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Systemic uptake of carbofuran in maize genotypes to control first and second generation European corn borers (Ostrinia nubilalis Hübner)

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Systemic uptake of carbofuran in maize genotypes to control first and second generation European corn borers (*Ostrinia nubilalis* Hübner)

by

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ABSTRACT

Corn genotypes were evaluated to determine if carbofuran is effective in controlling European corn borers (Ostrinia nubilalis Hübner) and if there is a differential response among corn genotypes. Carbofuran 10G applied to the soil at planting time is effective for first-generation borer control, and a lay-by application applied over the row is effective for second-generation borer control. The uptake and translocation of soil-applied carbofuran is dependent, in part on the corn genotype.

PART I: FIRST-GENERATION EUROPEAN CORN BORER

INTRODUCTION

Carbofuran has shown promise as a systemic insecticide for control of first-generation European corn borers, Ostrinia nubilalis (Hübner). Harding (1967) showed that granular formulations of carbofuran, applied at planting time, are effective in reducing number of cavities caused by European corn borers in stalks of field corn. Edwards and Berry (1972) reported carbofuran is effective as a soil-applied insecticide for first-generation corn borer control in field tests and laboratory bioassays. However, Berry and Robinson (1975) found that the degree of control obtained with soil applications of carbofuran was, in part, dependent on the selection of corn hybrid.

The objectives of these studies were to: (1) determine if carbofuran, applied at planting time, is effective in controlling first-generation European corn borers in inbred lines of corn and test crosses of inbred lines, and (2) determine if uptake and translocation of soil-applied carbofuran is the same among corn genotypes.

METHODS AND MATERIALS

Eleven inbred lines of corn were evaluated in 1974, 21 inbred lines plus 11 test crosses in 1975, and 21 inbred lines plus 20 test crosses in 1976. Most of the inbred lines were selected because they or their derivatives are used extensively in the production of corn hybrids. Several inbred lines were selected because they are either highly susceptible (W182E) or highly resistant (Oh43, B75) to leaf-feeding and stalk damage by first-generation European corn borers. Inbred line B73, although susceptible to the European corn borer, has several desired agronomic traits and is used to produce many modern hybrids; thus it was used as test cross parent. Planting dates were May 24 in 1974, May 12 in 1975 and May 10 in 1976.

A split-plot design with whole plots arranged in blocks was used; genotypes were randomized on the whole plots within a block, and carbofuran-treated plots vs. nontreated plots were randomized within the whole plots. Nine blocks were used in 1974, and four blocks were used in 1975-1976. Each block was separated by a 6 m alleyway.

Each whole plot contained a carbofuran-treated row, a noninsecticide treated row and three guard rows (each row with 20 plants); there was one guard row between the carbofuran-treated row and the nontreated row and one guard row on each side of these two rows. Carbofuran 10G was placed in the seed furrow at planting time with a Noble® applicator attached to the planter (Edwards and Berry, 1972); 3.4 kg AI/ha was applied in 1974-1975 and 6.7 kg AI/ha in 1976.

Twenty plants in each row (2 rows/plot) were artificially infested with 6 blackheading egg masses/plant (ca. 150 eggs) in 3 applications of 2 masses each spaced 2 days apart. Plants were infested when 75% of the genotypes reached the midwhorl stage of plant development. Larval rearing, egg mass production and infestation techniques were described by Guthrie et al. (1971).

Plant heights, from the tip of the tassel to the soil surface, were recorded at plant maturity. Leaf-feeding ratings (1 = no damage to 9 = extensive damage to leaf tissue), described by Guthrie et al. (1960), were made on an individual plant basis ca. 30 days after egg hatch. Stalk damage was determined by splitting stalks from the tassel to the soil surface and recording number of cavities; each 2.5 cm of damage was counted as 1 cavity (Pesho et al., 1965). Cavity counts in cornstalks were made ca. 60 days after egg hatch.

Differences among genotypes were examined using Duncan's multiple range test (.05 level of significance).

RESULTS AND DISCUSSIONS

Treatments refer to plots treated with carbofuran vs. nontreated plots. Genotypes were inbred lines of corn and test crosses of inbred lines.

Carbofuran significantly reduced leaf-feeding damage and stalk cavities caused by European corn borers in 1974 and 1976. No significant treatment differences were obtained in 1975 for leaf-feeding damage or stalk cavities (Table 1). The genotype x treatment interactions will be discussed independently for each year.

The average plant heights were not significantly different in the two treatment groups in 1974 and 1975 (Tables 17 and 18 in Appendix).

Complete analyses of variance tables for each year are presented in Tables 19 through 26 in Appendix.

1974

Differences between leaf-feeding ratings of carbofuran-treated and nontreated plots ranged from 0 to 0.7 (Table 2). One inbred, B75, had a significant reduction in leaf-feeding damage. The genotype x treatment interaction was not significant at the .05 level of probability but was significant at the .09 level.

A highly significant genotype x treatment interaction was obtained for stalk cavities, indicating that genotypes differed in their ability to absorb and translocate carbofuran. Carbofuran significantly

Table 1. Summary of analyses of variance of the effect of first-generation European corn borers on leaf-feeding damage and stalk cavities, Ankeny, Iowa

Source of variation	1974 Leaf-feeding damage	1974 Stalk cavities	1975 Leaf-feeding damage	1975 Stalk cavities	1976 Leaf-feeding damage	1976 Stalk cavities
	Year[a]					
Genotype	**	**	**	**	**	**
Treatment	**	**	ns	ns	**	**
Genotype x treatment	ns	**	ns	ns	**	**

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 2. Effect of carbofuran on leaf-feeding damage caused by European corn borers, Ankeny, Iowa, 1974

Genotype	Mean plant damage rating: Nontreated	Carbofuran-treated	Difference[a]
B75	2.7	2.0	0.7 a*
B14A	5.6	5.0	0.6 ab
A239	8.9	8.4	0.5 a-c
Oh43	2.8	2.6	0.2 a-c
B70	7.9	7.8	0.1 a-c
W182E	8.1	8.0	0.1 a-c
WF9	8.9	8.8	0.1 a-c
B37	8.4	8.3	0.1 a-c
B73	8.3	8.3	0.0 bc
Mo17	5.1	5.2	-0.1 bc
B52	4.6	4.8	-0.2 c
Overall mean	6.5	6.3	0.2

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significantly greater than zero at the 5% level.

reduced stalk cavities caused by European corn borers in two inbred lines; B75 (50% control) and Oh43 (42% control). Excluding inbred WF9, all plots had some reduction of stalk cavities caused by European corn borers. (Table 3).

Table 3. Effect of carbofuran on stalk damage caused by European corn borers, Ankeny, Iowa, 1974

Genotype	Mean no. stalk cavities/plant: Nontreated	Carbofuran-treated	Difference[a]	Percent reduction
B75	8.0	4.0	4.0 a*	50
Oh43	6.2	3.6	2.6 ab*	42
Mo17	9.4	7.7	1.7 bc	18
B73	17.1	15.7	1.4 bc	8
B37	10.8	9.4	1.4 bc	13
B14A	6.3	5.3	1.0 bc	16
B70	9.2	8.2	1.0 bc	11
B52	3.7	3.0	0.7 bc	19
A239	9.4	8.8	0.6 bc	6
W182E	9.7	9.6	0.1 c	1
WF9	9.6	9.8	-0.2 c	0
Overall mean	9.2	8.9	1.3	14

[a] Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significantly greater than zero at the 5% level.

1975

Larval establishment was relatively lower in 1975 than in 1974; the mean leaf-feeding rating was 6.5 in nontreated plots in 1974 and 3.8 in 1975; the mean number of cavities/plant was 9.2 in nontreated plots in 1974 and 3.2 in 1975.

Differences in leaf-feeding ratings between carbofuran-treated and nontreated plots were nonsignificant in 1975 (Table 4); although the genotype by treatment interaction was nonsignificant, these data indicate a differential response among genotypes, with leaf-feeding rating differences ranging from 0 (in 13 genotypes) to 1.4 (in A239).

Differences in stalk cavities between carbofuran-treated and nontreated plots ranged from 0 (in 14 genotypes) to 1.3 (in W182E); these differences were also nonsignificant. Eighteen genotypes, however, did show a reduction in stalk cavities in treated plots compared to nontreated plots (Table 5).

A dry spring may have contributed to the reduced response in 1975. Carbofuran was applied on May 12, and only traces of rainfall were recorded from May 7 to May 30, when 5.3 cm. were recorded. No measurable rainfall was recorded from May 31 to June 9. Plant growth may have been delayed during this time, as most genotypes did not reach midwhorl stage of plant development until ca. 47 days after planting, at which time plants were artificially infested. Edwards and Berry (1972) reported that carbofuran may lose its toxicity in field corn between 45 and 52 days after application to the soil. Thus, infestations may have occurred at a time when carbofuran was becoming ineffective in the plant.

