Heterotic Patterns among Open-pollinated Sweet Corn Cultivars

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ABSTRACT. Heterotic patterns in sweet corn are weakly defined. Most sweet corn inbreds are descended from three open-pollinated cultivars: 'Golden Bantam', 'Stowell's Evergreen', and 'Country Gentleman'. Heterotic and phylogenetic relationships among these three cultivars and others are not clearly known. This investigation was designed to investigate the heterotic patterns among some historically important open-pollinated sweet corn cultivars: 'Country Gentleman', 'Golden Bantam', 'Lindsey Meyer Blue', 'Stowell's Evergreen', 'Howling Mob', and 'Pease Crosby'. The 15 possible hybrids from the diallel cross plus the 6 parents were grown in midspring and late summer plantings. Heterosis and combining ability effects were estimated for 13 traits. Hybrid $\times$ planting date interactions were significant for most of the main traits, hence, planting dates were analyzed separately. Average midparent heterosis for grain yield was 29.17% in the first planting date and 57.04% in the second planting. Midparent heterosis for yield and plant height were highest for hybrids with 'Country Gentleman' as a parent. 'Stowell's Evergreen' when crossed to 'Pease Crosby', 'Lindsey Meyer', and 'Golden Bantam' exhibited high heterosis. The two late-maturity cultivars 'Country Gentleman' and 'Stowell's Evergreen' had higher general combining ability than the four early-maturity cultivars for most traits. Specific combining ability was seldom significant. Yield of 'Country Gentleman' hybrids averaged over all crosses and planting dates was the highest. These data indicate a strong heterotic pattern—'Country Gentleman' $\times$ 'Pease Crosby', 'Golden Bantam', and 'Lindsey Meyer Blue'—and a weaker one—'Stowell's Evergreen' $\times$ 'Pease Crosby', 'Golden Bantam', and 'Lindsey Meyer Blue'.

Early in the history of hybrid corn, field corn breeders commonly evaluated combining ability in diallel crosses among inbreds. The discovery of heterotic patterns in field corn simplified such evaluations by reducing the number of testcrosses (Jenkins, 1978). In field corn breeding, the almost-exclusive emphasis on harvestable yield made it possible to include any new inbred, with good combining ability, in a breeding program. Sweet corn breeding has been directed toward product quality and appearance as well as yield and agronomic performance (Tracy, 1994). Many selection criteria are considered in sweet corn breeding and few germplasm sources fit the commercial standards. As a consequence, the genetic base of sweet corn breeding programs is relatively narrow and related inbreds often are crossed to make hybrids that meet the strict market requirements on quality and appearance (Tracy, 1994).

Several open-pollinated sweet corn cultivars are still publicly available. They have been characterized and the phylogenetic relationships among them have been studied (Revilla and Tracy, 1995a, 1995b). These cultivars could be useful for sweet corn breeders interested in broadening the genetic base of their breeding programs. The potential utility of these cultivars would be greatly clarified with the knowledge of their heterotic relationships. Heterotic patterns in sweet corn are weakly defined, though the main publicly available open-pollinated sweet corn cultivars, and inbreds have been characterized and classified (Gerdes and Tracy, 1994; Revilla and Tracy, 1995a, 1995b).

Most sweet corn inbreds are descended from three open-pollinated cultivars: 'Golden Bantam', 'Stowell's Evergreen', and 'Country Gentleman' (Gerdes and Tracy, 1994; Huelsen, 1954; Tracy, 1993, 1994). 'Stowell's Evergreen' was developed in 1851 from a cross between 'Menomony' soft corn (probably a Southern Dent) and an unnamed sweet corn (Tapley et al., 1934). Based on its pedigree and morphology 'Golden Bantam' is a sugary representative of the race Northern Flint (Galinat, 1971). The ancestors of 'Country Gentleman' are unknown. In 'Country Gentleman' both florets of the female spikelets develop and form kernels, resulting in crowding of the kernels on the ear and the lack of discrete rows. This is unique among North American races.

