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Economic losses attributed to pests are usually estimated by visual assessments of the damage. In all cases, the amount of injury to plant parts is correlated with reduction in production, and any effects of plant response or compensation are ignored.

Some recent experiments, using prairie grass grown with different degrees of grasshopper feeding activity, indicated that some plant processes were triggered by insect feeding (Dyer and Bokhari, 1976). Responses, such as the increase of net primary production on grasslands by livestock grazing, have been suggested in studies by Westlake (1963), Pearson (1965), and Hutchinson (1971); Vickery (1972) confirmed these findings by showing that maximum net primary production can be achieved on grasslands through optimum stocking densities.

Studies by Kirby (1967) on the relationship of plant densities to yields show that plant compensation permits crops sown at low densities to produce yields as high as those sown at higher densities. Feare (1974) stated that any grain (barley and oat seeds) removed by Rooks (*Corvus frugilegus*) resulted in a reduced yield; but, owing to limited ability of the crops to tiller, the reduction in yield was not proportional to the number of grains (seeds) removed. Thus, to a certain extent, the crops compensated for the reduced plant densities caused by Rook feeding. Wright and Summers (1960) studied bullfinch (*Pyrrhula pyrrhula*) damage to buds of pear trees and found that the trees compensated for much of the damage by producing ancillary buds the following year. Hints of a similar compensation from bird damage in maturing grain crops have been made by Linehan (1967), Dawson (1970), and Dyer (1975).

Blackbird (Icteridae) damage to maturing corn has long been considered a severe problem in certain areas of the United States (Stone, et al., 1972). Almost all estimates of damage to maturing corn are based on a comparison of the damaged and undamaged ears of corn converted to bushels per acre lost (Linehan, 1967; DeHaven, 1974). Dyer (1975) hypothesized that bird damage to maturing corn may in certain cases even increase the yield.

Birds damaging kernels on the apical portion of ears could stimulate growth in other parts of the corn plant. At the time birds damage maturing corn, most kernels destroyed have not matured and therefore do not contain all of their potential biomass. Thus, surplus production may be channeled into the remaining undamaged kernels or other plant parts. A better understanding of this phenomenon is needed to truly evaluate the impact of blackbird depredation on maturing corn crops. This experiment was designed to permit a regression analysis of compensation (net loss in weight of shelled corn) as a function of two treatment factors: (1) level of simulated blackbird damage inflicted and (2) level of corn maturity at time of damage.

ACKNOWLEDGMENTS

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STUDY AREA, PROCEDURES, AND DESIGN

This experiment was conducted in an area of Huron County, Ohio normally subjected to negligible bird damage as indicated by U.S. Fish and Wildlife Service Statewide Surveys of bird damage to corn for the years 1969-74. A 0.4-acre plot (0.16 ha) within a 30-acre field planted on 27 May 1975 with DeKalb XL-43 was selected for the study. The plot, located at least 40 m from any field edge to minimize mammal damage, contained plants of uniform height and maturity; there was no noticeable variation in terrain. At the time of silking (when cobs, husks, and shank are nearly developed), the plot was gridded and marked into 110 rectangular subplots (4 rows by 14 feet). Subplots with voids or gaps or having fewer than 40

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plants with silking ears of corn were considered unsatisfactory for treatment. A carbide exploder and shotgun patrol were intermittently maintained in the field to insure that the subplots did not receive any actual bird damage.

Experimental units (66 subplots and 5 alternates) were randomly selected from the satisfactory subplots. At the blister stage of growth (70 days after emergence), the first 40 ears within each experimental unit (including the alternates) that met criteria were tagged 1-40. The criteria for ears were: (1) top ear on stalk if stalk contained more than one ear, (2) at least 11 cm in length from the base of the butt to the top, (3) regular in shape and development, (4) no signs of tip emergence, and (5) no obvious fungus, bird, or insect damage. Within each experimental unit, 20 of the 40 tagged ears were randomly selected to form the damage sample, and the remaining 20 ears formed the control sample.

We used three maturity levels of corn and 11 levels of simulated bird damage to form a total of 33 treatments. Each treatment was replicated twice so that a total of 66 maturity-damage-level combinations were randomly assigned to the 66 experimental units (subplots). The three maturity stages were: (1) early milk (16-20 days after silking), (2) middle milk (6 days after early milk), and (3) late milk-dough (4 days after middle milk). The 11 damage levels are listed in Table 1.