Table 4. Effect of carbofuran on leaf-feeding damage caused by European corn borers, Ankeny, Iowa, 1975

	Mean plant damage rating		
Genotype	Nontreated	Carbofuran treated	Difference[a]
A239	6.9	5.5	1.4 a
B70	4.9	3.6	1.3 ab
N28 x B73	3.9	2.8	1.1 ab
WF9	6.5	5.5	1.0 ab
A619	1.9	1.1	0.8 ab
B75 x B73	2.6	1.9	0.7 ab
W64A	4.5	3.8	0.7 ab
B37 x B73	3.6	3.1	0.5 ab
B57	1.9	1.5	0.4 ab
B52	4.5	4.2	0.3 ab
N7A	5.5	5.2	0.3 ab
Va26	4.5	4.2	0.3 ab
A632	4.2	3.9	0.3 ab
Mo17 x B73	4.3	4.0	0.3 ab
Va26 x B73	4.5	4.3	0.2 ab
B57 x B73	3.3	3.1	0.2 ab
H98	3.5	3.4	0.1 ab
A239 x B73	4.4	4.3	0.1 ab
B75	1.5	1.4	0.1 ab
C123	1.7	1.7	0.0 ab
N7A x B73	4.2	4.3	-0.1 ab
Mo17	3.2	3.4	-0.2 ab
B14A	3.2	3.4	-0.2 ab
B73	4.3	4.6	-0.3 ab
W182E	3.5	4.0	-0.5 ab
Oh43	2.6	3.2	-0.6 ab
H95 x B73	3.5	4.1	-0.6 ab
B37	5.1	5.7	-0.6 ab
B70 x B73	2.8	3.6	-0.8 ab
H95	4.1	4.9	-0.8 ab
B14A x B73	2.4	3.4	-1.0 b
N28	3.2	4.2	-2.0 b
Overall mean	3.8	3.7	0.1

[a]Any two means not followed by the same letter are significantly different at the 5% level.

Table 5. Effect of carbofuran on stalk damage caused by European corn borers, Ankeny, Iowa, 1975

	Mean no. stalk cavities/plant			
Genotype	Nontreated	Carbofuran treated	Difference[a]	Percent reduction
W182E	5.6	4.3	1.3 a	23
Mo17 x B73	4.8	4.1	0.7 ab	15
B70 x B73	2.9	2.2	0.7 ab	24
B37 x B73	3.5	2.9	0.6 ab	17
B57 x B73	4.2	3.6	0.6 ab	14
A239 x B73	3.6	3.0	0.6 ab	17
B73	3.8	3.2	0.6 ab	16
WF9	4.9	4.5	0.4 ab	8
B14A	2.3	1.9	0.4 ab	17
B52	1.4	1.1	0.3 ab	21
H98	4.2	3.9	0.3 ab	7
Va26 x B73	3.1	2.8	0.3 ab	10
N28 x B73	5.0	4.7	0.3 ab	6
Mo17	3.8	3.6	0.2 ab	5
H95	2.4	2.2	0.2 ab	8
A239	3.3	3.2	0.1 ab	3
Oh43	2.3	2.2	0.1 ab	4
H95 x B73	3.7	3.6	0.1 ab	3
N7A	2.7	2.8	-0.1 ab	0
C123	2.9	3.0	-0.1 ab	0
A632	3.1	3.2	-0.1 ab	0
N7A x B73	2.9	3.0	-0.1 ab	0
B57	0.8	0.9	-0.1 ab	0
B75	2.4	2.6	-0.2 ab	0
N28	2.5	2.7	-0.2 ab	0
B70	3.0	3.3	-0.3 ab	0
W64A	2.8	3.1	-0.3 ab	0
B37	3.3	3.7	-0.4 ab	0
Va26	2.1	2.5	-0.4 ab	0
B14A x B73	2.7	3.3	-0.6 ab	0
B75 x B73	3.8	4.5	-0.7 b	0
A619	3.3	4.3	-1.0 b	0
Overall mean	3.2	3.1	0.1	3

[a]Any two means not followed by the same letter are significantly different at the 5% level.

1976

Due to small differences in treated vs. nontreated plots in 1974 and 1975, a higher rate of carbofuran (6.6 kg AI/ha) was applied to the soil in 1976. With the exception of B14A x B73, all genotypes had a reduction in leaf-feeding damage (Table 6). The genotype x treatment interaction was highly significant. B14A x B73 had no reduction in leaf-feeding damage, whereas WF9 had a great reduction in leaf-feeding damage, demonstrating a large differential response to carbofuran among corn genotypes.

Table 6. Effect of carbofuran on leaf-feeding damage caused by European corn borers, Ankeny, Iowa, 1976

	Mean plant damage rating		
Genotype	Nontreated	Carbofuran-treated	Difference[a]
WF9	7.8	1.2	6.6 a*
A239	8.4	3.5	4.9 ab*
A239 x B73	6.5	1.8	4.7 a-c*
H95	6.6	2.0	4.6 b-d*
A632	6.1	1.5	4.6 b-d*
B73	6.9	2.6	4.3 b-e*
B52	5.7	1.4	4.3 b-e*
H98	5.0	1.0	4.0 b-f*
B70	5.5	1.6	3.9 b-g*
N7A x B73	5.9	2.3	3.6 b-h*
W64A	6.4	2.9	3.5 b-h*
B52 x B73	5.7	1.3	3.4 b-h*

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Table 6 (Continued)

Genotype	Mean plant damage rating: Nontreated	Carbofuran-treated	Difference[a]
N7A	6.4	3.2	3.2 b-i*
B37	5.9	2.8	3.1 b-i*
WF9 x B73	4.9	2.0	2.9 b-j*
Va26	5.1	2.3	2.8 b-j*
B37 x B73	5.0	2.4	2.6 b-k*
N28	5.8	3.4	2.4 c-l*
H95 x B73	4.0	1.7	2.3 c-l*
Mo17	5.0	2.8	2.2 d-m
Mo17 x B73	4.5	2.3	2.2 d-m
N28 x B73	4.9	2.8	2.1 e-m
H98 x B73	3.7	1.6	2.1 e-m
Oh43 x B73	3.4	1.3	2.1 e-m
A632 x B73	3.4	1.7	1.7 f-m
W64A x B73	4.1	2.5	1.6 f-m
C123 x B73	2.9	1.4	1.5 g-m
W182E	4.7	3.2	1.5 g-m
C123	1.5	1.0	1.5 g-m
B70 x B73	3.2	1.8	1.4 h-m
B14A	6.2	4.8	1.4 h-m
Oh43	2.5	1.2	1.3 h-m
B57 x B73	2.9	1.6	1.3 h-m
Va26 x B73	3.3	2.5	0.8 i-m
W182E x B73	3.6	3.0	0.6 j-m
A619	1.6	1.1	0.5 j-m
B75 x B73	1.9	1.4	0.5 j-m
A619 x B73	1.8	1.4	0.4 k-m
B57	2.4	2.1	0.3 k-m
B75	1.2	1.1	0.1 lm
B14A x B73	3.2	3.4	-0.2 m
Overall mean	4.5	2.1	2.4

The genotype x treatment interaction for stalk cavities was also highly significant. The reduction of stalk cavities in carbofuran-treated plots compared with nontreated plots ranged from 0% to 61% (Table 7). Two gentotypes had a significant difference between treated and nontreated plots (WF9 and B73), and 31 out of 41 genotypes displayed a trend of having fewer cavities/stalk in treated plots than in nontreated plots.

Some genotypes showed a relatively small difference in stalk cavities between carbofuran-treated and nontreated plots compared with other genotypes. On a percent control basis these small differences may represent a large reduction of stalk cavities. For example, B52 had a mean of 1.5 cavities/plant in nontreated plots and 0.8 cavities/plant in treated plots, a difference of 0.7 (Table 7). This represents a 47% reduction of stalk cavities caused by corn borers.