Recent studies have attempted to classify the remaining open-pollinated sweet corn cultivars. A classification of open-pollinated sweet corn based on morphology grouped 'Stowell's Evergreen' and 'Golden Bantam' with about half of the 58 cultivars in the study (Revilla and Tracy, 1995a). A similar study using isozymes as descriptors separated 'Stowell's Evergreen' and 'Golden Bantam' into distinct clusters (Revilla and Tracy, 1995b). In both studies, 'Country Gentleman' was distinct from all other cultivars (Revilla and Tracy, 1995a, 1995b). In a study using inbreds derived from these and other cultivars, Tracy (1990) observed that 'Golden Bantam' inbreds combined better with 'Country Gentleman' inbreds and 'Stowell's Evergreen' inbreds than they did with other Northern Flint type inbreds. Thus a rudimentary heterotic pattern might exist between 'Country Gentleman' inbreds and 'Golden Bantam' inbreds and 'Stowell's Evergreen' inbreds and 'Golden Bantam' inbreds (Tracy, 1990, 1994). However, the heterosis study involving inbreds is not definitive due to mixed parentage of some of the inbreds.

Heterosis in maize appears to increase with increased genetic divergence of the parents (Moll et al., 1962, 1965). Diallel crosses among corn populations have been extensively used to define heterotic patterns (Hallauer and Eberhart, 1966; Ordas, 1991; Vasal et al., 1992a, 1992b, 1993; Widstrom et al., 1992).

Our objective was to define heterotic patterns among some historically important open-pollinated sweet corn cultivars.

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Table 1. Planting date, hybrid, and planting by hybrid mean squares, and coefficients of variation for 13 traits from the analysis of variances of 15 diallelic hybrids made with 6 open-pollinated sweet corn cultivars (not including the parents), at 2 planting dates.

Trait	Mean squares			CV
	Planting date	Hybrid	Planting $\times$ hybrid	
Yield (Mg·ha ⁻¹)	269.73**	1.54*	0.44*	9.89
Plant height (cm)	834.77	2631.46**	80.79	3.61
Ear height (cm)	1463.01	2029.66**	61.64	6.35
Pollen date (d)	658.01**	75.21**	2.88**	1.17
Silking date (d)	410.70**	76.66**	3.18**	1.20
Prolificacy (n)	5.42**	0.04	0.05**	8.64
Ear length (cm)	76.00**	1.01	0.65	4.25
Ear diameter (cm)	1.75	0.92**	0.01	2.90
Number of kernel rows	1.04	44.34**	0.18	4.88
Kernels per row (n)	471.24**	6.55	6.54*	5.50
Kernel length (cm)	0.29**	0.04**	0.00	7.07
Kernel thickness (cm)	0.00	0.27**	0.07*	4.54
Kernel mass (g)	94360.21**	2482.18**	400.23**	6.29

*,** Significant at $P \leq 0.05$ or 0.01 , respectively.

Materials and Methods

Six open-pollinated sweet corn cultivars were used as parents: 'Country Gentleman', 'Golden Bantam', 'Stowell's Evergreen', and 'Lindsey Meyer Blue' from the collection maintained in the College of Agricultural and Life Sciences, Univ. of Wisconsin-Madison; 'Howling Mob' (SS IA DR G) from the Seed Saver collection (Adelman et al., 1993); and 'Pease Crosby' (PI 255983) from the North Central Plant Introduction Center, Ames, Iowa. 'Howling Mob' and 'Pease Crosby' were chosen because they were among the most important cultivars before introduction of hybrids (Galinat, 1971; Tapley et al., 1934). 'Lindsey Meyer Blue' represents the well known Black Mexican group (Revilla and Tracy, 1995a). Based on morphology and pedigrees 'Howling Mob', 'Pease Crosby', and 'Lindsey Meyer Blue' are unrelated to 'Stowell's Evergreen', 'Golden Bantam', or 'Country Gentleman' (Galinat, 1971; Gerdes et al., 1993; Revilla and Tracy, 1995a).

