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Evaluating Corn Varieties for Resistance to Damage by Blackbirds and Starlings

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ABSTRACT: Because of many uncontrolled variables, it is difficult to study the influence of crop varieties and crop maturity on bird damage under field conditions. To achieve some degree of control in our evaluations of bird damage to corn, we constructed an outdoor aviary with 24 cages (1.5 by 5.0 by 1.0 m), each capable of holding up to ten birds. Racks designed to hold eight husked or unhusked ears of corn in a natural field position were constructed for the cages. This design allowed the evaluation of bird damage to field and sweet corn, controlling for such factors as bird species and sex, bird numbers, duration of damage, maturity of corn, and varieties. In addition, varieties could be tested under both free-choice (up to eight varieties) and no-choice (only one variety) regimes in replicated experiments. By measuring ear and husk characteristics, we could determine which characteristics were most closely associated with differences in damage among varieties. Varieties showing high degrees of resistance in the aviary could then be evaluated in replicated field experiments. With minor modifications, these procedures could be used to evaluate bird damage resistance in other agricultural crops.

KEY WORDS: field corn, sweet corn, resistance, damage, blackbirds, starlings, aviary, test methods, vertebrate pest control, hybrids, varieties, cultivars

Bird damage to various agricultural crops is a serious problem in localized areas throughout the world [*1*]. In the United States the greatest economic loss is caused by blackbirds (Icterinae) feeding on ripening field and sweet corn [*2-4*]. The concept of using varieties[3] of corn and other crops resistant to bird damage has been considered since at least the 1950s [*5-8*]. Resistance is a particularly attractive concept for corn because blackbirds feed on insect pests in cornfields during the period of flowering and early ear development [*9,10*]. If resistant varieties reduced the amount of corn consumed, the insectivorous feeding habits of the birds could be used to the farmer's advantage.

Because of experimental and economic constraints, little progress has been made in the development of bird-resistant lines of corn and other crops. Experimentally, the evaluation of varieties for resistance in field trials is difficult because of the inconsistency of bird feeding pressure. Furthermore, varieties of corn develop at different rates so even if birds do enter a test site, some varieties may be in a more vulnerable stage of ear development than others. Therefore, field trials to evaluate varietal resistance often fail because of temporal and spacial variability in bird feeding pressure.

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[3]For convenience we refer to both hybrids and varieties simply as varieties.

Economically, seed companies do not foresee a large demand for specially developed bird-resistant varieties because of the localized nature of the problem, even though damage to commercial fields is sometimes severe. Therefore, seed companies have not pursued this approach, especially after considering the difficulty and expense of incorporating bird-resistance into their field trial and breeding programs.

Our objective was to develop a procedure for evaluating varieties of sweet and field corn for resistance to bird damage that would eliminate much of the uncertainty of field trials. We report here the design and procedures for an aviary system developed over the past six years for such evaluations. In addition, we present some examples of experimental work to demonstrate the response of birds to selected corn varieties under various test conditions.

Procedures

Structure of Aviary

An aviary was constructed in Erie County, Ohio by enclosing a 6.6 by 12.8-m outdoor pavilion with 2.5 by 2.5-cm chicken wire fabric to protect captive birds from predators and to retain any birds escaping from cages located therein. The aviary was open on all sides, had a pitched roof and concrete floor, and was situated in a wooded area isolated from human activity. Its open structure provided caged birds with the seasonal environmental conditions of light, temperature, and other weather factors except direct rain. The surrounding trees provided additional shade and shelter from wind.

Inside the wire-enclosed pavilion, test cages made from 2.5 by 2.5-cm welded wire were used to house the birds and place the ears of corn to be evaluated. Since our initial evaluations of corn varieties in 1979, several changes in the number and size of cages, the number of birds and ears of corn per cage, and the hours of exposure of the corn to the birds have been incorporated to improve and expand testing procedures.

