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Relationship between Starchy versus Sugary Endosperm and Head Smut Susceptibility of Corn Seedlings

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Abstract. **Incidence of head smut *[Sphacelotheca reiliana* (Kuhn) Clinton] in F_3 corn *(Zea mays* L.) families derived from homozygous starchy *(Su)* F_2 ears was less than that observed in starchy or sugary *(su)* families derived from segregating ears or sugary families derived from homozygous sugary ears. This difference was observed at high levels of disease incidence resulting from clipping seedlings and at a lower disease incidence in unclipped plants. Differences in seedling vigor and earliness of starchy and sugary families and differences related to homozygous and heterozygous sources suggest that seedling vigor may be involved in the observed differences in head smut susceptibility.**

Sphacelotheca reiliana, the incitant of head smut disease, infects corn seedlings mostly before about the sixth leaf stage (V3 to V4 stages of Ritchie et al., 1989) by means of germinating spores in the soil (H.S. Fenwick, personal communication). Genetic susceptibility is characterized by differences in potential for seedling infection and is expressed as differences in disease incidence. The principal symptoms in infected plants of relatively resistant or susceptible corn lines are the same and consist of production of massive sori replacing the ear and sometimes the tassel, along with a degree of plant stunting (Baggett and Kean, 1989; Foster and Frederiksen, 1977; Halisky, 1963; Maytac and Windels, 1984).

In many years of testing commercial sweet corn (sugary, *su)* F_1 hybrids and inbred lines, using furrow inoculation (Baggett and Koepsell, 1983), infection incidence has ranged from 0% to 100%. Potential for infection was shown to be inherited in a quantitative, mostly additive manner, with resistance showing a degree of dominance over susceptibility when infection levels were low. In F_2 and backcross populations, where starchy *(Su)* and sugary *(su)* segregates were planted in separate adjacent plots, plants with sugary endosperm had significantly higher head smut incidence than plants with starchy endosperm (Ali and Baggett, 1990). No evidence was available to explain the reduced infection incidence in starchy plants, but it was assumed to be related to seedling vigor. The objective of the present study was to further measure the effect of starchy vs. sugary endosperm from homozygous and heterozygous sources, and to determine possible relationships between disease incidence, starchy/sugary endosperm, and some other characteristics, including seedling vigor.

Populations were obtained by crossing dent corn inbred line Nebraska 6 (N6) with sugary inbred lines SD1 and SM7. SD1 was derived by selfing the commercial hybrid 'Sugar Daddy' (Ferry Morse Seed Co., Stockton, Calif.). SM7 was derived from a breeding line provided by W. Crookham Seed Co. (Caldwell, Idaho). N6 is highly resistant to head smut, rarely being infected even under high disease pressure. Infection incidence in highly susceptible SD1 and SM7 may reach ≥90%. F_3 families for study were obtained by self-pollinating 80 F_2 plants from each of the four reciprocal crosses. To ensure that enough homozygous sugary *(su/su)* families were obtained, starchy and sugary F_2 seeds were sorted and planted separately. For each reciprocal cross, 40 homozygous sugary ears were obtained, and the remaining 40 ears per cross included starchy ears from homozy-

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Table 1. Effect of starchy vs. sugary endosperm and clipping of seedlings on incidence of head smut in corn F_3 families.

Endosperm		Cross[z]			
		N6 x SD1		N6 x SM7	
Type	Source[y]	N[x]	Infected[w] (%)	N	Infected (%)
Clipped					
Starchy	Homozygous	60	21.4 A	50	38.1 A
	Heterozygous	100	39.4 B	110	43.8 AB
Sugary	Heterozygous	100	47.6 C	110	49.8 B
	Homozygous	160	43.0 BC	160	46.5 B
Unclipped					
Starchy	Homozygous	60	8.4 A	50	11.1 A
	Heterozygous	100	15.5 B	110	15.2 AB
Sugary	Heterozygous	100	24.5 C	110	19.4 BC
	Homozygous	160	19.8 C	160	21.8 C
Starchy	All plots	320	22.7 A	320	28.0 A
Sugary	All plots	520	33.2 B	540	34.3 B
Clipped	All plots	420	40.1 B	430	45.7 B
Unclipped	All plots	420	18.3 A	430	18.3 A

[z]Reciprocal crosses have been combined.
[y]Genotype of the F_2 ear from which the planted F_3 seeds were obtained.
[x]N = number of plots from which the means were derived; number of families represented was one-half the number shown for the clipped or unclipped plots; each family was replicated two times in clipped and two times in unclipped treatments.
[w]Means bearing the same letter within a cross-clipping combination, between overall starchy–sugary means, and between overall clipping means were not different at $P = 0.05$ using Student's t test. Arcsin-transformed values were used to determine mean separations.