On the day that each specified maturity level was achieved, simulated bird damage was inflicted by three people to the 20 randomly-selected ears in each of the 22 experimental units (11 damage levels x 2 replications). The three people worked together in one experimental unit, damaging six, seven, and seven ears, respectively, before moving to the next experimental unit. Damage was inflicted with fine-tipped dissecting forceps. The husk was shredded on the upper side of the ear to expose the appropriate number of apical kernels, which then were damaged by pinching and removing the majority of the kernels' internal biomass. Damage commenced from the tip; any earworms encountered were removed. After the damage was inflicted, the shredded husk was repositioned over the damaged kernels.

Experimental units were harvested 148 days after planting. The 20 damaged and undamaged ears from each of the 66 experimental units were placed in separate burlap bags and taken to the laboratory where they were husked and re-placed in the same sample bags. Bags were then placed in seed driers (140°-160°F) for 27 days; ears were dried to a moisture level between 1 and *2%.* The bags were then stored at room temperature (65°-69°F) for 30 days, which allowed ears to reach an equilibrium moisture level between 6 and 10*%*. After equilibrium had been achieved, experimental units were randomly selected for measurement of net shelled-corn loss. The damage and control samples from each unit were shelled and weighed in random order. Each sample was weighed in five separate aliquots (because of the capacity of the balance used).

In addition to net kernel weight, other data were collected on the samples and the individual ears within the samples (e.g., damage other than simulated bird [mold and worms], abnormal ears [short and poor kernel development], cob weight, and percent moisture). Table 2 summarizes the chronology of activities associated with the experiment.

Net shelled-corn loss (hereafter called net loss) was computed as difference between weight of damaged sample and control sample. Net loss was used as the dependent variable in a regression analysis involving a quantitative independent variable, number of kernels damaged, and indicator variables to denote the levels of the qualitative independent variable maturity level.

RESULTS AND DISCUSSION

Stepwise regression analysis (Table 3) indicates that the relationship between net loss and the two treatment factors is best described by a family of curves given by the following equation:

$$Y = B_0 = B_1 X_1 + B_2 X_1 X_2 + B_3 X_1 X_3 + \varepsilon \qquad (1)$$

where

Y is the net weight loss in shelled corn (gm)
X_1 is the number of kernels damaged
X_2 is 1 if maturity level 2, 0 otherwise
X_3 is 1 if maturity level 3, 0 otherwise
ε is experimental error which is normally and independently distributed about a zero mean with variance σ_{ε}^2.

The indicator variables, X_2 and X_3, in Equation (1) permit determination of the form of the change in the linear relationship between net loss and the quantitative factor, number of kernels damaged, with a change in the levels of the qualitative factor, maturity. The base for this equation is the linear relationship between number of kernels damaged and net loss for maturity level 1 given by: $Y = B_0 + B_1 X_1 + \varepsilon$.

For maturity level 2, indicator variable $X_2 = 1$ and the relationship becomes: $Y = B_0 + B_1 X_1 + B_2 X_1 + \varepsilon = B_0 + (B_1 + B_2) X_1 + \varepsilon$.

Thus, the coefficients, B_2 and B_3 of Equation (1) are change-in-slope coefficients that indicate how the rate of change in net loss (as a function of number of kernels damaged) changes with a change in maturity level of the corn. In common analysis-of-variance terminology, the significance (Table 3) of the coefficients, B_2 and B_3, indicates that there is a significant interaction between the treatment factors: (1) number of kernels destroyed, and (2) maturity. This is to say that, to adequately predict net loss, one must know not only The number of kernels damaged but also the maturity of the corn at the time damage occurred and the form of the relationship involving these variables.

To understand the nature of this interaction and to determine whether or not compensation exists, we must examine the fitted equation:

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_1 X_2 + \hat{\beta}_3 X_1 X_3 =$$
$$- 60.08 + 10.75 X_1 - 3.69 X_1 X_2 - 5.54 X_1 X_3.$$

As shown in Fig. 1(A), $\hat{Y}$ defines three straight-line curves with a common Y intercept $(\hat{\beta}_0)$ at - 60.08. The slopes for these curves [given in Fig. 1(B) through (D)] are positive, thereby yielding the expected result that as the number of kernels damaged increases, the net loss increases. However, the slope is greatest for maturity level 1 and lowest for maturity level 3, thereby indicating that damage has a more pronounced effect early in the maturation process. (The reader should note that this result could be determined directly from the equation $\hat{Y}$ because $\hat{\beta}_3 < \hat{\beta}_2 < 0.$)