In 1979 and 1980, four to six test cages with eight to ten birds per cage were used to evaluate corn varieties [*11,12*]. The cage size was 1.5 (length) by 1.0 (width) by 1.0 (height) m as recommended by J. T. Linehan, Denver Wildlife Research Center, Newark, Delaware (personal communication). In 1981, six more of these cages were constructed, for a total of twelve, and each cage was subdivided with a vertical plywood partition into two 1.5 by 0.5 by 1.0-m compartments. This provided 24 test compartments with a visual barrier between adjacent compartments in each duplex cage (Fig. 1). The twelve duplex cages were suspended 1 m off the floor by cables from the rafters in two rows of six cages each with a 3-m-wide aisle between the two rows. Duplex cages within rows were 0.6 m apart. Hereafter we will simply refer to each 1.5 by 0.5 by 1.0-m compartment as a test cage.

Three 1 by 2-m tables were located in the aisle between cage rows to facilitate placement and removal of test ears from cages. Two 2.4 by 2.4 by 1.8-m holding cages were located at one end of the aviary to maintain birds not being used in tests. The suspended cages and concrete floor allowed for convenient removal of feces and food residue by scraping, sweeping, and hosing.

Each test cage was identically supplied with the following: a 1.5-m-long perch located 0.2 m from the top and 0.2 m from the plywood side of the cage to minimize the contamination of underlying food, water, and test material with droppings from perching birds; a Hart trigger cup waterer attached to the side of the cage 5 cm from the cage floor with a 3.8-L plastic reservoir on top of the cage; a 46-cm slide-top poultry feeder; a shallow 13-cm diameter cup for grit; a 5-cm-wide by 1-m-long wooden board for the birds to walk and feed on; a 10-cm piece of concrete block for the grooming of bill and nails; and a 20-cm-diameter pan for bath water (provided once a week). Each cage had a 23 by 53-cm welded-wire door, hinged on the top, on the side facing the aisle.

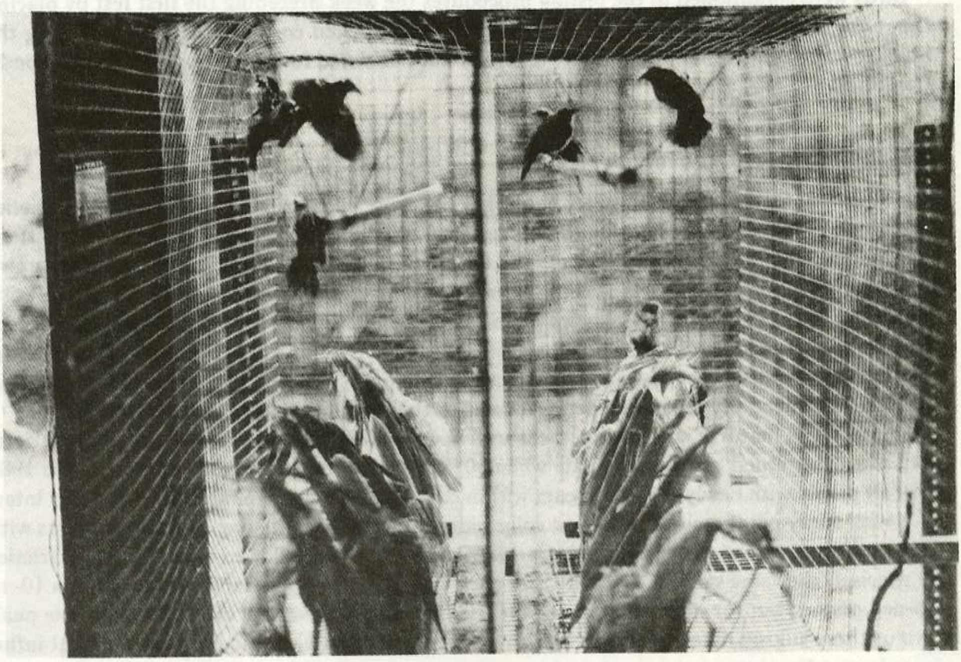

FIG. 1—*View of two 1.5 by 0.5 by 1.0-m cages used for evaluating field and sweet corn varieties for resistance to damage by birds.*

Capture and Maintenance of Birds

Mist-netting birds as they entered night-time roosts was the preferred method of capture because netting probably provides a more random sample of birds than is obtained from decoy traps [*13*]. Most mist-netting was done in July in marsh roosts along the south shore of Lake Erie in Northern Ohio within 5 km of cornfields that were being depredated by birds. All red-winged blackbirds *(Agelaius phoeniceus)* used in tests were mist-netted, whereas some of the common grackles *(Quiscalus quiscula)*, brown-headed cowbirds *(Molothrus ater)*, and European starlings *(Sturnus vulgaris)* were captured in traps. Most tests have been conducted using after-hatching year male redwings.

