TB 822 (1942) USDA TECHNICAL BULLETINS UPDATE

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PATCH, L. H.; HOLBERT, J. R.; EVERLY, R. T. 1 OF 1

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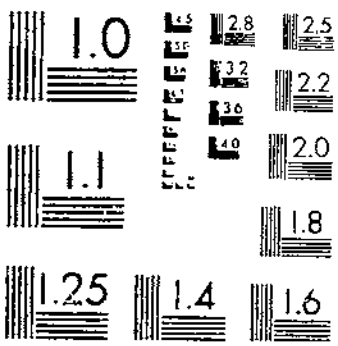

MICROCOPY RESOLUTION TEST CHART
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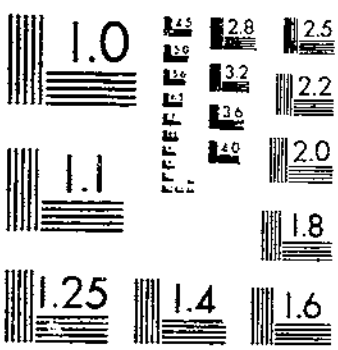

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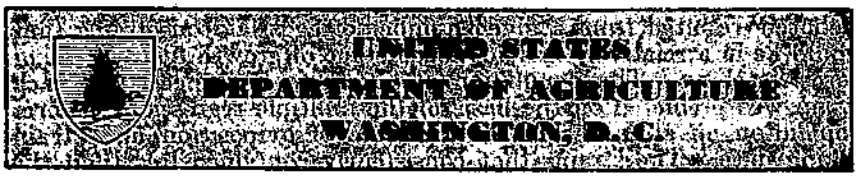
Technical Bulletin No. 823 • May 1942



Strains of Field Corn Resistant to the Survival of the European Corn Borer[1]

By L. H. Patch, *associate entomologist, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine;* J. R. Holbert, formerly *senior agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry;* and R. T. Everly, *junior entomologist, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine*[2]

CONTENTS

INTRODUCTION

The problem of the control of the European corn borer (*Pyrausta nubilalis* (Hbn.)) through the use of borer-resistant strains of corn has been extensively investigated by various workers. One of the most complete studies of this problem has been made by Meyers and others,[3] who have included in their report many references to previous publications on the subject. These workers tested large numbers of strains under conditions of natural oviposition by first-generation moths and found that plots of taller corn tended to re-

[1] Received for publication May 14, 1941.

[2] The authors express their appreciation to the cooperating agencies and individuals who grew and supplied hybrids and inbred lines of corn reported on in this bulletin; to Funk Bros. Seed Co., Bloomington, Ill.; I. J. Johnson, associate professor in genetics, University of Minnesota; E. W. Lindstrom, professor of genetics, Iowa State College; A. R. Marston, research assistant, Michigan State College; N. P. Neal, assistant professor in genetics, University of Wisconsin; C. M. Woodworth, professor in genetics, University of Illinois; and to the following workers of the Bureau of Plant Industry: A. M. Brunson, agronomist, stationed at the Kansas and later at the Indiana Agricultural Experiment Station; R. O. Eckhardt, assistant agronomist, stationed at the Iowa Agricultural Experiment Station; R. W. Jugenheimer, associate agronomist, stationed at the Iowa and later at the Kansas Agricultural Experiment Station; G. F. Sprague, agronomist, stationed at the Missouri and later at the Iowa Agricultural Experiment Station; and G. H. Stringfield, agronomist, stationed at the Ohio Agricultural Experiment Station.

Acknowledgement is made of the assistance in the field work by members of the staff engaged in European corn borer research. The transformation to logarithms in the analysis of the data was suggested by C. I. Bliss. The inception of the project was made at the suggestion of W. P. Flint, chief entomologist, Illinois Agricultural Experiment Station. The interest and support of W. A. Baker, D. J. Caffrey, W. H. Larrimer, P. N. Annand, and C. M. Packard, of the Bureau of Entomology and Plant Quarantine, and Merle T. Jenkins, of the Bureau of Plant Industry, have made this work possible. The addition to the study of inbred lines was a valuable suggestion from W. A. Baker, under whose general supervision the work has been conducted since 1933.

[3] Meyers, Marion T., Huber, L. L., Neiswander, C. R., Richey, F. D., and Stringfield, G. H. Experiments on breeding corn resistant to the European corn borer. U. S. Dept. Agr. Tech. Bul. 583, 30 pp., illus. 1937.

ceive more eggs than plots of shorter corn, and that smaller numbers of borers resulted from a given number of eggs laid on strains that would be in a relatively less advanced stage of growth at the time of borer hatching. The population of borers to be expected in each strain was predicted on the basis of the multiple regression of borer population on strain height at the time of oviposition and strain silking date. The strains that consistently contained less than the predicted number of borers were classed as inherently borer resistant.

Marston[4] mentioned the possible influence of strain maturity on resistance. He interpreted his data on the basis of percentage of plants infested and the number of borers per 100 plants.

Ficht[5] also indicated the possible importance of the maturity of strains in evaluating their borer resistance. He reported the numbers of full-grown larvae surviving on different strains as a percentage of the estimated number of eggs deposited naturally on a given number of plants.

Thompson[6] reported the performance of various strains of standard and hybrid corn under natural infestation on the basis of the average number of borers per 10 stalks.

It is the purpose of this bulletin to show the relative resistance to corn borer survival contributed by inbred lines of field corn to hybrid combinations. The measurement of the relative resistance is the percentage deviation of the observed population of borers from the predicted population on the date of silking of the strain. The predicted values were obtained from the analysis of covariance.

