Resistance to Second-Brood European Corn Borer Attack in Dent Inbred 'B52' and in Progeny from Crosses with Four Sweet Corn Inbreds[1, 2]

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Abstract. Artificial infestation with egg masses to simulate severe natural second brood European corn borer, *Ostrinia nubilalis* (Hubner), infestation caused less stalk and stalk-associated damage in the resistant field corn inbred 'B52' *Zea mays* L. than in susceptible sweet corn inbreds. Relatively severe damage, however, occurred on and around the region of the primary ear in both 'B52' and the sweet inbreds. Because direct kernel damage is of paramount economic importance in sweet corn as opposed to field corn, forms of second-brood resistance in addition to that found in 'B52' should be sought in sweet corn improvement. For stalk tunneling and number of sheath and collar lesions the resistance of F_1 and F_2 progenies was intermediate between the resistance of 'B52' and the sweet inbreds. Although there were no parental differences in damage to the ear, F_1 and F_2 means showed some indication of resistance.

European corn borer causes severe losses to the sweet corn industry in the midwest each year. Direct and indirect costs of insecticide usage, unharvested fields due to heavy infestation, increased factory costs due to added trimming, and lower market grades resulting from ear damage cause these losses. Much of the loss could be avoided if resistant cultivars were developed.

Through most of the corn belt, the corn borer has 2 broods each season (3). The biological relationship between the borer and the plant differs for the 2 broods (5). During first-brood egg deposition most corn is in the pretassel (whorl) stage, while most corn completes tasseling and pollen shedding during second-brood egg deposition.

Chiang and Hodson (2) studied the relationship between ear damage and heavy natural first- and second-brood borer infestations on 'Golden Cross Bantam' sweet corn at 3 planting dates at Waseca, MN, in 1949 and 1950. They found that the trimming necessary to eliminate injured kernels for processing in the early (first-brood infested), mid-season (maturing between major moth flights), and late (second-brood infested) plantings in 1949 was 7.0%, 3.3% and 14.8% of the total crop, respectively.

Screening for resistance has been in progress for a number of years in field corn. Many sources of first-brood leaf feeding resistance (antibiosis) have been identified (9), but few sources were found to have high second-brood resistance (7, 10). However, in one inbred, 'B52', more than 95 percent second-brood larval mortality was found to occur within 4 days after egg hatching, indicating a high degree of antibiosis to first and second instar larvae (7). In inheritance studies with field corn, resistance to the second brood (8) and to the first brood (4) was found to be largely controlled by additive gene action. There has been some indication of partial dominance for resistance. Good progress has been shown possible in breeding for resistance to the first brood (9).

Second-brood resistance for sweet corn is of primary interest because of the larger amount of ear damage done by this brood. High resistance to second-brood attack has not been identified in sweet corn, with limited screening under controlled infestation. In contrast to field corn, borer damage to the ear in sweet corn has grave economic consequences while stalk and sheath damages are somewhat less important. The usefulness of 'B52' as a source of resistance in sweet corn breeding would be influenced by its degree of resistance to the borer in the ear region of the plant.

Our objectives were 1) to examine the resistance of 'B52' to stalk injury and ear feeding, and 2) to study the transmission of this resistance to F_1 and F_2 progenies following hybridization of 'B52' with susceptible sweet corn inbreds (8).

Materials and Methods

Inbreds and crosses. Inbred 'B52' and 4 sweet corn inbreds ('Ia5125', '101t', 'P39' and 'Green Giant #62') were studied. These sweet inbreds are widely used commercially in the production of hybrids and have no known second-brood resistance. Crosses were produced in 1972 between 'B52' and the 4 sweet inbreds. Part of the seed from each of the 4 F_1s was used to produce F_2 seed in Florida during winter, 1972–73.

Field plots. Inbred 'B52', 4 sweet inbreds, 4 F_1s and 4 F_2s were planted in May, 1973, at the University of Minnesota farm in St. Paul. The experimental design was a randomized block with 3 replications in which each block contained one 15-plant row of each of the 5 inbreds and 4 F_1s, and five 15-plant rows of each of the 4 F_2s. Within-row spacing was 30 cm; between-row spacing, 90 cm. Fertilizer (12-12-12) was broadcast preplant at the rate of 449 kg per ha.

