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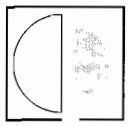

Ranking and evaluation of field corn hybrids for resistance to blackbird damage

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We measured husk characteristics for a sample of ears from each of 229 hybrids grown in a performance test in Ohio in 1987 and ranked these hybrids for potential resistance to bird damage. Hybrids predicted to be resistant (i.e. with heavier husks) tended to mature later and have lower yields in the 1987 performance test than did the lighter-husked hybrids. We selected three hybrids from the 10 predicted to be most resistant, three from the 10 predicted to be least resistant and two intermediate hybrids to be evaluated in a free-choice aviary test with red-winged blackbirds (*Agelaius phoeniceus* L.) in 1988. The three resistant hybrids averaged 2.5% corn loss, significantly ($P < 0.01$) less than the 26.1% loss for the three susceptible hybrids. The two intermediate hybrids had intermediate damage levels. In a 1989 field evaluation in New York, damage was substantial in all hybrids although the three predicted-resistant hybrids still averaged significantly ($P < 0.05$) less loss (20.5 bu/ac) than did the predicted-susceptible hybrids (27.4 bu/ac). Final yield was not significantly different between the two hybrid groups. The ranking system accurately predicted resistance but additional evaluation is recommended regarding within-hybrid variation in husk characteristics among planting sites and years.

Keywords: corn; *Zea mays*; red-winged blackbird; *Agelaius phoeniceus*; resistance

Blackbird (Icterinae) depredations to ripening grain crops, especially corn, have been a problem in North America since pre-colonial times (Cardinell and Hayne, 1945). Blackbird populations continue to thrive with the red-winged blackbird, the chief depredator of corn, being the most abundant bird species in North America (Dolbeer and Stehn, 1983; Robbins, Bystrak and Geissler, 1986).

Depredations to ripening field corn presently are not severe on a national scale since less than 1% of the U.S. and Canadian crop is destroyed annually by blackbirds (Weatherhead, Tinker and Greenwood, 1982; Besser and Brady, 1986). However, in some localities near Wetlands, damage can be economically important with losses of 5–15% commonly occurring to individual fields (Bollinger and Caslick, 1985). Depredation problems, besides their economic impact, also generate opposition within agricultural communities to important conservation programs such as wetland habitat preservation. Farmers sometimes resort to illegal poisoning programs to reduce populations causing damage (Stone, Overman and Okoniewski, 1984).

One research area that bears promise for reducing bird damage is hybrid resistance. Caccamise (1975) and Linehan (1977) reported that bird damage varied widely among hybrids grown in experiment station plantings. Dolbeer, Woronecki and Stehn (1982, 1984, 1986a) showed in aviary tests that certain ear and husk characteristics were correlated with this relative damage among hybrids. Field tests (Dolbeer *et al.*, 1984; Dolbeer, Woronecki and Stehn, 1986b; Woronecki, Dolbeer and Otis, 1987; Dolbeer, Woronecki and Mason, 1988) have supported these aviary findings.

If bird-resistant hybrids are to serve a useful role in integrated pest management programs for corn, they must be competitive with the high-yielding hybrids that farmers are already growing (Dolbeer *et al.*, 1986b). Because the number of farmers affected by economically significant bird damage is small, it is unlikely that commercial seed companies will invest to produce special hybrid lines that are resistant to bird damage. An alternative is to develop a bird-resistance rating system for commercial seed corn hybrids based on husk and ear characteristics known to be correlated with bird damage. This would allow large numbers of hybrids (which are already evaluated for various agronomic characteristics annually under controlled conditions at state agricultural experiment stations) to be inexpensively and objectively rated for their predicted resistance to bird damage. Then, farmers in high-damage areas could include bird resistance along with other characteristics normally considered (e.g. yield, per cent water) in selecting a hybrid for a particular situation.

