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INTRODUCTION

Blackbird (Icteridae) damage to maturing corn (*Zea mays*) in the milk and dough stages has long been considered a severe problem in localized areas of the United States (Stone et al. 1972). Most estimates of primary loss to corn yields are based on visual or measured surface area estimates of damage to individual ears (Linehan 1967; De Grazio et al. 1969; DeHaven 1974; Granett et al. 1974). These estimates of loss ignore any compensating growth in the undamaged kernels and secondary losses from insects and disease that may have occurred following damage.

Numerous studies of fruit, small grain, and hay have shown that moderate injury or loss to stems, leaves, roots, or fruit can occur before yield is actually affected (reviewed by Stern 1973). Compensation in maturing corn has been suggested by Linehan (1967), Dawson (1970), Dyer (1975; 1976), and Woronecki et al. (1976).

The present study was conducted to quantify possible compensatory growth responses and to estimate the effects of secondary losses associated with bird damage to maturing corn. If compensatory growth is a significant factor, visual assessments of bird damage should be adjusted to reflect more accurately the impact of bird depredations.

Our previous study (Woronecki et al. 1976) suggested that net loss of shelled corn weight was a function of both the level of damage and the maturity of the ear at time of damage. The study also showed that low levels of bird damage could be partially compensated by increased kernel weight. Regardless of maturity, damage of less than six kernels per ear resulted in no net loss and in some instances resulted in increased yield. The results from that experiment were considered preliminary, because certain disparities left a doubt whether or not the data were confounded by plant responses to other primary and secondary damage.

The present experiment, a modification of our previous study (Woronecki et al. 1976), was designed to provide a more sensitive test of the direct effects of bird damage on maturing field corn. Modifications were made to improve procedures, eliminate some of the disparities contributing to weight loss of shelled corn, and reduce sampling errors.

METHODS

This experiment was conducted in Huron County, Ohio, in a 0.2-ha plot within a 32.4-ha field planted on 1 May 1977 with Pioneer 3518 (120 day) field corn. The plot, in addition to normal commercial agricultural practices, was aerially treated with an insecticide (Sevin) at seven and 14 days after silking to reduce insect damage. A propane exploder and shotgun patrol were maintained in the field to ensure that the subplots received negligible bird damage.

The experimental units were 56 subplots, each 6 rows by 5 m, randomly selected from the 80 established subplots. At the blister stage of ear growth (76 days after emergence), the first 70 top ears within each subplot that met the following criteria were tagged: (1) at least 11 cm in length from the base of the corn ear to tip of ear; (2) not irregular in shape or improperly developed or pollinated; and (3) not showing any signs of tip emergence, fungus, insect, or bird damage. Thirty of the tagged ears were randomly selected to be artifically damaged, and another 30 tagged ears were controls.

We used two stages of corn maturity and seven levels of simulated bird damage to form a total of 14 treatments (Table 1). The two maturity stages, named in reference to the consistency of the kernel's endosperm, were (I) milk (22 days after silking) and (II) dough (7 days after milk). Each treatment was replicated 4 times forming a total of 56 maturity and damage combinations.

Damage was inflicted with fine-tipped dissecting forceps, simulating actual bird damage. First, the husk was shredded on the upper side of the ear near the tip to expose only the necessary number of apical kernels. Then, beginning with tip kernels and proceeding in a predetermined pattern (Table 1), the kernels were damaged by pinching and removing most of the internal kernel biomass. To further simulate bird damage activity, any insects encountered were removed.

At weekly intervals, starting with first damage until harvest, 30 acceptable top ears of corn were collected from randomly selected alternate subplots to determine dry matter accumulation of cobs and kernels. The ears were husked, weighed, and dried. Each sample was weighed in seven separate aliquots composed of those kernels removed from each ear at each of the six levels of damage and then all remaining kernels. In addition, data were recorded on the incidence and surface area of fungus, insect and bird damage, and abnormal kernel development.

Damaged and undamaged ears from each of the 56 experimental units were harvested 160 days after planting, husked, and placed in burlap bags. The damaged and undamaged samples from each unit were dried, examined, shelled, and weighed.