Table 7. Effect of carbofuran on stalk damage caused by European corn borers, Ankeny, Iowa, 1976

	Mean no. stalk cavities/plant			
Genotype	Nontreated	Carbofuran-treated	Difference[a]	Percent reduction
WF9	5.7	2.2	3.5 a*	61
B73	4.8	2.1	2.7 ab*	56
H95	3.7	2.1	1.6 bc	43
B52 x B73	2.5	1.0	1.5 bc	60

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Table 7 (Continued)

Genotype	Mean no. stalk cavities/plant Nontreated	Carbofuran-treated	Difference	Percent reduction
B70	3.3	1.9	1.4 b-d	42
H98	5.4	4.0	1.4 b-d	26
H7A x B73	2.8	1.6	1.2 b-d	43
Va26 x B73	2.6	1.5	1.1 b-d	42
A619 x B73	2.3	1.3	1.0 b-d	43
C123 x B73	3.0	2.0	1.0 b-d	33
Oh43 x B73	2.8	1.9	0.9 b-d	32
B70 x B73	2.0	1.2	0.8 b-d	40
A239 x B73	2.8	2.0	0.8 b-d	29
A632	4.3	3.5	0.8 b-d	19
B37	2.8	2.1	0.7 cd	25
B52	1.5	0.8	0.7 cd	47
Mo17 x B73	1.9	1.3	0.6 cd	32
H98 x B73	2.9	2.3	0.6 cd	21
A619	2.9	2.3	0.6 cd	21
B75 x B73	1.8	1.3	0.5 cd	28
WF9 x B73	2.3	1.8	0.5 cd	22
A239	3.2	2.8	0.4 cd	12
B57 x B73	1.6	1.2	0.4 cd	25
A632 x B73	1.9	1.6	0.3 cd	16
B14A x B73	1.7	1.4	0.3 cd	18
W64A x B73	1.6	1.3	0.3 cd	19
Va26	2.6	2.3	0.3 cd	12
N7A	2.1	1.9	0.2 cd	10
N28 x B73	3.3	3.1	0.2 cd	6
W64A	4.2	4.1	0.1 cd	2
C123	2.6	2.6	0.0 cd	0
W182E	5.4	5.4	0.0 cd	0
B14A	2.9	3.0	-0.1 cd	0
B57	2.3	2.5	-0.2 cd	0
Oh43	3.5	3.9	-0.4 cd	0
H95 x B73	1.2	1.6	-0.4 cd	0
N28	3.3	3.7	-0.4 cd	0
B37 x B73	2.0	2.5	-0.5 cd	0
B75	2.2	2.7	-0.5 cd	0
W182E x B73	3.0	3.6	-0.6 d	0
Mo17	3.0	3.6	-0.6 d	0
Overall mean	2.9	2.3	0.6	21

PART II: SECOND-GENERATION EUROPEAN CORN BORER

INTRODUCTION

Control of second-generation European corn borers (*Ostrinia nubilalis* Hübner) is obtained with foliar applications of insecticide applied during the pollen-shedding stage of plant development. Munson et al. (1970), however, demonstrated that 1 application of insecticide applied over the row as a postplant treatment and incorporated into the soil is effective in controlling first-generation European corn borers and western corn rootworms (*Diabrotica virgifera* LeConte). Hills and Peters (1972) reported that a postplant treatment at cultivation was more effective than planting time applications for controlling western corn rootworms. Hills et al. (1972) reported carbofuran applied at cultivation was more effective than a planting time application for controlling first-generation European corn borers and western corn rootworms.

Second-generation European corn borers begin egg deposition approximagely 30 days after lay-by time (final cultivation). Edwards and Berry (1972) found that effective control of first-generation European corn borers was obtained 45 days after carbofuran was applied to the soil.

Therefore, the present studies were conducted to: (1) determine if a lay-by application of carbofuran, applied over the row and incorporated into the soil, is effective for controlling second-generation European corn borers and (2) determine if uptake and translocation of carbofuran, applied over the row and incorporated into the soil, is the same among corn genotypes.

METHODS AND MATERIALS

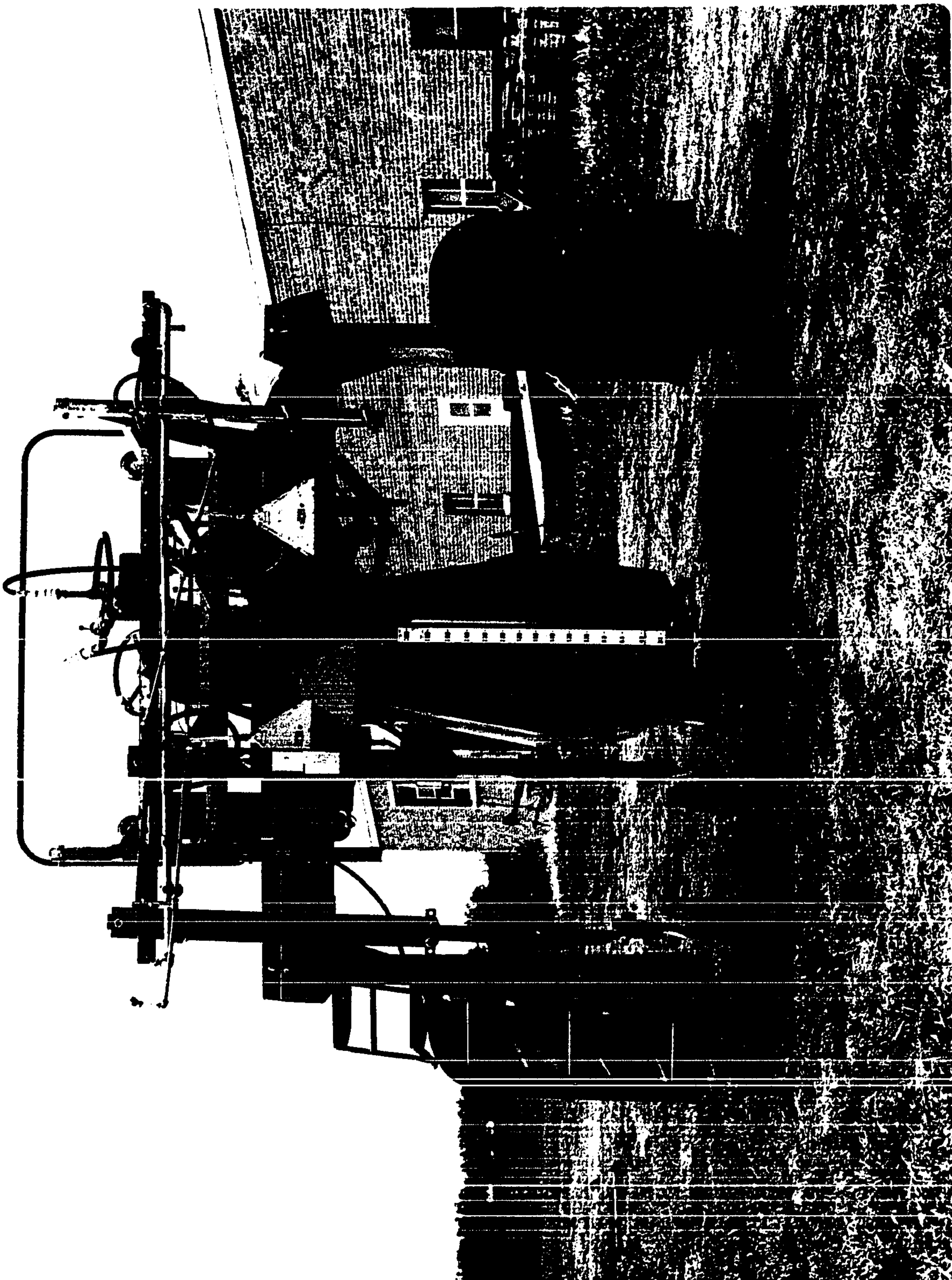
Eleven inbred lines of corn were evaluated in 1974, 21 inbred lines plus 11 test crosses in 1975, and 21 inbred lines plus 20 test crosses in 1976. Most of the inbred lines were selected because they or their derivatives are used extensively in the production of corn hybrids. Several inbred lines were selected because they are either highly susceptible (W182E) or highly resistant (B52, N7A) to sheath-collar feeding by second-generation European corn borers. Inbred line B73 was used as test cross parent in 1975 and 1976. Planting dates were May 24 in 1974, May 12 in 1975 and May 10 in 1976.

A split-plot design with whole plots arranged in blocks was used; genotypes were randomized on the whole plots within a block, and carbofuran-treated plots vs. nontreated plots were randomized within the whole plots. Nine blocks were used in 1974 and four blocks were used in 1975-1976. Each block was separated by a 6 m alleyway.

Each whole plot contained a carbofuran-treated row, a noninsecticide treated row and three guard rows (each row with 20 plants); there was one guard row between the carbofuran-treated row and nontreated row and one guard row on each side of these two rows.