PLANT MATERIAL

During the 10-year period from 1930 to 1939 tests of the material available have been conducted for the purpose of discovering inbred lines of corn that would contribute resistance to corn borer establishment and survival. During the early years of the work single-cross, three-way cross, and a few double-cross hybrids and open-pollinated varieties were used, with inbreds Ill.A, Ill.R4, Ill.Hy, Ill.L, Ill.A48, Ill.90, and Ind.TR predominating in the pedigrees of the hybrids. From 24 to 36 strains were tested from 1930 to 1935, inclusive, the number being limited by the fact that the tests were made at several levels of borer population induced by varying the number of egg masses placed on the plants.[7]

During the early tests certain hybrids showed a decided resistance to survival of larvae of the corn borer, and other hybrids showed a marked susceptibility. These resistant and susceptible hybrids were used as standards for evaluating the results obtained from later experiments. In 1936 and 1937 the emphasis was placed on determining the relative borer survivals in these hybrids as related to the stage of plant development at the time of hatching of the eggs and on determining when and where the differentiation in borer survival

[4] MARSTON, A. R. RECENT PROGRESS IN BREEDING BORER RESISTANT CORN. Mich. Agr. Expt. Sta. Quart. Bul. 15: 264-268, illus. 1933.

[5] FICHT, C. A. RELATIVE RESISTANCE OF SELECTED STRAINS OF CORN TO EUROPEAN CORN BORER. Jour. Econ. Ent. 29: 687-691. 1936.

[6] THOMPSON, R. W. NOTES ON CORN BORER RESISTANCE IN HYBRID CORN. Ontario Ent. Soc. Ann. Rpt. (1937) 68: 28-32, illus. 1938.

[7] PATCH, L. H., STILL, G. W., APP, B. A., and CROOKS, C. A. COMPARATIVE INJURY BY THE EUROPEAN CORN BORER TO OPEN-POLLINATED AND HYBRID FIELD CORN. Jour. Agr. Res. 63: 355-368, illus. 1941.
PATCH, L. H., STILL, G. W., SCHLOSBERG, M., and BOTTGER, G. T. FACTORS DETERMINING THE REDUCTION IN YIELD OF FIELD CORN BY THE EUROPEAN CORN BORER. [To be submitted for publication.]

occurred with reference, respectively, to the age of the borers and their location in the plants. The plant characters associated with borer resistance were also considered.[8]

In 1938 tests were conducted with over 200 top-cross strains, including an early group of segregating and advanced lines top crossed with the Waugh variety, a later group of lines top crossed with the Krug variety, one lot of lines top crossed with the Western Plowman variety, and another lot top crossed with Iowa synthetic hybrid 8037. More than 100 single-cross and top-cross strains were tested in 1939. The performance of the strains tested during the 10-year period has been used as a basis for this bulletin.

Inbred lines were first tested as such in 1935, and similar tests were made each year thereafter. Lines that showed promise as inbreds were later tested in single-cross combinations.

EXPERIMENTAL PROCEDURE AND METHODS OF ANALYSIS

The possibility of finding inadequate samples of borers resulting from natural infestation and the necessity of counting the eggs laid naturally were obviated by placing on the plants by hand eggs produced by moths confined in laboratory cages. In appraising the borer resistance of the strains, their stage of maturity at time of hatching of the eggs and differences due to sampling errors were considered, and it is believed that the large numbers of eggs placed on the plants by hand subordinated any possible effect of the differences in natural oviposition among the strains. Furthermore, the use of check plots showed repeatedly that the ranking of the strains based on infestations induced largely by hand was not materially different from the ranking resulting from infestations produced wholly by the moths in nature.

The strains were planted in several blocks, or replications. Each strain was assigned at random to one plot within each block. The corn was planted in hills 42 inches apart each way with six kernels to the hill and thinned later to three plants. The number of hills per plot and the number of replicated plots varied among the experiments. All the plots within one or more blocks were planted on the same day, and the plants were infested with egg masses on the same dates as described in an earlier paper.[9] An endeavor was made each year to complete the manual infestations before the availability of the tassel buds made them a factor in borer survival. Each plant was marked with a tag showing the date of silking and was later dissected so that the mature or nearly mature borers present could be counted before the migration of some of the full-fed borers away from the plant.

The experiments of 1938 and 1939 are given as examples of the procedure followed in testing large numbers of strains and for analyzing the data from them, the methods here presented being those finally adopted as the most efficient for the purpose. The strains were planted in 2-hill plots of 6 plants each, randomized within each of 6 or 7 replication blocks per planting. In 1938 the hybrids were

[8] PATCH, L. H. SURVIVAL, WEIGHT, AND LOCATION OF EUROPEAN CORN BORER LARVAE FEEDING ON RESISTANT AND SUSCEPTIBLE FIELD CORN. [To be submitted for publication.]

[9] PATCH, L. H., and PEIRCE, L. L. LABORATORY PRODUCTION OF CLUSTLES OF EUROPEAN CORN BORER EGGS FOR USE IN HAND INFESTATION OF CORN. Jour. Econ. Ent. 28: 196-201, illus. 1935.

hand-infested with 6 egg masses per plant, or about 180 eggs, in addition to the natural infestation, which resulted in a mean of 1.6 mature borers per plant on the earlier planting made that year. In 1939 the hybrids and inbreds received 5 and 4 egg masses per plant, respectively, or about 150 and 120 eggs, in addition to the natural infestation, which resulted in a total of 6.1 and 6.8 borers per plant, respectively, from both sources of infestation. The mean number of borers in the different strains of corn varied from these means for 4 reasons: (1) The later silking strains contained fewer borers because of a lower rate of survival in plants in a less advanced stage of development at time of borer hatching, (2) the moths laid more eggs on some strains than on others because some strains were taller than others, (3) the strains differed in their inherent resistance or susceptibility to the borer, and (4) the mean number recorded showed variability because of sampling errors.