Prior to shelling, a visual estimate was made of percentage surface area damaged and categorized as abnormal kernel development, fungus, sprouting, insects, birds, simulated damage, and unknown. Before the undamaged sample was shelled, the kernels from the same location and pattern as were previously destroyed in the damaged sample were removed from all 30 ears and weighed. After shelling the 30 ears, the following data were collected: total weight, kernel weight, cob weight, and percentage moisture. Net weight loss (hereafter called net loss) was computed as the difference between the kernel weight of the 30-ear damaged sample and the 30-ear undamaged sample for each plot. Table 2 summarizes the chronology of activities associated with the experiment.

RESULTS AND DISCUSSION

Maximum dry-matter accumulation in the cob occurred about seven weeks after silking, whereas maximum dry-matter accumulation in kernels occurred 10 weeks after silking (Fig. 1). At the time of milk-and dough-stage damage, 26 and 44%, respectively, of the dry matter had accumulated in all the kernels, although only 19 and 41 %, respectively, had accumulated in the damaged tip kernels (Table 3). Thus, from 81 to 59% of the dry matter that would have been incorporated into those kernels damaged was potentially still available for placement (translocation) into remaining undamaged kernels.

In spite of measures employed to minimize real bird damage, 6.5% of the ears in the undamaged sample showed bird or bird-like damage at the time of shelling. In the damaged sample, 10% of the 1440 ears with simulated bird damage showed no sign of damage. Apparently low levels of damage, especially early in the development, can be obscured by the growth of adjacent kernels. For example, 38 and 17% of the ears that had six kernels removed at the milk and dough stages, respectively, showed no visual evidence of damage at the time of shelling (Table 4). At harvest, the visual assessment underestimated both the incidence of damage (Table 4) and the kernel surface area destroyed (Tables 3 and 4) in this experiment.

Net loss in yield, the difference in dry weight of kernels between the paired 30-ear damaged and undamaged samples, is shown for each damage and maturity level in Figure 2. In only 11 of the 56 plots did damaged ears outweigh the undamaged ears. These results were markedly different from those shown in Figure 4 of Dyer (1975), where all plots had increased yield following bird damage. Our results established no increased average yield at any damage level, but it was possible that partial compensation or some translocation of available biomass had occurred that partially reduced net loss. The expected loss, assuming no compensation, was given by the dry weight of the same number of kernels removed at the same ear locations after harvest from the undamaged 30-ear samples (Table 3). The difference between net loss (damaged minus undamaged ears) and expected loss was not significantly affected by damage level (F = 0.336) or maturity (F = 0.444) (2x7 ANOVA).

The above analysis demonstrated no significant compensation in kernel weight following bird damage. However, two problems in the experimental design and the analysis became apparent during examination of the data. First, the amount of secondary damage (fungus, sprouting, and insect loss) was influenced by the damage treatment. Second, the experimental design with paired 30-ear samples of damaged and undamaged ears from each plot did not seem to reduce sampling error enough to allow sensitive statistical tests for low amounts of compensation. The variation in the average kernel weight of each sample was largely due to the individual variation in the 30 ears comprising the sample; therefore a method for predicting the weight of the damaged sample based on individual ears would be needed.

The incidence of secondary damage differed between control and damaged ears at different damage and maturity levels (Table 5). Simulated bird damage increased the frequency of fungus, especially when damage was inflicted at milk stage. Sprouting of kernels was increased only in ears having high simulated damage, 24 or more kernels removed, and was greatest for milk stage damage. The frequency of insect damage increased following simulated bird damage inflicted at the milk stage of maturity. The frequency of abnormal kernel development did not differ among treatments.

Since secondary damage was confounded with simulated damage treatment, it was necessary to estimate the kernel weight loss due to fungus, sprouting, or insect damage to separate the two. The dry kernel weight of each 30-ear sample was adjusted upward based on visual estimation of the proportion of the total surface area with secondary loss. In the damaged samples, secondary loss averaged 0.78 and 0.32% of the surface area per ear at milk and dough stages, respectively, which was equivalent to 34.1 g (range 3.7 to 95.4 g) and 14.1 g (range 4.1 to 26.6 g) for the 30-ear samples. For the undamaged samples, secondary loss averaged 0.19% surface area per ear and 8.8 g (range 0.7 to 18.6 g) per sample.