Birds were placed in the holding cages within 4 h of capture and held there for at least one week to adjust to captivity and to allow us to remove any injured or sick birds prior to the placement of birds in test cages. Only birds in good physical condition (normal appearance and weight) were removed from the holding cages and distributed randomly among test cages, one bird at a time. This balanced all test cages with an equal number of first and last caught birds from the holding cages. The number of birds per cage has ranged from two to ten in our tests. The birds remaining in the holding cages served as reserve birds for those that needed replacement due to abnormal appearance, escape, or death before tests. Only on rare occasions was this necessary.

All test birds were provided with grit, fresh water, a mixture of cracked corn, millet, and sunflower seeds, and poultry pellets (starlings only) *ad libitum* except that food was removed during most tests. Vitamins and minerals (Vita-Stress) were provided in the water supply.

Birds were conditioned to the testing procedures the week preceding the first test by placing the racks (to be described below) with ears of freshly picked corn in all cages (including the holding cages) for several 6-h periods. A variety not scheduled for evaluation was used to condition birds.

Preparation of Corn Varieties to be Tested

Since 1979, 27 field and 32 sweet corn varieties have been grown and evaluated. Varieties exhibiting a broad range of husk and ear characteristics and those suspected of being resistant or susceptible to bird damage were selected for study. Most varieties were already being grown commercially; however, several sweet corn varieties were still considered experimental. All varieties to be tested in a year were planted on the same day (between 5 May and 6 June) in adjacent three or six-row plots under identical conditions in a field 7 km from the aviary. Row spacing was 0.75 m, plant spacing averaged 20 cm, and plot lengths ranged from 30 to 150 m. The crop received commercially recommended fertilizer, herbicide, and insecticide applications.

Initially, the maturity of the ears [measured in days after silking (DAS)] within each varietal plot was determined by using the date when 50% of the plants had silked, but starting in 1980 [*12*] all plants with newly silked top ears within each variety plot were marked at two-day intervals with spray paint, using a different color paint for each marking day. This provided us with populations of ears of a known (within one day) silking date and allowed us to compare varieties at precisely the same stage of maturity. For each variety, silking generally occurred over a 10- to 14-day period, but for most studies we only used the ears of a variety marked during the peak two or three silking dates (covering four to six days). To avoid genetic or environmental influence from adjacent varieties or plot edges, only ears from plants in center rows of a variety plot and at least 3 m from the plot ends were used.

Tests focused on ear maturities between 14 and 20 DAS for sweet corn and 22 to 28 DAS for field corn to coincide with the milk stage period of kernel maturation when most damage by red-winged blackbirds occurs [*9,14,15*]. However, some varieties were tested from 10 to 60 DAS [*12,16*].

Tests were scheduled according to the type of evaluation planned and the maturity of the ears required. We began each test day at 0700 by randomly picking a predetermined number of ears from plants marked with a specific color (indicating maturity or DAS) from the varietal plots. The ears were transported to the aviary for placement in cages by 0900. Generally, at least five ears more than were needed in the test were picked to allow for the rejection of ears that appeared to be poorly developed or showed husk damage or abnormalities.

Corn to be evaluated was placed in cages on wooden racks designed to securely hold ears with husks and shanks intact at an angle of 30° from the vertical and with the same orientation as on the plants. Racks were 1.5 m long and were constructed so that with ears attached they could be inserted into or removed from cages rapidly. Ears were either fastened to the racks with wire holders [*11*] or skewered on nails (Fig. 2) [*12*]. Ears were spaced at 20-cm intervals and the rack was placed in the cage center to prevent birds from feeding on one ear while perched on an adjacent ear or on the cage side. In the larger cages [*11*] racks were capable of holding 16 ears (angled in two directions). In the smaller cages that have been used since 1980 [*12*], only eight ears (angled in one direction) could be positioned in the cage.

