Evaluation of Iowa Stiff Stalk Synthetic for Resistance to Gray Leaf Spot

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ABSTRACT

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Gray leaf spot (GLS) of maize (*Zea mays*), caused by *Cercospora zeae-maydis,* has become an increasing disease problem in the United States. Resistance to this pathogen is generally higher in inbred lines of Lancaster origin compared to lines derived from Iowa Stiff Stalk Synthetic (BSSS). This study was conducted to determine whether recurrent selection for yield had altered the level of GLS resistance in BSSS and to identify BSSS(R)C11 S_1 lines that combine GLS resistance with high yield. The distribution of GLS ratings for S_1 lines derived from BSSSC0 and BSSS(R)C11 were very similar, indicating that selection for yield had not altered GLS resistance levels. Although the mean rating for both cycles was a susceptible 7 (1 = resistant, 9 = susceptible), S_1 lines with intermediate levels of resistance (4–6) were identified. The 250 BSSS(R)C11 S_1 lines were crossed to LH51, and the testcrosses were evaluated for yield and agronomic performance. S_1 lines were identified which combine intermediate levels of GLS resistance with above-average standability and yield. These S_1 lines will be recombined to develop an Iowa Stiff Stalk Synthetic population adapted to eastern maize growing conditions.

Additional keywords: maize breeding

Gray leaf spot (GLS) of maize, *Zea mays* L., caused by *Cercospora zeae-maydis* Tehon & E.Y. Daniels (12), has become an increasing problem in the United States (3,6,10). The increased severity and spread of GLS has been primarily associated with no-till, continuous maize-production practices which provide an overwintering site for the pathogen and a source of early inoculum the following season (3,8). Early infection may result in substantial yield losses and the predisposition of plants to secondary plant pathogens (9,11).

The adverse economical and ecological effects of moldboard tillage and commercial fungicides make genetic resistance the best strategy for GLS control. Studies have been conducted to determine the mode of inheritance of genetic resistance. Manh (7) determined, by generation mean analysis, that inheritance of resistance in the inbred Va14 is predominantly quantitative and possibly additive. Thompson et al (13) indicated that additive effects are of major importance and that inbred evaluation per se should provide a good estimate of hybrid performance for GLS resistance. Similar results have also been reported by Elwinger et al (2), Huff et al (5), and Ulrich et al (14).

Although GLS resistance has been reported in some inbreds, until recently very few commercial hybrids or elite inbreds have shown resistance to this pathogen (1,4,11). GLS resistance is generally higher in inbreds of Lancaster origin than in lines developed from Iowa Stiff Stalk Synthetic (BSSS) (14). For this reason, research was initiated to determine whether 11 cycles of recurrent selection for yield in BSSS had altered the susceptibility of this synthetic to GLS. An additional objective was to identify S_1 lines of BSSS(R)C11 that combined GLS resistance with adequate yield, standability, and grain moisture.

MATERIALS AND METHODS

One hundred random, self-pollinated ears were harvested from both BSSSC0 and BSSS(R)C11 at Newark, Delaware, in the summer of 1988. In a separate planting of BSSS(R)C11, an additional 1,000 plants were self-pollinated; and the best 250 S_1 ears were selected at maturity based on early pollination date, standability, root lodging, and general plant appearance. Two separate experiments were conducted on the above lines in the summer of 1989.

Experiment 1: S_1 line evaluation for GLS resistance. In experiment 1, the 450 S_1 lines (100 random C0, 100 random

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C11, and 250 selected C11) were evaluated for GLS resistance. Plot size and test sites were as follows: 2.8-m single-row plots at Millersville and Bainbridge in Pennsylvania, and Marion in North Carolina; and 5.8-m single-row plots at Chambersburg, Pennsylvania. Row spacing was approximately 0.75 m at all locations, with all plots being thinned to 60,000 plants per hectare. All four sites had been in continuous corn production for several years prior to experiment 1 and had histories of GLS development. Reduced tillage practices were used at all sites except Marion, where conventional tillage was employed. Plants at Marion were inoculated at the midwhorl stage with sorghum grains that were colonized with a local isolate of *C. zeae-maydis*. This inoculum was placed in the whorl to initiate disease development. All plots in experiment 1 were rated on a 1–9 scale, with 1 being the most resistant.