Carbofuran was applied over the row with a Noble® applicator attached to a high-clearance self-propelled vehicle (Berry et al., 1974) at a rate of 3.4 kg AI/ha. Treatments were applied and immediately incorporated into the soil (Figure 1) on July 10 in 1974, July 28 in 1975 and July 7 in 1976. The nontreated row in each plot received no

Figure 1. High-clearance self-propelled vehicle with attached cultivator



insecticide, but was cultivated the same as the treated row.

Twenty plants in each row were artificially infested when 75% of the genotypes were in the pollen-shedding stage of plant development (ca. 30 days after insecticide application) with 6 blackheading egg masses (ca. 150 eggs) per plant in 3 applications of 2 masses each, spaced 2 days apart. Larval rearing, egg production and plant infestation techniques were described by Guthrie et al. (1971).

Damage ratings (1 = no damage to 9 = extensive damage to sheath-collar tissue), described by W. Guthrie (Department of Entomology, Iowa State University, unpublished data, 1977) were made on a plot basis. Damage in the stalks was determined by splitting the stalks from the tassel to the soil surface and recording the number of cavities; each 2.5 cm of damage was counted as 1 cavity (Pesho et al., 1965). Prior to splitting the stalks, the total number of ear shanks per row was recorded, split in half, and the cavities counted in the same manner as stalk cavities.

Damage ratings were made ca. 50 days after egg hatch; cavity counts in cornstalks and ear shanks were made ca. 60 days after egg hatch.

Differences among genotypes were examined using Duncan's multiple range test (.05 level of significance).

Munson et al. (1970) reported that 15% of a granular insecticide, when applied over the row, is retained by the plant; the remaining material falls to the soil. Thus, the results of these experiments were based on the activity of carbofuran that remained on the plant combined with the systemic activity of carbofuran that fell to the soil and was incorporated.

RESULTS AND DISCUSSIONS

Carbofuran significantly reduced sheath-collar damage, stalk cavities and ear shank cavities caused by European corn borers in all 3 years (Table 8). Although this study is involved with second-generation European corn borers, it appears possible that a single lay-by application of carbofuran applied over the row and incorporated into the soil could be used to control first- and second-generation European corn borers and western corn rootworms.

Complete analyses of variance tables are presented in Tables 27-34 (Appendix). The genotype x treatment interactions will be discussed separately for each year.

Table 8. Summary of analyses of variance of the effect of second-generation European corn borers on sheath-collar damage, stalk cavities and ear shank cavities, Ankeny, Iowa

Method of evaluation	Year	Source of variation[a]		
		Genotype	Treatment	Genotype x treatment
Sheath-collar damage	1974	**	**	**
	1975	**	**	*
	1976	**	**	ns
Stalk cavities	1974	**	**	**
	1975	**	**	ns
	1976	**	**	ns
Ear shank cavities	1975	**	**	ns
	1976	**	**	*

[a]ns = nonsignificant at the 5% level of probability.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

1974

Plots treated with carbofuran had a reduction in sheath-collar damage compared with nontreated plots; this reduction was significant in 8 of 11 inbred lines (Table 9).

Table 9. Effect of carbofuran on sheath-collar damage caused by European corn borers, Ankeny, Iowa, 1974

	Mean plot damage rating		
Genotype	Nontreated	Carbofuran treated	Difference[a]
A239	6.9	4.0	2.9 a*
B37	6.8	3.9	2.9 a*
WF9	7.2	4.3	2.9 a*
B75	5.6	3.2	2.6 ab*
Oh43	6.4	4.0	2.4 ab*
W182E	9.0	6.6	2.4 ab*
B73	6.7	4.6	2.1 ab*
B70	6.8	4.8	2.0 ab*
B14A	5.6	3.9	1.7 bc
Mo17	5.2	4.3	0.9 c
B52	4.0	3.2	0.8 c
Overall mean	6.4	4.3	2.1

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Plots treated with carbofuran had a reduction in stalk cavities compared with nontreated plots, with percent control ranging from 27% in W182E to 79% in B52 (Table 10). These data may be misleading, however, as genotypes resistant to feeding by European corn borers may show a

Table 10. Effect of carbofuran on stalk damage caused by European corn borers, Ankeny, Iowa, 1974

Genotype	Mean no. cavities/plant			Percent reduction
	Nontreated	Carbofuran-treated	Difference[a]	
A239	13.3	4.0	9.3 a*	70
WF9	13.6	4.7	8.9 ab*	65
Oh43	12.0	3.1	8.9 ab*	74
B75	12.3	4.1	8.2 ab*	67
B73	15.0	7.1	7.9 ab*	53
B37	10.0	2.4	7.6 a-c*	76
B14A	10.9	3.9	7.0 a-c*	64
B70	13.7	7.5	6.2 b-d*	45
W182E	18.7	13.7	5.0 cd*	27
Mo17	8.1	4.4	3.7 de	46
B52	2.8	0.6	2.2 e	79
Overall mean	11.8	5.2	6.8	58

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

relatively small difference in stalk cavities between carbofuran-treated and nontreated plots compared to susceptible genotypes. On a percent control basis these small differences may represent a large reduction of stalk cavities. For example, B52 had a mean of 2.8 cavities/plant in nontreated plots and 0.6 cavities/plant in treated plots, a difference of 2.2 (Table 10). This represents a 79% reduction of cavities caused by corn borers. B37 is susceptible to feeding by European corn borers and had a mean of 10.0 and 2.4 cavities/plant in nontreated and carbofuran-treated plots, respectively. This relatively large difference of 7.6, however, represents a 76% reduction of stalk cavities caused by corn borers. Averaged over all genotypes a 58% reduction of stalk cavities was obtained.

The genotype x treatment interaction was highly significant for both sheath-collar damage and stalk cavities, indicating that genotypes differ in their response to carbofuran.

1975

Plots treated with carbofuran, excluding W182E plots, had a reduction in sheath-collar damage compared with nontreated plots. Significant differences obtained between treated and nontreated plots generally were in test cross plots rather than inbred plots. For example, 8 genotypes showed a significant difference in sheath-collar damage between treated and nontreated plots (Table 11), 7 of which were test crosses.

Table 11. Effect of carbofuran on sheath-collar damage caused by European corn borers, Ankeny, Iowa, 1975

	Mean plot damage rating		
Genotype	Nontreated	Carbofuran-treated	Difference[a]
B75 x B73	6.8	3.5	3.3 a*
B57 x B73	5.3	2.1	3.0 ab*
B37 x B73	7.0	4.0	3.0 ab*
B14A	7.0	4.0	3.0 ab*
B14A x B73	6.8	4.0	2.8 a-c*
Va26 x B73	6.3	3.5	2.8 a-c*
A239 x B73	7.5	5.0	2.5 a-d*
N7A x B73	6.8	4.5	2.3 a-e*
A619	8.3	6.5	1.8 a-f

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Table 11 (Continued)

Genotype	Mean plot damage rating: Nontreated	Carbofuran-treated	Difference [a]
H98	6.0	4.2	1.8 a-f
Mo17 x B73	7.0	5.5	1.5 a-f
B37	7.0	5.5	1.5 a-f
Mo17	7.5	6.0	1.5 a-f
H95 x B73	7.0	5.5	1.5 a-f
H95	8.8	7.5	1.3 a-f
Va26	6.5	5.2	1.3 a-f
B73	8.5	7.5	1.0 b-f
B70 x B73	7.0	6.0	1.0 b-f
N28 x B73	6.8	5.8	1.0 b-f
OH43	7.8	6.8	1.0 b-f
B57	4.8	4.0	0.8 c-f
C123	6.8	6.0	0.8 c-f
A239	6.3	5.5	0.8 c-f
B75	5.8	5.0	0.8 c-f
W64A	6.8	6.0	0.8 c-f
B52	3.3	2.5	0.8 c-f
A632	7.0	6.5	0.5 d-f
N28	4.8	4.3	0.5 d-f
N7A	3.3	3.0	0.3 ef
B70	8.3	8.0	0.3 ef
WF9	7.0	6.7	0.3 ef
W182E	9.0	9.0	0.0 f
Overall mean	6.7	5.3	1.4

The genotype x treatment interaction for sheath-collar damage was significant, suggesting that genotypes display a differential response to carbofuran.