A diallel cross (Method II of Griffing, 1956) was made among the six cultivars, in 1993. At least 50 plants from each cultivar were used to make each cross. The 15 hybrids and 6 parents were entries in the diallel. They were planted on 16 May 1994 and 8 June 1994 at the West Madison Agricultural Research Station in a Plano silt loam (fine-silty, mixed, mesic Typic Argiudolls) soil. The two planting dates are within the range used by sweet corn producers in Wisconsin. The first planting date represented good environmental conditions for sweet corn production, while the second planting was exposed to more stress factors, typical of later plantings in the upper midwestern United States, mainly, common rust (*Puccinia sorghi* Schw.), and maize dwarf mosaic virus (MDMV) infestations, and cooler late-season growing conditions. The experimental design was a randomized complete block with four replications in each planting date. Four-row 3.5-m-long plots, with 76 cm between rows, were overplanted with 30 seeds per row and thinned to a stand of 15 plants per row in the first planting date. In the second planting date the rows were 4.1 m long and the final stand was 17 plants per row. The final population density approximated 44,500 plants/ha at both planting dates. Weeds were controlled with 2.3 L·ha⁻¹ cyanazine, 2.3 L·ha⁻¹ alachlor, and cultivation.

The following traits were recorded before harvest: days to 50% pollen shedding, days to 50% silking, degree of prolificacy (num-

ber of ears/plant), plant height (from the soil to the ligule of the leaf subtending the tassel), and ear height (from soil to the ligule of the leaf subtending the ear). After all entries had completed dry matter accumulation (black layer formation) all ears from the center two rows were harvested, husked, and weighed. Ten representative ears were drawn from each plot, weighed, and dried at 52 °C until constant weight. Ear length, ear diameter, kernel row number, number of kernels per row, kernel length, kernel width, thousand kernel mass, and total grain mass were measured. Based on gross total plot yield, percent moisture loss, and dried grain mass, yield per hectare was calculated. Yield calculation was based on dry grain production to more closely estimate physiological efficiency than would be possible from yield based on fresh ears at the normal eating stage (about 75% H₂O). Yield estimates based on dry grain also usually have a lower coefficient of variation than estimates of yield based on fresh ear mass.

Analysis of variance was performed for each of the 13 traits combined across planting dates. Entry effects were considered fixed while all other effects were random. SAS was used for combined analysis of variance (SAS, Cary, N.C.). For each planting date heterosis, combining abilities, and mean comparisons for the parents across hybrids, were computed using the program Diallel analysis and simulation (Burow and Coors, 1994). However, due to space limitations only selected traits will be discussed in detail. Spearman's rank correlation coefficient was calculated for yield at the two planting dates.

Results and Discussion

Eight of the 13 traits differed over planting dates (Table 1). Plant and ear height, ear diameter, row number, and kernel width were not affected by planting date. Hybrids differed for every trait except prolificacy, ear length, and kernels per row (Table 1). The hybrid $\times$ planting date interaction was significant for 7 of the 13 traits: pollen and silking dates, prolificacy, kernels per row, kernel width and mass, and yield (Table 1). These differences were due to changes in magnitude and ranking, thus, planting dates were analyzed separately. While there were minor differences in ranking, hybrid yields were significantly correlated ($r_s = 0.76^{**}$) across the two planting dates. Thus, the hybrid $\times$ planting date interaction minimally affected the expression of heterotic patterns. When

Table 2. Mean yield (Mg·ha⁻¹) (above the diagonal) and midparent heterosis (percent) (below the diagonal) of the 15 hybrids of the diallel cross among six open-pollinated sweet corn cultivars² (on the diagonal) grown in two environments.

	CG	GB	HM	LM	PC	SE	Mean
First planting date³							
CG	4.93	6.62	6.85	6.06	6.55	6.65	6.55
GB	45	4.22	5.87	5.59	5.07	6.87	6.00
HM	25	15	5.99	6.14	5.84	6.67	6.27
LM	37	38	24	3.89	5.25	6.45	5.90
PC	51	27	20	37	3.75	6.57	5.85
SE	21	34	11	30	34	6.02	6.64
Second planting date⁴							
CG	1.21	3.20	3.55	3.58	3.79	3.83	3.41
GB	121	1.77	2.81	2.85	2.38	3.03	2.87
HM	74	21	2.87	3.58	3.31	3.51	3.35
LM	112	45	42	2.17	2.83	3.61	3.29
PC	141	29	38	38	1.93	3.10	3.08
SE	62	49	36	62	47	2.30	3.22

²CG = Country Gentleman, GB = Golden Bantam, HM = Howling Mob, LM = Lindsey-Meyer, PC = Pease Crosby, SE = Stowell's Evergreen.

³LSD(0.05) = 0.81 for comparisons between hybrid yields. LSD(0.05) = 0.36 for comparisons between parent mean yields across hybrids. LSD(0.05) = 0.82 for comparisons between parent yields.

