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The yield performance of a resistant and a susceptible field corn hybrid under different intensities of European corn borer infestation

EDWIN T. HIBBS

W. D. GUTHRIE

C. R. NEISWANDER

Ohio Agricultural Experiment Station

Wooster, Ohio

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THE YIELD PERFORMANCE OF A RESISTANT AND A SUSCEPTIBLE FIELD CORN HYBRID UNDER DIFFERENT INTENSITIES OF EUROPEAN CORN BORER INFESTATION

EDWIN T. HIBBS[1], W. D. GUTHRIE[2], and C. R. NEISWANDER[3, 4]

INTRODUCTION

With the advance of the corn improvement programs in the United States, dent corn strains which have been selected for desirable agronomic qualities and resistance to the damage of first-brood infestations of the European corn borer, **Pyrausta nubilalis** (Hbn.), have been introduced and are being used in commercially available corn hybrids. But little yield data have appeared to demonstrate the value of these resistant hybrids to growers in the infested area of the Corn Belt. In the experiments devised it was the investigators' purpose to manipulate dates of planting thereby influencing maturity of plants at the time of initial infestation and to vary the intensity of borer infestation in order to facilitate a comparison of the performance of a borer-resistant and a borer-susceptible hybrid.

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[1]Formerly with the Ohio Agricultural Experiment Station, now with Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.

[2]Entomologist, U. S. Department of Agriculture, Agricultural Research Service, Entomology Research Division.

[3]Associate Chairman, Department of Entomology, Ohio Agricultural Experiment Station.

[4]The experiments reported scarcely could have been initiated in 1951 except for the interest and wholehearted cooperation of C. A. Crooks, formerly Entomologist of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. Mr. Crooks contributed to the success of the experiments during 1951 and part of 1952. The writers gratefully acknowledge the invaluable contribution of time and attention given during the planning and execution of these experiments on the part of F. F. Dicke, Entomologist of the Entomology Research Division, and G. H. Stringfield, Agronomist of the Crops Research Division, Agricultural Research Service, United States Department of Agriculture and of the Ohio Agricultural Experiment Station.

The methods and procedures were planned so as to simulate the natural seasonal conditions of infestation and plant growth as nearly as possible. The experiments were carried out at Toledo, Ohio, cooperatively by the Ohio Agricultural Experiment Station and the United States Department of Agriculture.

METHODS AND PROCEDURE IN 1951

The two hybrids selected for testing their yielding abilities under different intensities of infestation and dates of planting were Iowa 4316 (WF9 × M14) × (L289 × I205) and Ohio K62 (Oh51 × Oh26) × (Oh43 × Oh45) which are nearly equal in maturity in this section. The first named is a well-established hybrid similar in pedigree to many hybrids grown in the Corn Belt. All of the inbred components of Iowa 4316 favor the survival of first-brood borers and are not related to lines in Ohio K62. The latter hybrid is of more recent development with three of its parent inbred lines possessing a good degree of first-brood resistance. It is widely grown in Ohio and parts of Indiana.

The inbred WF9 is a derivative of the open-pollinated variety Reid Yellow Dent. It has several agronomic characteristics that have made it an extensively-used inbred in commercial hybrids. Important among these characteristics is its desirability as a seed parent. It is attractive to the moths for oviposition and possesses qualities that make it favorable to the survival of larvae. Both of these factors are transmitted to hybrids.

M14 was derived from the single cross (BR10 × R8) and is extensively used in combination with WF9 as a parent single-cross in commercial hybrids. It favors larval survival and lacks qualities that contribute to good tolerance or standability.

The inbred L289, a derivative of the open-pollinated variety, Lancaster Surecrop, favors larval survival somewhat less than either WF9 or M14, but contributes poor tolerance and standability.

I205 was derived from the open-pollinated variety Iodent. Although favoring larval survival it is less attractive to the moths for oviposition than the other components of the hybrid Iowa 4316.

All of the component inbred lines of Ohio K62 (Oh51 × Oh26) × (Oh43 × Oh45) were developed at the Ohio Agricultural Experiment Station. Oh51 is a derivative of the open-pollinated variety, Clarage. It has consistently shown a good level of resistance to larval survival and contributes tolerance in hybrid combinations. The inbred Oh26 has consistently favored larval survival and is the least desirable inbred in this hybrid from the standpoint of contributing tolerance.

The inbreds Oh43 and Oh45 are derivatives of (W8 × Oh40B) and were released in 1949. These sister lines are used as the single-cross pollen parent in several Ohio hybrids. They are also coming into common use in commercial hybrids in the Central Corn Belt. Neither of these lines favors the survival of the first-brood borer (Oh45 is somewhat more resistant than Oh43). Under severe infestation tests, borer mortality on Oh43 and Oh45 usually ranges from 60 to 70 percent greater than on WF9 and M14.