With reference to the first reason given, data from the 10 years of study show that the rate of change in the borer population due to differences in the stage of plant development depends on the level of borer population. When the borer population in all the strains tested averaged 1.4 borers per plant, the number of borers in any one strain decreased or increased 0.06 borer from this average for each day later or earlier than the average in silking. The value 0.06 was found to increase by linear regression to 0.27 as the general average increased from 1.4 to 5.5 borers per plant. To allow for the correlation between borers and stage of plant development, the number of borers predicted for any strain was the average number expected for its date of silking calculated on the basis of the regression of the observed numbers of borers on silking dates.

With reference to the second reason, no count was made of the number of eggs laid on the different strains, but the mean height of the strains during the oviposition period was measured. The half of the hybrid strains silking earliest in 1939 averaged 3.4 inches taller at the time of moth flight than the half silking latest. Since plots of tall corn tend to receive more eggs than plots of shorter corn,[10] the earlier silking strains contained more borers because of the larger numbers of naturally laid eggs as well as because of their more mature stage of development. While the regression of the observed numbers of borers on silking dates is not a direct expression of the function of height, any possible effect of the number of eggs laid is excluded from the deviations of the observed numbers of borers from the numbers predicted, owing to the relationship of height with stage of development as measured by silking.

As a group, the hybrids containing less than the number predicted for them in 1939 averaged within one-half inch as tall at the time of moth flight as the hybrids containing more than the predicted number. It is not probable, therefore, that the differences in height of the strains and resulting differences in the numbers of eggs laid were factors entering into the question of inherent resistance or susceptibility of the hybrid strains in 1939. As a final test the deviations of the observed from the predicted numbers of borers were compared with the heights of the strains, resulting in the nonsignificant correlation coefficient (r) of $-0.0874 \pm .08771$.

[10] PATCH, L. H. HEIGHT OF CORN AS A FACTOR IN EGG LAYING BY THE EUROPEAN CORN BORER MOTH IN THE ONE-GENERATION AREA. Jour. Agr. Res. 64 (9): 503-515, illus. 1942.

Substantially the same results and the same conclusions were arrived at with the inbreds tested in 1939. A nonsignificant correlation coefficient (r) of $+0.1072 \pm .09062$ between the deviations of the observed from the predicted numbers of borers and the heights of the strains was obtained.

To determine whether the strains differed among themselves in inherent susceptibility to the borer, the third reason for variance, the results were statistically analyzed with special attention to tests of significance. As a first step in the analysis, the mean number of borers per plant in each plot was transformed to its logarithm. The condition premising such a transformation was the relationship existing between the variance and the mean. Such a relationship would invalidate the F test. The standard deviation among seven plots of six plants each of the hybrids in 1939 was calculated to be 1.90 borers for strains averaging 6.1 borers per plant. The standard deviation increased or decreased $0.314 \pm .0212$ borer for each increase or decrease of 1 borer in the mean. On this basis the hybrids with minimum borer populations in 1939 had $3.2 \pm .99$ borers per plant per plot compared with 9.6 ± 3.00 borers in the strains with the most borers. The standard deviation is seen to be nearly proportional to its mean. By transforming the figures to their logarithms the plot variability of the strains was put on a common basis, making it possible to treat the data from all the strains as one set.[11] Moreover, the relationship between borers and silking date was curvilinear in two experiments. The transformation to logarithms resulted in a linear relationship between the two variates in the different strain groups and permitted the use of the method of covariance with the data.

When the mean square between strains (the variability among strains) was divided by the mean square within strains (the variability from plot to plot within the strains) the ratios obtained for 235 hybrids subject to the first-generation borers on the May 20 planting of 1938, for 62 hybrids on the May 26 planting of 1938, for 128 hybrids on the May 11 planting of 1939, and for 119 inbreds planted May 18, 1939 were 2.42, 2.84, 4.50, and 5.17, respectively. The corresponding F values for odds of 99 to 1 were 1.26, 1.54, 1.37, and 1.39. It is, therefore, concluded that the strains differed among themselves in inherent susceptibility to the borer.

Finally, the difference obtained by subtracting algebraically the predicted number of borers per plant from the observed number in each strain, expressed as a percentage of the predicted number, was desired. Hybrids or inbreds that averaged a relatively large percentage more than the predicted borer population in several tests or comparisons were considered as being borer susceptible, whereas those that averaged a relatively large percentage less than the predicted number of borers were considered as being borer resistant. Strains whose borer populations fluctuated around the predicted populations during the period of testing were considered as intermediate in susceptibility or partially resistant to the corn borer. Since numbers of borers were converted to logarithms, the difference obtained by subtracting the logarithm of the predicted number of borers from the logarithm of the observed number was used to cal-

[11] SNEDECOR, GEORGE W. STATISTICAL METHODS APPLIED TO EXPERIMENTS IN AGRICULTURE AND BIOLOGY. Rev. ed., 388 pp., illus. Ames, Iowa. 1938. (See sect. 10-16.)

culate the desired percentage. The predicted value corresponded to 100 percent. The logarithm of 100 is 2. When the logarithmic deviation is added to or subtracted from 2, depending on the sign before the deviation, the antilog of the sum or remainder, after conversion, will then be the observed number of borers expressed as a percentage of the predicted number. After subtracting 100 percent from this percentage, the remainder will be the percentage deviation of the observed from the predicted with its appropriate sign.