The experimental design for experiment 1 was an incomplete block with locations serving as individual replicates of the experiment. Each location (replication) had 10 sets (blocks), with each set including 10 random BSSSC0 S_1 lines, 10 random BSSS(R)C11 lines, 25 selected BSSS(R)C11 lines, and three inbred checks (LH191, LH51, and B73Ht). The composition of the individual sets was constant across locations. The resistant and susceptible inbred checks were used to monitor disease progression but were not included in the analysis.

To determine the variation within the three BSSS groups, degrees of freedom were partitioned into the variation among S_1 lines for the three groups. In addition, degrees of freedom were partitioned into two comparisons to determine whether the mean GLS rating for BSSSC0 was significantly different from each of the two BSSS(R)C11 groups.

Experiment 2: Evaluation of BSSS(R) C11 select testcrosses for yield and agronomic performance. Experiment 2 evaluated the yield and agronomic performance of the 250 selected BSSS(R) C11 S_1 lines in hybrid combination. Hybrids were formed by planting 12 kernels of each S_1 ear in an isolation block in Homestead, Florida. All S_1 plants were detasseled, with LH51 used as the male tester. In early January 1989, five ears from each S_1 row were harvested, shelled, and bulked to form the 250 BSSS(R)C11 testcrosses.

Entries for experiment 2 were planted in the spring of 1989 at four locations: Georgetown, Little Creek, and Odessa in Delaware; and Queenstown, Maryland. All locations utilized two-row plots 5.8 m in length with 0.75-m spacings between rows. Plots were overplanted and thinned to 59,000 plants per hectare at Queenstown, 64,000 plants per hectare at Little Creek, and 69,000 plants per hectare at the remaining two locations. All sites received fertilizer and herbicide applications based on University of Delaware soil-test results and weed-control recommendations. At Georgetown, a solid-set irrigation system was used to ensure a minimum of 3.8 cm of water per week including rainfall. The remaining three sites were not irrigated. All plots were machine harvested and yield adjusted to 15.5% moisture. Data were collected on final stand counts, grain weight, grain moisture, and the number of plants per plot that stalk lodged, root lodged, and dropped ears.

The experimental design for experiment 2 was a 16 × 16 simple lattice with two replications at each location. Each replication consisted of 250 S_1 hybrids plus six commercial checks (Agway 788, Agway 838, Hytest 712, Cargill 7877, Cargill 7993, and Pioneer 3343).

RESULTS AND DISCUSSION

Experiment 1: S_1 line evaluations for GLS resistance. Environmental conditions for experiment 1 were very favorable for disease development, i.e., high relative humidity, prolonged morning dews, and abundant rainfall. At Millersville, mature lesions were observed in mid-June. Unfortunately, the plants at this location were severely infected by *Bipolaris zeicola* (G.L. Stout) Shoemaker; therefore, this location was not used in the combined analyses. Disease symptoms were observed in mid-July at both Marion and Bainbridge. Plants at Marion were rated on 15 August and 1 September, and at Bainbridge they were rated on 10 August and 6 September. Disease development at Chambersburg was later, with initial disease symptoms observed in mid-August. Only one rating was taken at this location (7 September). Because of the limited number of locations evaluated for the early rating, only data from the later ratings are presented.

The frequency distributions of second GLS ratings for the three groups of S_1 lines were very similar (Fig. 1). The mean rating for BSSSC0 was 7.0, which was similar to the BSSS(R)C11 populations, which rated 7.1. The range of ratings for BSSSC0 was from an intermediate 4.5 to a susceptible 9.0. The range for the BSSS(R)C11 groups was similar, from an intermediate 5.0 to a susceptible 9.0. Means of LH51, LH191, and B73Ht were 5.3, 5.7, and 8.7, respectively.

The pooled analysis of variance (Table 1) for the GLS disease rating indicated no significant difference due to location. The location by set interaction was highly significant ($P = 0.001$). This occurred because some sets performed differently across locations. Highly significant variation among S_1 lines within each set reflects the heterogeneity expected between S_0 plants in the BSSS synthetic. Both comparisons, BSSSC0 vs. BSSS(R)C11 random and BSSSC0 vs. BSSS(R)C11 select, were not significant, indicating that selection for yield in BSSS had not changed GLS resistance.