The variation in plant development at the time of initiation of borer infestation was introduced by making plantings on different dates. In 1951 the planting dates were May 21 and June 8. Both hybrids of the two planting dates were subjected to different intensities of borer infestation which were established by the treatments described below:

1. Parathion sprayed to eliminate as much of both first- and second-brood natural infestation as possible.
2. Naturally infested by both first and second broods.
3. Naturally infested by both first and second broods plus one manually applied first-brood egg mass per plant.
4. Naturally infested by both first and second broods plus three manually applied first-brood egg masses per plant.
5. Infested by the natural second brood. Plots in this treatment were sprayed with parathion to eliminate as much first-brood infestation as possible during the period of first-brood establishment.

A split-plot design including two dates of planting, two hybrids, four replicates, and five treatments was used. Main plots were made up of planting dates, while the split plots consisted of the 12 hybrid × treatments combinations. Individual treatment plots consisted of 2 rows by 11 hills of three plants each exclusive of guard hills. Data were analyzed by methods outlined for the split-plot design by Snedecor (1956). A test for significant differences between treatment means applied to the data was that of Duncan's multiple range test (Duncan 1955). In the analysis of the data, since estimated plot totals were used, no transformation of the data was made.

The manual application of first-brood egg masses was accomplished July 5 through 12, a period of natural egg deposition by moths in the area.

The following is a description of the procedures employed in taking the records during the 1951 season.

1. The samplings to measure the intensities of the first-brood infestation were made on August 16. The number of plants infested per 25 plants examined in each plot was recorded. Two hills of three plants each, one hill from each row in each plot of treatments 1, 2, 3, and 4, were randomly selected. The infested plants were dissected. The number of borers per 100 plants was derived by multiplying the number of borers per infested plant by the number of plants per hundred infested. The larvae observed were recorded as first brood (fourth instar and above) or second brood (instars 1, 2, and 3). The natural oviposition period of the second brood was approximately from August 1 to September 1.

2. Plant dissections were made on October 8 and 9 in all treatments in order to measure the intensities of infestation in the fall following the establishment of the second brood.

3. The yield data in each plot were taken in mid-October on 5 hills of 3 plants each in each of 2 rows. Yield hills were surrounded by 3-plant hills. Moisture determinations in each plot were taken on samples of 2 kernel rows from 10 random ears. The yield of each plot, in pounds, was adjusted to 15.5 percent moisture as measured by the Steinlite method.

METHODS AND PROCEDURE IN 1952

The methods and procedures used in 1952 were substantially the same as in 1951. Seasonal conditions were different than in 1951 and some changes were necessary on this account. The same two corn hybrids selected for nearly uniform maturity used in the 1951 experiments were used in 1952. Both hybrids were planted on May 26 and June 11. The treatments were designed to introduce different intensities and types of borer infestations as variables using the same plot design as was used in 1951.

It was planned to add both first- and second-brood egg masses uniformly to designated plots of the May and June plantings of both hybrids. However, since the supply of eggs was limited, no applications of first-brood masses were made to plots of the June 11 planting. These plants were still at an early stage of development when first-brood egg masses were applied to the May 26 planting.

In the 1952 experiment the May 26 planting with controlled infestations of both first- and second-brood borers will be considered apart from the June 11 planting which was infested with only second-brood borers.

The alteration of the design of the experiment in 1952 changed the analysis from the split-plot of 1951 to a more simplified design with hybrids and treatments the main factors within single dates of planting. The test of Duncan (1955) was applied to differences between treatment means. Again, estimated plot totals were used without transformation of the data.

May 26 Planting: Treatments in the May 26 planting were: (1) parathion sprayed to control both first- and second-brood borers, (2) naturally infested by both broods, (3) naturally infested plus 3 first-brood egg masses, (4) naturally infested plus 5 first-brood egg masses, (5) naturally infested by only second brood (the first brood was controlled with parathion sprays during the period of first-brood establishment), (6) naturally infested by only second brood (as in 5 above) plus 3 second-brood egg masses.

First-brood egg masses were uniformly applied to both hybrids in designated plots by placing the masses in the leaf-whorl. The three masses were applied, one per plant, on three successive dates. The five masses were applied, two at a time, on the same successive dates, except only one was applied on the final date. Second-brood egg masses were pinned on the midrib close to the stalk on the lower side of the leaf. Egg masses of both broods were applied during the period of egg laying by moths of the natural population.

Samples of the first-brood borers were taken July 28 in plots of treatments 1, 2, 3, and 4. Fifty plants, twenty-five from each of the two rows of the plots, were examined. The number infested with borers was recorded. Of these infested plants six were removed. All three plants of the infested hill were taken, thus removing two entire hills from the plot. The six plants were dissected and the number of borers and the stages of their development were recorded. The number of borers per 100 plants was computed by multiplying the number of plants per hundred infested by the number of borers per infested plant.

The fall borer population was sampled September 3 in the same manner described for the first brood.

Yield samples were taken October 23 by the method described for 1951.