In this study groups of single- or top-cross hybrids determined to be susceptible to the corn borer because of borer susceptibility transmitted to them by susceptible inbreds averaged 16, 24, 27, and 33 percent more than the predicted borer populations according to the inbreds involved. Groups of single- or top-cross hybrids determined to be partially resistant to the corn borer averaged 12, 6, and 5 percent less and 1 and 3 percent more than the predicted populations according to the inbreds involved. Groups of single- or top-cross hybrids determined to be resistant to the corn borer averaged 36, 34, 25, 14, and 12 percent less than the predicted populations according to the inbreds involved. The criteria upon which the determinations were based differed according to circumstances and the strains of corn available in the tests, and are given for each inbred.

BORER POPULATIONS IN OPEN-POLLINATED VARIETIES

The experiments of 6 seasons included 15 tests of 10 open-pollinated varieties. The average performance on all the plantings made in one season is considered as a single test. The borer populations in these tests ranged from 7 to 98 percent more, and averaged 25 percent more, than the predicted populations. A group of single-cross and top-cross hybrids discussed later, having the same inbred for one of their parents, averaged a maximum of 27 percent more than the predicted number of borers. The open-pollinated varieties as a group were therefore nearly as susceptible to the corn borer as any strains of corn studied. The data are presented in table 1.

TABLE 1.—*Deviation of the observed from the predicted population of the European corn borer in open-pollinated varieties of field corn, Sandusky and Toledo, Ohio, in certain years from 1930 to 1938*

Variety	Deviation, by years					
	1930	1931	1933	1934	1935	1938
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Longfellow Flint	+26					
Reb Cob ensilage	+35					
Golden King		+15				
Krug		+9		+9		+7
Doubet			+17			
Canterbury Yellow Dent			+19			
Smoky Dent			+14			
Olarnge			+17	+10	+98	
Johnson County White			+19			
Woodburn				+24	+58	

RESISTANCE TO BORER SURVIVAL CONTRIBUTED BY INBREDS ILL.R4, ILL.L, AND ILL.HY RELATIVE TO INBRED ILL.A

Tests of inbreds Ill.R4, Ill.A, and Ill.Hy or Ill.L, each crossed with the same inbred or variety, were made in single-cross or top-cross combination during a period of 6 years as shown in the first two sections of table 2. Other tests of inbreds Ill.R4 and Ill.A, each crossed with the same inbred, were made also. The resulting hybrids made possible a comparison of the relative resistance against corn borer survival contributed by these inbreds. In addition, tests of inbreds as such were made of inbreds Ill.R4, Ill.Hy, and Ill.A in each of the years 1935, 1936, and 1939. The results from the tests of single or top crosses are given in table 2, and the data from tests of the inbreds are presented in table 3.

TABLE 2.—*Deviation of the observed from the predicted population of the European corn borer in single-cross or top-cross hybrid strains of field corn produced by crossing an inbred or variety with each of 8 inbreds to be contrasted for their resistance to borer survival, Sandusky and Toledo, Ohio, in certain years from 1930 to 1938*

Year	Inbred or variety crossed with inbreds in the boxes on right to produce single-cross or top-cross plants	Deviation of the observed from the predicted number of borers per plant of the inbreds compared—		
		Ill.R4	Ill.Hy	Ill.A
		Percent	*Percent*	*Percent*
1930	Ill.L	−46	−15	+38
1931	Do	−30	−14	+30
1931	Ind.TR	−7	−7	+16
1934	Variety Krug	−12	+16	+9
1937	Ind.TR	+29	+26	+55
1938	Variety Krug	−31	0	−9
	Average	−16	+1	+23
		Ill.R4	Ill.L	Ill.A
1930	Ill.B	−32	−22	+35
1931	Do	−24	+14	+29
1931	Ill.Hy	−46	−14	+39
1932	Do	−35	−2	+45
1932	Ind.TR	−42	−7	+23
	Average	−36	−6	+34
		Ill.R4		Ill.A
1931	Ill.A48	−48	.....	+24
1932	Ill.L	−19	.....	+38
1933	Ill.Hy	−22	.....	+9
1933	Ind.TR	−14	.....	+20
1937	Ill.Hy	−13	.....	+20
	Average of all comparisons	−25	.....	+27

As an average of 6 comparisons, table 2 shows that 16 percent less than the predicted number of borers were found in Ill. R4 crosses, 1 percent more in Ill.Hy crosses, and 23 percent more in Ill.A crosses. As an average of 5 comparisons, 36 percent less than the predicted number of borers were found in Ill.R4 crosses, 6 percent less in Ill.L crosses, and 34 percent more in Ill.A crosses. The data in table 2 offer 16 comparisons between Ill.R4 crosses and Ill.A crosses. The Ill.R4 crosses averaged 25 percent less and the Ill.A crosses 27 percent more than the predicted numbers of borers.

TABLE 3.—*Deviation of the observed from the predicted population of the European corn borer in inbred lines of field corn, Toledo, Ohio, 1935–39*

Inbred line	Deviation of the observed number of borers per plant from the predicted number in test year—				
	1935	1936	1937	1938	1939
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
U.S.187-2			+86	+67	+34
Ill. A	+6	+2			+48
Ill. 90	+33	+1			+18
Ind. WF9	−3				+32
Ill. Hy	+9	0	+13		−6
Ind. TR	+11		−22		+5
U. S. 540	+9		−11		−25
Wis. CC1					−7
Ill. A48	+11	−4			
Ia. I205	−28	−20	−41		+4
Ia. L317	−54	−27	+12		−13
Ill. R4	−31	−47	−42	−44	−7
Mich 106	−33	−44	+7		−44
Mich. 77	−40	−76	−36		
Wis. CC5					−44

Inbreds Ill.R4, Ill.Hy, and Ill.A were in the tests of inbreds in 1935, 1936, and 1939 (table 3). They averaged 28 percent less, 1 percent more, and 19 percent more, respectively, than the predicted numbers of borers. As an average of all 5 tests given inbred Ill.R4 and of 4 tests given inbred Ill.Hy, 34 percent less and 4 percent more, respectively, than the predicted numbers of borers were found in the two lines.