A test consisted of placing the racks with corn of one or more varieties in cages with two or more birds for usually 6 h (0900 to 1500). Tests were classified as no-choice or free-choice. In no-choice tests, racks contained all ears of the same variety whereas in free-choice tests equal numbers of each variety being tested on that day were randomly positioned on the same rack. The number of replications that were possible for any test was dependent on the number of varieties and the type of test. In our 24-cage aviary we could conduct six, four, and three replications in a no-choice test with four, six, and eight varieties, respectively, or 24 replications in a free-choice test with either two, four, or eight varieties.

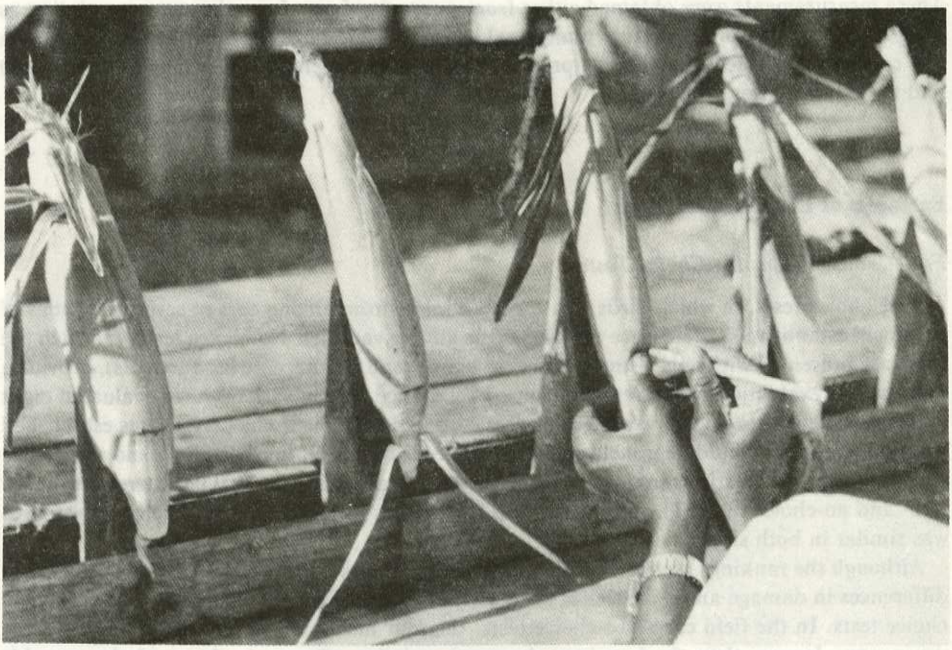

FIG. 2—*Wooden rack on which eight ears of corn could be attached at 30° angles from the vertical by skewering on nails protruding from the blocks of wood.*

Each year, tests were randomly assigned to cages of birds with the restriction that all cages were used equally throughout the evaluation period, which generally ran from early August to mid-September. All birds used in a test were without fresh corn the preceding day (that is, no cage of birds was used in a test two days in a row). During most tests birds were deprived of normal rations for 1 h before and during the test, but water and grit were available. The rations were returned to the cages immediately after each test.

Damage Assessment

Immediately after racks were removed from the cages, all ears were assessed for bird damage. One or more measurements were made to estimate the amount of bird damage on each ear. The response most used in field corn tests was a visual estimate of the percent of kernel surface damaged (hereafter referred to as percent damage) to the nearest percentile [*17*]. Other methods included determining the surface area of damage (cm^2) by placing a clear plastic bag over each ear and tracing the outline of the damaged area with a fine-tipped permanent marker and measuring the area with a planimeter [*11,12*]. For sweet corn, bird damage was estimated for each ear by measuring the maximum length of damage down a corn row. The percent of ears damaged by variety was also used [*4*].

Varietal Measurements

Certain husk, ear, and kernel characteristics have been measured for most of the 59 corn varieties grown since 1979 to examine correlations with the amount of bird damage. These characteristics and the methods used to measure them are described in Dolbeer et al. [*11,12,4*].

