP2123BtXND07-229	103.51	15.71	27.73	0.00	60.47
[(GEM21xND2000)XND2000]-37	NP2123BtXND07-237	102.79	14.31	23.43	0.46	60.65
[(GEM21xND2000)XND2000]-35	NP2123BtXND07-235	102.60	15.65	20.61	0.00	60.76
	<b>ND2000 X TR4615</b>	101.11	14.51	12.82	1.43	60.30
[(GEM21xND2000)XND2000]-58	NP2123BtXND07-258	101.10	15.01	25.49	0.00	61.49
[(GEM21xND2000)XND2000]-16	NP2123BtXND07-216	100.31	14.97	13.83	0.00	60.33
[(GEM21xND2000)XND2000]-50	NP2123BtXND07-250	99.41	<b>12.87</b>	27.27	0.00	<b>61.88</b>
[(GEM21xND2000)XND2000]-45	NP2123BtXND07-245	99.38	14.81	25.82	0.00	<b>61.71</b>
[(GEM21xND2000)XND2000]-48	NP2123BtXND07-248	98.94	13.74	27.38	0.00	60.90
[(GEM21xND2000)XND2000]-34	NP2123BtXND07-234	98.60	<b>16.57</b>	26.29	0.00	61.04
[(GEM21xND2000)XND2000]-23	NP2123BtXND07-223	98.25	<b>12.98</b>	27.30	0.00	61.11
[(GEM21xND2000)XND2000]-32	NP2123BtXND07-232	97.41	15.04	16.10	1.43	61.07
[(GEM21xND2000)XND2000]-57	NP2123BtXND07-257	97.36	14.35	25.42	0.00	60.26
[(GEM21xND2000)XND2000]-47	NP2123BtXND07-247	97.13	14.20	21.60	<b>2.74</b>	61.28
[(GEM21xND2000)XND2000]-6	NP2123BtXND07-206	96.62	14.85	17.70	0.00	<b>62.37</b>
[(GEM21xND2000)XND2000]-31	NP2123BtXND07-231	95.69	14.25	26.23	0.00	60.19
[(GEM21xND2000)XND2000]-2	NP2123BtXND07-202	95.54	<b>16.80</b>	14.76	<b>2.03</b>	<b>59.31</b>
[(GEM21xND2000)XND2000]-1	NP2123BtXND07-201	95.46	15.71	19.62	1.48	60.90
[(GEM21xND2000)XND2000]-51	NP2123BtXND07-251	94.65	<b>16.17</b>	21.80	0.00	60.09
[(GEM21xND2000)XND2000]-54	NP2123BtXND07-254	94.63	14.29	27.55	0.90	<b>61.92</b>
[(GEM21xND2000)XND2000]-21	NP2123BtXND07-221	94.50	14.87	<b>9.77</b>	0.00	59.84

[(GEM21xND2000)XND2000]-49	NP2123BtXND07-249	94.40	13.82	18.34	0.00	61.49
[(GEM21xND2000)XND2000]-36	NP2123BtXND07-236	93.97	13.92	15.35	1.11	60.76
[(GEM21xND2000)XND2000]-53	NP2123BtXND07-253	93.45	13.91	24.04	0.41	61.53
[(GEM21xND2000)XND2000]-30	NP2123BtXND07-230	91.00	<b>16.60</b>	24.48	0.93	<b>59.52</b>
[(GEM21xND2000)XND2000]-56	NP2123BtXND07-256	90.47	14.03	19.77	0.00	61.28
	ND07-227XNP2123Bt	90.19	15.64	26.13	<b>2.27</b>	61.00
[(GEM21xND2000)XND2000]-42	NP2123BtXND07-242	87.06	14.80	16.24	0.48	61.56
[(GEM21xND2000)XND2000]-5	NP2123BtXND07-205	80.20	14.88	23.18	0.56	60.54
<b>Experiment</b>	<b>Mean</b>	104.45	14.77	21.02	0.62	60.85
	<b>CV (%)</b>	15.68	8.81	47.5	263.11	0.89
	<b>LSD(0.05)</b>	21.34	4.22	16.1	2.59	1.08
<b>Check</b>	<b>Mean</b>	118.67	13.73	17.64	0.88	60.13

Table 2 showed GEM-derived Stiff Stalk lines did not have a good combining ability with an Iodent tester across dry land ND locations or at least as good as with unrelated LH82 derived testers.

### Future Work

The nutritional evaluation and analyses of hybrids will be completed. Depending on funding we will extend this type of work to the other eight GEM-derived populations that are in need of extensive testing. In addition, we plan to increase the number of industry testers on pedigrees that have been advanced based on benchmarks related to commercial popular checks. Benchmarks will increase to 105% of check mean yield at second year testing in 2008. Release decisions will follow. We also plan to develop new early-maturing GEM populations including top lines.

### Summary of Accomplishments

This is the first research devoted to germplasm enhancement incorporating tropical and late-temperate genetic materials with <90RM. As a consequence of long-term efforts we currently have early maturing GEM materials adapted to the northern U.S. Corn Belt which are competitive products for industry use. Winter nurseries with three generations per year could provide new 90RM lines in 4 years.