Plots treated with carbofuran, excluding C123 plots, had a reduction in stalk cavities compared to nontreated plots. Four genotypes, all test crosses, showed at least a 50% reduction of stalk cavities caused by European corn borers (Table 12). All 11 test crosses had a greater

Table 12. Effect of carbofuran on stalk damage caused by European corn borers, Ankeny, Iowa, 1975

Genotype	Mean no. cavities/plant			Percent reduction
	Nontreated	Carbofuran-treated	Difference[a]	
B37 x B73	16.4	7.6	8.8 a*	54
B57 x B73	13.0	4.2	8.8 a*	68
B14A x B73	14.8	6.4	8.4 ab*	57
A239	18.1	11.4	6.7 a-c*	37
B14A	16.8	10.1	6.7 a-c*	40
A619	17.4	11.4	6.0 a-d	34
N7A x B73	11.7	5.8	5.9 a-d	50
B75 x B73	12.4	6.9	5.5 a-d	44
B75	12.8	7.9	4.9 a-d	39
A239 x B73	11.1	6.6	4.5 a-d	41
Mo17 x B73	12.6	8.2	4.4 a-d	35
W64A	15.3	11.2	4.1 a-d	27
H95 x B73	9.2	5.2	4.0 a-d	43
B37	12.8	8.9	3.9 a-d	30
B70 x B73	12.1	8.4	3.9 a-d	32
N28 x B73	16.4	12.8	3.6 a-d	22
B57	12.3	8.7	3.6 a-d	29
Mo17	15.1	11.6	3.5 a-d	23
H95	10.7	7.6	3.1 a-d	29
A632	14.4	11.4	3.0 a-d	21
H98	12.4	9.6	2.8 a-d	23
B73	15.3	12.5	2.8 a-d	18
B52	7.6	4.8	2.8 a-d	37
WF9	12.0	9.3	2.7 a-d	23
Va26	11.2	8.5	2.7 a-d	24
W182E	19.5	16.9	2.6 a-d	13
Va26 x B73	9.7	7.3	2.4 b-d	25
N7A	9.4	7.0	2.4 b-d	26
Oh43	11.6	9.2	2.4 b-d	26
B70	18.0	16.1	1.9 cd	11
N28	17.7	16.7	1.0 cd	6
C123	11.2	11.2	0.0 d	0
Overall mean	13.5	9.4	4.1	30

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

percent reduction of stalk cavities than did their respective inbred parents (Figure 2).

Greater reduction of damage was obtained in test cross plots than in inbred plots. It is hypothesized that: (1) hybrids may have a larger root system compared to smaller, slower growing inbred lines and thus have a greater ability to absorb carbofuran from the soil, and (2) hybrids mature faster than inbreds and may have had larger whorls than inbreds when carbofuran was applied over the row, enabling more carbofuran granules to be trapped by the leaves.

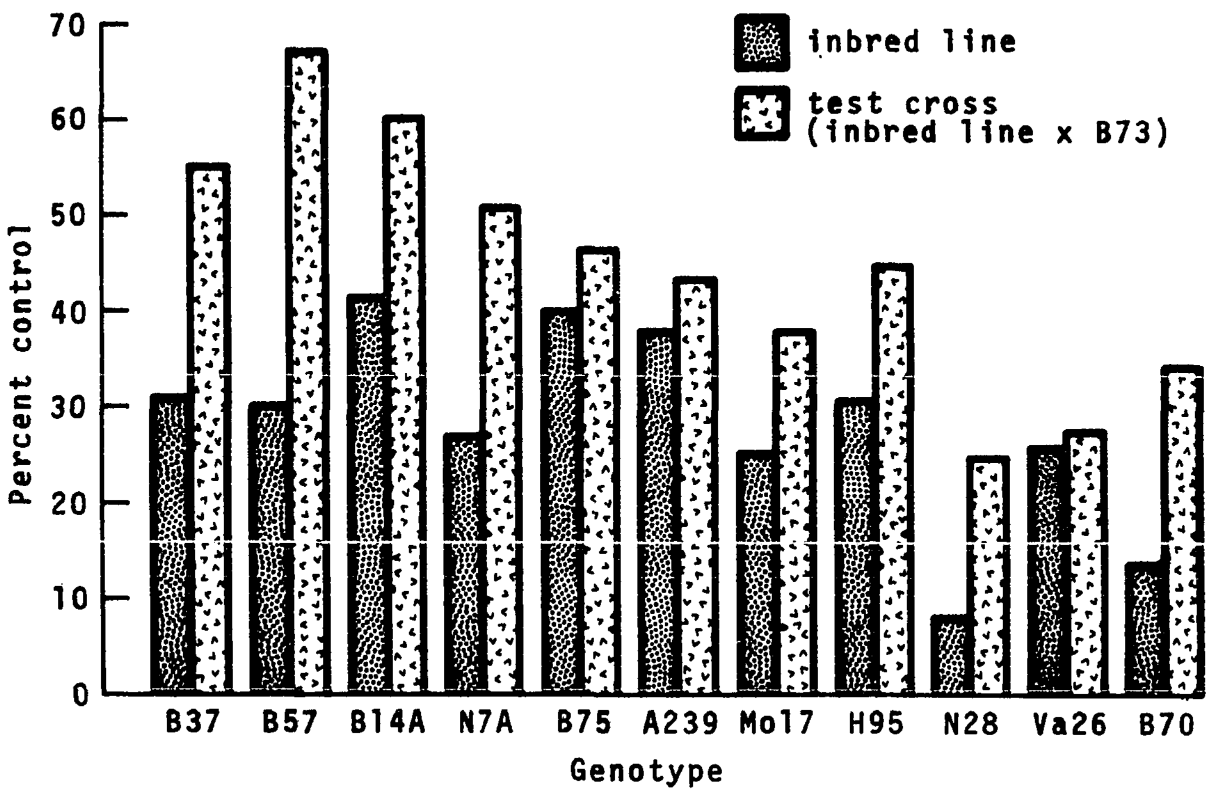
Most genotypes had a reduction in shank cavities between treated and nontreated plots (Table 13). Two genotypes (B14A x B73 and B37 x B73) had a significant reduction (75% and 67%, respectively) of shank cavities caused by second-generation corn borers.

1976

Compared with nontreated plots, 31 of 41 genotypes treated with carbofuran had a reduction in sheath-collar damage (Table 14); 35 of 41 had a reduction in stalk cavities (Table 15). In all 3 years genotypes resistant to European corn borer feeding (N7A and B52) generally had less sheath-collar damage and stalk cavities in nontreated plots than susceptible genotypes had in treated plots. These data suggest that insecticide treatments may be unnecessary with resistant lines of corn.

A greater percent reduction of stalk cavities caused by European corn borers was generally obtained in test crosses rather than in inbred lines of corn (Figure 3).

Figure 2. Effect of carbofuran on second-generation European corn borers (as measured by stalk damage) in inbred lines of corn and test crosses. Ankeny, Iowa, 1975



70
60
50
40
30
20
10
0
Percent control
inbred line
test cross
(inbred line x B73)
B37
B57
B14A
N7A
B75
A239
Mo17
H95
N28
Va26
B70
Genotype

Table 13. Effect of carbofuran on ear shank damage caused by European corn borers, Ankeny, Iowa, 1975

Genotype	Mean no. cavities/shank Nontreated	Carbofuran-treated	Difference[a]	Percent reduction
B14A x B73	1.2	0.3	0.9 a*	75
B37 x B73	1.2	0.4	0.8 ab*	67
B75 x B73	1.2	0.6	0.6 a-c	50
B75	1.1	0.5	0.6 a-c	55
H98	1.5	0.9	0.6 a-c	40
A239	1.8	1.2	0.6 a-c	33
N7A	1.2	0.8	0.4 a-d	33
B14A	1.0	0.6	0.4 a-d	40
N7A x B73	0.8	0.4	0.4 a-d	50
A619	2.0	1.6	0.4 a-d	20
N28 x B73	0.9	0.6	0.3 a-d	33
B57	1.4	1.1	0.3 a-d	21
WF9	1.1	0.8	0.3 a-d	27
C123	1.5	1.3	0.2 a-d	13
Oh43	1.4	1.2	0.2 a-d	14
Mo17 x B73	1.0	0.8	0.2 a-d	20
Va26 x B73	0.6	0.4	0.2 a-d	33
B70	1.7	1.5	0.2 a-d	12
Va26	0.6	0.5	0.1 b-d	17
H95 x B73	0.6	0.5	0.1 b-d	17
B52	1.1	1.0	0.1 b-d	9
H95	1.1	1.0	0.1 b-d	9
W182E	2.2	2.1	0.1 b-d	4
N28	1.5	1.4	0.1 b-d	7
A632	0.8	0.8	0.0 b-d	0
A239 x B73	0.7	0.7	0.0 b-d	0
B57 x B73	0.9	0.9	0.0 b-d	0
B37	1.0	1.1	-0.1 cd	0
W64A	1.4	1.5	-0.1 cd	0
B70 x B73	1.0	1.1	-0.1 cd	0
B73	0.8	0.9	-0.1 d	0
Mo17	1.2	1.4	-0.2 d	0
Overall mean	1.2	0.9	0.3	25