$\hat{Y}$ clearly indicates that compensation occurred in this experiment and that the effect of compensation was more pronounced in ears that were damaged later in maturation. Figure 1 further suggests that, regardless of maturity level, damage of less than six kernels (to an individual ear) results in no expected net loss and could possibly result in increased yield from that ear. Furthermore, as indicated in Figure 2, although some net loss occurred starting at six kernels destroyed per ear, the mean loss appeared to remain level through 24 kernels destroyed per ear, increasing thereafter. This was illustrated by a post hoc Duncan's New Multiple Range Test of the damage levels (Table 4) that revealed no significant difference in net loss of shelled corn weight for ears with 0, 6, 9, 12, 18, and 24 kernels destroyed.

The results from this experiment must be considered as preliminary because they come from a single experiment conducted in a single location with a single variety of corn and during only one growing season. The procedures, though well-conceived and executed, can be improved to eliminate some of the apparent disparities that are presented in Table 5. Although these disparities (with the exception of short and abnormal ears) are possibly secondary effects of bird damage, further refining of methodology can yield more sensitive tests of the direct effects of bird damage. Likewise, the width of the 95% confidence intervals given in Figure 1 shows that the error of estimation for the regression is large. Future experiments will be designed to reduce this error through additional replication of treatments and/or using more ears to form the damage and control samples within an experimental unit.

Nevertheless, the results of this experiment suggest that stimulated kernel growth can compensate for low levels of damage because greater weight of corn results. Compensation is affected by the level of maturity when the ears are being damaged and by the number of kernels damaged. Thus, this study suggests that low levels of bird damage may be partially compensated for by increased kernel growth. The obvious management implication that follows from this finding about compensatory growth is that cornfields may not need protecting when the level of bird activity is low. Also, any estimation procedure that is based on the surface area of ear destroyed tends to over-estimate when damage is at a low level.

LITERATURE CITED

Dawson, D. G. 1970. Estimation of grain loss due to sparrows (*passer domesticus*) in New Zealand. New Zealand J. Agric. Res. 13(3):681-688.

DeHaven, R. W. 1974. Bird damage appraisal methods in some agricultural crops. Proc. Vertebr. Pest Conf. 6:246-248.

Dyer, M. I. 1975. The effects of red-winged blackbirds (*Agelaius phoeniceus*) on biomass production of corn grains (*Zea may*s). J. Appl. Ecol. 12(3):719-726.

Dyer, M. I., and U. G. Bokhari. 1976. Plant-animal interactions: Studies of the effects of grasshopper grazing on Blue Grama Grass. Ecology 57(4):762-772.

Feare, C. J. 1974. Ecological studies of the rook (*Corvus frugilegus* L) in north-east Scotland. Damage and its control. J. Appl. Ecol. 11(3):897-913.

Hutchinson, K. J. 1971. Productivity and energy flow in fodder conservation/grazing systems. Herb. Abstr. 41:1-10.

Kirby, E. J. M. 1967. The effect of plant density upon the growth and yield of barley. J. Agric. Sci. Camb.:317-324.

Linehan, J. T. 1967. Measuring bird damage to corn. Proc. Vertebr. Pest Conf. 3:50-56.

Pearson, L. C. 1965. Primary production in grazed and ungrazed desert communities of eastern Idaho. Ecology 46:278-285.

Stone, C. P., D. F. Mott, J. F. Besser, and J. W. De Grazio. 1972. Bird damage to corn in the United States in 1970. Wilson Bull. 84(1):101-105.

Vickery, P. J. 1972. Grazing and net primary production of a temperate grassland. J. Appl. Ecol. 9(1):307-314.

Westlake, D. P. 1963. Comparison of plant productivity. Biol. Res. 39:385-425.

Wright, E. N., and D. D. Summers. 1960. The biology and economic importance of the bull-finch. Ann. Appl. Biol. 48:415-418.

TABLE 1. Description of the 11 levels of simulated bird damage to corn ears used in the experiment.

Damage level number	Number of apical kernels destroyed	Approximate percentage of corn destroyed[a]
1	0[b]	0.0
2	3	0.5
3	6	1.0
4	9	1.5
5	12	2.0
6	18	3.0
7	24	4.0
8	36	6.0
9	48	8.0
10	60	10.0
11	72	12.0

[a]Based on data collected prior to the test.

[b]Husk was slit open at apical end but kernels were not damaged.

