Contributions of Dent Corn Germplasm to Stalk and Root Quality in Sweet Corn

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Abstract. Root or stalk lodging can be a serious problem in sweet corn (Zea mays L.) production. Four dent corn inbreds, crossed to five sweet corn inbreds in a design II mating system, and a half diallel with five sweet corn inbreds were used to 1) determine the effect and potential contribution of dent corn germplasm on stalk and root quality traits in sweet corn, 2) examine the variation for stalk and root quality traits in some sweet corn germplasm, and 3) evaluate the utility of traits used in improving dent corn root and stalk quality in sweet corn improvement. The dent corn germplasm used in this study had a favorable affect on stalk and root quality in the dent × sweet hybrids. Compared to the sweet × sweet hybrids, the dent × sweet hybrids had significantly higher stalk crushing strength and stalk soluble carbohydrates, while having significantly less stalk lodging. The mean stalk lodging for the dent × sweet hybrids was 4.4% while the sweet × sweet hybrids averaged 18.7%. Within the diallel, effects due to hybrids were highly significant for stalk section weight, rind thickness, and stalk diameter. Percent stalk lodging was negatively correlated with stalk section weight \( r = (-0.63) \), \( P \leq 0.05 \) and crushing strength \( r = (-0.64), P \leq 0.05 \). No traits were significantly correlated with root lodging within the sweet corn crosses. Dent corn has potential as a source of improved stalk and root quality in sweet corn.

Materials and Methods

To evaluate the potential contributions of dent corn germplasm for improving stalk and root quality in sweet corn, we used a design II mating design (Comstock and Robinson, 1948), with 20 dent × sweet hybrids and a half diallel consisting of 10 sweet × sweet hybrids without parents or reciprocals (Griffing’s experimental
Table 1. Year means and total means for the design II (D2) and diallel (Dial) experiments for corn grown in 1988 and 1989.

|                | Stalk lodging (%) | Root lodging (%) | Root pull (load-kg/ plant) | Crushing strength (load-kg/ plant) |
|----------------|-------------------|------------------|-----------------------------|-----------------------------------|
|                | D2                | Dial             | D2                          | Dial                              |
| 1988           | 4.7               | 21.2             | 5.9                         | 25.8                              |
| 1989           | 4.2               | 16.2             | 18.4                        | 25.8                              |
| Mean           | 4.4               | *                | 11.5                        | 25.8                              |
| 1989 controls  |                   |                  |                             |                                   |
| A632 × B73     | 0.0               |                  | 3.6                         |                                   |
| A632 × Mo17    | 0.9               |                  | 14.8                        |                                   |

*Non\$significant or significant difference at \$P < 0.05, respectively.

Stalk soluble carbohydrates were measured in the following manner: 1) internodes were thawed and pith bored with a 10-mm-diameter cork borer; 2) pith sections 30 mm long were weighed, placed in a small paper bag, dried at 49°C, and reweighed to correct for moisture content in the stalk (Campbell and Hume, 1970); 3) juice from the remaining bore sample was placed on the prism of a hand refractometer (0\% to 90\% Brix) to determine percent Brix. Soluble carbohydrates in the pith, for a constant volume, were calculated as: (percent Brix) × (fresh weight-dry weight) = weight of stalk soluble carbohydrates.

A 51-mm stalk section was cut from the center of the dried internodes using a double-bladed circular saw. The diameter and weight of these sections were determined, and then the sections were placed on a hand-pumped press to measure the pressure (load-kg) required to crush the section. The pith from each dried internode was scraped from the rind and the thickness of the rind was measured using a pressure micrometer.

Analysis of data was based on plot mean using SAS statistical software (SAS Institute, 1985). Because of missing plots in 1988, the general linear model (GLM) procedure was used to partition the variance components. The hybrid sums of squares were partitioned into design II hybrids, diallel hybrids, and design II × diallel hybrids. The design II hybrids were further partitioned into males (GCA), females (GCA), and males × females [specific combining ability (SCA)]. The diallel hybrids were partitioned into GCA and SCA. The F tests of significance were performed using the appropriate error term, with years and replications random and hybrids fixed.

Results and Discussion

Interval to 50\% silking ranged from 73.7 days for CG2730 × B84 to 65.7 days for P51 × Ia191. Because of this difference, the analysis of covariance procedure was performed on all traits, using days to 50\% silking as the covariate to correct for the effect of maturity on the traits. This covariate was significant only for stalk diameter. Therefore, the mean squares, means, and phenotypic correlation coefficients for stalk diameter were calculated after adjusting for days to 50\% silking.

