Comparison of Two Visual Scales for Estimating European Corn Borer Ear Damage in Maize

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Abstract. Some scales combine quantitative and qualitative components that inadvertently may skew damage estimates and eliminate potentially useful germplasm. Two visual evaluation scales to estimate European corn borer feeding damage were compared for their effectiveness in classifying sweet corn germplasm. Both the traditional 1 to 9 scale, combining ear feeding damage and damage location, and the alternative 1 to 5 scale, based solely on ear feeding damage, consistently separated sweet corn genotypes into resistant, marginally resistant, and susceptible classes. Inbred MN 3002, Hybrid MN 3004, 'Apache', and 'More' were classified as having marginally acceptable resistance levels. Inbred MN 3003, Inbred W182E, and 'Jubilee' were susceptible to European corn borer. Individual genotype rankings varied by scale, but genotype classifications were consistent with regard to the degree of commercial acceptability. The combination of quantitative and qualitative components did not compromise genotypic characterization, as the previously untested hybrid, MN 3004, was placed in the marginally acceptable class by both scales. Plant breeders should carefully evaluate the efficacy of individual visual scales before incorporating them into a selection program.

Most insect resistance breeding programs efficiently identify variation among genotypes by visual evaluation. In many instances, however, increasing the speed of evaluation decreases precision (Guthrie et al., 1978). Breeders must decide between slow, precise methods vs. faster methods with large sampling errors, which may obscure genetic differences (Fehr, 1987). High error rates may eliminate potentially useful germplasm. Sampling error is reduced with uniform cultural practices, identifiable standards, and appropriate evaluation procedures (Fehr, 1987).

Germplasm evaluation techniques in resistance breeding programs may inadequately characterize insect damage. For example, the relationship between economic damage levels and biological damage levels may not be linear. Variation for ear damage from European corn borer (ECB) [*Ostrinia nubilalis* (Hübner)] in our breeding program traditionally has been quantified by using a 1 to 9 visual rating scale where 1 = no damage to husk, silk, or kernels, 2 = damage to silk and/or husk only, 3, 4, and 5 = < 1%, 1% to 5%, and 6% to 10% of tip kernels damaged, respectively, 6 and 7 = up to 5% and 6% to 10% of tip and side or side only kernels damaged, respectively, 8 = cob tunnel-

ing >1 cm from tip, and 9 = >10% of the kernels damaged.

This scale combines quantitative (ear damage) and qualitative (ear damage location) criteria. Thus, a mean rating <3.0 is acceptable, a rating between 3.0 and 4.0 is marginally acceptable, and a rating >4.0 is unacceptable commercially. Although the scale has been used to select improved genotypes for release (Davis et al., 1993), and is linear based on the failure to meet processing industry standards (Davis et al., 1994), the qualitative damage criteria may skew plot means upward making the scale nonlinear from a biological standpoint. For instance, ears with little total feeding damage, but with damage located well below the ear tip, receive high ratings, as these ears would be discarded by processors. Over the years, we have questioned whether the use of a biologically nonlinear scale and consequent high ratings of a few individual ears might overlook potentially useful germplasm.

To reduce the possible biases of our 9-point traditional scale, a 1 to 5 alternative scale based solely on a visual percentage assessment of ear damage was developed, where 1 = no ear damage, and 2, 3, 4, and 5 = damage on <1%, 1% to 5%, 6% to 10%, and >10% of kernels, respectively. Initially, a damage location rating (silk, tip, side, base) was combined with the 1 to 5 scale to aid in genotype characterization. Subsequent analysis (data not presented) indicated the damage location information did not aid in germplasm separation for this experiment. With the 1 to 5 scale, germplasm receiving damage ratings of <2.0 are commercially acceptable, with 2.0 to 3.0 marginally acceptable, and >3.0 unacceptable. Our objective was to compare the traditional and the alternative scale and determine if they

similarly grouped genotypes for degree of commercial acceptability.

Materials and Methods

Two replications of seven maize genotypes—two *sugary* (*su*) inbreds, the dent (*Su*) inbred, W182E, and three (*su*) hybrids with known levels of ear feeding resistance or susceptibility, and one (*su*) hybrid unknown for response—were planted in a completely randomized block design at two locations in 1994 and in 1995. About 75 seeds of each genotype were planted into 3.3-m three-row plots on 0.75-m centers at Chanhassen, Minn., on 28 and 25 May (1994 and 1995, respectively) and at St. Paul, Minn., on 5 June and 26 May (1994 and 1995, respectively). Plots were bordered with commercial hybrids. Plots were thinned to ≈39 evenly spaced plants (13 per 3.3-m row) after plant emergence. Within 3 d after silk emergence, a single application of ≈50 ECB neonate larvae mixed with maize cob grits were applied with a Davis inoculator to the silk brush of the primary ear on each plant (Wiseman et al., 1980). After inoculation, and the accumulation of ≈225 heat units (base 10 °C), up to 13 husked ears from the center row of each genotype in each replication were evaluated using both scales. Data were analyzed on an individual plant basis with the GLM procedure of SAS software (SAS Institute, 1990) in a combined analysis of variance for each scale. Means were separated via Fisher's Protected LSD. The relationship between the traditional and alternative scale was estimated via Spearman's Rank Correlation with the CORR procedure of SAS.