June 11 Planting: Although the planting was planned to accommodate the treatment of the June 11 planting with both first- and second-brood egg masses, only four of the treatments were actually accomplished. They were applied to both hybrids and were the following: (1) borer-free through the use of parathion spray applications throughout the season, (2) naturally infested by the second brood (the first brood was controlled with parathion spray), (3) infested by natural second brood (as in 2 above) plus 3 second-brood egg masses, (4) infested by the natural second brood (as in 2 above) plus 6 second-brood egg masses.

The larval population of the first brood was not sampled in July as was done in the May planting. The control of the first brood with parathion was considered satisfactory for the purposes of the experiment.

The fall borer populations and corn yields were sampled in the same manner as in the May planting reported above.

RESULTS AND DISCUSSION OF THE 1951 EXPERIMENT

The silking dates of the two hybrids in both plantings were recorded for comparison of the relative rates of maturity in 1951. By the method of M. T. Meyers (1930) the date of 50 percent silking in the May 21 planting was July 27 in plots of the resistant Ohio K62, and July 29 in plots of the susceptible Iowa 4316. In the June 8 planting the mid-silking date was August 8 in the resistant Ohio K62, and August 11 in the susceptible Iowa 4316. The period from planting to mid-silking corresponds closely with that reported by Stringfield (1951) for the two hybrids in previous tests.

The two hybrids were considered to exhibit, for the purposes of the experiment, practically uniform rates of maturity within dates of planting. The dates of planting provided plants in the late-whorl stage of development in the May planting and more immature plants in the June planting during the period of first-brood oviposition and establishment which ranged from early July through July 15.

When the second brood was becoming established during August, the May planting had passed mid-silking but plants of the June planting attained mid-silking during this period.

The survival of the first-brood larvae in the experimental plots in 1951 was measured by the dissection of stalks on August 16. Analysis of variance indicated that of the major controlled factors in the experiment the hybrids and treatments were independent sources of variance in the numbers of first-brood borers present in mid-August (table 1). At that time the first brood had attained 12 percent pupation in plots of borer-susceptible Iowa 4316. In plots of Ohio K62 only 7.3 percent had pupated. Moths which had developed from first-brood larvae began oviposition within the plots soon after August 1. By August 16 many second-brood larvae had hatched. In the records of the August 16 dissection of plants the first brood included larvae of instars 4 and 5, pupae, and pupal cases. Larvae of the first, second and third instars were recorded as belonging to the second brood which will be discussed later.

There was a significantly greater number of borers in the susceptible Iowa 4316 than in the resistant Ohio K62, 114.0 borers per 100 plants compared with 66.3, respectively. The influence of the treatments was reflected as three discrete mean levels of intensity of first-brood infestation in mid-August as measured by Duncan's multiple range test for differences between treatment means. The three levels of intensity expressed as the mean number of borers per 100 plants were in ascending order: 14.2 in parathion-treated plots (treatment 1), 92.2 in plots naturally infested, combined with those which received in addition one first-brood egg mass per plant (treatments 2 and 3 which were not significantly different), and 161.9 in plots which received three egg masses per plant (treatment 4).

The initial trend of establishment of the second brood was apparent in the numbers of first, second and third instar larvae taken in the mid-August dissection of stalks. These forms obviously belonged to the second brood.

In contrast to the concentration of the first brood in the May planting, the second brood was concentrated in the June 8 planting. There were 1.7 second-brood borers per 100 plants in the May planting but there were 94.3 in the June planting. In borer-susceptible Iowa 4316, 69.3 second-brood borers per 100 plants survived while in resistant Ohio K62 there were only 26.7.

On October 8 the population intensity within the plots was again measured (table 2). The data reflect the effect of the super-imposed natural second brood and, as well, the differential response of borers to the two hybrids. There were 188.2 borers per 100 plants counted on Iowa 4316 and 155.1 on Ohio K62 (statistically different at 0.01 probability). At that time the intensity of infestation in the May and June planting was the same statistically. Biologically the infestations were comprised of unidentifiable proportions of first- and second-brood larvae.

Nevertheless, the effect of treatment was still traceable, and in the statistical analysis treatments provided a significant source of variance in the fall-infestation data. The fewest borers, 64.1 per 100 plants, were found in plots which had been sprayed throughout the season (treatment 1). The most borers were found in plots naturally infested by both first and second broods, 226.9 per 100 plants (treatment 2), and plots which had received three first-brood egg masses per plant, 246.7 per 100 plants (treatment 4). On the basis of the August dissection and the number of borers present in treatment 5, it was clear that the population infesting treatments 2 and 4 though statistically

TABLE 1.—Analysis of August 16 infestation of first-brood borers (instars IV, V, pupae and pupal cases) per 100 plants. Toledo, Ohio, 1951

Source	Analysis of variance	
	Degrees of freedom	Mean square
Replication	3	1446.0292
Planting date (D)	1	23088.8025
Error (a)	3	2820.2758
Hybrid (H)	1	36423.7225**
Treatment (T)	3	60002.7092**
H × T	3	5347.5425
H × D	1	418.2025
T × D	3	1789.5025
H × T × D	3	1692.9558
Error	42	2168.7715

**Significant at .01 probability.

Hybrid	Iowa 4316	Ohio K62
Mean	114.0	66.3

Duncan's multiple range test for differences between treatment means

	Treatment			
	1 Parathion sprayed	2 Natural 1st brood	3 Natural + 1 egg mass 1st brood	4 Natural + 3 egg masses 1st brood
Means	14.2	79.6	104.8	161.9

(79.6 and 104.8 are underscored by the same line.)