⁴LSD(0.05) = 0.52 for comparisons between hybrid yields. LSD(0.05) = 0.230 for comparisons between parent mean yields across hybrids. LSD(0.05) = 0.4745 for comparisons between parent yields.

planting dates were analyzed separately, hybrids were significantly different for every trait, except for kernels per row in the first planting date.

Average midparent heterosis for yield was 29.17% in the first planting date and 57.04% in the second. Both values exceed those of many field corn cultivar diallels in the literature, such as insect resistant maize populations (midparent heterosis was 22.5%) (Widstrom et al., 1993), temperate synthetic cultivars (12%) (Hallauer and Eberhart, 1966), Spanish cultivars (20.1%) (Ordas, 1991), or Caribbean populations (20%) (Moll et al., 1962). Higher midparent heterosis (76.04%) for yield has been reported after reciprocal recurrent selection in BSSS and BSCB1 synthetics (Keeratinijakal and Lamkey, 1993). An explanation for high heterosis among these sweet corn cultivars may be the great genetic distance between 'Country Gentleman' and the other cultivars (Revilla and Tracy, 1995b). The sweet corn cultivars in

this study may have been more inbred than the field corn cultivars in other studies. Midparent heterosis for yield in the second planting date was almost twice that of the first planting date, because the yields of the six open-pollinated cultivars were more depressed by the stressful conditions of the late planting than were the yields of their hybrids.

In general, both planting dates indicated similar heterotic patterns; therefore, the following discussion will be based over both planting dates, unless otherwise stated.

Midparent heterosis for yield (Table 2) was highest in hybrids made with 'Country Gentleman' x 'Golden Bantam' and 'Country Gentleman' x 'Pease Crosby' in both environments. 'Lindsey Meyer Blue' also had high heterosis with 'Country Gentleman'. 'Country Gentleman' per se yielded less than any other cultivar in the second planting date, perhaps due to MDMV infection, but the average yield of its hybrids was the highest. 'Stowell's Evergreen'

Table 3. Mean plant height (cm) (above the diagonal) and midparent heterosis (percent) (below the diagonal) of the 15 hybrids of the diallel cross among six open-pollinated sweet corn cultivars² (on the diagonal) grown in two environments.

	CG	GB	HM	LM	PC	SE	Mean
First planting date³							
CG	217.3	225.5	212.6	222.4	220.5	256.3	227.5
GB	9.0	196.7	212.3	192.4	193.1	233.4	211.3
HM	3.8	9.1	192.5	189.1	192.3	229.0	207.1
LM	15.3	5.4	4.8	168.4	183.6	223.3	202.2
PC	13.7	5.2	5.9	8.4	170.5	221.4	202.2
SE	11.3	6.1	5.1	8.4	7.0	243.4	232.7
Second planting date⁴							
CG	188.6	226.6	213.1	205.1	210.0	238.1	218.6
GB	20.4	187.9	208.3	190.3	195.3	225.6	209.2
HM	9.5	7.2	200.8	191.5	191.3	222.0	205.2
LM	15.1	7.0	3.9	167.8	178.9	216.4	196.4
PC	20.0	11.9	5.7	8.7	161.3	215.5	198.2
SE	15.4	9.5	4.5	10.4	11.8	224.1	223.5

²CG = Country Gentleman, GB = Golden Bantam, HM = Howling Mob, LM = Lindsey-Meyer, PC = Pease Crosby, SE = Stowell's Evergreen.

³LSD(0.05) = 11.9 for comparisons between hybrid plant height. LSD(0.05) = 5.3 for comparisons between parent mean plant height across hybrids. LSD(0.05) = 11.5 for comparisons between parent plant height.

⁴LSD(0.05) = 10.3 for comparisons between hybrid plant height. LSD(0.05) = 4.7 for comparisons between parent mean plant height across hybrids. LSD(0.05) = 9.9 for comparisons between parent plant height.

Table 4. Mean silk date, in days, (above the diagonal) and midparent heterosis (percent) (below the diagonal) of the 15 hybrids of the diallel cross among six open-pollinated sweet corn cultivars² (on the diagonal) grown in two environments.