Our objectives were to (1) measure characteristics for a sample of ears from 229 hybrids grown at a state agricultural experiment station, (2) rank these hybrids for predicted resistance to blackbird damage using previously developed equations relating husk and ear characteristics to bird damage, and (3) evaluate a sample of these hybrids for bird damage under aviary and field conditions to compare actual with predicted rankings.

Methods

Ranking of hybrids

We sampled ears on 2 and 5 October 1987 from 229 hybrids grown at the Northwestern Branch of the Ohio Agricultural Research and Development Center in Wood County, Ohio. Each hybrid was planted on 8 May in an 8-m long by 4-row wide plot in each of two blocks (Jordan, 1987). Row spacing was 0.7 m. We collected 12 ears from each hybrid, three ears from the outer two rows of each hybrid plot. A rubber band was secured around each ear at the time of removal from the stalk to ensure the husk would remain in place. Ears from each hybrid plot were placed together in a labeled paper sack.

The ears were brought to the laboratory for measurement. First the shank and cob stem were separated from each ear by sawing through the husk precisely at the cob butt. The maximum and minimum husk length (mm) from butt to husk tip was measured for each ear. The husk was then separated into two components by cutting with scissors exactly at the cob tip. The two components (husk from butt to cob tip, husk extension beyond cob tip) were placed in separate bags in a drying room (38°C) for at least 1 week before weighing (0.1 g). Finally, the maximum corn kernel row length and cob length were measured (mm). Mean and variance values were then calculated for each husk and ear characteristic of each hybrid. We used mean weight of husk extension beyond cob tip as our initial ranking factor for resistance because this variable has consistently shown the highest correlation (negative) with damage (Dolbeer *et al.*, 1988). Spearman's rank correlation coefficients were used to compare the relative rankings of hybrids for various characteristics.

Aviary test

After ranking the 229 hybrids, we selected three from the 10 with the heaviest husk extension (predicted to be most resistant), two from the middle 10, and three from the lightest 10 to be evaluated in an aviary test in 1988 (*Table 1*). These eight hybrids were planted on 3 June 1988 in plots 70 m by six rows (4.5 m) in Erie County, Ohio. Plant spacing averaged 20 cm. At 2-day intervals from 3 to 13 August, all plants with newly silked ears in rows two to five of each plot were marked with spray paint. A different color was used each day to allow use of ears of the same silking date in the evaluation.

In July, 150 adult male red-winged blackbirds were captured in mist nets in Erie County, Ohio. Birds from this population were placed, four to a cage, in 16 1.5 × 1.0 × 0.5-m cages in an outdoor pavilion. The birds were adapted to feeding on ears of corn in captivity for 2 weeks before the experiment began (Woronecki *et al.*, 1987).

On 27 August at 0800, 16 ears at 21 days after silking were picked from each hybrid and brought to the aviary. One ear from each hybrid, with husk and shank intact, was placed in each of the 16 cages for 6 h (0900–1500). The ears were skewered to nails on a board at 20-cm intervals at an angle of 30° from vertical and with the same orientation as on the plants. Ears were assigned randomly to positions on the board. For 1 h before and during the 6-h test, all other food, but not water and grit, was removed from the cages. Upon removing the ears from the cages, the per cent of kernel biomass removed was visually estimated (Woronecki, Stehn and Dolbeer, 1980).

A randomized block analysis of variance [16 cages (blocks) and eight hybrids per cage] with a planned linear comparison was used to test for differences in mean damage (per cent corn loss, per cent of ears damaged) between the three predicted-resistant and three predicted-susceptible hybrids.

Field test

In 1989 we evaluated three predicted-resistant and three predicted-susceptible hybrids (*Table 1*) in a field test in Cayuga County, New York. Two of the three hybrids in each group had been evaluated in the aviary test in 1988. The test was located in a 25-ha commercial corn field adjacent to Montezuma National Wildlife Refuge, 6 km north of Cayuga Lake. Corn grown in this location historically has received substantial damage by red-winged blackbirds; several roosts containing up to one million birds in late summer traditionally are located within 10 km of the test site (Cutright, 1973; Bollinger and Caslick, 1985).