Results and Discussion

For both the traditional and the alternative scale, mean ear damage varied with year and location ($P \leq 0.01$). In 1994, ears from the Chanhassen location had higher mean damage ($\pm$ SEM) on both scales (4.7 ± 0.13 and 2.8 ± 0.05) than ears from the St. Paul location (3.9 ± 0.12 and 2.6 ± 0.05 for traditional and alternative, respectively). In 1995, damage ratings of ears from the Chanhassen location (5.1 ± 0.14 and 3.0 ± 0.06) and from the St. Paul location (5.3 ± 0.13 and 3.0 ± 0.06 for traditional and alternative, respectively) were similar for both scales. Environmental differences between locations and years may have contributed to the variation associated with ear damage.

The genotype main effect for both evaluation scales have large F values and meet the criteria ($F = 119.35$ and $F = 183.35$ for traditional and alternative, respectively) outlined by Little and Hills (1978) for significance ($P \leq 0.05$) in a combined analysis. Thus, ears from Inbred MN 3002, Hybrid MN 3004, 'Apache', and 'More' had lower mean damage ratings than ears from 'Jubilee', Inbred W182E, and Inbred MN 3003 for both the traditional and alternative scales (Table 1). Thus, four genotypes—Inbred MN 3002, Hybrid MN 3004, 'Apache', and 'More'—were classified as marginally acceptable and three genotypes—

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Table 1. Mean European corn borer ear damage for seven sweet corn genotypes evaluated with two visual scales at two Minnesota locations across two years.

Genotype	Mean damage rating ^a		Resistance classification ^b
	Traditional 1 to 9	Alternative 1 to 5	
Hybrid MN 3004	3.4 a ^c	2.2 a	moderately resistant
Inbred MN 3002	3.4 ab	2.4 b	moderately resistant
'Apache'	3.6 ab	2.2 a	moderately resistant
'More'	3.8 b	2.3 ab	moderately resistant
'Jubilee'	5.3 c	3.3 d	susceptible
Inbred W182E	5.6 c	3.0 c	susceptible
Inbred MN 3003	7.3 d	4.2 e	susceptible

^aMeans based on visual evaluation of 129 to 156 plants across three replications, two locations, and two years using a traditional 1 to 9 scale combining ear feeding damage levels and damage location or an alternative 1 to 5 scaled based solely on ear feeding damage levels.

^bResistance classifications are based on economic damage in terms of degree of failure to meet the requirements of the commercial processing industry.

^cMean separation within columns by Fisher's protected LSD, $P \leq 0.05$.

'Jubilee', Inbred W182E, and Inbred MN 3003—were classified as commercially unacceptable. These classifications correspond well with previous data acquired on the six known genotypes (Davis et al., 1994). For Hybrid MN 3004, previous data on ear damage were not available; however, both scales placed this genotype in the marginally acceptable class.

Year $\times$ genotype ($Y \times G$) and location $\times$ genotype ($L \times G$) interactions significantly ($P \leq 0.05$) affected ear damage ratings when the alternative scale was used ($F = 4.99$ and $F = 2.53$ for $Y \times G$ and $L \times G$, respectively). The two-way interaction F values, however, do not meet the criteria of Little and Hills (1978).

For ear damage across all genotypes, the two scales similarly ranked genotypes ($r = 0.78$) based on Spearman rank correlation estimates. Individual genotype rankings var-

ied by scale, but there were no rank changes in the degree of commercial acceptability. Though the nine levels on the traditional scale were based on economic consequences and the five on the alternative scale were based strictly on amount of feeding, excluding damage location, both scales effectively identified a fixed set of genotypes historically classified as marginally acceptable and unacceptable. The traditional scale, with ear damage location and economic impact information, allows selection among genotypes having similar percentage biological damage, which should be useful in resistance breeding programs. Additionally, the combination of quantitative and qualitative criteria in the traditional scale did not compromise genotype characterization, as the previously untested hybrid, MN 3004, was classed as marginally acceptable by both scales.

Both scales separate commercially acceptable, marginally acceptable, and commercially unacceptable genotypes; however, perhaps neither scale effectively separates genotypes within each of these three categories. To further separate genotypes within the commercially acceptable and marginally acceptable classes, both scales could be expanded to include the amount of feeding in the silk channel (i.e., distance of feeding from silk channel tip).

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