	CG	GB	HM	LM	PC	SE	Mean
First planting date¹							
CG	73.8	67.3	66.0	66.3	65.8	70.5	67.2
GB	2.2	63.8	63.0	62.3	62.3	65.5	64.1
HM	3.3	0.4	62.8	61.5	60.8	65.0	63.3
LM	3.3	2.0	2.4	63.3	61.0	64.5	63.1
PC	3.1	1.0	2.6	2.6	62.0	64.0	62.8
SE	1.7	1.9	1.9	3.0	2.8	69.8	65.9
Second planting date^x							
CG	75.0	63.5	62.0	63.0	60.5	70.8	64.0
GB	5.4	59.3	58.3	58.5	58.0	62.5	60.2
HM	7.6	1.7	59.3	58.0	57.0	61.8	59.4
LM	5.4	0.4	1.3	58.3	56.3	60.0	59.2
PC	8.2	0.0	1.7	2.2	56.8	60.0	58.4
SE	2.1	2.9	4.1	6.1	5.0	69.5	63.0

²CG = Country Gentleman, GB = Golden Bantam, HM = Howling Mob, LM = Lindsey-Meyer, PC = Pease Crosby, SE = Stowell's Evergreen.

¹LSD(0.05) = 1.1 for comparisons between hybrid silking dates. LSD(0.05) = 0.5 for comparisons between parent mean silking date across hybrids. LSD(0.05) = 1.1 for comparisons between parent silking date.

^xLSD(0.05) = 1.1 for comparisons between hybrid silking dates. LSD(0.05) = 0.5 for comparisons between parent mean silking date across hybrids. LSD(0.05) = 1.1 for comparisons between parent silking date.

had relatively high heterosis with 'Golden Bantam', 'Lindsey Meyer Blue', and 'Pease Crosby', especially in the second planting.

Crosses that exhibited low heterosis for yield included 'Golden Bantam' x 'Pease Crosby', and 'Lindsey Meyer Blue' x 'Pease Crosby' (Table 2). Use of 'Howling Mob' as a parent resulted in little heterosis in any cross.

Mean yields were consistently higher for hybrids involving 'Country Gentleman' or 'Stowell's Evergreen' as one of the parents (Table 2). The highest yielding hybrid was 'Golden Bantam' x 'Stowell's Evergreen' in the first planting (6.87 Mg·ha⁻¹) and 'Country Gentleman' x 'Stowell's Evergreen' in the second planting (3.83 Mg·ha⁻¹). In both planting dates, the highest yielding hybrid, not involving 'Country Gentleman' or 'Stowell's Evergreen', was 'Howling Mob' x 'Lindsey Meyer Blue'.

Midparent heterosis for plant height (Table 3) was highest for 'Country Gentleman' x 'Lindsey Meyer Blue', 'Pease Crosby', 'Golden Bantam', and 'Stowell's Evergreen', followed by 'Golden Bantam' x 'Howling Mob', 'Lindsey Meyer Blue' x 'Stowell's Evergreen', and 'Pease Crosby'. It was lowest for 'Howling Mob' x 'Country Gentleman', 'Lindsey Meyer Blue', or 'Pease Crosby', as well as 'Golden Bantam' x 'Lindsey Meyer Blue' or 'Pease Crosby'. Overall, heterotic relationships based on yield and plant height were similar. Mean plant height was highest for 'Stowell's Evergreen' x 'Country Gentleman' followed by the hybrids involving either 'Country Gentleman' or 'Stowell's Evergreen' as one of the parents.

Like yield and plant height, maturity is strongly affected by heterosis in corn. We chose to examine midparent heterosis for days to mid-silk to determine if maturity data supported the yield and plant height data. Differences among hybrids in midparent heterosis for silk date (Table 4) were smaller than for yield or plant height. Heterosis for silk date was highest for 'Country Gentleman' crosses and lowest for 'Golden Bantam' x 'Howling Mob' or 'Golden Bantam' x 'Pease Crosby'. Mean silk date was later for crosses between 'Country Gentleman' or 'Stowell's Evergreen' and the other cultivars, 'Stowell's Evergreen' x 'Country Gentleman' was the latest maturing hybrid. 'Pease Crosby' x 'Lindsey Meyer Blue' and 'Pease Crosby' x 'Howling Mob' were the earliest hybrids.