Artificial infestation. Eggs to produce the second-brood infestation were obtained from moths collected from large emergence cages which had been filled with infested corn stalks the previous fall (6). When the plants began to tassel, tillers were removed to concentrate borers on the central stalk for each evaluation. Artificial infestation was achieved on the first 10 plants in each row by use of egg masses incubated to the near-hatch point and pinned through the leaf from the lower midrib surface on each of 3 leaves, the primary ear leaf, the leaf above the ear, and the leaf below the ear, during the active pollen shedding stage as described by Pesho, Dicke, and Russell (10). Three applications were spread 3 days apart to reduce escapes. Two egg masses (ca. 50 eggs) were used for each application. The ear leaf received the first application, the leaf above the ear the second, and the leaf below the ear the third.

Evaluation. Evaluation began shortly after the corn was optimally mature for processing. The plants were examined for 7 types of injury: 1) sheath damage, 2) collar feeding, 3) stalk injury, 4) shank damage, 5) husk penetration, 6) silk feeding, and 7) kernel damage on the tip and side of the ear. The number and stage of development of larvae on each plant were recorded.

Sheath damage was determined by counting the number of lesions on all sheaths of each plant. The lesions were calculated on the basis of the number and size of the lesions, i.e. lesions one and 6 cm long, to

[1] Received for publication May 14, 1974. MN Agricultural Experiment Station Journal Series No. 8678.
[2] The authors wish to express appreciation to Dr. W. D. Guthrie, USDA Corn Borer Investigations Laboratory, Ankeny, IO for his advice and counsel.
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cite an example, were counted as one and 6 lesions, respectively (7). Collar injury was determined by the amount of girdling. Lesions girdling one-third, two-thirds, or all of the collar were counted as 1, 2 or 3 lesions, respectively (7). Stalk injury was determined by splitting the stalk and scoring in cm the total length of all tunnels in each plant (10).

Shank damage ratings were based on the number and length of tunnels in the main ear shank. Most tunnels ranged from 1 to 4 cm; any tunnel exceeding 4 cm in length was counted as 2 tunnels (10).

Husk feeding was ascertained by counting the number of penetrations through the husk to the kernels. Presence or absence of damage to silk was recorded for each primary ear.

Larval damage to kernels was evaluated by a modification of the grading system described by Walter (11) for evaluating resistance of sweet corn to corn earworm feeding. The main ear on each plant was graded from 1 to 5 at harvest according to the amount of feeding: 1) no injury; 2) tip injury or less than 5 kernels destroyed; 3) kernels destroyed to 2.5 cm below tip or 5 to 15 kernels destroyed; 4) kernels destroyed to 5 cm below the tip or 16 to 30 kernels destroyed; 5) kernel destruction 5 cm below the tip or more than 30 kernels destroyed.

Results And Discussion

Inbreds. Weather favorable to hatch and establishment of borers followed artificial infestation. Susceptible plants were heavily infested but were able to continue normal ear development.

'B52' had significantly less stalk injury than the 4 sweet corn inbreds (Table 1). There were no significant differences at the 5% level among the 4 sweet inbreds, but the mean number of tunnels ranged from 9.7 in '101t' to 12.8 in 'Ia5125'. The number of sheath lesions on 'B52' was also significantly lower than on the 4 other inbreds (Table 1). The number of collar lesions on the 5 inbreds did not differ at the 5% level, but 'B52' seemed to be the most severely damaged.

For kernel, husk, silk, and shank damage the 5 inbreds did not differ at the 5% level (Table 2); hence the resistance of 'B52' to stalk feeding appears not to include strong resistance to feeding in the region of the primary ear.

No distinction was made between kernel damage at the ear tip and kernel damage to the side of the ear. However, when borers had fed through the husk into the ear, the kernels adjacent to the point of entry were damaged most often. Most of the damage associated with husk penetration was thus side damage unless the larvae penetrated the husk near the tip of the ear. Many larvae which entered the ear through the husk fed on only a few kernels and then tunneled into the cob. Approximately 65% of the ears had at least one husk penetration.

