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Electrolyte Leakage and Seed Quality in a Shrunken-2 Maize Selected for Improved Field Emergence

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Abstract. **Acceptance of shrunken-2 (*sh2*) sweet corn (*Zea mays* L.) hybrids is limited by poor seed quality and seedling emergence, especially in cold soils. The conductivity of the electrolytes leached from imbibing seeds, a rapid measurement of seed quality, is highly correlated with field emergence among sweet corn hybrids. Our objective was to determine if conductivity is related to field emergence in a *sh2* population that had undergone selection for improved field emergence for 10 cycles. The response of conductivity to indirect selection was linear, and the linear trend accounted for a large portion of the variation in conductivity (r^2 = 0.70). Conductivity ranged from 82.0 $dS \cdot m^{-1}$ in cycle 0 to 35.3 $dS \cdot m^{-1}$ in cycle 8, with cycle 10 not differing from cycle 8. High conductivity indicates greater electrolyte leakage. At $P \leq 0.01$, conductivity was negatively correlated with all seed performance ratings; field emergence ($r = -0.82$), plant height ($r = -0.81$), uniformity ($r = -0.92$), and relative emergence ($r = -0.85$).**

Sweet corn hybrids with shrunken-2 (*sh2*) endosperm are sweeter, maintain sugar levels longer, and are preferred in taste tests compared to standard sugary (*su*) hybrids. However, acceptance of *sh2* hybrids has been limited due to inferior seed quality, germination, and field emergence (2, 4). A major goal of many sweet corn breeding program is improved seed quality in *sh2* hybrids (4). Progress in improving seed quality is slow due to the low correlations between laboratory seed screening methods and field emergence.

A rapid measure of seed quality is the conductivity of electrolytes that leach from imbibing seeds. Conductivity is a measurement of electrolyte leakage and is negatively correlated with germination and field emergence in a number of species (1, 6, 7). Artificially aged seed has higher conductivity and lower germination than nonaged seeds, as does mechanically damaged seed (1). Among 13 *su* sweet corn hybrids, conductivity was negatively correlated with field emergence ($r = -0.58$**), but standard lab germination tests and field emergence were uncorrelated ($r = 0.18$)(9). However, when conductivity data were combined with data on dry weights of seedlings from cold germination tests, the correlation with field emergence was increased ($r = 0.80$**)(9). Thus, conductivity of seed leachates is a useful tool in determining the field emergence potential of hybrids. However, its usefulness as a breeding tool depends on whether electrolyte conductivity reflects differences in field emergence within a breeding population and whether changes in field emergence during selection also result in changes in conductivity. Our objectives were to determine if conductivity changed as a result of selection for improved field emergence in a *sh2* sweet corn population, and, if so, how the changes in the two traits were related.

A population homozygous for *sh2* and synthesized by M.S. Zuber of the Univ. of Missouri, Columbia, formed the basis for the plant material used in this study. The population underwent 10 cycles of selection for improved field emergence and seed weight as described by Bell et al. (3). Significant gains in field emergence were made, with an average gain of 3.3% per cycle based on cycle 0 (3).

Cycles 0 through 10 were grown in Urbana, Ill. in 1985. Plants were sib-pollinated and ears were hand-harvested ≈60 days after pollination, dried in a forced-air oven, and stored in a walk-in cooler at 10°C and 20% RH. A balanced seed composite was made for each cycle by combining equal amounts of seed from 20 to 30 ears.

The procedure used to measure conductivity followed that outlined by Waters and Blanchette (9). Conductivity was measured with a temperature compensated Beckman SD-4251 solu-bridge conductivity meter. Ten seeds were soaked in 50 ml of deionized water for 24 hr. Only intact seeds, as determined visually, were included. Ten-seed weight of each sample was obtained, and the data were converted to conductivity per gram of seed weight. There were eight replications, and data were analyzed as a randomized complete block design with replications and cycles as the factors.

Four replicates of 200 seeds from each of the 1985 sib-pollinated cycles were hand-planted in a randomized complete block design at Urbana on 18 Apr. 1986. Soil temperature at the 5-cm (2-inch) level was 11°C. During the next 2 weeks, mean daily soil temperatures ranged from 8° to 14°, temperatures known to stress germinating *sh2* seed.

Table 1. Means of conductivity and seed performance for cycles 0–10 of a *sh2* population selected for improved field emergence.