The hybrid and inbred tests show rather definitely that inbred Ill.R4 resisted the survival of the corn borer as an inbred, and also transmitted its resistance character to the single and top crosses. Inbred Ill.A, on the other hand, showed a lack of resistance as an inbred relative to inbreds Ill.R4 and Ill.Hy, and the single-cross hybrids containing it in their pedigrees showed as much susceptibility as any group tested. Inbreds Ill.Hy and Ill.L tested in single-cross combination were found to be partially borer resistant relative to inbred Ill.A.

BORER RESISTANCE CONTRIBUTED BY INBREDS IA.L317, WIS.CC5, MICH.77, AND MICH.106

The consistency with which the use of inbred Ill.A in single-cross hybrids resulted in considerable borer susceptibility when crossed with certain inbreds and also the consistency with which inbred Ill.R4 contributed considerable borer resistance to hybrids when crossed with the same inbreds led to the use of these two inbreds, whenever possible, to evaluate the borer resistance or susceptibility contributed by other inbreds. A point that was not fully appreciated at first was the desirability of using for the common parent in the single crosses an inbred that was partially resistant to the borer. As is shown from the data in table 2 and from data presented later in this paper, four of the five inbreds listed in the second column of table 2 are partially borer resistant. Inbred Ill.B, the other inbred, is probably also partially borer resistant, but data are not available to prove this point.

Inbred Ia.L317 was compared in top-cross combination with inbreds Ill.R4 and Ill.A in 1934, each inbred being crossed with the

Krug variety. In 1939 each inbred was crossed with each of six other inbreds. As an average of the seven comparisons the Ill.R4 hybrids contained 3 percent less, the Ia.L317 hybrids 12 percent less, and the Ill.A hybrids 37 percent more than the predicted numbers of borers.

In four tests given inbred Ia.L317 as such (table 3) the observed numbers averaged 21 percent less than the predicted numbers of borers.

The inbred and hybrid tests show that inbred Ia.L317 was borer resistant as an inbred and transmitted factors for borer resistance to the single and top crosses.

A group of 4 inbreds, tested as such with 20 other inbreds in 1938, averaged 26 percent less than the predicted numbers of borers. The 4 inbreds are second-cycle lines recovered from a single-cross hybrid. They were produced by backcrossing once or twice followed by 5 to 7 generations of inbreeding. In backcrossing onto one of the parents in the single cross the recurrent line was inbred Ia.Ldg, a sister strain of Ia.L317 separated at the fourth generation of inbreeding.

Next to the above group of four inbreds in resistance to the borer in 1938 were two inbreds recovered from another single-cross hybrid. They were produced by using inbred OSF as the recurrent line in the process of backcrossing.

Seed of seven single crosses involving recovered inbred Ia.Ldg and three crosses involving recovered inbred OSF was available in 1939. Of the seven hybrids involving inbred Ia.Ldg, all but one contained less than the predicted numbers of borers, five averaging 27 percent less than the predicted numbers. The three hybrids involving inbred OSF averaged 6 percent more than the predicted numbers. It appears that the results from the hybrids involving inbred Ia.Ldg give additional evidence that inbred Ia.L317 and sister lines transmit borer resistance to single-cross hybrids.

The first test given inbred Wis. CC5 was in top-cross combination in 1938. Wis.CC5 × Waugh variety averaged 46 percent less than the predicted numbers of borers on the two plantings made that year, compared with 51 percent less and 38 percent more, respectively, than the predicted numbers in borer-resistant hybrid Ill. R4 × Ill. Hy and borer-susceptible Ill.A × Ind.TR. Wis.CC5 was compared in single-cross combination in 1939 with inbreds Wis.CC1 and an Ohio segregate out of 56 × 616B, both of which indicated borer resistance in the 1938 experiment. Four comparisons were made with Ohio inbreds 02, 28, 33, and 40B as the common parents (table 4). The Wis.CC5 hybrids averaged 31 percent less than the predicted numbers of borers compared with 12 percent less than the predicted numbers in the Wis.CC1 hybrids and 5 percent less in the hybrids having the Ohio segregate in common.

Tested in the 1939 planting of inbreds, the number of borers in Wis.CC5 was 44 percent less than the predicted number.

The inbred and hybrid tests indicate that inbred Wis. CC5 was borer resistant as an inbred and transmitted factors for borer resistance to the single crosses.

In three tests given inbred Mich.77 as such (table 3) the observed numbers averaged 51 percent less than the predicted numbers of borers in the same experiments in which inbreds Ill.R4 and Ia.L317 averaged 40 and 23 percent less, respectively.

TABLE 4.—*Deviation of the observed from the predicted population of the European corn borer in single-cross hybrid field corn in a comparison of 3 inbred lines crossed with each of 4 early inbred lines to produce the single crosses, Toledo, Ohio, 1939*

Early inbred lines below crossed with inbreds shown in boxes on right	Deviation of population of the inbreds compared—			
	Wis. CC6	Wis. CC1	Ohio segregate out of 56 × 616 B	Mean
	Percent	*Percent*	*Percent*	*Percent*
Ohio 02	−40	−35	−3	−26
Ohio 28	−29	−5	−8	−14
Ohio 33	−28	0	−12	−13
Ohio 40B	−27	−6	+4	−10
Mean	−31	−12	−5	

Inbred Mich.77 was compared with inbreds Ill.R4 and Ia.L317 in single-cross combination in 1939. Three comparisons were made using inbreds Ia. 1224, Ia. L289, and Ia.MC401 as the common parents, respectively. The data presented in table 5 indicate that Mich.77 contributed borer resistance to the hybrids.