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Table 14. Effect of carbofuran on sheath-collar damage caused by second-generation European corn borers, Ankeny, Iowa, 1976

Genotype	Mean plot damage rating: Nontreated	Carbofuran-treated	Difference[a]
B75	7.8	4.5	3.3 a*
A239 x B73	6.0	3.7	2.3 ab*
B57 x B73	6.3	4.8	1.5 bc
H95	8.3	6.8	1.5 bc
A619 x B73	6.8	5.3	1.5 bc
Va26	7.5	6.0	1.5 bc
A619	8.0	6.8	1.3 bc
B52 x B73	4.3	3.0	1.3 bc
WF9	7.6	6.3	1.3 bc
B52	3.5	2.2	1.3 bc
Oh43 x B73	8.1	7.8	1.3 bc
H98	7.8	6.5	1.3 bc
B14a x B73	6.3	5.0	1.3 bc
H95 x B73	6.0	5.0	1.0 bc
WF9 x B73	6.8	5.8	1.0 bc
B57	5.8	4.8	1.0 bc
B75 x B73	4.8	3.8	1.0 bc
B73	6.0	5.0	1.0 bc
B37	7.5	6.5	1.0 bc
W64A x B73	7.0	6.0	1.0 bc
A632 x B73	6.5	5.8	0.8 bc
Va26 x B73	5.3	4.5	0.8 bc
C123 x B73	5.3	4.5	0.8 bc
H98 x B73	6.0	5.2	0.8 bc
Mo17 x B73	6.6	5.8	0.8 bc
W64A	7.0	6.5	0.5 bc
A632	8.0	7.5	0.5 bc
B37 x B73	6.0	5.5	0.5 bc
Mo17	7.8	7.3	0.5 bc
N28	6.5	6.0	0.5 bc
W182E	9.0	8.5	0.5 bc
N7A x B73	5.3	4.8	0.5 bc
Oh43	8.0	7.7	0.3 c
A239	6.1	5.8	0.3 c

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Table 14 (Continued)

Genotype	Mean plot damage rating Nontreated	Carbofuran treated	Difference	
W182E x B73	6.8	6.8	0.0	c
B14A	8.3	8.3	0.0	c
C123	6.8	6.8	0.0	c
N28 x B73	4.8	4.8	0.0	c
B70	6.8	6.8	0.0	c
N7A	4.3	4.3	0.0	c
B70 x B73	5.3	5.3	0.0	c
Overall mean	6.5	5.6	0.9	

Table 15. Effect of carbofuran on stalk damage caused by second-generation European corn borers, Ankeny, Iowa, 1976

Genotype	Mean no. cavities/plant Nontreated	Carbofuran-treated	Difference[a]	Percent reduction
A619	10.4	4.9	5.5 a*	53
H98	9.5	5.7	3.8 ab*	40
W64 x B73	7.0	4.0	3.0 a-c	43
B75	6.8	3.8	3.0 a-c	44
Va26	6.9	4.0	2.9 a-c	42
B73	6.5	3.7	2.8 a-c	43
A239 x B73	6.3	3.6	2.7 a-c	43
A619 x B73	5.9	3.2	2.7 a-c	46
Mo17 x B73	6.6	4.0	2.6 a-c	39
N28	6.8	4.3	2.5 a-c	37
B75 x B73	5.1	2.8	2.3 a-c	45
Oh43 x B73	4.4	2.1	2.3 a-c	52
H95	9.3	7.2	2.1 a-c	23

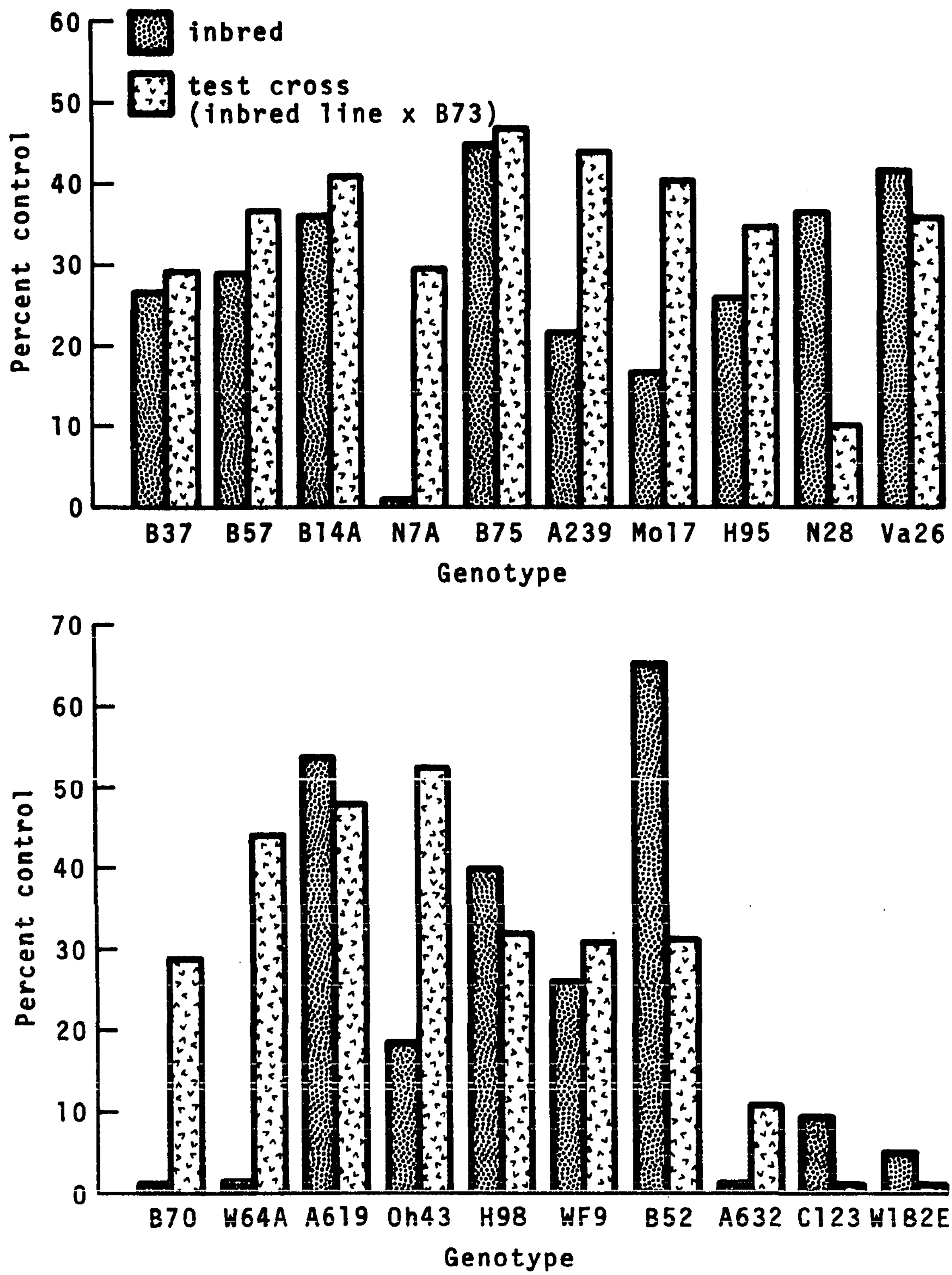
[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Table 15 (Continued)

Genotype	Mean no. Cavities/plant Nontreated	Carbofuran treated	Difference	Percent reduction
H95 x B73	5.8	3.8	2.0 a-c	34
B14A	5.3	2.4	1.9 a-c	36
B14A x B73	4.8	2.9	1.9 a-c	40
B52	3.0	1.1	1.9 a-c	63
B57	6.7	4.8	1.9 a-c	28
WF9	6.9	5.1	1.8 bc	26
H98 x B73	6.1	4.3	1.8 bc	30
B37	6.6	4.9	1.7 bc	26
Oh43	9.7	8.0	1.7 bc	18
B57 x B73	4.6	2.9	1.7 bc	37
WF9 x B73	4.9	3.5	1.4 bc	29
A239	7.1	5.7	1.4 bc	20
Va26 x B73	4.0	2.6	1.4 bc	35
Mo17	8.9	7.6	1.3 bc	15
B37 x B73	4.5	3.2	1.3 bc	29
N7A x B73	4.5	3.3	1.2 bc	27
B70 x B73	3.3	2.3	1.0 bc	30
W182E	15.6	14.6	1.0 bc	6
B52 x B73	3.0	2.1	0.9 bc	30
C123	9.0	8.2	0.8 bc	9
A632 x B73	4.2	3.7	0.5 bc	12
N28 x B73	3.9	3.6	0.3 bc	8
C123 x B73	4.6	4.6	0.0 c	0
W182E x B73	8.5	8.6	-0.1 c	0
N7A	3.1	3.3	-0.2 c	0
A632	7.7	8.0	-0.3 c	0
W64A	10.5	10.8	-0.3 c	0
B70	8.0	8.7	-0.7 c	0
Overall mean	6.5	4.8	1.7	26