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

Activity		Date(s) of activity
Cornfield planted		21 May 1975
Sprout emergence	*circa*	26 May 1975
Ears silking	*circa*	24 July 1975
Kernels at blister stage	*circa*	5 August 1975
Damage maturity level 1		15 August 1975
Kernels at dough stage	*circa*	20 August 1975
Damage maturity level 2		21 August 1975
Damage maturity level 3		25 August 1975
Kernels at dent stage	*circa*	10 September 1975
Corn plants at physiologic maturity	*circa*	22 September 1975
Harvest, experimental units		16 October 1975
Harvest, commercial	*circa*	10 November 1975
Samples dried		
Commenced		21 October 1975
Terminated		17 November 1975
Moisture equilibrium		
Commenced		17 November 1975
Terminated		17 December 1975
Measurements taken on samples		
Commenced		17 December 1975
Terminated		7 January 1976

TABLE 3. Analysis summary for stepwise regression of net loss in shelled corn weight as a function of number of kernels damaged and maturity level. X_2 and X_3 are indicator variablesto detail the effects of maturity levels 2 and 3, respectively.

Stepwise Procedures

Step no.	Variable(s) entered (description)	Multiple correlation squared (R^2)	Increase in R^2
1	X_1 (damage)	0.4198	0.4198
2	X_1 X_3 (change in slope, maturity level 3)	0.4692	0.0494
3	X_1 X_2 (change in slope, maturity level 2)	0.5060	0.0368

Analysis of Variance

Source	df	Sums of squares	Mean square	F-ratio
Treatment				
Regression:				
Damage ($\hat{\beta}_1$)	1	2107471.875	2107471.875	46.51 ***
Change in slope for maturity levels 2 and 3 ($\hat{\beta}_2$, $\hat{\beta}_3$ given $\hat{\beta}_1$)	2	433012.812	216506.406	4.78 **
Total for regression	3	2540484.687		
Residual:				
(Change in intercept for maturity levels 2 and 3)	(2)	(16191.781)	(8095.890)	< 1 NS
Total lack of fit	29	98249.547	33939.640	< 1 NS
Error				
Experimental error	33	1495497.640	45318.080	

*** significant $P < 0.01$

** significant $P < 0.05$

NS not significant ($P > 0.10$)

TABLE 4. Average net loss of shelled corn (undamaged ear weight - damaged ear weight) for the 11 different damage categories at all maturity levels.

Damage level (no. kernels destroyed)	Mean net loss	Duncans New Multiple Range Test[a]					
3	- 183.9	|					
0	- 113.7	|	|				
12	17.4	|	|	|			
18	55.5	|	|	|	|		
9	118.5	|	|	|	|	|	
6	124.5		|	|	|	|	
24	137.0		|	|	|	|	
36	217.9		|	|	|	|	|
48	328.5			|	|	|	|
60	389.0				|	|	|
72	472.8					|	|

[a]Mean loss is not significantly different (P > 0.05) for those damage levels covered by same line

TABLE 5. Disparities contributing to net loss of shelled corn that may have influenced experimental results.

Description of ears with disparities[a]	Number of ears: Undamaged samples	Number of ears: Damaged samples
Procedural		
Short ears (< 11.0 cm of kernel length)	1	2
Abnormal (kernel development incomplete or abnormal)	23	22
Totals	24	24
Secondary		
Mold damage[b]	146	85
Sprouted kernels[b]	1	29
Worm damage[b]	54	118
Totals	201	232

[a]Procedural disparities are ears included in experiment that did not meet procedural criteria; secondary disparities are ears with damage (other than simulated bird damage) that may have been related to the bird damage (or lack of bird damage)