TABLE 5.—*Deviation of the observed from the predicted population of the European corn borer in single-cross hybrid field corn showing the comparisons with respect to borer resistance among 5 inbred lines, each of which was crossed with inbreds Ia. 1224, Ia.L289, and Ia.MC401 as common parents, Toledo, Ohio, 1939*

Inbreds compared	Deviation in population in inbreds below crossed with inbreds in first column to produce single-cross hybrids			
	Ia.1224	Ia.L289	Ia.MC401	Mean
	Percent	*Percent*	*Percent*	*Percent*
Mich.77	−33	−15	−28	−35
Mich.106	0	+4	−39	−12
Ill.R4	+4	−13	−29	−13
Ia.L317	−15	−19	−2	−12
Ia.1205	+29	+7	+1	+12
Mean	−3	−13	−19	

In those tests (1935, 1936, and 1937) of inbreds as such in which inbreds Mich.77, Ill.R4, and Ia.L317 averaged 51, 40, and 23 percent less than the predicted numbers of borers, inbred Mich.106 averaged 23 percent less than the predicted number (table 3).

In the same manner in which Mich.77 was contrasted with inbreds Ill.R4 and Ia.L317 in table 5, Mich.106 averaged 12 percent less than the predicted numbers of borers when tested in single-cross combination, compared with 13 and 12 percent less than the predicted numbers in the Ill.R4 and Ia.L317 hybrids.

Since the inbred and hybrid tests of Mich.106 are both comparable with the results from inbreds Ill.R4 and Ia.L317, it appears that inbred Mich.106 may be considered as transmitting factors for borer resistance to single-cross combinations.

Taken as a class, inbreds Ill.R4, Ia.L317, Wis.CC5, Mich.77, and Mich.106 averaged 32 percent less than the predicted number of borers and in hybrid combinations were classed as transmitting borer resistance.

PARTIAL RESISTANCE CONTRIBUTED BY INBREDS IND.TR, U.S.540, IA.1205, WIS.CC1, AND ILL.A48

In addition to inbreds Ill.Hy and Ill.L, previously discussed, five other inbreds, it is believed, may be ranked as definitely transmitting factors for partial resistance to the borer in hybrid combinations.

Inbred Ind.TR may be compared in hybrid combination with inbreds Ill.R4 and Ill.A. In 1932, 1934, and 1937 each of these inbreds was crossed with inbred Ill.L, the Krug variety, and inbred Ill.Hy, respectively. As an average of the three tests, the Ill.R4 hybrids contained 15 percent less, the Ind.TR hybrids 7 percent more, and the Ill.A hybrids 25 percent more than the predicted numbers of borers. Inbred Ind.TR was compared in single-cross combination with inbreds Ill.A and Ia.L317 when inbreds Ill.Hy and Ill.R4 were the parents common to the crosses in 1939. Table 6 shows that the Ia.L317 hybrids averaged 31 percent less, the Ind.TR hybrids 4 percent less, and the Ill.A hybrids 41 percent more than the predicted numbers of borers.

TABLE 6.—*Deviation of the observed from the predicted population of the European corn borer in single-cross hybrid field corn showing the comparisons with respect to borer resistance among 8 inbred lines each of which was crossed with inbreds Ill.Hy and Ill.R4 as the common parents, Toledo, Ohio, 1939*

Inbreds compared	Deviation in population in inbreds below crossed with inbreds in the first column to produce single-cross hybrids			Inbreds compared	Deviation in population in inbreds below crossed with inbreds in the first column to produce single-cross hybrids		
	Ill.Hy	Ill.R4	Mean		Ill.Hy	Ill.R4	Mean
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Ill.A	+42	+39	+41	U.S.540	+21	−26	−1
Ill.90	+42	+22	+32	Ind.TR	−6	−2	−4
U.S.187.2	+36	+11	+24	Ia.1205	−5	−5	−5
Ind.WF9	+21	+2	+12	Ia.L317	−27	−35	−31

Three tests given to inbred Ind.TR as such (table 3) showed an average of 2 percent less than the predicted numbers of borers, and these and hybrid tests showed that inbred Ind.TR was partially borer resistant as an inbred and transmitted factors for partial borer resistance to the single and top crosses.

Ind.TR was used during the period of the study in 7 single-cross, top-cross, or 3-way cross hybrids in which known resistant or susceptible inbreds were not involved. Ind.TR was used also in 9 double crosses, 8 of which contained either resistant Ill.R4 or resistant Ia.L317 in their pedigrees, but other inbreds known to be resistant or susceptible were not involved. As an average of 21 tests, the results of which are shown in table 7, 7 percent more than the predicted numbers of borers were found, indicating partial resistance to the corn borer. As data considered later will show, hybrids involving susceptible inbreds Ind.WF9 and Ill.90 were grouped with the same restrictions used in grouping the hybrids involving inbred Ind.TR. These groups contained, respectively, an average of 21 and 23 percent more than the predicted numbers of borers. It appears, therefore, that the partial resistance of the group of hybrids involving inbred Ind.TR was in general due to the absence of susceptible inbreds in the pedigrees and to the partially resistant character of Ind.TR and the more or less resistant character of the other inbreds involved with it.