Figure 3. Effect of carbofuran on second-generation European corn borers (as measured by stalk damage) in inbred lines of corn and test crosses. Ankeny, Iowa, 1976


60
50
40
30
20
10
0
inbred
test cross
(inbred line x B73)
Percent control
B37
B57
B14A
N7A
B75
A239
Mo17
H95
N28
Va26
Genotype
70
60
50
40
30
20
10
0
Percent control
B70
W64A
A619
Oh43
H98
WF9
B52
A632
C123
W182E
Genotype

Although small differences were obtained, most genotypes showed a reduction of ear shank cavities in carbofuran-treated plots compared with nontreated plots (Table 16). The genotype x treatment interaction was significant for shank cavities. The 2 genotypes resistant to European corn borer feeding (N7A and B52) had the same number of cavities/shank as the overall mean number of cavities/shank. These data suggest that factors responsible for resistance to sheath-collar and stalk feeding by corn borers have little effect on corn ear shanks. However, these data should be interpreted with caution as ear shank lengths were variable among genotypes.

Inbred lines resistant to corn borer feeding, crossed with susceptible inbred B73, generally resulted in a test cross that was intermediate in resistance to corn borer feeding. In other genotypes, however, the response of test crosses could not be predicted on the basis of the response of inbred parents.

Table 16. Effect of carbofuran on ear shank damage caused by second-generation European corn borers, Ankeny, Iowa, 1976

Genotype	Mean no. cavities/shank: Nontreated	Mean no. cavities/shank: Carbofuran-treated	Mean no. cavities/shank: Difference[a]	Percent reduction
A619	1.9	1.0	0.9 a*	47
H98	2.0	1.3	0.7 b	35
H95	2.1	1.5	0.6 bc	29
W64A x B73	1.8	1.2	0.6 b-d	33
A619 x B73	1.4	0.8	0.6 b-e	43

[a]Any two means not followed by the same letter are significantly different at the 5% level.

*Difference between treated and nontreated plots within a genotype is significant at the 5% level.

Table 16 (Continued)

Genotype	Mean no. cavities/shank Nontreated	Carbofuran treated	Difference		Percent reduction
B75	1.3	0.9	0.4	b-e	31
B57	1.5	1.1	0.4	b-e	27
WF9	1.6	1.2	0.4	b-e	25
Va26	0.9	0.5	0.4	b-e	44
A239 x B73	0.8	0.4	0.4	b-e	50
H98 x B73	0.9	0.6	0.3	b-e	33
B52	1.1	0.8	0.3	b-e	27
A239	1.3	1.0	0.3	b-e	23
B14A	0.7	0.4	0.3	b-e	43
B57 x B73	0.9	0.6	0.3	b-e	33
A632	1.0	0.7	0.3	b-e	30
B75 x B73	0.7	0.5	0.2	b-e	29
Oh43 x B73	0.6	0.4	0.2	b-e	33
Mo17	1.7	1.5	0.2	b-e	12
WF9 x B73	1.5	1.3	0.2	b-e	13
H95 x B73	1.0	0.8	0.2	b-e	20
W64A	1.3	1.1	0.2	b-e	15
A632 x B73	0.7	0.5	0.2	b-e	29
N28 x B73	0.6	0.5	0.1	b-f	17
B37	0.9	0.8	0.1	b-f	11
Oh43	1.0	0.9	0.1	b-f	10
B52 x B73	0.7	0.6	0.1	b-f	14
N7A	1.1	1.0	0.1	b-f	9
B73	0.9	0.8	0.1	b-f	11
B14A x B73	0.5	0.4	0.1	b-f	20
Mo17 x B73	0.8	0.7	0.1	b-f	13
Va26 x B73	0.6	0.5	0.1	b-f	17
N7A x B73	0.6	0.5	0.1	b-f	17
B70 x B73	0.8	0.8	0.0	b-f	0
N28	1.1	1.1	0.0	b-f	0
W182E	1.9	1.9	0.0	b-f	0
B37 x B73	0.7	0.8	-0.1	c-f	0
B70	1.6	1.7	-0.1	d-f	0
C123 x B73	0.6	0.7	-0.1	d-f	0
C123	1.0	1.2	-0.2	ef	0
W182E x B73	2.0	2.6	-0.6	f	0
Overall mean	1.1	0.9	0.2		18

SUMMARY AND CONCLUSIONS

Applied to the soil at planting time, a rate of 3.4 kg AI/ha of carbofuran is effective in controlling first-generation European corn borers. Applied over the row and incorporated into the soil at lay-by time, a rate of 3.4 kg AI/ha of carbofuran is effective in controlling second-generation European corn borers.

The effectiveness of soil-incorporated carbofuran may be related to the time of application of carbofuran relative to the time of infestation. Thus, one application of 3.4 kg AI/ha of carbofuran applied over the row and incorporated into the soil at lay-by time may be effective in controlling first- and second-generation European corn borers and western corn rootworms.

The uptake and translocation of carbofuran is influenced by corn genotypes. As measured by sheath-collar feeding and stalk cavities, test crosses generally showed a greater reduction of damage caused by European corn borers than did inbreds when carbofuran was applied to the soil.

At a rate of 6.7 kg AI/ha, carbofuran did not influence corn plant heights and phytotoxicity was not observed.

Rates of 3.4 and 6.7 kg AI/ha are probably not practical for farmers use because of high cost. It will be necessary to determine if corn genotypes respond differently with lower rates of carbofuran.

LITERATURE CITED

Berry, E. C., and J. F. Robinson. 1975. European corn borer control: Relationship of corn hybrids and uptake of a systemic insecticide. Proc. North Central Branch Entomol. Soc. Amer. 30:94. (Abstr.)

Berry, E. C., J. F. Robinson, W. G. Lovely, and G. M. McWhorter. 1974. European corn borer: Field trials with insecticides. Proc. North Central Branch Entomol. Soc. Amer. 29:128-131.

Edwards, C. R., and E. C. Berry. 1972. Evaluation of five systemic insecticides for control of the European corn borer. J. Econ. Entomol. 65:1129-1132.

Guthrie, W. D., F. F. Dicke, and C. R. Neiswander. 1960. Leaf and sheath feeding resistance to the European corn borer in eight inbred lines of corn. Ohio Agr. Exp. Sta. Bull. 860. 38 pp.

Guthrie, W. D., W. A. Russell, and C. W. Jennings. 1971. Resistance of maize to second-brood European corn borers. Proc. Corn and Sorghum Res. Conf. 26:165-179.

Harding, J. A. 1967. Field studies with crop protection chemicals against the European corn borer. U.S. Dep. Agr., ARS Special Report V-369.

Hills, T. M., and D. C. Peters. 1972. Methods of applying insecticide for controlling western corn rootworm larvae. J. Econ. Entomol. 65:1714-1718.

Hills, T. M., D. E. Peters, and E. C. Berry. 1972. Timing of insecticidal applications to control the western corn rootworm and the European corn borer. J. Econ. Entomol. 65:1697-1700.

Munson, R. E., T. A. Brindley, D. C. Peters, and W. G. Lovely. 1970. Control of both the European corn borer and western corn rootworm with one application of insecticide. J. Econ. Entomol. 63:385-390.

Pesho, G. R., F. F. Dicke, and W. A. Russell. 1965. Resistance of inbred lines of corn (*Zea maize* L.) to the second brood of the European corn borer (*Ostrinia nubilalis* Hübner). Iowa State J. Sci. 40:85-98.

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APPENDIX

Table 17. Effect of carbofuran on plant heights of corn genotypes, Ankeny, Iowa, 1974

Genotype	Mean plant height (cm)		
	Nontreated	Carbofuran-treated	Difference[a]
B75	81.0	91.3	-10.3 a
B52	87.0	92.0	-5.0 ab
Mo17	74.5	78.5	-4.0 ab
B14A	80.5	81.5	-1.0 ab
B70	93.8	94.5	-0.7 ab
B73	86.0	86.5	-0.5 ab
W182E	61.3	61.3	0.0 ab
Oh43	81.2	81.0	0.2 ab
A239	74.3	74.0	0.3 ab
WF9	71.5	62.8	8.7 b
B37	100.0	91.0	9.0 b
Overall mean	83.0	83.3	-0.3

[a]Any two means not followed by the same letter are significantly different at the 5% level.