The hybrids were planted on 18 May in six replicate blocks, each containing six plots measuring eight rows (7.3 m) by 91 m. Plant spacing averaged 16 cm. The six hybrids were randomly assigned to plots in each block. Blocks were 15 m apart with bare ground maintained between and around blocks.

On 31 August, 4 weeks after silking and when husk growth was complete (Hanway, 1971), 40 ears were randomly picked from rows four and five of the six plots of each hybrid. Husk and ear measurements, as described above, were made on these ears. On 5 October we assessed bird damage and yield. In each plot, 20 subplots consisting of five consecutive plants were located, 10 in rows two and three and 10 in rows six and seven. The first subplot was randomly located on one of the two rows within the first 9 m of the row pair. The remaining nine subplots were systematically located at intervals of 9 m, alternating between rows.

The ear on each plant in a subplot was picked and the husk removed before the per cent of kernel biomass destroyed by birds was visually estimated as in the aviary and the maximum kernel row length was measured to the nearest mm. Per cent loss per ear was weighted by corn length to avoid bias resulting from possible differential damage to different-sized ears. All ears within a subplot were placed in a burlap bag and the length of each subplot was measured. The corn from each group of 10 subplots was weighed. The per cent water content was measured with a moisture meter for a sample of these ears. Yield (bushels of corn/acre adjusted to 15.5% water, multiply by 61.4 to convert to kg/ha) was obtained for each plot by combining the water-adjusted weight of corn with the length of the subplots and spacing between rows. Yield lost to birds was estimated by adjusting the final yield by the per cent loss to birds.

A randomized block analysis of variance (six blocks and six hybrids per block) with planned linear comparisons was used to test for differences in bird damage

Table 1. The 10 hybrids of field corn with the heaviest and lightest husk extensions (i.e. predicted most resistant and susceptible, respectively, to damage by blackbirds) out of the 229 hybrids measured in Ohio, 1987

Predicted-resistance rank	Seed company	Hybrid name	Husk extension weight (g)		Days from planting to 50% silking	Yield (bu/ac)*	Evaluated for bird damage†
			$\bar{x}$ SD	(n = 12)			
1	Shur Grow	SG836	2.64	0.56	67	79.1	
2	Funk Seeds	G4543	2.58	0.49	68	78.9	A, F
3	Walton	WX39	2.57	0.32	66	73.5	A, F
4	Seedex	1110	2.57	0.56	68	68.3	
5	Steyer Seeds	2500	2.54	0.56	68	77.3	
6	GSF	X665	2.54	0.49	72	81.3	
7	Jacques	7820	2.53	0.61	69	71.0	
8	Pettigrew	SX51A	2.47	0.64	68	64.6	
9	Golden Harvest	H2572	2.47	0.72	71	74.9	F
10	Walton	WX35	2.45	0.35	71	73.1	A
220	Robinson	R327	0.72	0.20	67	86.7	
221	Exseed	XS1131	0.72	0.28	71	80.3	F
222	Cargill	7877	0.72	0.23	68	81.9	A, F
223	Northrup King	PX9527	0.70	0.30	67	81.4	
224	Pioneer	3352	0.70	0.42	66	104.4	A, F
225	Frenchs	750	0.68	0.19	69	89.7	
226	Anderson	PSX114	0.68	0.40	72	68.8	
227	Pioneer	3295	0.60	0.36	71	84.3	A
228	Northrup King	PX9385	0.56	0.13	62	77.8	
229	King Grain	K416	0.41	0.19	61	81.9	

*From Jordan (1987); multiply by 61.4 to convert to kg/ha
†A = Aviary test, 1988; F = Field test, 1989

Table 2. Damage by red-winged blackbirds to eight hybrids of field corn in an aviary test in Ohio, 1988