Any two means not underscored by the same line are significantly different at .05 probability

alike were not alike biologically. Those infesting treatment 2 were predominantly larvae of the second brood. Those in treatment 4 were mostly residuals of the first brood. Likewise in the combination of treatments 3 and 5, a substantial part of the former were residuals of the first brood. An estimate of the number of residual first-brood larvae remaining in the fall was obtained by subtracting from the numbers in treatment 4 those in treatment 5, 246.7 - 162.9 = 83.8 per 100 plants; likewise 226.9 - 162.9 = 64.0, the number of first-brood larvae in treatment 2.

In any case, all of the plots were uniformly exposed to the natural infestation of the second brood. The parathion applications to treatment 5 had been discontinued in advance of second-brood activity so that the natural infestation of the second brood was allowed to accumulate in those plots. It was apparent that the previous parathion sprays did not leave residues which interfered with the establishment of the second brood.

The yield performance of the hybrids of the two dates of planting was sufficiently influenced by the scheduled treatments to reflect clearly the effect of first-brood infestation differentials in spite of the superimposed second-brood infestation (table 3). Plots receiving parathion spray (treatment 1) throughout the season yielded most (62 bushels per acre) while yields were depressed significantly by the addition of one egg mass per plant (treatment 3), 56.53 bushels per acre, and three egg masses per plant (treatment 4), 55.79 bushels per acre. Of the natural infestation of both broods (treatment 2), 59.2 bushels per acre, and of second brood (treatment 5), 61.25 bushels per acre, neither caused significant yield reductions. Variance in yield could not be traced either to hybrid or to date of planting. Anticipated trends which existed in the data and which were in part supported by statistical tests encouraged further exploration of the methods and procedures followed as means toward revealing some of the complexities of hybrid response to borer infestation.

The following data summarize, apart from the statistical analysis of the major variables of the experiment, trends of corn yield under differing intensities of borer infestation of the May planting (table 4). When arranged in descending order of yields in bushels per acre the data reflect hybrid response to infestation.

TABLE 2.—Analysis of October 8 infestation of borers per 100 plants. Toledo, Ohio, 1951

Source	Analysis of variance	
	Degrees of freedom	Mean square
Replication	3	10240.114
Planting date (D)	1	61.250
Error (a)	3	32208.647
Hybrid (H)	1	21846.050**
Treatment (T)	4	81794.302**
H × T	4	10083.530
H × D	1	12034.418
T × D	4	4597.248
H × T × D	4	1397.860
Error	54	5598.994

**Significant at .01 probability.

Hybrid	Iowa 4316	Ohio K62
Mean	188.2	155.1

Duncan's multiple range test for differences between treatment means

	Treatment				
	1	3	5	2	4
	Parathion sprayed	Natural 1st & 2nd broods + 1 1st brood egg mass	Natural 2nd brood	Natural 1st & 2nd broods	Natural 1st & 2nd broods + 3 1st brood egg masses
Means	64.1	158.1	162.9	226.9	246.7

(Underscore lines: 158.1–162.9; 226.9–246.7)

Any two means not underscored by the same line are significantly different at .05 probability

TABLE 3.—Analysis of corn yields in pounds (adjusted to 15.5% moisture) per plot. Toledo, Ohio, 1951

Source	Analysis of variance	
	Degrees of freedom	Mean square
Replication	3	1.421792
Planting date (D)	1	61.425125
Error (a)	3	22.073458
Hybrid (H)	1	1.653125
Treatment (T)	4	3.151375**
H × T	4	.670000
H × D	1	.045125
T × D	4	.825125
H × T × D	4	.875750
Error	54	.541329

**Significant at .01 probability.

Duncan's multiple range test for differences between treatment means

	Treatment				
	4	3	2	5	1
	Natural 1st & 2nd broods + 3 1st brood egg masses	Natural 1st & 2nd broods + 1 1st brood egg mass	Natural 1st & 2nd broods	Natural 2nd brood	Parathion sprayed
Mean Lbs./plot	8.99	9.11	9.54	9.87	9.99
Mean Bu./acre	55.79	56.53	59.20	61.25	62.00

(Underscoring lines: one line under 59.20, 61.25, 62.00; one line under 56.53, 59.20.)