Hybrid effects were significant (P < 0.05) for all traits except percent root lodging, while year × hybrid effects were significant for all traits (P < 0.05). Years were significant (P < 0.05) for all traits except soluble carbohydrates and rind thickness. The significance of these effects establishes the diversity of the material used in this study and demonstrates the effect the environment can have on these traits in these hybrids.
A goal of this study was to compare design II hybrids, which involved dent corn parents, with diallel hybrids, which involved only sweet corn parents. In this regard, design II vs. diallel effects were highly significant for percent stalk lodging, soluble carbohydrates, and crushing strength, while the year x design II vs. diallel effects were significant or highly significant for the rest of the traits. For percent stalk lodging, all of the variation among hybrids was explained by the design II vs. diallel. The hybrids in the design II had about one-fourth as much stalk lodging as the diallel (Table 1). The range for stalk lodging for the hybrid means in the design II was from 0.6% for CG2730 × B84 to 12.9% for Ia191 × B84. Stalk lodging for hybrids in the diallel ranged from 14.7% for CG4189 × P39 to 28.9% for CG4189 × P51. The hybrid in the design II with the second highest degree of stalk lodging was CG4189 × A632, with 12.2%, and this was significantly less than design II with the second highest degree of stalk lodging was CG4189 × P39 to 28.9% for CG4189 × P51. The hybrid in the diallel, the hybrid P39 × Ia191 had the lowest stalk soluble carbohydrates with 29.4 mg, and P39 × CG2730 had the highest with 57.7 mg. The design II hybrids varied from 1.41 to 2.77 g for stalk weight and from 1.68 to 2.55 mm in stalk diameter. The diallel hybrids ranged from 0.92 to 1.67 g for stalk weight and from 1.37 to 1.89 mm for stalk diameter. The interactions of the environment with other sources of variation mask some of the effect that the dent corn males had on these traits. Comparing the means of all hybrids, it is clear that those hybrids having a dent corn parent had better stalk and root quality traits than did the hybrids from the diallel. The range in trait values over hybrids helps exemplify this point. The favorable contribution of dent corn to sweet corn for stalk quality is not unexpected since dent corn has been selected intensively for improved stalks and roots, while sweet corn has not. However, until now, the magnitude of difference between the two germplasm groups has not been demonstrated under experimental conditions and without the confounding effects of different endosperm types.

The design II hybrid effects were significant for all traits except percent stalk lodging. Either the male effects or year x male effects were significant for all traits except percent stalk lodging, percent root lodging, and soluble carbohydrates. When the year x male effects were significant, the male effects were not significant. Thus the lack of significance for males for root pull, stalk section weight, crushing strength, and stalk diameter may be explained by the interaction of males with years. Effects due to females, year x females, or both were significant or highly significant for all traits except percent stalk lodging. Male x female effects were highly significant for root lodging and rind thickness. Among the design II hybrids averaged over male inbreds, CG2730 had the highest root pull resistance, crushing strength, rind thickness, stalk diameter and stalk section weight (Table 2). Inbred P51 contributed the least to stalk and root quality in the design II. It had the lowest root pull resistance, crushing strength, rind thickness, stalk section weight, and stalk diameter (Table 2).

The effects due to the diallel hybrids were highly significant for stalk section weight, rind thickness, and stalk diameter. General combining ability effects for the diallel were significant for root pull, stalk section weight, rind thickness, and stalk diameter, while SCA effects were not significant for any trait. Year interactions with the diallel hybrids, GCA, and SCA also existed, again showing the importance of the environment on the expression of these traits in these hybrids.

The diallel had eight significant correlations, while the design II had 15 (Tables 3 and 4). Because the means of the design II and diallel were so different, the phenotypic correlations were calcul-
lated for both mating designs.

In the diallel, stalk section weight, rind thickness, crushing strength, and stalk diameter all correlated highly significantly (Table 3). Percent stalk lodging was negatively correlated with stalk section weight and crushing strength (Table 3). These two traits were among the easiest to measure and thus could be useful to sweet corn breeders wishing to improve stalk quality. While not significant, stalk section weight also had the highest correlation with root lodging. The most difficult trait to evaluate was root pull, which had a very low correlation coefficient \[ r = (-0.04) \] with root lodging. Even if the correlation had been much stronger, the difficulty in measuring root pull would exclude it as a useful tool in sweet corn improvement. In the design II experiment, significant correlations were observed between all pair-wise combinations of the following traits: root pull, soluble carbohydrates, stalk section weight, rind thickness, crushing strength, and stalk diameter (Table 4).