These measurements were obtained either from a sample of ears from the same population as used in the tests or from the ears actually used in the tests. Some of the measurements taken on test ears were obtained immediately prior to tests, but others (requiring removal of the husk) had to be taken after the tests.

Examples of Experimental Work

Free-Choice Versus No-Choice Tests

Free-choice tests, in which birds in a cage can select from among ears of several varieties of corn, will establish if a preference ranking exists among varieties. No-choice tests, in which the birds are presented with only a single variety at a time (and no alternate food sources), provide a more severe evaluation of the relative damage resistance among varieties. We evaluated eight varieties of field corn and 13 varieties of sweet corn to determine if any preferences established in free-choice tests would be upheld in the no-choice tests [*12,4*]. For both field and sweet corn we found that the relative rankings of varieties were significantly ($P < 0.05$) correlated in the free- and no-choice tests. This indicated that the process by which the birds selected varieties was similar in both situations.

Although the rankings among varieties were similar in free- and no-choice tests, the absolute differences in damage among varieties were diminished in no-choice tests compared with free-choice tests. In the field corn free-choice tests, the four most preferred varieties averaged 5.1 times more damage than the four least damaged varieties, whereas in the no-choice test this ratio was only 1.3 [*12*]. Similarly, in the sweet corn evaluations the ratio of damage for the four most and four least damaged varieties was 3.1 in the free-choice and only 1.3 in the no-choice tests [*4*]. No variety tested so far has shown absolute resistance under a no-choice test regime; however, under a free-choice regime certain varieties have been shown to be highly preferred (Table 1).

In conclusion, our evaluations have indicated that no-choice and free-choice tests give similar results when it is desired to rank varieties to their relative susceptibility to damage. However, the no-choice tests provide a more severe evaluation and generally show that the birds are capable of damaging even the least preferred varieties when no alternate food is available. However, even under these severe conditions there are significant differences in damage among varieties, indicating that some resistance factors are operating.

Influence of Supplemental Food on Test Results

An issue related to the influence of free- and no-choice regimes on the damage amounts and patterns among corn varieties is the effect of a supplemental or alternative food source during tests. To evaluate this effect we ran a test [*16*] in which three cages of starlings were presented with two varieties of field corn and a supplemental, preferred food (Pullet starter). Three other cages of starlings received the two corn varieties, but no other food. Cages with and without supplemental food were alternated on a subsequent day.

We found that the birds damaged 3.2 times more corn without supplemental food available than with pullet starter available. However, under both regimes the starlings demonstrated a similar, significant ($P < 0.05$) preference for the same variety, consuming 6.5 to 6.6 times more of it than of the less preferred one. Thus, a supplemental preferred food source had no influence on the relative degree of preference between two varieties even through the corn consumption was reduced by 69%.

TABLE 1—*Comparison of damage (% corn removed/ear) ranking of eight varieties of field corn in free-choice aviary tests with four levels of bird pressure, 1982. At each bird pressure level, ears from the eight varieties were presented in six cages (blocks or replications) for 6 h on four dates (repeated measures) following methods of Dolbeer et al.* [10].

	No. of Red-Winged Blackbirds/Cage									
	2		4		6		10		Total[b]	
Rank[a]	Variety	% Damage	Variety	% Damage	Variety	% Damage	Variety	% Damage	Variety	% Damage
1	7	0.1	5	1.8	7	1.4	7	3.1	7	1.8A
2	9	0.8	3	1.9	3	3.5	9	6.5	3	3.5A
3	3	0.8	7	2.4	5	4.7	3	7.7	5	4.2A
4	5	1.8	9	3.0	9	6.5	5	8.5	9	4.2A
5	6	2.7	8	5.8	6	8.7	6	14.9	6	8.4B
6	2	2.8	6	7.3	2	10.3	2	17.7	2	10.9B
7	8	3.3	2	12.7	8	15.1	8	20.3	8	11.1B
8	10	10.1	10	13.3	10	18.8	10	22.9	10	16.3C
$\bar{x}$/cage	...	2.8	...	6.0	...	8.6	...	12.7	...	7.5
$\bar{x}$/bird/cage[c]	...	1.4	...	1.5	...	1.4	...	1.3	...	1.4
Range, least to most damaged variety	...	10.0	...	11.5	...	17.4	...	19.8	...	14.5
CV of treatment mean[d]		0.360		0.398		0.251		0.207		...