General combining ability (GCA) was significant in both planting dates for every trait, except for ear length in the second planting date and for kernels per row in the first planting date (Table 5). GCA effects often are significant in breeding experiments involving corn cultivars (Vasal et al., 1992a, 1992b, 1993; Widstrom et al., 1992).

In the first planting date, 'Country Gentleman' and 'Stowell's Evergreen' had significant positive GCAs for yield, plant and ear height, pollen and silk date, and kernel length (Table 5). The other four cultivars had negative GCAs for all these traits, except for 'Howling Mob', which had a very small nonsignificant positive GCA for yield. Thus, for yield and traits related to plant type and maturity, 'Country Gentleman' and 'Stowell's Evergreen' grouped together as did 'Golden Bantam', 'Howling Mob', 'Lindsey Meyer Blue', and 'Pease Crosby'. 'Golden Bantam', 'Howling Mob', 'Lindsey Meyer Blue', and 'Pease Crosby' are derived largely from the Northern Flint race, which is characterized by a relatively short statured, early maturing growth habit. 'Stowell's Evergreen' has Southern Dent in its background and 'Country Gentleman' has germplasm from unknown races of corn and plants of these cultivars are late maturing and tall. 'Country Gentleman', 'Stowell's Evergreen', and 'Pease Crosby' all had negative GCAs for kernel mass and positive GCAs for kernel row number. This indicates the inverse relationship between kernel size and number of rows on an ear. GCAs for the other traits did not follow any particular relationships across the six parent cultivars.

In the second planting date, 'Country Gentleman' and 'Stowell's Evergreen' have large positive GCAs for plant and ear height, and pollen and silk date. The other cultivars all had either negative GCAs or nonsignificant positive for these traits. 'Country Gentleman' had a significant positive GCA for yield and 'Golden Bantam' had a significant negative GCA. Other than maturity and height, no patterns in GCA related to phylogenetic background were discernible in the second planting. Differential reactions of the cultivars to diseases and abiotic stresses present in the second planting may have influenced GCA patterns for some traits.

Over both plantings, 'Country Gentleman' and 'Stowell's Evergreen' had the fewest negative GCA values. However, positive GCAs are not always desirable. For example, 'Country Gentle-

man' and 'Stowell's Evergreen' produced hybrids with bigger ears, more kernels, and higher yields, but the plants were later maturing and taller. Late maturity and excessive height are considered undesirable. The three most Northern Flint-like cultivars, 'Golden Bantam', 'Lindsey Meyer Blue', and 'Pease Crosby', had the most negative GCAs. Their hybrids tended to be shorter, early maturing, and lower yielding.

Specific combining ability (SCA) was not significant for most traits in the first planting date. Exceptions were ear height, kernel length, and kernel width (data not shown). In the second planting date SCA was significant for pollen and silk date, ear length and diameter, kernels per row and yield. Only 'Country Gentleman' x 'Stowell's Evergreen' (-0.646) and 'Country Gentleman' x 'Pease Crosby' (0.482) had significant SCAs for yield. No traits had significant SCA in both planting dates. Specific combining ability is seldom of great importance in research involving open-pollinated corn cultivars (Vasal et al., 1992a, 1992b, 1993; Widstrom et al., 1992).

Based on midparent heterosis for yield in both plantings, 'Howling Mob' did not group with any of the other five cultivars. 'Golden Bantam' and 'Pease Crosby' had similar heterotic responses to the other parents and could be grouped together. 'Lindsey Meyer Blue' had higher average heterosis when crossed to 'Country Gentleman' and 'Stowell's Evergreen' than when crossed to 'Golden Bantam' and 'Pease Crosby'. Therefore, 'Lindsey Meyer Blue' could be grouped with 'Golden Bantam' and 'Pease Crosby'. 'Country Gentleman' and 'Stowell's Evergreen' are distant from this group and not related to one another. Revilla

and Tracy (1995a) classified open-pollinated sweet corn cultivars, including the six used here, based on morphology and on allozyme frequencies (Revilla and Tracy, 1995b). The researchers found that by both classification methods 'Country Gentleman' was quite distant from the other cultivars. 'Stowell's Evergreen' was next in distinctiveness, but grouped closer to 'Pease Crosby' and 'Howling Mob' based on isozymes. 'Golden Bantam' and 'Lindsey Meyer Blue' were relatively close based on isozymes and morphology. Our interpretation is that there is good coincidence between the isozyme classification and the heterotic groups reported here.