TABLE 7.—*Deviation of the observed from the predicted population of the European corn borer in certain double-cross hybrid field corns and other hybrids containing inbred Ind.TR in their pedigree. Sandusky and Toledo, Ohio, 1932–37 and 1939*

Pedigree of hybrids	1932	1933	1934	1935	1936	1937	1939
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Ill.L × Ind.TR	−7						
Ind.TR × C2	+5						
Ind.(TR × 66) × Ill.L	+7		+3				
Ind.TR × Ia.(BL345 × BL351)		−1					
Ind.TR × Krug			+3				
Ill.Hy × Ind.TR			−7			+26	−6
Ill.(R4 × Hy) × Ind.(66 × TR)			−4	+20			
Ill.(R4 × K) × Ind.(66 × TR)			−26	+09			
Ill.(R4 × Hy) × (Ia.PR × Ind.TR)				+5			
(Ill.R4 × Ohio 20) × (Ohio 51 × Ind.TR)				+32			
(Ill.Hy × U.S.540) × (Ia.L317 × Ind.TR)				−1			
(Ill.R4 × Ind.TR) × (U.S.4-8 × Ia.Ldg)					−4		
Ind.TR × B2					−15		
(Ind.TR × Ia.L317) × (Ia.I198 × Ill.5120)					+15		
(Ind.TR × Ia.L317) × Ia.(I198 × PR)					+7		
Ind.(TR × 66) × Ind.(461 × V.P.)					−11		

Inbreds U.S.540 and I.T.E.701 are sister lines and no differences in their reaction to the survival of the corn borer have been noted. The designation U.S.540 used in this bulletin refers to either one of the inbreds, U.S.540 being used in some tests and I.T.E.701 in others.

U.S.540 was compared in top-cross combination with inbreds Ill.R4 and Ill.A in 1934 and 1938, each inbred being crossed with the Krug variety. It was compared in single-cross combination with inbreds Ill.A and Ia.L317 when inbreds Ill.Hy and Ill.R4 were the parents common to the crosses in 1939 (table 6). As an average of the four comparisons, the Ill.R4 or Ia.L317 hybrids contained 26 percent less, The U.S.540 hybrids 4 percent more, and the Ill.A hybrids 20 percent more than the predicted numbers of borers.

In three tests given inbred U.S.540 as such (table 3) the observed numbers averaged 9 percent less than the predicted numbers of borers.

The inbred and hybrid tests show that inbred U.S.540 was partially borer resistant as an inbred and transmitted factors for partial borer resistance to the single and top crosses.

Inbred Ia.I205 was tested in four plantings of inbreds made since 1934 and in single-cross combination in 1939. In the inbred tests inbred Ia.I205 averaged 24 percent less than the predicted numbers of borers (table 3). Ia.I205 was compared in 1939 with inbreds Ill.A and Ia.L317 when inbreds Ill.Hy and Ill.R4 were the parents common to the single crosses (table 6). As an average of the two comparisons, the Ia.L317 hybrids contained 31 percent less, the Ia.I205 hybrids 5 percent less, and the Ill.A hybrids 41 percent more than the predicted numbers of borers.

The inbred and hybrid tests indicate that inbred Ia.I205 was at least partially borer resistant as an inbred and transmitted factors for partial borer resistance to the single crosses in which it was tested.

The first test given inbred Wis.CC1 was in top-cross combination in 1938. Wis.CC1 × the Waugh variety averaged 52 percent less than the predicted numbers of borers in the two plantings made that year, compared with 51 percent less and 38 percent more, respectively, than the predicted numbers in borer-resistant hybrid Ill.R4 × Ill.Hy and borer-susceptible Ill.A × Ind.TR. Wis.CC1 was compared in single-cross combination in 1939 with inbreds Wis.CC5 and an Ohio segregate

out of 56 × 616B. Four comparisons were made with Ohio inbreds 02, 28, 33, and 40B as the parents common to the crosses (table 4). The Wis.CC1 hybrids averaged 12 percent less than the predicted numbers of borers compared with 31 percent less and 5 percent less, respectively, than the predicted numbers in the Wis.CC5 hybrids and the hybrids having the Ohio segregate in common.

Tested in the 1939 planting of inbreds, the number of borers in Wis.CC1 was 7 percent less than the predicted number.

The inbred and hybrid tests indicate that Wis.CC1 was partially borer resistant as an inbred and transmitted factors for partial borer resistance to the single crosses.

Data are not available to compare Ill.A48 in hybrid combination with inbreds Ill.R4 and Ill.A. The tests given Ill.A48 as an inbred averaged 3.5 percent more than the predicted numbers of borers (table 3), indicating a possibility that Ill.A48 is at least partially borer resistant.

Tests of single crosses and double crosses made in 1931, 1935, and 1936 also indicate that Ill.A48 is at least partially borer resistant. Ill.A48 was used in six single-cross hybrids in which known resistant or susceptible inbreds were not involved. Ill.A48 was used also in two double crosses which contained either resistant Ill.R4 or resistant Ia.L317 in their pedigrees, but other inbreds known to be resistant or susceptible were not involved. Eight tests given to these eight hybrids showed an average of 20 percent less than the predicted numbers of borers. The data are presented in table 8.

TABLE 8.—*Deviation of the observed from the predicted population of the European corn borer in double-cross hybrid field corn and other hybrids containing inbred Ill.A48 in their pedigree, Sandusky and Toledo, Ohio, 1931, 1935, and 1936*

Pedigree of hybrids	Year		
	1931	1935	1936
	Percent	*Percent*	*Percent*
Ill.A48 × A956	−17		
(Ill.Hy × U.S.540) × (Ia.L317 × Ill.A48)		−16	
U.S.540 × Ill.A48		−45	
Ill.A48 × Kan.K.Y.S.		+20	
Ill.A48 × St.22		−37	
Ill.A48 × U.S.617		−19	
Ill.A48 × 5120		−15	
Ill.(R4 × Hy) × (Ill.A48 × U.S.540)			−42

Taken as a class, inbreds Ill.Hy, Ind.TR, U.S.540, Ia.I205, Wis.CC1, Ill.A48, and Ill.L showed an average of 8 percent less in the observed number of borers as compared with the predicted number and were considered as transmitting partial resistance to hybrids into which they entered.