An additional objective of experiment 1 was to identify S_1 lines from the BSSS(R)C11 groups that had good GLS ratings. Elite inbreds currently available from BSSS generally have low levels of resistance to GLS (14). Several S_1 lines were identified that performed as well as or better than the two resistant checks. The mean GLS rating for this group was an intermediate 5.0 compared to a susceptible rating of 7.1 for all BSSS(R)C11 S_1 lines. In addition, general field observations indicated that several of these lines had desirable agronomic characteristics, i.e., good stalk quality and

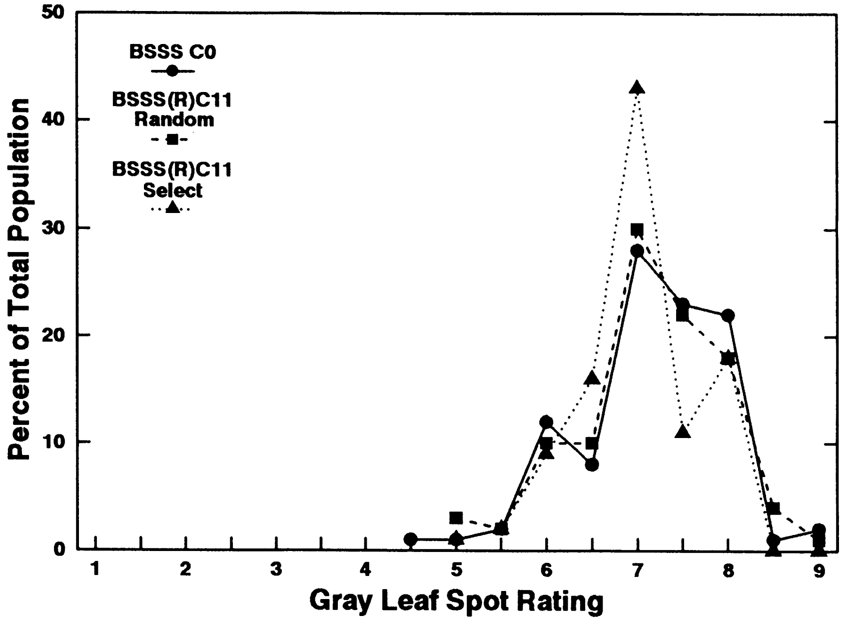

Fig. 1. Distribution of mean gray leaf spot ratings for 100 random BSSSC0, 100 random BSSS(R)C11, and 250 select BSSS(R)C11 S_1 lines evaluated at three locations, 1989.

ear development, and stay green.

Experiment 2: Evaluation of BSSS(R)C11 select testcrosses for yield and agronomic performance. Experiment 2 measured the yield and agronomic performance of the 250 BSSS(R)C11 select testcrosses. Significant differences for yield, percentage of stalk lodging, and percentage of grain moisture at harvest existed among locations (Tables 2 and 3). Differences in yield and percentage of stalk lodging were primarily a result of conditions at some locations that were not optimal for maize growth, i.e., high rainfall, below-average temperatures, a limited number of cloud-free days during the grain-filling period, and high levels of European corn borer (*Ostrinia nubilalis* Hübner).

Significant testcross differences were observed for yield, percentage of grain moisture at harvest, and percentage of stalk lodging (Table 3). Significant variation among testcrosses was expected, because each S_1 line was derived from a different S_0 plant in the heterogeneous BSSS(R)C11 population. The lack of significant testcross differences for dropped ears and percentage of root lodging was because of the low occurrence of these traits during the 1989 growing season. For all traits, the treatment by location interaction was not significant, indicating similar ranking of testcrosses across locations.

Testcross differences resulted in a wide distribution of measurements for yield, percentage of stalk lodging, and percentage of grain moisture at harvest (Table 2). The mean yield of all BSSS(R)C11 hybrids was 7,738 kg/ha, with a range from 6,122 to 9,324 kg/ha. The mean yield of the commercial checks (9,618 kg/ha) was 1,880 kg/ha greater than the BSSS(R)C11 testcross mean. None of the BSSS(R)C11 testcrosses outyielded the commercial checks.