These data indicate one strong heterotic pattern; 'Country Gentleman' x 'Golden Bantam', 'Pease Crosby', and 'Lindsey Meyer Blue', and a weaker one; 'Stowell's Evergreen' x 'Golden Bantam', 'Pease Crosby', and 'Lindsey Meyer Blue'. This conclusion agrees with an earlier pedigree analysis of inbreds and hybrids (Tracy, 1990, 1994), as well as with inbred and cultivar classifications based on biochemical and morphological distances (Gerdes and Tracy, 1994; Revilla and Tracy, 1995a, 1995b). Few 'Pease Crosby' inbreds exist today, so speculation based on inbred data on 'Pease Crosby's place in heterotic patterns was not possible. Given the historical importance of 'Golden Bantam' (Tapley et al., 1934; Huelsen, 1954; Galinat, 1971; Gerdes and Tracy, 1994) it may be appropriate to define the heterotic patterns as 'Country Gentleman' x 'Golden Bantam' and 'Stowell's Evergreen' x 'Golden Bantam' with 'Lindsey Meyer Blue' and 'Pease Crosby' grouped in the 'Golden Bantam heterotic group'. 'Howling Mob' did not fit decisively in any of the heterotic groups.

Table 5. General combining ability for 13 traits from the 15 hybrids of the diallel cross among six open-pollinated sweet corn cultivars² grown in two environments.

Trait	CG	GB	HM	LM	PC	SE	LSD(5%)	SE ^y
First planting								
Yield	0.43	-0.25	0.09	-0.38	-0.44	0.55	0.40	0.13
Plant height	17.06	-3.09	-8.44	-14.56	-14.53	23.56	5.89	1.84
Ear height	16.43	-3.20	-4.54	-9.85	-14.42	15.58	4.83	1.51
Pollen date	3.28	-0.54	-1.17	-1.35	-2.35	2.15	0.54	0.17
Silking date	3.48	-0.40	-1.40	-1.58	-2.02	1.92	0.55	0.17
Prolificacy	-0.01	0.09	-0.03	0.02	-0.14	0.08	0.10	0.03
Ear length	0.02	0.05	0.23	-0.45	0.37	-0.22	0.51	0.16
Ear diameter	0.34	-0.42	0.06	-0.26	0.03	0.26	0.10	0.03
Row number	2.39	-2.42	-0.56	-2.06	1.33	1.32	0.44	0.14
Kernels per row	No significant differences between hybrids							
Kernel length	0.07	-0.06	-0.04	-0.02	-0.02	0.06	0.04	0.01
Kernel width	-0.11	0.05	0.06	-0.14	0.28	-0.14	0.15	0.05
Kernel mass	-23.63	16.62	18.81	12.00	-11.19	-12.62	10.07	3.15
Second planting								
Yield	0.26	-0.41	0.18	0.11	-0.15	0.02	0.26	0.08
Plant height	12.59	0.84	-4.12	-15.12	-19.94	18.75	5.22	1.63
Ear height	14.39	0.57	-2.71	-13.68	-14.77	16.20	4.29	1.34
Pollen date	4.00	-0.87	-1.37	-1.87	-2.94	3.06	0.49	0.15
Silking date	4.10	-0.65	-1.58	-1.90	-2.90	2.92	0.55	0.17
Prolificacy	-0.06	-0.02	0.04	0.12	0.00	-0.07	0.06	0.02
Ear length	No significant differences between hybrids							
Ear diameter	0.27	-0.40	0.08	-0.24	0.03	0.26	0.06	0.02
Row number	2.45	-2.37	-0.33	-2.08	1.23	1.10	0.41	0.13
Kernels per row	-0.42	-0.89	0.64	1.08	-0.31	-0.11	1.22	0.38
Kernel length	0.09	-0.07	-0.02	-0.02	-0.03	0.05	0.03	0.01
Kernel width	0.02	0.13	0.05	-0.20	0.09	-0.09	0.12	0.04
Kernel mass	-11.90	11.60	10.98	4.29	-15.96	0.98	8.266	2.58

²CG = Country Gentleman, GB = Golden Bantam, HM = Howling Mob, LM = Lindsey-Meyer, PC = Pease Crosby, SE = Stowell's Evergreen.

^ySE is for the combining ability effects of parents.

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