[a]The ranking of varieties was significantly ($P < 0.05$) correlated for all six pair-wise comparisons of bird levels [Spearman's coefficient of rank correlations, 6 degrees of freedom (df)].

[b]There were significant ($P < 0.01$) differences in mean damage among varieties and bird levels (split plot ANOVA with cages as blocks—7, 3, 21, 20, and 140 df for varieties, bird levels, variety-bird level (v-bl) interaction, blocks and error, respectively). The bird level-variety interaction effect was not significant ($P = 0.10$). Means with different letters are significantly ($P < 0.05$) different, Duncan's Multiple Range Test.

[c]The mean damage/bird/cage was not significantly ($P > 0.10$) different among bird levels (one-way ANOVA, 3 and 20 df).

[d]Coefficient of variation (CV) of treatment mean is a measure of the relative variability associated with the estimate of the mean damage per variety for a given level of birds = $\sqrt{EMS/r}/\bar{x}$, where *EMS* is the error mean square for varieties within a given level of birds, *r* is the number of replicates (that is, six cages) and $\bar{x}$ is the mean damage per ear.

Influence of Number of Birds Per Cage on Test Results

To examine the influence of bird numbers per cage on damage amounts and patterns, we ran a free-choice test in 1982 with eight varieties of field corn under regimes of two, four, six, and ten redwings per 1.0 by 0.5 by 1.5-m cage (0.25, 0.50, 0.75, and 1.25 birds per ear of corn). We found no significant ($P > 0.05$) difference in the relative ranking of varieties for damage under the various bird pressures (Table 1). In addition, we found no significant ($P > 0.10$) difference in the overall mean percent damage per ear per bird with two, four, six, or ten birds per cage (Table 1). A no-choice test comparing damage to three varieties of field corn also showed no significant ($P > 0.10$) difference in the mean damage per bird per ear under these four levels of bird pressure (Table 2).

Although the relative rankings of varieties did not change significantly, the range in mean percent damage levels among varieties increased as the bird numbers increased from two to ten per cage. There was also a tendency for the variation in damage among ears of a given variety and bird level (as measured by the coefficient of variation of the treatment mean) to decrease as the bird level increased. Finally, coefficients of variation of treatment means were consistently lower for the no-choice test compared with the free-choice test, suggesting that no-choice tests are more powerful in detecting varietal differences in mean damage (Tables 1 and 2).

In conclusion, we found that within the range of two to ten birds per cage (each with eight ears of corn), the number of birds per cage had little influence on the relative rankings of varieties or on food consumption per bird. We have generally used four to six birds per cage (5.3 to 8.0 birds per m^3), a number that provides sufficient feeding pressure to obtain a good range in damage among varieties without overtaxing our ability to feed and maintain the birds under experimental conditions. However, the analyses summarized in Tables 1 and 2 suggest that ten birds per cage may be a more optimum number because the range in damage among varieties is maximized and the coefficient of variation of treatment means is minimized. One minor disadvantage of having more than six birds per cage is that it becomes difficult to accurately count them when preparing and inspecting the cages.

The conclusion that ten birds per cage is the most optimum number is based upon the assumption that availability of birds for the experiment is not limited. If, however, there is a fixed number of available birds and there are no limitations on cages, then the selection of the optimum bird number per cage involves a trade-off between the number of possible replications and the number of birds per cage (that is, the product of these two variables must equal the fixed number of available birds). Using the same data sets and coefficient of variation criterion as before, our analysis indicated the use of two birds per cage is best if the number of birds is limited. The slightly larger variation associated with this smallest group size was more than offset by the increased number of replications made possible by using the smallest group size.

Sex and Species Differences in Variety Selection

The male red-winged blackbird is generally acknowledged as the most important bird depredator of ripening corn in North America [*14*]. However, female redwings and common grackles frequently feed on ripening corn and there is limited evidence that starlings also cause damage [*16*]. Because these species (and sexes within species) have different body sizes, bill morphologies, and feeding habits, their selection in feeding among varieties might be different.