Table 1. Pooled analysis of variance for gray leaf spot ratings at Marion, North Carolina, and Bainbridge and Chambersburg, Pennsylvania, 1989

Source of variation	df	Mean squares
Location	2	0.08
Sets	9	4.63***[a]
Location × set	18	2.14***
Entries/set	440	1.70***
Among BSSSC0	90	1.89***
Among BSSS(R)C11 random	90	1.54***
Among BSSS(R)C11 select	240	1.58***
BSSSC0 vs. BSSS(R)C11 random	1	0.34
BSSSC0 vs. BSSS(R)C11 select	1	1.82
Location × entry/set	859	0.65
Total	1,328	

[a] *** = Significant at the 0.001 level.

Table 2. Mean yield, percentages of stalk lodging, grain moisture at harvest, and root lodging, and number of dropped ears for 250 BSSS(R)C11 select testcrosses and six commercial checks grown at four locations in 1989

Location	Yield (kg/ha)	Stalk lodging (%)	Grain moisture (%)	Root lodging (%)	Dropped ears (no.)
Odessa, DE	6,799	19.2	19.2	2.5	0.5
Georgetown, DE	7,794	20.3	21.5	6.7	0.1
Little Creek, DE	7,903	32.9	29.2	0.8	0.7
Queenstown, MD	8,630	31.1	23.0	0.8	1.3
Mean	7,782	25.9	23.2	2.7	0.7
CV	11	34.9	6.0	173.7	209.3
LSD (0.05)	1,028	9.6	1.7	NS[a]	NS

[a] Not significant.

Table 3. Pooled analysis of variance across locations for yield, percentages of stalk lodging, grain moisture at harvest, and root lodging, and number of dropped ears for 250 BSSS(R)C11 select testcrosses and six commercial checks

		Mean squares				
Source of variation	df	Yield (kg/ha)	Stalk lodging (%)	Grain moisture (%)	Root lodging (%)	Dropped ears (no.)
Locations	3	289,973,760***[a]	25,883.9***	1,104,460.2***	3,978.2	135.5
Replicates/loc	4	24,889,520***	1,543.9***	9,440.2***	324.1	2.2
Treatments	255	2,903,423***	295.3***	14.5**	44.0	2.0
Trt. × location	765	1,100,864	97.5	3.1	28.5	1.8
Pooled error	900	852,113	81.9	1.9	21.9	1.8
Total	2,047					

[a] *** = Significant at the 0.001 level; ** = significant at the 0.01 level.

The percentage of stalk lodging for BSSS(R)C11 testcrosses across locations ranged from 10 to 42.5% with a mean of 26.3%. The percentage of stalk lodging for the commercial checks ranged from 6.9 to 15.6% with a mean of 9.9%. The choice of a different inbred tester may improve the stalk-lodging performance of the testcrosses. Although LH51 is a commonly used inbred in hybrid development, other inbred testers may decrease the amount of stalk lodging.

The best 10 S_1 (elite group) lines were selected based on independent culling for above-average yield, standability, and GLS resistance obtained from data in experiments 1 and 2. The mean yield for the elite group was 8,439 kg/ha. This was 701 kg/ha greater than the mean yield of all BSSS(R)C11 hybrids, but it was 1,179 kg/ha less than the mean of the six commercial hybrids. The mean percentage of stalk lodging of the elite group was 19.3%, compared to 26.3% for all BSSS(R)C11 testcrosses and 9.9% for the commercial checks. The mean GLS rating for the elite S_1 testcrosses was 5.7, with a range from 5.3 to 6.7. The mean for all BSSS(R)C11 S_1 testcrosses was 1.4 rating units higher, at 7.1.

These results indicate that variation exists in BSSS(R)C11 for GLS resistance and important agronomic traits. S_1 lines which combine intermediate levels of GLS resistance and desirable agronomic traits will be used to initiate a recurrent selection program to adapt the BSSS synthetic to eastern growing conditions.

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