Any two means not underscored by the same line are significantly different at .05 probability

TABLE 4.—Mean first-brood borer infestation and associated corn yield. May planting, 1951

Treatment	Susceptible Iowa 4316			Resistant Ohio K62		
	Borers per 100 plants 8/16	Bushels per acre	Percent reduction	Borers per 100 plants 8/16	Bushels per acre	Percent reduction
1. Parathion sprayed	34.2	70.7	----	2.5	67.0	----
5. Natural 2nd brood	—*	68.3	3.4	—*	65.8	1.8
2. Natural 1st & 2nd broods	145.0	63.3	10.5	53.8	67.0	0
3. Natural + 1 egg mass 1st brood	130.0	60.2	14.8	137.5	62.7	6.4
4. Natural + 3 egg masses 1st brood	212.5	55.2	21.9	157.5	62.7	6.4

*Same as treatment 1 up to this date.

Under practically equal opportunity for first-brood infestation of the two hybrids the most borers survived on the susceptible Iowa 4316 in treatment 4. Its yield was reduced from a potential 70.7 bushels per acre to 55.2 bushels, 15.5 bushels per acre or a reduction of 21.9 percent. The yield of resistant Ohio K62 was reduced from 67.0 to 62.7 or 4.3 bushels, a reduction of only 6.4 percent. A comparable summary of data from the June planting follows:

TABLE 5.—Mean first-brood borer infestation and associated corn yield. June planting, 1951

Treatment	Susceptible Iowa 4316		Resistant Ohio K62	
	Borers per 100 plants 8/16	Bushels per acre	Borers per 100 plants 8/16	Bushels per acre
1. Parathion sprayed	9.0	52.1	11.0	57.1
5. Natural 2nd brood	—*	55.2	—*	55.8
2. Natural 1st & 2nd broods	97.6	54.0	22.0	52.1
3. Natural + 1 egg mass 1st brood	97.2	49.6	54.6	53.4
4. Natural + 3 egg masses 1st brood	161.4	50.9	91.3	54.6

*Same as treatment 1 up to this date.

In the June planting fewer borers had survived on Ohio K62 than on Iowa 4316 when the infestation was sampled August 16. In the same sampling it was evident that the second brood was concentrated in the June planting. It seems reasonable to assume that the accumulation of the second brood in the June planting obscured the influence upon yield of the relatively low incidence of first-brood infestation. But little difference in yield resulted among treated plots of the June planting.

RESULTS AND DISCUSSION OF THE 1952 EXPERIMENT

The experiment was repeated a second season in essentially the same form except that an additional series of plots was kept free of first-brood infestation. This series subsequently received infestation by the second brood. Some of the plots received second-brood egg masses applied by hand in addition to the natural second-brood infestation. These added treatments were considered to be feasible following the successful establishment in 1951 of second-brood borers after plants had been sprayed with parathion to control first-brood borers. The series was expected to provide conditions that would yield more information than the 1951 series concerning the response of the two hybrids to the second-brood infestation. The number of first-brood egg masses added manually was increased to 3 masses per plant in treatment 3 and to 5 masses per plant in treatment 4 in an effort to obtain a wider range of intensities of borer infestations in 1952.

In 1952, plantings of Iowa 4316 and Ohio K62 were made May 26 and June 11, a few days later than in 1951.

Since in 1952 the May planting received treatments involving both first- and second-brood infestations and the June planting only infestations of the second brood, the data from the two were analyzed singly.

MAY PLANTING

The intensity of infestation in the May planting was evaluated July 28 in treatments 1 through 4. Up to that time treatments 5 and 6 had been sprayed with parathion on the same schedule treatment 1 had received. The July date was selected in order that the sampling would be completed prior to the beginning of second-brood establishment. The first-brood infestation, July 28, was measurably influenced by corn hybrid (table 6). There were 206.8 borers per 100 plants in Iowa 4316 compared with only 46.2 borers in Ohio K62. The accumulation of borers was progressively greater as the number of egg masses was increased on Iowa 4316 but this was not true in the corresponding

TABLE 6.—Analysis of July 28 infestation of first-brood borers per 100 plants in the May planting. Toledo, Ohio, 1952

Source	Analysis of variance	
	Degrees of freedom	Mean square
Total	31	
Replication (R)	3	4831.87
Hybrid (H)	1	206242.53**
Treatment (T)	3	128332.12**
T × H	3	69545.61**
Error	21	3245.84

**Significant at .01 probability.

Hybrid	Iowa 4316	Ohio K62
Mean	206.8	46.2

Treatment × hybrid means

	Treatment[1]			
	1 Parathion sprayed	2 Natural 1st brood	3 Natural + 3 egg masses 1st brood	4 Natural + 5 egg masses 1st brood
Iowa 4316	2	63	279	483
Ohio K62	0.2	30	79	75

[1]The sampling of first-brood borers was completed prior to the beginning of second-brood establishment.

treatments of Ohio K62. This relationship was apparent as a treatment × hybrid interaction, significant at the 1 percent level of probability.