Table 1. Mean comparisons among inbreds and their F_1 and F_2 hybrid progenies for stalk and stalk-associated damage caused by second-brood corn borer.[z]

Generation	No. of stalk tunnels	No. of sheath lesions	No. of collar lesions
Inbred			
B52	2.8b	3.2b	6.1a
GG62	10.6a	9.6a	3.5a
P39	12.7a	7.4a	2.0a
Ia5125	12.8a	10.9a	3.0a
101t	9.7a	7.2a	2.6a
F_1			
GG62 x B52	4.2a	8.7a	5.1a
P39 x B52	7.7a	9.7a	7.1a
Ia5125 x B52	5.3a	8.8a	6.0a
101t x B52	8.1a	8.5a	5.5a
F_2			
GG62 x B52	6.5a	9.4a	4.8a
P39 x B52	8.3a	9.5a	5.0a
Ia5125 x B52	8.2a	10.4b	4.9a
101t x B52	7.4a	8.7a	4.9a

[z] Means are presented on a per plant basis. Within generation, means not followed by the same letter differ at the 5% level (Duncan's new multiple range test).

Table 2. Mean comparisons among inbreds and their F_1 and F_2 hybrid progenies for damage to the primary ear by second-brood corn borer.[z]

Generation	Kernel damage rating[y]	No. of husk penetrations	No. of shank tunnels	% of ears with silk feeding
Inbred				
B52	2.9a	1.7a	0.4a	74.6a
GG62	3.4a	2.1a	1.0a	79.0a
P39	3.3a	1.2a	0.7a	79.7a
Ia5125	3.0a	1.0a	1.2a	73.3a
101t	2.2a	1.3a	1.0a	80.0a
F_1				
GG62 x B52	2.4a	0.3a	0.1a	90.0a
P39 x B52	2.7a	0.1a	0.1a	86.6a
Ia5125 x B52	2.6a	0.2a	0.5a	90.0a
101t x B52	2.4a	0.1a	0.1a	93.3a
F_2				
GG62 x B52	2.6a	0.7a	0.4a	87.3a
P39 x B52	3.0a	0.7a	0.7a	92.0a
Ia5125 x B52	2.9a	0.5a	0.9a	89.3a
101t x B52	2.6a	0.5a	0.5a	88.7a

[z] Means are presented on a per plant (or primary ear) basis. Within character, means not followed by the same letter differ at the 5% level (Duncan's new multiple range test).

[y] Based on a 1 to 5 rating scheme where 1 = no injury and 5 = severe injury as described in the text.

Larvae which entered the ear by feeding on silk also fed on kernels at the point of entry. Larvae appeared to prefer silk tissue to kernel tissue. If a concentration of green silks was available, many of the larvae on that ear were found feeding on silk tissue. Often, larvae which finished feeding on the available silk supply did not feed on kernels, but tunneled directly down the center of the cob. Approximately 78% of the ears had some type of silk damage with more than one larva normally present. Larvae entering through the silks accounted for a substantially larger amount of the total kernel damage than those entering through the husk.

Larvae feeding on shank tissue did virtually no kernel damage. There were a few ears in which the larvae fed from the shank up into the base. When this occurred, the ear feeding was usually confined to cob tunneling. Shank damage is related to kernel damage only as a mutual indicator of larval feeding in the ear area. Shank damage is contrasted with the relationship between kernel damage and damage to the silks and husks. Damage by larvae to silks or husks preceded kernel damage.

According to Guthrie, et al. (7), second-brood larval mortality within 3 days after egg hatch on 'B52' is high. The mean number of larvae on the 5 inbreds at the time of evaluation ranged from 4.1 for 'B52' to 7.6 for 'Ia5125', but did not differ at the 5% level.