In these crosses, dent corn germplasm significantly improved

| Hybrid | Stalk lodging (%) | Root lodging | Root pull (load-Kg/plant) | Crushing strength (mg) | Soluble solids (µm) | Rind thickness (g/plant) | Stalk section wt | Stalk diam (mm) |
|--------|-------------------|--------------|--------------------------|------------------------|---------------------|-------------------------|-----------------|----------------|
| A632   | 6.4               | 14.8         | 138                      | 147                    | 47.1                | 733                     | 1.95            | 1.99           |
| B73    | 2.8               | 11.3         | 149                      | 182                    | 50.0                | 844                     | 2.19            | 2.16           |
| Mol7   | 2.6               | 11.2         | 125                      | 143                    | 43.4                | 772                     | 1.84            | 1.94           |
| R84    | 5.7               | 8.8          | 143                      | 166                    | 46.8                | 825                     | 2.03            | 2.10           |
| LSD(0.05) | NS               | NS           | NS                       | NS                     | NS                  | 32.0                   | NS              | NS             |
| P39    | 2.2               | 4.9          | 136                      | 142                    | 45.2                | 773                     | 1.79            | 1.79           |
| P51    | 5.5               | 7.7          | 119                      | 115                    | 36.7                | 665                     | 1.54            | 1.79           |
| Ia91   | 6.2               | 30.8         | 125                      | 164                    | 47.6                | 859                     | 2.29            | 2.32           |
| CG4189 | 6.3               | 9.7          | 138                      | 146                    | 44.4                | 738                     | 1.86            | 1.95           |
| CG2730 | 2.0               | 5.2          | 176                      | 220                    | 59.6                | 929                     | 2.54            | 2.37           |
| LSD(0.05) | NS               | NS           | NS                       | NS                     | NS                  | 116.3                  | 0.10            | 0.19           |

| Percent root lodging | Root pull | Soluble solids | Stalk section wt | Rind thickness | Crushing strength | Stalk diam |
|----------------------|-----------|----------------|------------------|---------------|-------------------|------------|
| % Stalk lodging       | -0.11     | -0.17          | -0.39            | -0.63         | -0.54             | -0.64      | -0.53        |
| % Root lodging        | -0.04     | 0.11           | 0.58             | 0.38          | 0.38              | 0.38       | 0.34         |
| Root pull             | 0.38      | 0.45           | 0.51             | 0.55          | 0.55              | 0.55       | 0.42         |
| Soluble solids        | 0.44      | 0.15           | 0.15             | 0.08          | 0.08              | 0.08       | 0.08         |
| Stalk section weight  | 0.87**    | 0.95**         | 0.83**           | 0.94**        | 0.87**            | 0.87**     | 0.87**       |
| Rind thickness        |           |                |                  |               |                   |            |              |
| Crushing strength     |           |                |                  |               |                   |            |              |

** Significant difference from 0 at \( P \leq 0.05 \) and 0.01, respectively.

| Percent root lodging | Root pull | Soluble solids | Stalk section wt | Rind thickness | Crushing strength | Stalk diam |
|----------------------|-----------|----------------|------------------|---------------|-------------------|------------|
| % Stalk lodging       | 0.21      | -0.30          | -0.27            | -0.20         | -0.40             | -0.29      | -0.08        |
| % Root lodging        | -0.40     | -0.18          | 0.20             | 0.11          | 0.03              | 0.40       | -0.08        |
| Root pull             | 0.82**    | 0.70**         | 0.63**           | 0.76**        | 0.53**            | 0.68**     |               |
| Soluble solids        | 0.81**    | 0.77**         | 0.75**           | 0.93**        | 0.98**            | 0.93**     |               |
| Stalk section weight  |           |                |                  |               |                   |            |              |
| Rind thickness        |           |                |                  |               |                   |            |              |
| Crushing Strength     |           |                |                  |               |                   |            |              |

** Significant difference from 0 at \( P \leq 0.05 \) and 0.01, respectively.
stalk and root quality and stalk and root quality component traits. Even though the environment affected the design II and diallel differently for the different traits, the material in the design II was always better. In a segregating population containing dent and sweet germplasm, enough variation for stalk and root quality likely would be present to make selection effective.

If dent corn were used to improve sweet corn root and stalk quality, vigilance in maintaining and improving traits that determine sweet corn quality would be required (Haber 1945). However, the utility of exotic corn in sweet corn improvement has been demonstrated by Haber in developing the important inbred In2132, which is apparently 25% dent corn (Tracy, 1993), and by Rhodes and the development of III677a, which is ≈25% Bolivian flour corn (Ferguson et al., 1978). Commercial sweet corn breeders also have successfully used nonsweet germplasm in sweet corn improvement programs, but due to trade secrets, this is difficult to document. In a previous study using similar germplasm, Tracy (1990) demonstrated that field corn had positive effects on some ear appearance and plant performance traits. However, he did not evaluate eating quality, and this is the trait that will require the greatest attention (Haber 1945).

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