To test this hypothesis, we compared the damage patterns of the above four classes of birds in a free-choice test among 13 varieties of sweet corn [*4*]. There were significant ($P < 0.05$) differences among bird classes and among varieties in the amount of damage. However, the ranking of varieties for damage was not significantly different among the four bird classes, indicating that the varietal selection process was similar. Thus, the morphological and chemical factors associated with the ears of certain corn varieties that influence bird feeding levels are not species specific, but instead appear rather universal.

TABLE 2—*Comparison of damage (% corn removed/ear) ranking of three varieties of field corn in no-choice aviary tests with four levels of bird pressure, 1982. At each bird-pressure level, eight ears of corn of a given variety were presented for 6 h in two cages (replications) on four dates (repeated measures) following methods of Dolbeer et al.* [10].

	No. of Red-Winged Blackbirds/Cage									
	2		4		6		10		Total[a]	
Rank	Variety	% Damage	Variety	% Damage	Variety	% Damage	Variety	% Damage	Variety	% Damage
1	3	2.2	10	4.9	3	8.9	3	9.6	3	6.4A
2	10	2.7	3	5.3	2	9.1	2	13.8	10	8.1B
3	2	3.9	2	6.3	10	9.3	10	15.3	2	8.3B
$\bar{x}$/cage	...	2.9	...	5.6	...	9.0	...	12.9	...	7.6
$\bar{x}$/bird/cage[b]	...	1.5	...	1.4	...	1.5	...	1.3	...	1.4
Range, least to most damaged variety	...	1.7	...	1.4	...	0.4	...	5.7	...	1.9
CV of treatment mean[c]		0.094		0.179		0.047		0.010		

[a]There were significant ($P < 0.05$) differences in mean damage among varieties and bird levels (two-way ANOVA with 2, 3, 6 and 12 df for varieties, bird levels, v-bl interaction, and error, respectively). The variety-bird level interaction was not significant ($P > 0.10$). Means with different letters are significantly ($P < 0.05$) different, Duncan's Multiple Range Test.

[b]The mean damage/bird/cage was not significantly ($P > 0.10$) different among bird levels (one-way ANOVA, 3 and 20 df).

[c]Coefficient of variation of treatment mean is a measure of the relative variability associated with our estimate of the mean damage per variety for a given number of birds = $\sqrt{EMS/r}/\bar{x}$ where *EMS* is the error mean square for varieties within a given level of birds, *r* is number of replications (that is, two cages), and $\bar{x}$ is the mean percent damage.

One notable finding of this study was that starlings did the most damage, consuming 40% more sweet corn than did male redwings. This supported results from a previous aviary experiment where starlings did twice the damage of redwings to field corn [16] and indicates that the abundant starling has the potential to be a serious depredator of ripening corn in North America.

Influence of Corn Maturity on Variety Selection

Blackbirds initially damage ripening corn at about 15 to 20 DAS when the kernels are in the milk stage and have only about 25% of their final biomass [17]. Field corn does not reach physiologic maturity until about 50 to 60 DAS. Damage can occur throughout this period, although damage generally declines as the kernels mature and harden [18].

We conducted aviary studies to determine if birds consistently selected the same field corn varieties over others at various stages of kernel maturity. Our results indicated that stage of maturity can have a profound influence on the relative resistance of varieties to bird damage. For example, in a free-choice test, Variety 10 had about four times the damage of Variety 3 on five dates from 14 to 27 DAS. From 30 to 50 DAS these preferences were reversed with Variety 3 receiving two times the damage of Variety 10. A third, more resistant variety (No. 7) received almost no damage at any stage of maturity [12].

In conclusion, various stages of ear maturity from about 15 to 50 DAS should be examined when evaluating varieties of field corn for resistance. For sweet corn this is not necessary since the ears are usually harvested by 20 DAS. We evaluated the relative damage resistance among 13 varieties of sweet corn at 16 and 20 DAS and found no significant difference in selection by birds among varieties at these two maturity dates [4].