Table 2. Relation of seedling height, earliness, and mature plant height with endosperm type and source in corn F_3 families.[z]

Endosperm		Seedling ht[y]				Earliness[x]		Mature ht[w]	
		N6 x SD1		N6 x SM7		N6 x SD1	N6 x SM7	N6 x SD1	N6 x SM7
Type	Source[v]	N	cm	N	cm	(days)	(days)	(cm)	(cm)
Starchy	Homozygous	120	24.8 C	100	24.9 B	75.0 BC	72.7 B	82.1 A	80.0 B
Starchy	Heterozygous	200	25.6 D	220	25.3 B	73.6 A	71.5 A	84.7 BC	79.3 B
Sugary	Heterozygous	200	21.8 A	220	21.5 A	74.7 B	72.3 AB	84.2 BC	77.6 A
Sugary	Homozygous	320	22.1 A	320	21.6 A	75.5 C	74.1 C	83.9 AB	79.7 B
Starchy	All sources	320	25.3 B	320	25.1 B	74.1 A	71.9 A	83.7 A	79.5 A
Sugary	All sources	520	22.0 A	540	21.6 A	75.2 B	73.4 B	84.0 A	78.9 A

[z]Reciprocal crosses combined.
[y]Plot average of height of seedlings to tip of longest leaf 23 to 26 days after seeding; one replication of each family measured each of 4 days. Means bearing the same letter within a column (starchy vs. sugary, all sources compared separately) did not differ at $P = 0.05$, determined by Student's t test. N = number of plots measured to derive means shown.
[x]Earliness expressed as days from seeding to 50% silk emergence.
[w]Mature plant height measured to top of tassel after all growth had ceased.
[v]Genotype of the F_2 plant from which families were derived.

gous starchy F_2 plants and segregating ears from heterozygous *(Su/su)* F_2 plants. Starchy and sugary F_3 kernels on the segregating F_2 ears were sorted into separate lots that were planted together as a single plot in the head smut test and observation plots described below. For the two crosses and reciprocals combined, 425 F_3 families were studied. The number of families studied for each endosperm type is shown in Table 1.

The following season, seed of each F_3 family was divided into eight lots. Four replications of each F_3 family were planted in a head smut-infested field with inoculum consisting of teliospores mixed with vermiculite applied in the seed furrow as described by Baggett and Koepsell (1983). Plots were arranged in a randomized complete-block design except that starchy sublines were planted adjacent to sugary sublines derived from the same segregating ear. Each 3-m plot contained ≈10 plants in rows 90 cm apart.

Seedlings of two replications in the inoculated field were clipped at ground level at the V2 to V3 stage (four to five visible leaves), a treatment known to substantially increase the incidence of head smut (Ali and Baggett, 1986). General cultural practices were similar to those used in commercial sweet corn production in the area. The presence of infection, expressed as sori on an ear or tassel, was determined at crop maturity.

Four replications were planted in a similar arrangement in a head smut-free field on the same research farm. Characters measured were seedling height 23 to 26 days after planting (one replication measured on each of these 4 days); earliness, determined by date when silks had emerged on 50% of the plants; and mature plant height to the top of the tassel. Endosperm type (starchy or sugary) was predetermined by sorting ears or kernels as previously described.

The percentage of clipped seedlings infected, averaged over the two crosses, was more than double that of unclipped seedlings, providing two distinct levels of disease incidence in the study. The effect of clipping was highly significant in each cross (Table 1).

Overall (with sources of starchy and sugary seeds not considered), disease incidence was significantly higher in sugary plants than in starchy plants (Table 1). In N6 × SD1, there were also significant differences in percentage infected between starchy families derived from homozygous ears and those derived from segregating ears. This difference was marked in clipped and unclipped plots and was larger than the consistent (but not always significant) differences between starchy and segregating ears and both sugary categories. In N6 × SM7 progeny, all differences due to endosperm type followed a similar pattern, but the difference between starchy sources, and some other comparisons, were nonsignificant at $P = 0.05$.

Because starchy corn often is observed to have stronger germination and seedling vigor than sugary corn, seedling vigor expressed as height, earliness, and mature plant height were measured to determine whether these factors would explain the tendency of starchy corn to be less susceptible to head smut infection. Starchy seedlings were significantly taller than sugary (Table 2), which supported the hypothesis that increased seedling vigor was associated with less infection. However, the small differences in seedling height between starchy and heterozygous and homozygous sources failed to support, and even contradicted, this hypothesis since seedlings from the homozygous source were slightly shorter and had lower disease incidence. Seedling height of the sugary plants from the two sources was nearly identical.

Sugary and starchy plants from heterozygous sources were earlier to flower than counterparts from homozygous sources, and, overall, starchy corn was earlier than sugary corn. Differences in mature plant height were small and there was no obvious pattern.

This study confirmed previous observations that starchy corn plants were less susceptible to head smut infection than sugary plants. While it seems likely to us that differences in susceptibility between sugary and starchy plants are related to differences in seedling vigor associated with the presence or absence of the *Su* allele, differences between starchy lines from homozygous and heterozygous sources are more difficult to explain. It is possible that the differences observed were accidental and resulted from general diverse segregation occurring within the F_3 families. However, this difference might also be related in some way to greater heterosis in starchy plants derived from heterozygous sources, since we would expect two-thirds of these starchy plants to be heterozygous for the *Su* factor. While we favor the hypothesis that reduced disease incidence, whether associated with seedling vigor or not, is a pleiotropic effect of the *Su* allele (when compared with the *su* allele), we cannot exclude the possibility that increased vigor

and/or resistance may be conditioned by factors linked to the *Su* gene.

That lower seedling vigor is associated with higher susceptibility is suggested by the conspicuous increase in disease incidence caused by seedling clipping. The effect of clipping on infection percentage is apparently related to a setback of seedlings that, while considered to be temporary, can be easily observed for several weeks.

It should be noted that we have tested very resistant sugary hybrids and inbreds and very susceptible starchy accessions. Thus, differences in susceptibility described here represent tendencies only and do not preclude the possibility of breeding head smut-resistant sugary corn cultivars.

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