Cycle	Conductivity ($dS \cdot m^{-1}$)	Field emergence (%)	Plant height (vigor) (cm)	Uniformity[z]	Relative[y] emergence
10	39.4	52	21.2	3.5	0.64
9	53.4	27	18.7	2.3	0.40
8	35.3	43	19.5	3.3	0.58
7	49.6	44	19.5	2.9	0.56
6	48.3	38	18.4	2.9	0.50
5	59.3	35	17.9	2.6	0.48
4	46.0	29	16.4	2.8	0.41
3	60.6	25	16.4	2.6	0.35
2	66.5	22	16.4	2.2	0.30
1	65.5	20	15.1	2.0	0.27
0	82.0	20	15.6	1.8	0.27
b_l^x	0.34**	2.71**	0.54**	0.12**	0.03**
b_q^x	0.04	0.20	0.01	0.01	0.00
r^{2x}	0.70	0.68	0.89	0.62	0.75
LSD (0.05)	6.08	11	0.7	0.9	0.15

[z]Uniformity on a 0 to 5 scale, where 5 = very uniform and 0 = very irregular.
[y]Average emergence of early planting (18 Apr. 1986) divided by emergence of later planting (12 May 1986).
[x]Linear regression coefficient (b_l), quadratic regression coefficient (b_q), and coefficient of determination, (r^2). **Significant at the 0.01 level of probability.

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As a nonstressed control, a fifth replicate was planted 24 days later, when soil temperature exceeded 20°.

On 2 June, 41 days after planting, emergence, plant height, and stand uniformity were recorded for each of the populations of the cold-stressed replicate blocks. Percent emergence was determined by direct count. Mean plant height (vigor) was calculated from individual measurements of 25 plants per plot. Each population in each replicate was assigned a stand uniformity value on a scale ranging from 0 to 5: where 0 = 0% to 10% of the population had plant heights within 2.5 cm of the mean plant height; 1 = 11% to 20%; 2 = 21% to 50%; 3 = 51% to 80%; 4 = 81% to 90%; and 5 = 91% to 100%. For the control plot, percent emergence was recorded 30 days after planting. Relative emergence was determined by dividing emergence from each block in the 18 Apr. planting by emergence of the same populations in the nonstressed control. This method tends to isolate the variation among the populations in germination and emergence due to temperature effects from other sources of variation.

Differences ($P \leq 0.05$) among cycles of selection were found for conductivity of the leachate of imbibing seeds (Table 1). The response of conductivity to indirect selection was linear, and the linear trend accounted for a large portion of the variation (r^2 = 0.70). Conductivity was highest in cycle 0 ($82.0\ dS \cdot m^{-1}$), which was significantly higher than for any other cycle. Cycles 1, 2, and 3 were also high. Cycles 8 and 10 had the lowest conductivity. Thus, it appears that selection for improved field emergence and seed weight resulted in a reduction in conductivity. Furthermore, a large drop in conductivity occurred after the first cycle. However, cycles 9 and 4 do not fit the pattern of decreasing conductivity with increasing cycles of selection for field emergence. Cycle 9 ranked sixth and did not differ from 5, 6, and 7, but was higher than 8 and 10. Conductivity of cycle 4 did not differ from that of 6, 7, and 10.

Cycles also differed for field emergence, plant height, stand uniformity, and relative emergence and, for all traits, the differences were largely due to linear trends (Table 1). Cycles 0, 1, 2, and 3 had the lowest performance for all traits, although they were not always different from all other cycles for all traits. Cycles 7, 8, and 10 performed best for all seedling characteristics; other cycles were not always significantly lower. These data confirm the gains due to selection in this material reported by Bell et al. (3). As was the case for conductivity, cycle 9 performed more poorly than expected. It ranked with the lower half for all traits except plant height. The reasons for the poor performance of cycle 9 are unknown; however, the poor performance does support the relationship between conductivity and seed performance. This relationship was not true for cycle 4, where conductivity was low while ranking in field performance was generally as expected.

Carbohydrates are a major component of sweet corn leachates (5). Sucrose, glucose, and fructose make up the major water-soluble carbohydrate fraction in dry mature corn kernels homozygous for the *sh2* mutation (8), suggesting that conductivity is correlated with kernel sugar content. Our observed correlation between leachate conductivity and field emergence may reflect a proximate relationship between the water soluble carbohydrate reserves (primarily sucrose) of *sh2* kernels and cold soil germination and emergence.

Conductivity was negatively correlated ($P \leq 0.01$) with field emergence ($r = -0.82$), plant height ($r = -0.81$), uniformity ($r = -0.92$), and relative emergence ($r = -0.85$). Thus, as previously noted for *su* sweet corn hybrids (9), conductivity may be used to predict field emergence and other seedling characters, in this instance in a breeding population. The seed performance data were from only one environment and the experiment should be repeated to confirm the relationship of conductivity and field emergence characters. However, the primary goal of this experiment was to determine the effects of selection for improved field emergence on conductivity. Conductivity was changed by indirect selection, and thus it may be useful as a breeding tool to aid in selection for improved field emergence. Due to the many factors affecting field emergence, leachate conductivity should be only one of the screening procedures but, due to its rapidity and high correlation with field emergence, it may prove useful.

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