Table 18. Effect of carbofuran on plant heights of corn genotypes, Ankeny, Iowa, 1975

Genotype	Mean plant height (cm) Nontreated	Carbofuran-treated	Difference[a]
A239 x B73	179.3	191.5	-12.2 a
Va26 x B73	189.0	201.0	-12.0 a
B70	147.5	158.5	-11.0 ab
N28	119.3	129.0	-9.7 ab
W64A	119.5	128.0	-8.5 ab
Mo17	144.8	151.3	-6.5 a-c
A239	114.0	120.0	-6.0 a-c
B75	131.5	135.0	-3.5 a-c
H98	133.0	136.5	-3.5 a-c
Va26	125.3	128.8	-3.5 a-c
A619	142.0	144.5	-2.5 a-c
B75 x B73	191.0	193.3	-2.3 a-c
B14A x B73	172.8	174.8	-2.0 a-c
WF9	125.3	127.0	-1.7 a-c
B70 x B73	214.8	216.0	-1.2 a-c
H95	103.0	103.3	-0.3 a-c
N7A x B73	170.8	169.8	1.0 a-c
Oh43	120.0	117.5	2.5 a-c
B14A	124.5	122.0	2.5 a-c
B37 x B73	179.5	176.5	3.0 a-c
Mo17 x B73	200.5	197.5	3.0 a-c
B57	102.8	99.5	3.3 a-c
B52	130.0	125.8	4.2 a-c
C123	129.3	125.0	4.3 a-c
A632	131.8	127.3	4.5 a-c
N28 x B73	164.5	159.8	4.7 a-c
W182E	127.3	120.0	7.3 a-c
N7A	124.5	117.0	7.5 a-c
B57 x B73	189.0	181.3	7.8 a-c
H95 x B73	182.5	174.7	7.8 a-c
B37	132.5	121.5	11.0 bc
B73	146.5	132.5	14.0 c
Overall mean	147.0	147.1	0.1

[a]Any two means not followed by the same letter are significantly different at the 5% level.

Table 19. Analysis of variance of leaf-feeding damage by first-generation European corn borers on corn genotypes, 1974

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	8	0.70	
Genotypes	10	107.30	175.96**
Error (a)	80	0.60	
Treatments	1	1.55	6.06**
Genotype x treatment	10	0.43	1.69ns
Error (b)	88	0.25	
Total	197	5.86	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 20. Analysis of variance of stalk damage by first-generation European corn borers on corn genotypes, 1974

Source of variation	Degrees of freedom	Mean squares	F-values
Replicates	8	9769.17	
Genotypes	10	92350.24	32.38**
Error (a)	80	2851.77	
Treatments	1	23607.29	29.49**
Genotype x treatment	10	1928.33	2.41*
Error (b)	88	800.58	
Total	197	6817.96	

*Significant at the 5% level.

**Significant at the 1% level.

Table 21. Analysis of variance of leaf-feeding damage by first-generation European corn borers on corn genotypes, 1975

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	3	7.11	
Genotypes	31	11.04	8.26**
Error (a)	93	1.33	
Treatments	1	0.77	0.89ns
Genotype x treatment	31	0.80	0.93ns
Error (b)	96	0.87	
Total	255	2.34	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 22. Analysis of variance of stalk damage by first-generation European corn borers on corn genotypes, 1975

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	3	3.28	
Genotypes	31	7.99	2.98**
Error (a)	93	2.68	
Treatments	1	0.66	1.09ns
Genotype x treatment	31	0.46	0.76ns
Error (b)	96	0.60	
Total	255	2.27	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 23. Analysis of variance of leaf-feeding damage by first-generation European corn borers on corn genotypes, 1976

Source of variation	Degrees of freedom	Mean squares	F-values
Replicates	3	3.57	
Genotypes	40	10.30	6.68**
Error (a)	120	1.54	
Treatments	1	471.44	424.23**
Genotype x treatment	40	4.90	4.41**
Error (b)	123	1.11	
Total	327	4.31	

**Significant at the 1% level.

Table 24. Analysis of variance of stalk damage by first-generation European corn borers on corn genotypes, 1976

Source of variation	Degrees of freedom	Mean squares	F-values
Replicates	3	8.30	
Genotypes	40	7.25	3.23**
Error (a)	120	2.24	
Treatments	1	24.76	36.30**
Genotype x treatment	40	1.37	2.01**
Error (b)	123	0.68	
Total	327	2.28	

**Significant at the 1% level.

Table 25. Analysis of variance of plant heights of corn genotypes, 1974

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	8	10.23	
Genotypes	10	68.34	16.05**
Error (a)	80	4.25	
Treatments	1	0.24	0.08ns
Genotype x treatment	10	1.89	0.60ns
Error (b)	88	3.17	
Total	197	7.12	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 26. Analysis of variance of plant heights of corn genotypes, 1975

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	3	701.23	
Genotypes	31	1216.74	11.00**
Error (a)	93	110.56	
Treatments	1	0.02	0.00ns
Genotype x treatment	31	14.28	1.14ns
Error (b)	96	12.54	
Total	255	202.95	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 27. Analysis of variance of sheath-collar damage by second-generation European corn borers on corn genotypes, 1974

Source of variation	Degrees of freedom	Mean squares	F-values
Replicates	8	1.63	
Genotypes	10	19.46	24.47**
Error (a)	80	0.79	
Treatments	1	226.98	460.96**
Genotype x treatment	10	2.56	5.21**
Error (b)	88	0.49	
Total	197	2.87	

**Significant at the 1% level.

Table 28. Analysis of variance of stalk damage by second-generation European corn borers on corn genotypes, 1974

Source of variation	Degrees of freedom	Mean squares	F-values
Replicates	8	10292.14	
Genotypes	10	99118.23	34.22**
Error (a)	80	2896.47	
Treatments	1	763469.82	450.64**
Genotype x treatment	10	7946.65	4.69**
Error (b)	88	1694.18	
Total	197	11661.22	

**Significant at the 1% level.

Table 29. Analysis of variance of sheath-collar damage by second-generation European corn borers on corn genotypes, 1975

Source of variation	Degrees of freedom	Mean squares	F-values
Replicates	3	2.89	
Genotypes	31	15.59	12.49**
Error (a)	93	1.24	
Treatments	1	125.16	182.40**
Genotype x treatment	31	1.78	2.61*
Error (b)	96	0.68	
Total	255	3.35	

*Significant at the 5% level.

**Significant at the 1% level.

Table 30. Analysis of variance of stalk damage by second-generation European corn borers on corn genotypes, 1975

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	3	45.80	
Genotypes	31	67.97	2.77**
Error (a)	93	24.50	
Treatments	1	1005.47	158.86**
Genotype x treatment	31	9.06	1.36ns
Error (b)	96	6.64	
Total	255	25.48	

[a] ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 31. Analysis of variance of ear shank damage by second-generation European corn borers on corn genotypes, 1975

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	3	1.31	
Genotypes	31	1.54	3.00**
Error (a)	93	0.51	
Treatments	1	3.44	38.21**
Genotype x treatment	31	0.13	1.48ns
Error (b)	96	0.09	
Total	255	0.45	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 32. Analysis of variance of sheath-collar damage by second-generation European corn borers on corn genotypes, 1976

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	3	4.65	
Genotypes	40	12.46	6.00**
Error (a)	120	2.07	
Treatments	1	59.75	97.35**
Genotype x treatment	40	0.86	1.42ns
Error (b)	123	0.61	
Total	327	2.84	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 33. Analysis of variance of stalk damage by second-generation European corn borers on corn genotypes, 1976

Source of variation	Degrees of freedom	Mean squares	F-values[a]
Replicates	3	173.11	
Genotypes	40	50.84	4.30**
Error (a)	120	11.82	
Treatments	1	219.59	86.49**
Genotype x treatment	40	2.97	1.17ns
Error (b)	123	2.53	
Total	327	14.13	

[a]ns = nonsignificant at the 5% level.

**Significant at the 1% level.

Table 34. Analysis of variance of ear shank damage by second-generation European corn borers on corn genotypes, 1976

Source of variation	Degrees of freedom	Mean squares	F-values
Replicates	3	4.92	
Genotypes	40	1.54	4.31**
Error (a)	120	0.35	
Treatments	1	3.22	35.95**
Genotype x treatment	40	0.14	1.60**
Error (b)	123	0.08	
Total	327	0.42	

**Significant at the 1% level.