We now question the conclusions drawn from our analysis of the 1975 data as reported by Woronecki et al. (1976). Fungus incidence in 1975 was lower, whereas sprout and insect damage was higher, in damaged ears (Table 6). Unfortunately, although the incidence of secondary damage was recorded in that study, no estimate of the extent of secondary damage was made. Field data on actual bird damage to corn in Ohio show that the incidence of secondary damage varies considerably between years (Table 7). Comparing the 1975 and the 1977 incidence of secondary damage due to fungus, bird damage was seen to have opposing effects; loss was increased in 1977 and decreased in 1975.

An important result shown clearly in the present study was that corn kernels contain only 20 to 40% of their final biomass at the time they usually are consumed by blackbirds (Fig. 1 and Table 3). Thus, a blackbird consuming 5 g (dry weight) of corn per day during the milk and dough stages would actually reduce final yield of corn by 12 to 25 g a day plus possible additional secondary loss. This important fact has been overlooked in bioenergetics studies that use feeding rates and numbers of birds to estimate the impact of blackbird populations on corn crops (Wiens and Dyer 1975; Williams 1975).

The amount of compensation, if it occurs at all, following simulated bird damage to tip kernels is not very great. Differences in secondary damage and the variation in the average kernel weight of each sample exceeds the slight compensation that may have occurred. Some translocation into undamaged kernels cannot be ruled out. A more accurate method for determining the potential average kernel weight of each sample with no damage is needed to measure compensation accurately.

By way of summary, using the visual assessments of bird damage for the 30 damaged ears in each of these plots and other related data gathered in this study, we present the following example of damage estimation in a field of corn. Our simulated damage field had 85.7% of the ears damaged, an average primary loss to birds of 23.6 kernels per ear. The birds would have consumed from 0.73 to 1.55% (milk and dough stage damage, respectively) of the final kernel weight (Table 3). Visual assessment of damage at harvest would estimate 75.0 and 79.0% of the ears damaged with an average kernel surface area loss of 2.91 % and 3.40% for milk and dough stage damage, respectively (Table 4). Therefore the estimated weight loss based on visual estimation of kernel surface area damaged would underestimate actual loss of 0.91 and 0.42% of the total kernel weight; the actual loss was 31.3 and 12.4% greater than visually estimated for early and late damage, respectively. Secondary loss due to fungus and sprouting, increased the actual loss from 3.82% to 4.60% and 4.14% of the total dry weight for milk and dough stage damage: and unless percentage surface area affected by secondary loss also is visually estimated, this would increase the difference between actual and estimated loss.

This example illustrates that primary bird damage estimates based on surface area of kernels destroyed are affected by the development of the kernels at the time of damage, the amount of compensation, and any environmental factors influencing the severity of secondary loss.

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Table 1. Description of the seven levels of simulated damage to corn ears, 1977.

Damage level	Number of apical kernels damaged	Approx. percentage of total kernels that were damaged[a]	Pattern of damage (kernels across x kernels down)
1	0[b]	0.0	—
2	3	0.5	1x2
3	6	1.0	2x3
4	12	2.0	3x4
5	24	4.0	4x6
6	48	8.0	6x8
7	72	12.0	6x12

[a]Based on Woronecki et al. (1976) data.
[b]Two-cm longitudinal slit made in husk at tip end but no kernels damaged.

TABLE 2. Chronology of activities associated with the design and data collection for the experiment, 1977.

Activity	Date(s) of activity
Cornfield planted (Pioneer 3518)	1 May
Ears silking	11 July
Kernels at blister stage	21 July
Damage at milk stage of kernel development	2 August
Kernels at dough stage	4 August
Damage at dough stage of kernel development	9 August
Corn plants at physiologic maturity	29 August
Harvest of experimental units	6 and 7 October
Commerical harvest of field	22 October

TABLE 3. Percentage of the total dry matter of corn contained in the damaged kernels and the percentage of dry matter potentially available for translocation after damage occurs, 1977.