Seed company	Hybrid name	1987 Measurements		1988 Aviary results (n = 16 ears/hybrid)	
		Mean husk extension wt (g)	Predicted damage status	Mean per cent loss	Per cent of ears damaged
Funks	G4543	2.58	Resistant	0.3	6.3
Walton	WX39	2.57	Resistant	1.6	12.5
Walton	WX35	2.45	Resistant	5.6	25.0
Mean		2.53		2.5*	14.6*
Crows	488	1.24	Neutral	7.3	37.5
King Grain	K596	1.24	Neutral	6.9	62.5
Mean		1.24		7.1	50.0
Cargill	7877	0.72	Susceptible	20.6	75.0
Pioneer	3295	0.60	Susceptible	26.6	93.8
Pioneer	3352	0.70	Susceptible	31.1	100.0
Mean		0.67		26.1*	89.6*

*Means in same column with an asterisk are significantly ($P < 0.01$) different, randomized block analysis of variance with planned linear comparison

and yield between the three predicted-resistant and three predicted-susceptible varieties.

Results

Ranking of hybrids, 1987

Based on the relation between husk extension weight and bird damage shown previously (*Figure 1* in Dolbeer *et al.*, 1988), we predicted that those hybrids with a mean husk extension weight >2.0 g would be resistant and those with a mean weight <1.0 g would be susceptible to damage. Overall, 35 of the 229 hybrids had mean husk extension weights >2.0 g and 56 had weights <1.0 g. The 10 hybrids with the heaviest and lightest husk extension are listed in *Table 1*. The three 'predicted resistant' hybrids selected for aviary testing had mean husk extension weights of 2.45–2.58 g. In contrast, the husk extensions of the three hybrids selected from the 'predicted susceptible' group averaged 0.60–0.72 g, about 25% of the values for the hybrids predicted to be resistant (*Table 2*).

Although we chose to use husk extension weight as our ranking variable, the rankings would have been similar if we had used either husk extension length or a multiple variable of husk extension weight and total husk weight. These variables have also shown high correlations with damage and are highly correlated with husk extension weight (Dolbeer *et al.*, 1988). For the 229 hybrids, the correlation (r) between the rankings based on husk extension weight and husk extension length was 0.85 and between husk extension weight and a multiple variable of husk extension weight and total husk weight was 0.96 ($P < 0.001$, 227 d.f.).

Overall, rankings for husk extension weight and 50% silking date were correlated ($r = 0.33$, $P < 0.01$) for the 229 hybrids, suggesting that hybrids with heavier husks tended to mature later. For example, the 25 hybrids

with the heaviest husk extensions reached 50% silking an average of 69 days after planting compared with 66 days for the 25 hybrids with the lightest husk extensions ($t = 3.75$, 48 d.f., $P < 0.01$). Ranking for yield was negatively correlated ($r = -0.31$, $P < 0.01$) with ranking for husk extension weight for the 229 hybrids, indicating that hybrids with heavier husks tended to have lower yields than did hybrids with lighter husks. Yield for the 25 hybrids with the heaviest husk extensions averaged 75.5 bu/ac compared with 87.8 bu/ac for the 25 hybrids with the lightest husk extensions ($t = 5.46$, 48 d.f., $P < 0.01$).

Free choice aviary evaluation, 1988

There were highly significant ($P < 0.01$) differences between the three predicted-resistant and the three predicted-susceptible hybrids in the two measures of damage ($t = 9.1$ and 10.3 with 105 d.f. for per cent corn loss and per cent of ears damaged, respectively). The three resistant hybrids averaged 2.5% corn loss and 15% of the ears damaged compared with 26.1% corn loss and 90% of the ears damage for the three susceptible hybrids. The two hybrids predicted to be intermediate in resistance had damage levels intermediate to the above values (*Table 2*).