Correlation of Varietal Characteristics with Damage

We have examined in the aviary the relation between varietal characteristics and bird damage for field and sweet corn [11,12,4]. Our intent was to determine the morphological or chemical characteristics of ears that influence bird feeding selection.

Husk weight and husk extension beyond the ear tip were generally the factors most strongly correlated (both negatively) with damage, explaining up to 92% of the variation in mean damage among varieties. This pattern held both in tests in which we measured the characteristics on the specific ears placed in the cages with the birds [11] and in tests where we measured characteristics for an independent sample of ears from the same population as the ears selected for the cages [12,4]. We found similar significant correlations between husk characteristics and damage for ears within varieties [11]. We have done only limited evaluations of kernel characteristics. Our measurement of pericarp toughness and sugar content had little correlation with damage of ripening kernels [11,4]; however, tannin content of the mature kernels was negatively correlated with damage [19].

These findings suggest the possibility for developing an inexpensive system for rating varieties as to their relative resistance to bird attack based on mean husk, ear, and kernel characteristics. In addition, plant breeders can perhaps use this information to develop varieties with higher levels of resistance.

Comparison of Aviary Results with Field Results

In 1982, we planted the same eight varieties of field corn used in the aviary free-choice test (Table 1) in replicated plots at Ottawa National Wildlife Refuge, Ohio, within 2 km of a roost containing up to 100 000 blackbirds. The test design and damage assessment followed Dolbeer et al. [12].

TABLE 3—*Comparison of relative damage ranking of eight varieties of field corn in aviary and field tests, 1982. The field test consisted of eight replicated plots of each variety at Ottawa National Wildlife Refuge, Ohio. The aviary test was described in Table 1.*

	Free-Choice Aviary Test		Free-Choice Field Test	
Rank	Variety	% Damage[a]	Variety	% Damage[a]
1	7	1.8A	7	9.1A
2	3	3.5A	9	9.5A
3	5	4.2A	5	10.6A
4	9	4.2A	10	11.3A
5	6	8.4B	3	11.4A
6	2	10.9B	6	15.2B
7	8	11.1B	2	17.6B
8	10	16.3C	8	21.8C

[a]Means with different letters are significantly ($P < 0.05$) different, Duncan's Multiple Range Test.

With one exception (Variety 10), the ranking of varieties for damage was similar in the aviary and field tests (Table 3). Varieties 7, 3, 5, and 9 had significantly less damage than the remaining varieties in the aviary test. These same four varieties plus Variety 10 had significantly less damage than the remaining three varieties in the field test. The disparity in results for Variety 10 may have been related to the occurrence of damage in relation to corn maturity. As discussed above, variety 10 was shown in the aviary to be highly vulnerable to damage early in maturity [*12*], but relatively resistant later in maturity. Since Variety 10 was the earliest maturing variety of the eight tested, it may have passed the most vulnerable stage before the birds began feeding extensively in the test fields.

In another field evaluation of aviary results, we provided eight farmers in six Ohio counties with seed for Varieties 3 and 8 (a resistant and susceptible variety, respectively, based on 1982 aviary and field tests—Table 3). The farmers planted these varieties side by side in 1983 in 15 fields in localities where they felt blackbirds were a problem. Damage was assessed at harvest and the results supported our aviary findings. Hybrid 3 had significantly ($P < 0.05$) less loss (3.3%) and ears damaged (32%) than did Variety 8 (6.7% and 55%, respectively) [*20*].

Conclusions

Varietal resistance has the potential for reducing the amount of bird damage to ripening corn and perhaps other crops. The testing procedures we have developed in an aviary appear to provide a suitable and economical means of evaluating a large number of varieties for resistance. An aviary provides a technique for evaluating varieties under controlled conditions and a method of manipulating many variables (for example, bird species and numbers, maturity of corn at the time of damage, and the influence of alternate food) that are difficult to control in field evaluations. We also believe that the procedures described can be used, with perhaps some modifications, to evaluate varieties of other agricultural crops, such as sunflowers [*21*], for resistance to damage by birds. For the future, we feel additional studies are needed to compare the aviary results with evaluations conducted in the field.

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