The differential survival of borers in treatments 1 through 4 in each of the two hybrids is evident in the treatment × hybrid interaction (table 6).

On September 3 when the population intensity was again measured to include both broods, stalks were dissected in the same four treatments which were sampled in July (table 7). In addition, treatment 5, naturally infested by only the second brood, and treatment 6, which received in addition to the natural second-brood infestation three egg masses of the second brood, were dissected. In this sampling as in July both hybrid and treatment were sources of variance in infestation intensity at 1 percent probability. In plots of Iowa 4316 there were 214.7 borers per 100 plants compared with 126.01 in Ohio K62. A treatment × hybrid interaction significant at the .05 level of probability was evident in the analysis.

The differential survival of borers in the two hybrids under the series of treatments was the apparent source of this interaction. The reason for the survival of fewer borers in plots of treatment 4 than survived in plots of treatment 3 was not clearly understood. The fact that it occurred in both hybrids suggests that the high level of infestation intensity itself, resulting from the addition of five egg masses (approximately 100 eggs per plant) to the natural infestation of these plants, adversely affected borer survival.

The accumulation of the natural second brood in treatment 5 was slight and was nearly the same in plots of Iowa 4316 and Ohio K62. However, the addition of three second-brood egg masses (treatment 6) resulted in a definite increase of infestation of both hybrids.

Produced against this background of variance in intensity of infestation, the yields of Iowa 4316 and Ohio K62 in the May planting were measured on October 23. In the analysis of yield variance, both hybrid and treatment were significant sources of variance (table 8). Subjected to the same initial opportunity for infestation, the mean yield of Iowa 4316 representing all treatments was 8.44 pounds per plot (52.4 bushels per acre); the comparable yield from Ohio K62 was 10.54 pounds per plot (65.4 bushels per acre).

The yield of the insecticide treated plot (treatment 1) significantly exceeded yields from each of the other treatments except treatment 2 which was naturally infested. Further, the mean yield from plots infested with the first brood (treatment 3 plus 4), 9.09 pounds, and the yield from plots infested with the second brood (treatment 5 plus 6), 9.06 pounds, were equal but less than that of the mean yield, 10.34 pounds, of the insecticide treated plots and treatment 2, naturally infested, combined.

TABLE 7.—Analysis of September 3 infestation of borers per 100 plants in the May 26 planting. Toledo, Ohio, 1952

Source	Analysis of variance	
	Degrees of freedom	Mean square
Replication (R)	3	2687.34
Hybrid (H)	1	94397.20**
Treatment (T)	5	325066.85**
T × H	5	15963.36*
Error	33	5715.69

**Significant at .01 probability.
*Significant at .05 probability.

Hybrid	Iowa 4316	Ohio K62
Mean	214.7	126.01

Treatment × hybrid means

	Treatment					
	1	2	3	4	5	6
	Parathion sprayed	Natural 1st & 2nd broods	Natural 1st & 2nd broods + 3 1st brood egg masses	Natural 1st & 2nd broods + 5 1st brood egg masses	Natural 2nd brood	Natural + 3 egg masses 2nd brood
Iowa 4316	18.7	48.5	304.0	245.8	29.8	641.5
Ohio K62	15.9	19.5	162.5	83.5	32.9	441.8

TABLE 8.—Analysis of corn yields in pounds (adjusted to 15.5% moisture) per plot in the May planting. Toledo, Ohio, 1952

Source	Analysis of variance	
	Degrees of freedom	Mean square
Replication (R)	3	2.2071
Hybrid (H)	1	53.1092**
Treatment (T)	5	4.1728**
T × H	5	1.4784
Error	33	0.9711

**Significant at .01 probability.

Hybrid	Iowa 4316	Ohio K62
Mean Lbs./plot	8.44	10.54
Mean Bu./acre	52.4	65.4

Duncan's multiple range test for differences between treatment means

	Treatment					
	3	6	5	4	2	1
	Natural 1st & 2nd broods + 3 1st brood egg masses	Natural + 3 egg masses 2nd brood	Natural 2nd brood	Natural 1st & 2nd broods + 5 1st brood egg masses	Natural 1st & 2nd broods	Parathion sprayed
Mean Lbs./plot	8.71	8.98	9.13	9.46	10.07	10.61
Mean Bu./acre	54.05	55.73	56.66	58.71	62.49	65.84

Any two means not underscored by the same line are significantly different at .05 probability

Apart from the statistical analysis of the major variables of the experiment, table 9 brings together the yield and associated first-brood borer infestation when sampled July 28 in the May planting of the two hybrids. Except for treatment 1 which was sprayed throughout the season the other treatments, 2, 3, and 4, were presumed to have received uniformly the natural infestation of the second brood. If this were true, the reductions in yield among treatments 2, 3, and 4 would be attributable to the influence of first-brood infestation.