	No. of kernels damaged	% of total dry matter at maturity represented by these kernels	% of final dry matter accumulated in damaged kernels at time of damage		% of total kernel dry matter potentially available for translocation	
			milk	dough	milk	dough
	0	0.00	....	....	....	....
	3	0.42	16.56	40.29	0.35	0.25
	6	0.66	16.17	39.95	0.70	0.52
	12	1.80	16.76	40.48	1.46	1.07
	24	3.79	19.13	39.68	3.06	2.29
	48	7.40	20.15	40.86	6.22	4.61
	72	12.06	21.76	42.20	9.42	6.90
$\bar{x}$	23.6	3.82	19.09	40.55	3.54	2.62

TABLE 4. Visual assessment of percentage surface area of kernels damaged and percentage of ears showing bird-like damage by maturity level (undamaged samples in parentheses), 1977.

	MILK STAGE		DOUGH STAGE	
No. of kernels damaged	% of kernel surface area damaged	% of ears with damage	% of kernel surface area damaged	% of ears with damaged
0	0.15	20(8)	0.02	3(2)
3	0.32	49(11)	0.36	73(5)
6	0.55	62(14)	0.56	83(2)
12	1.27	94(11)	1.40	96(3)
24	2.25	99(8)	2.61	100(3)
48	6.24	100(7)	7.74	100(3)
72	9.59	100(13)	11.07	100(3)
$\bar{X}$23.6	2.91	75(10)	3.40	79(3)

Table 5. Percentage of ears with secondary damage following artificial bird damage. Asterisk (*) indicates a significant difference in frequency from undamaged ears(χ^2, $P \leq 0.05$).

	Number of kernels removed	Damaged ears		Undamaged ears
		Milk	Dough	
Fungus	0-12 24-72	16.9* 25.3*	6.7* 6.7*	3.0
Sprouted kernels	0-12 24-72	4.8 22.8*	6.2 10.6*	4.2
Insect damage	0-12 24-72	15.0* 15.0*	10.4 9.7	10.5
Abnormal kernel development	0-12 24-72	1.7 1.1	1.9 1.4	2.2

Table 6. Proportion of ears with secondary damage following artificial bird damage. Asterisk (*) indicates a significant difference in frequency compared to undamaged ears(χ^2, $P \leq 0.05$).

		Number of kernels removed	Damaged ears				Undamaged ears
			Milk	Dough	Late dough	Total	
1975	fungus	0-12 18-72	0.090 0.136	0.060* 0.038*	0.060* 0.008*	0.065*	0.111
	sprout	0-12 18-72	0.005 0.062*	0.000 0.029*	0.000 0.025*	0.022*	0.001
	insect	0-12 18-72	0.130* 0.108*	0.090* 0.067	0.065* 0.062	0.089*	0.041
	abnormal	0-12 18-72	0.015 0.012	0.025 0.021	0.010 0.017	0.016	0.017
1977	fungus	0-12 24-72	0.169* 0.253*	0.067* 0.067*		0.136*	0.030
	sprout	0-12 24-72	0.048 0.228*	0.062 0.106*		0.104*	0.042
	insect	0-12 24-72	0.150* 0.150*	0.104 0.097		0.126	0.105
	abnormal	0-12 24-72	0.017 0.011	0.019 0.014		0.015	0.022

TABLE 7. Estimated percentage loss of field corn to blackbirds in Ohio 1968-79. Estimates in the years 1968 to 1976 are for 19 counties only and do not represent statewide losses. Estimates for 1977-79 are for the entire State. Data are from unpublished reports, U.S. Fish and Wildlife Service. Animal Damage Control, Columbus, Ohio.

	Type of loss	
Year	Primary (%)	Secondary (%)
19 Ohio counties only		
1968	0.41	0.16
1969	0.63	0.23
1970	0.28	----
1971	0.20	----
1972	0.56	0.50
1974	0.41	<0.01
1975	0.27	0.17
1976	0.27	0.07
Statewide		
1977	0.59	0.08
1978	0.60	0.20
1979	0.67	0.04