Free choice field evaluation, 1989

The three predicted-resistant hybrids averaged 86% of the ears damaged and 20.5 bu/acre lost to birds which was significantly ($P < 0.05$) less than the estimates of 94% and 27.4 bu/acre for the predicted-susceptible hybrids ($t = 2.65$ for per cent of ears damaged and 2.07 for yield loss, 25 d.f.) (*Table 3*). These yield losses represented 13.0 and 17.2% of the crop for the predicted-resistant and -susceptible hybrids, respectively. Husk extension weights for the three predicted-resistant hybrids ($x = 1.1$ g), although substantially less than the 2.5–2.6 g level measured for the same hybrids in 1987 (*Table 1*), were still significantly ($P < 0.01$) greater than the mean weights for the three predicted-susceptible hybrids ($x = 0.6$ g) ($t = 4.02$, 25 d.f.). Mean yield lost per hybrid and mean husk extension weight were correlated ($r = -0.94$, 4 d.f., $P < 0.05$) for the six hybrids.

Despite significant differences in bird damage for the predicted-resistant and predicted-susceptible hybrids, mean final yields were similar ($P = 0.25$) for the two groups ($t = 1.11$, 25 d.f.). Yields ranged from 123.5 to 149.7 bu/acre for the six hybrids (*Table 3*).

Discussion

There was sufficient diversity in relevant husk characteristics among commercially available hybrids in the 1987 performance planting to obtain relatively large pools of hybrids predicted to be either resistant or susceptible. The 1988 aviary evaluation, in which ears were exposed to birds for 6 h, was highly supportive of the rating system. However, results from the field test in 1989, in which ripening ears were exposed to heavy bird pressure over several weeks, were not as encouraging. Although the predicted-resistant hybrids averaged significantly less loss to birds than did the predicted-susceptible hybrids, damage was still substantial (83–91% of ears damaged and 18–23 bu/ac lost). Furthermore, final yield, the ultimate measure of efficacy for field corn, did not average significantly higher for the predicted-resistant hybrids compared to the predicted-susceptible hybrids.

One factor that may have contributed to the substantial damage in the predicted-resistant hybrids during the 1989 field test was the reduced husk extension weights of the hybrids ($x = 1.1$ g) compared to the weights for the same hybrids in 1987 ($x = 2.5$ g) when the initial resistance ranking was done. The three predicted-resistant hybrids still had significantly heavier husk extensions in 1989 than the predicted-susceptible hybrids ($x = 0.6$ g) but the difference was substantially less than in the initial ranking. Our previous work (Dolbeer *et al.*, 1988) indicated mean husk extension weight should be >2.0 g for a hybrid to be considered resistant.

In conclusion, this study further substantiated that husk characteristics can influence blackbird damage to corn. The ranking system was successful in predicting resistant and susceptible hybrids; however, the degree of resistance exhibited in the field test under heavy bird pressure was economically insignificant. Unfortunately, we do not know what the level of resistance would have

Table 3. Damage by red-winged blackbirds and yield for six hybrids of field corn grown in six replicated blocks, Cayuga County, New York, 1989

Seed company	Hybrid name	Predicted damage status (see *Table 1*)	Loss to birds		Hybrid characteristics		Final yield (bu/ac)*
			Per cent ears damaged	Yield (bu/ac)*	Per cent water at assessment	Husk extension wt. (g)	
Funk	G4543	Resistant	83	18.0	45	1.2	125.5
Walton	WX39	Resistant	91	22.7	42	1.0	149.7
Golden Harvest	H2572	Resistant	85	20.7	46	1.2	135.4
Mean			85†	20.5†	44	1.1†	136.9
Cargill	7877	Susceptible	92	23.1	45	0.6	137.8
Exseed	S1131	Susceptible	92	27.7	45	0.6	123.5
Pioneer	3352	Susceptible	97	31.4	43	0.6	135.7
Mean			94†	27.4†	44	0.6†	132.4

*Adjusted to 15.5% water; multiply by 61.4 to convert to kg/ha
†Means in same column with † are significantly ($P < 0.05$) different, randomized block analysis of variance with planned linear comparison

been in the field test if husk extension weights had been higher. Additional work is needed to determine the degree and cause of within-hybrid variation in husk characteristics among planting sites and years to refine the ranking system. In the meantime, we recommend the use of heavy-husked hybrids in localities of high bird damage, but only if those hybrids have potential yields competitive with lighter-husked hybrids.

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