TABLE 9.—Mean first-brood borer infestation and associated corn yield. May planting, 1952

Treatment	Susceptible Iowa 4316			Resistant Ohio K62		
	Borers per 100 plants 7/28	Bushels per acre 10/13	Percent reduction	Borers per 100 plants 7/28	Bushels per acre 10/13	Percent reduction
1. Parathion sprayed	2	61.9	----	0.2	69.8	----
2. Natural 1st brood	63	57.8	6.6	30.0	67.3	3.6
3. Natural + 3 egg masses 1st brood	279	49.6	20.0	79.0	58.5	16.2
4. Natural + 5 egg masses 1st brood	483	50.3	18.7	75.0	67.2	3.7

In order to bring attention to the influence of the second-brood infestation of the May planting the data in table 10 were grouped.

TABLE 10.—Mean second-brood borer infestation and associated corn yield. May planting, 1952

Treatment	Susceptible Iowa 4316			Resistant Ohio K62		
	Borers per 100 plants 9/3	Bushels per acre	Percent reduction	Borers per 100 plants 9/3	Bushels per acre	Percent reduction
1. Parathion sprayed	18.70	61.9	----	15.93	69.8	----
5. Natural 2nd brood	29.77	45.9	25.8	32.90	67.3	3.6
6. Natural + 3 egg masses 2nd brood	641.50	48.7	21.3	441.75	62.7	10.2

The intensity of second-brood infestation measured September 3 in the May planting was greatest in treatment 6 which received approximately 60 second-brood eggs (3 egg masses) in addition to the natural second-brood infestation. Although the yield of the May planting of susceptible Iowa 4316 was measurably reduced by natural second-brood infestation (treatment 5) the addition of the 3 egg masses (treatment 6) which resulted in twenty times as many borers was scarcely reflected in corn yields. This emphasizes the importance of the stage of plant development at the time of initiation of infestations as a factor influencing hybrid response to borer infestation. Yield of Ohio K62 was depressed less than that of the susceptible hybrid.

JUNE PLANTING

Since the June planting in 1952 seemed undeveloped at the time of first-brood establishment, manipulations of the intensity of the first brood in that planting were not attempted. Instead, in the June planting treatments 1, 2, 3, and 4 each were sprayed throughout the period of establishment of the first brood. Subsequently second-brood treatments 1, 2, 3, and 4 were completed. The June planting provided nearly optimum conditions for the establishment of the second brood.

When the intensity of infestation was measured by dissections of plants September 3, hybrid and treatment provided significant sources of variance (table 11). The treatments established three discrete levels of infestation intensity. The insecticide treated check (treatment 1) and the plots naturally infested by only second brood (treatment 2) were not different; combined, their mean number of borers per 100 plants was 63.07. The manual addition of three and six second-brood egg masses to the natural second-brood infestation (treatments 3 and 4, respectively) established the other two levels, 608.5 and 1202.0 borers per 100 plants, respectively.

Produced against this background of variance in second-brood infestation intensity, the corn yields of the June planting were sampled and evaluated (table 12). Hybrid and treatments were again sources of significant variance in yield. The mean yield of all treatments representing Ohio K62 was 10.64 pounds per plot. The comparable yield of Iowa 4316 was 9.15 pounds per plot. The yields of treatment 1 and treatment 2 were not different; their combined mean was 10.68 pounds per plot. This was significantly more than the 9.60 pounds from treatment 3 and more than the 8.61 pounds from treatment 4 at the 5 percent level of probability.

TABLE 11.—Analysis of the September 3 infestation of second-brood larvae per 100 plants in the June planting. Toledo, Ohio, 1952

Source	Analysis of variance	
	Degrees of freedom	Mean square
Replication (R)	3	616.67
Hybrid (H)	1	141230.19*
Treatment (T)	3	2364447.74**
T × H	3	27835.23
Error	21	27473.35

*Significant at .05 probability.
**Significant at .01 probability.

Hybrid	Iowa 4316	Ohio K62
Mean	550.59	417.73

Duncan's multiple range test for differences between treatment means

	Treatment			
	1	2	3	4
	Parathion sprayed	Natural 2nd brood	Natural + 3 egg masses 2nd brood	Natural + 6 egg masses 2nd brood
Means	37.25	88.89	608.50	1202.00

(Means 37.25 and 88.89 are underscored by the same line.)

Any two means not underscored by the same line are significantly different at .05 probability

TABLE 12.—Analysis of corn yield in pounds (adjusted to 15.5% moisture) per plot in the June planting. Toledo, Ohio, 1952

Source	Analysis of variance	
	Degrees of freedom	Mean square
Replication (R)	3	0.7567
Hybrid (H)	1	17.8056**
Treatment (T)	3	8.1527**
T × H	3	2.0200
Error	21	1.1558

**Significant at .01 probability.

Hybrid	Iowa 4316	Ohio K62
Mean Lbs./plot	9.15	10.64
Mean Bu./acre	56.8	66.0

Duncan's multiple range test for differences between treatment means

	Treatment			
	4	3	1	2
	Natural + 6 egg masses 2nd brood	Natural + 3 egg masses 2nd brood	Parathion sprayed	Natural 2nd brood
Mean Lbs./plot	8.61	9.60	10.47	10.89
Mean Bu./acre	53.43	59.57	64.97	67.58

Any two means not underscored by the same line are significantly different at .05 probability

Data of the infestation intensity and associated yields for each of the two hybrids in the June 11 planting are summarized in table 13.