More larvae on 'B52' were found in the second instar and correspondingly fewer were found in the fourth and fifth instar stages as compared to those on the 4 susceptible sweet corn inbreds (Fig. 1), indicating larvae development was retarded on 'B52'. Larvae on the 4 susceptible inbreds appeared to be developing at the same rate, but there were some large differences between the percentages of the fourth and fifth instar larvae. We considered this difference to be unimportant since many of the larvae judged to be in the 4th instar when the evaluations were made could have been 5th instar larvae within a few days. The percentages of larvae in the 4th and 5th instar classes grouped together were basically the same for the 4 sweet inbreds.

We concluded that 'B52' is highly resistant to stalk feeding but quite susceptible to ear and kernel damage. Hence, 'B52' may be of limited usefulness as a source of effective resistance to 2nd brood attack in sweet corn improvement.

Behavior of progeny. No clear pattern of segregation could be detected for any of the characters within or across the F_2 families.

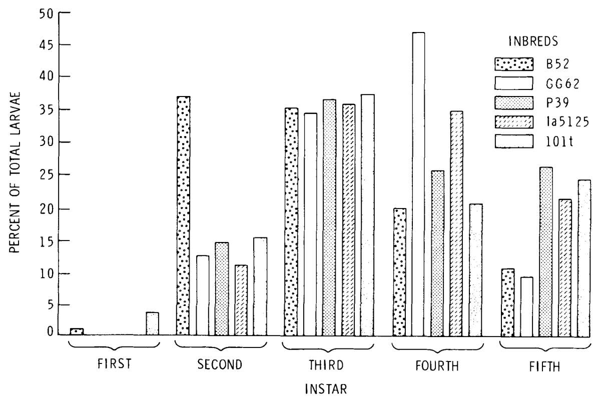

Fig. 1. Distribution of instar frequencies in the resistant field corn inbred 'B52' and in 4 sweet corn inbreds susceptible to secondbrood corn borer.

There was no evidence of the segregation of a small number of genes; variation was continuous.

For stalk and stalk-associated damage the 4 F_1s did not differ and were intermediate between their respective parents, although the resistance of 3 of the 4 tended to more closely approach the resistance of 'B52' (Table 1). The F_2 means also did not differ significantly; 3 of the 4 tended to be less resistant than the corresponding F_1s and were closer to their respective midparents. The F_2 tended to be at least as susceptible to borer attack in the sheath area as the susceptible sweet corn parents. The F_1 of the cross 'GG62' x 'B52' seemed especially low in numbers of stalk tunnels, although this was not detectable at the 5% level.

Although, as measured by silk damage, the F_1s and F_2s seemed to be more heavily attacked than their parents, they appeared more resistant than 'B52' when kernel damage and number of husk penetrations were used as criteria. For number of shank tunnels the F_1s were again quite resistant, while F_2 means tended to vary. This tendency for heterosis, if confirmed, could be advantageous in improvement of sweet corn to second brood attack. Further work in this area will be needed, however. The greater vigor of the F_1 and F_2 over the parental inbreds may be a confounding factor in an in-depth study of the inheritance of resistance.

To summarize, our data indicate that the high resistance of 'B52' to the second brood is transmitted fairly well to hybrids with sweet inbreds. 'B52' may not be sufficiently resistant to ear attack although F_1 and F_2 progeny appeared to have some resistance to kernel damage, husk penetration and shank tunneling. Additional study is needed to estimate accurately the relative degree of additive and non-additive effects in the inheritance of resistance, but the indication is that the resistance in 'B52' should be heritable (8).

It is not known at this time how large a role the resistance of 'B52' might play in reducing the amount of economically important damage to the ear in sweet corn. In addition to the use of 'B52' in breeding, it would seem prudent to search for genetic material having resistance in the ear region by virtue of reduced attractiveness for oviposition, reduced potential for survival of young larvae on the exterior of the ear, or reduced attractiveness or nutritional suitability of the kernels and silks. Mechanical or morphological features as well as antibiosis in the ear region were somewhat successfully used as a form of resistance to the corn earworm (1), and should be explored as a possible source of resistance to second-brood corn borer attack. Nevertheless, inclusion of the form of sheath and stalk feeding resistance found in 'B52' probably would be useful in a breeding program. This form of resistance should at the very least help to reduce larval effectiveness and population levels.

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