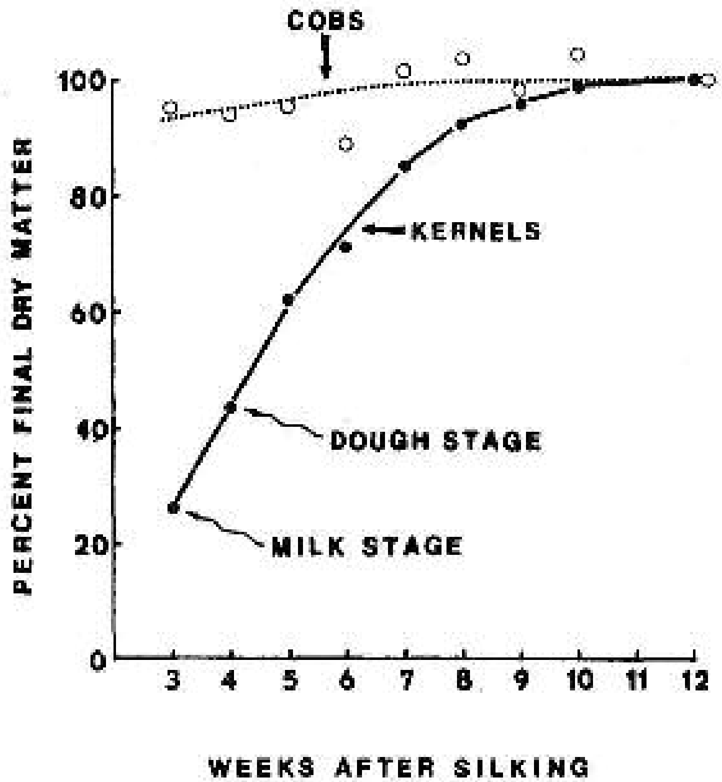

FIGURE 1. Biomass accumulation in corn cobs and kernels in relation to weeks after silking. 1977

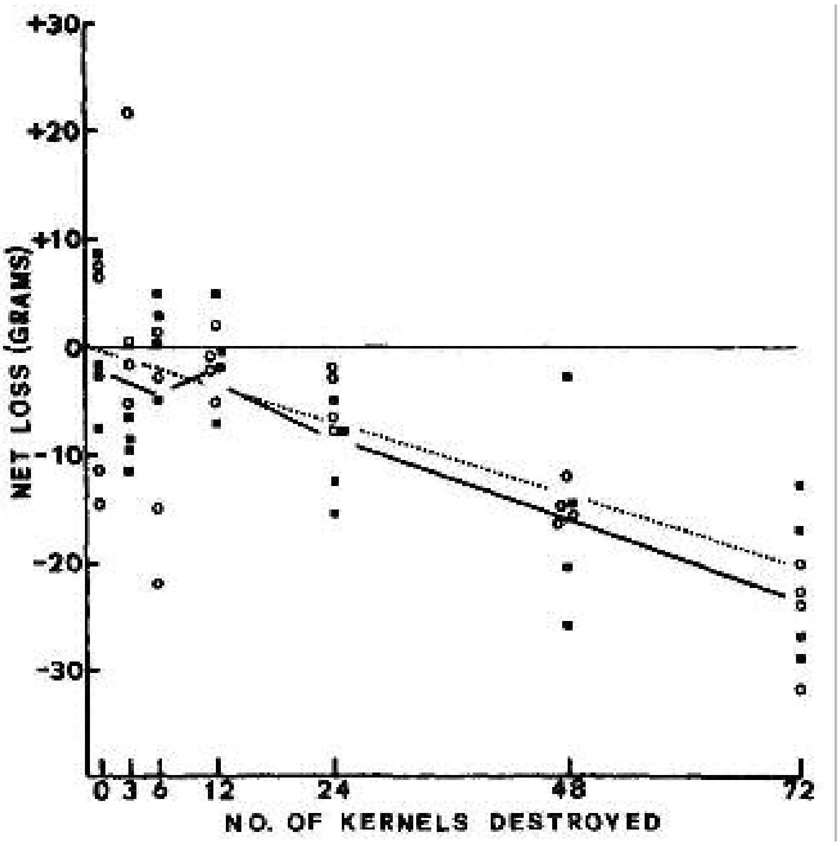

FIGURE 2. **Net loss of corn per ear (weight of 30 damaged ears minus 30 undamaged ears) for individual plots at each damage level, 1977. The circles represent milk-stage damage and the squares dough-stage damage. The solid line is the average net loss for the eight plots at each damage level and the broken line is the expected loss based on the weight of kernels removed at harvest from the undamaged sample.**