The second-brood infestation clearly reduced yields of the hybrids planted June 11. There was a trend of greater borer establishment in the susceptible Iowa 4316 and a greater reduction of yield in that hybrid in comparison with that of resistant Ohio K62.

TABLE 13.—Mean second-brood borer infestation and associated corn yield. June planting, 1952

Treatment	Susceptible Iowa 4316			Resistant Ohio K62		
	Borers per 100 plants 9/3	Bushels per acre	Percent reduction	Borers per 100 plants 9/3	Bushels per acre	Percent reduction
1. Parathion sprayed	46.12	62 5	----	28.38	67.5	----
2. Natural 2nd brood	135.25	65.7	none	42.53	69.5	none
3. Natural + 3 egg masses 2nd brood	671.00	50.8	18 7	546.00	68.3	none
4. Natural + 6 egg masses 2nd brood	1350.00	48.2	22.9	1054.00	58.8	12.9

SUMMARY AND CONCLUSIONS

The yield performance of a commercially available corn hybrid, Ohio K62 (Oh51 × Oh26) × (Oh43 × Oh45), resistant to the European corn borer, **Pyrausta nubilalis** (Hbn.), and a commonly grown borer susceptible hybrid, Iowa 4316 (WF9 × M14) × (L289 × I205), was compared under a range of intensities of infestation by first- and second-brood borers in two seasons.

A split-plot field design was used with dates of planting representing the major division. Treatment combinations including corn hybrids, treatments (i. e. intensity and character of infestation), and replications were tested as sources of variance. Duncan's multiple range test of differences between means was applied to evaluate treatment effects.

In many instances the character of infestation differed and different infestation intensities resulted from treatments which involved: the control of infestation by insecticidal sprays, the natural establishment of both first- and second-brood borers, the natural establishment of only second brood following the control of the intensity of infestation of each of the natural first and second brood through the manual addition of egg masses at times coincident with the natural establishment of borers.

The sampling reported comprised (1) the mid-summer infestation of plots by first-brood borers, (2) the fall infestation of plots by first- and/or second-brood borers, and (3) corn yield at harvest.

For both hybrids in 1951 the greatest yields were obtained from insecticide treated plots, their combined mean 61.62 bushels per acre. The natural infestation by first and/or second brood did not depress yields of the hybrids measurably but mean yields were reduced to 56.53 bushels per acre by the increased intensity of borer infestation resulting from the addition of one first-brood egg mass. The least mean yield, 55.79 bushels per acre, resulted from the addition of three first-brood egg masses.

It appeared that the greater proportion of yield reduction resulted from infestations of the susceptible Iowa 4316. Under equal initial opportunity for first-brood infestation in 1951 the yield of the May planted Iowa 4316 was reduced 21.9 percent, of Ohio K62 only 6.4 percent. Under a comparable situation in 1952 yield of Iowa 4316 was reduced 18.7 percent, Ohio K62 only 3.7 percent.

In the June plantings the first-brood infestations which were initiated when plants were more immature than were those in the May plantings yield reductions were negligible.

When second-brood borers infested the two hybrids in May plantings the plant had just passed tasseling. In this situation many borers survived. Yields of Iowa 4316 were reduced as much as 21.3 percent compared with 10.2 percent in the case of Ohio K62.

On the other hand the second-brood infestation which was initiated just prior to tasseling in the June planting caused a yield reduction of 22.9 percent in plots of Iowa 4316 but of 12.9 in Ohio K62.

The intensities of infestation associated with the reductions in yield appear in the text. They indicated that relatively few borers caused severe losses in the susceptible hybrid if the infestation was initiated prior to tasseling. Equally great yield reduction was caused by infestations originating after tasseling but only when infestation intensities were much greater.

The survival of borers was less in Ohio K62 in nearly every comparable instance involving first- or second-brood infestations.

The sensitivity of the experiments to differences in corn yield was as follows: 1951, 3.3 to 3.6 bushels per acre; 1952, May planting, 6.5 to 7.3 bushels per acre; and 1952, June planting, 7.3 to 7.9 bushels per acre.

Sensitivity to variance in the number of borers present was considered satisfactory for the purpose of the experiment. This ranged from 33 to 36 borers per 100 plants in 1951 when intensity of infestation ranged from 14 to 162 borers per 100 plants to as high as 155 to 168 borers per 100 plants when the second brood in the June planting of 1952 ranged from 37 to 1202 borers per 100 plants.

The methods used offer promise of successful application to future studies of interrelationships between the grain production of corn hybrids and infestation by the bivoltine form of the European corn borer.

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