[b]Affecting five or more non-tip kernels

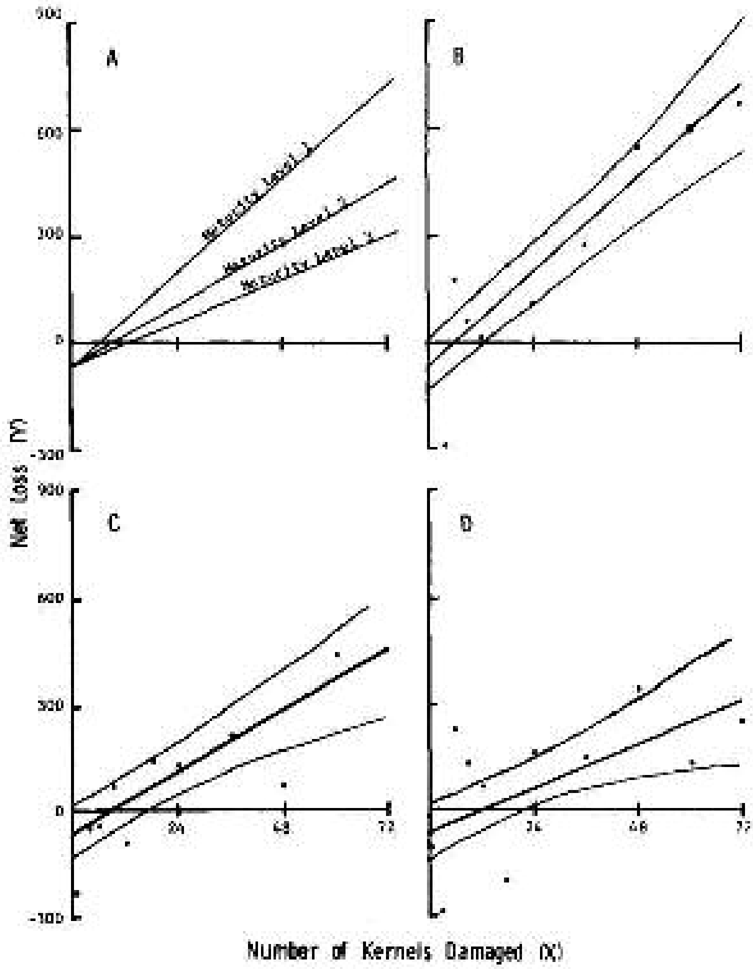

Figure I

Fig. 1. Regression using fitted equation ($\hat{Y} = -60.08 + 10.75 X_1 - 3.69 X_1 X_2 - 5.54 X_1 X_3$) to show the response Y (net loss - undamaged shelled corn weight - damaged shelled corn weight) from the interaction of the quantitative treatment factor X (number of kernels damaged) and the qualitative treatment factor (maturity level). Graph A compares the response (Y) for each maturity level. Graphs B, C, and D show the individual response (Y) at maturity levels 1, 2, and 3, respectively, with 95 percent confidence intervals and actual mean losses.

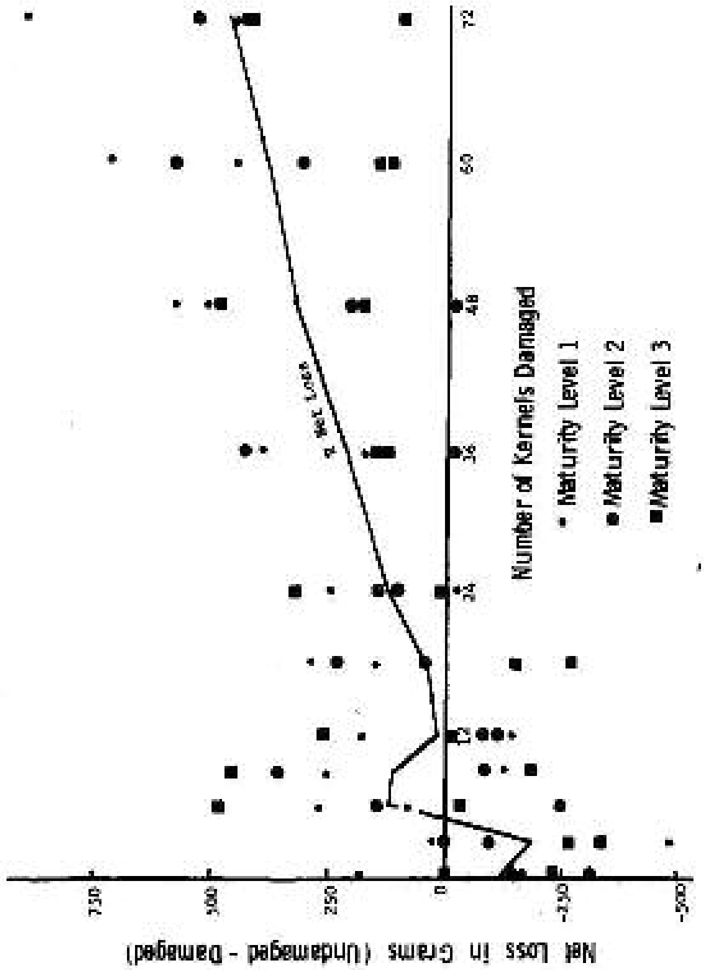

Figure 2

Net loss in grams for all Experimental Units at each damage level ("0" kernels damaged refers to slit husks without any kernel damage).