BORER SUSCEPTIBILITY CONTRIBUTED BY INBREDS IND.WF9, ILL.90, AND U.S.187–2

In addition to inbred Ill.A it is believed that data from three other inbreds are extensive enough to rank them as definitely transmitting qualities for borer suceptibility to hybrid combinations.

Inbred Ind.WF9 was compared in single-cross and top-cross combinations with inbreds Ill.R4 and Ill.A. Each of these three inbreds

was crossed with the Krug variety in 1934, with inbred Ill.Hy in 1937, and with the Krug variety again in 1938. Ind.WF9 was compared with inbreds Ia.L317 and Ill.A in two single-cross comparisons in 1939 (table 6). As an average of the five comparisons, the Ill.R4 hybrids and the Ia.L317 hybrids contained 24 percent less, the Ind.-WF9 hybrids 16 percent more, and the Ill.A hybrids 22 percent more than the predicted numbers of borers.

In two tests given to Ind.WF9 as an inbred (table 3) the observed numbers averaged 15 percent more than the predicted numbers of borers.

The inbred and hybrid tests show that Ind.WF9 was susceptible to the borer as an inbred and transmitted this quality to the single and top crosses.

Ind.WF9 was used during the period of the study in a top-cross hybrid and in a single-cross hybrid not involving a resistant or another susceptible inbred. Ind.WF9 was used also in 11 double crosses, 4 of which contained either resistant Ill.R4 or resistant Ia.L317 in their pedigrees, but other inbreds known to be resistant or susceptible were not involved. As an average of 16 tests, the results of which are shown in table 9, 21 percent more than the predicted numbers of borers was found, indicating susceptibility to the corn borer, as a result, probably, of the susceptible quality of inbred Ind.WF9.

TABLE 9.—*Deviation of the observed from the predicted population of the European corn borer in double-cross hybrid field corn and other hybrids containing inbred Ind.WF9 in their pedigree, Toledo, Ohio, 1934–39*

Pedigree of hybrids	Year					
	1934	1935	1936	1937	1938	1939
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
(Ill.Hy × Ind.WF9) × Ind. (66 × TR)	−13	+82				
Ind.WF9 × Ill.Krug	+21				−24	
Ind.(WF9 × TR) × Ill.(R4 × Hy)		+7				
(Ind.WF9 × Ill.My) × Ill.(R4 × Hy)			+58			
(Ind.WF9 × Ill.My) × (Ind.TR × Ia.L317)			+66			
(Ind.WF9 × Ia.PR) × (Ind.TR × Ill.R4)			+29			
Ind. (WF9 × TR) × (Ind.JSL5 × U.S.540)			+5			
Ind.(WF9 × TR) × Ind.(B2 × 38-10)			−2			
(Ind.51 × Ill.Hy) × Ind.(WF9 × TR)			+23			
(Ind.B2 × Ia.PR) × Ind.(WF9 × 66)			+2			
Ind.(B2 × WF9) × (Ind.JSL5 × U.S.540)			−11			
(Ind.WF9 × Ill.Hy) × (Ind.TR92 × U.S.540)			+5			
Ill.Hy × Ind.WF9				+58		+21

Inbred Ill.90 was compared in top-cross combination with inbreds Ill.R4 and Ill.A in 1934, and with inbreds Ia.L317 and Ill.A in two single-cross comparisons made in the 1939 experiment (table 6). As an average of the three comparisons the Ill.R4 hybrids and the Ia.L317 hybrids contained 25 percent less, the inbred Ill.90 hybrids 24 percent more, and the Ill.A hybrids 30 percent more than the predicted numbers of borers, respectively.

In three tests given Ill.90 as an inbred the observed numbers averaged 17 percent more than the predicted numbers of borers (table 3).

The inbred and hybrid tests show that inbred Ill.90 was susceptible to the borer as an inbred and transmitted this quality to the single and top crosses.

Ill.90 was used during the period of the study in four single-cross or top-cross hybrids in which known resistant or other susceptible inbreds were not involved. Ill.90 was used also in three double crosses, two of which contained either resistant Ill.R4 or resistant Ia.L317 in their pedigrees, but other inbreds known to be resistant or susceptible were not involved. As an average of eight tests, the results of which are shown in table 10, 23 percent more than the predicted numbers of borers was found, indicating susceptibility to the corn borer, as a result, probably, of the susceptible quality of inbred Ill.90.

TABLE 10.—*Deviation of the observed from the predicted population of the European corn borer in double-cross hybrid field corn and other hybrids containing inbred Ill.90 in their pedigree, Sandusky and Toledo, Ohio, for 1931, 1934, 1936, and 1939*

Pedigree of hybrids	Year			
	1931	1934	1936	1939
	Percent	*Percent*	*Percent*	*Percent*
Ill.90 × Lan	+10			
Ill.90 × R313	+43			
Ill.90 × Krug		+7	+26	
Ill.(90 × Hy) × (Ind.TR × Ia.L317)			+15	
(Ind.NI-1 × Ill.90) × Ind.(TR × B2)			+26	
(Ind.T92 × Ill.90) × (Ill. R4 × Ia.P16)			−13	
Ill.90 × Hy				+42

Inbred U.S.187–2 was compared in top-cross combination with inbreds Ill.R4 and Ill.A in 1938. Top cross Ill.R4×Krug, U.S.187–2×Krug, and Ill.A×Krug contained 31 percent less, 95 percent more, and 9 percent less than the predicted numbers of borers, respectively.

Two segregates out of U.S.187–2×LE23 crossed with the Krug variety resulted in two top crosses averaging 20 percent more than the predicted numbers of borers on two plantings in 1938. Five segregates out of U.S.187–2×LE23 crossed with the Krug variety resulted in five top crosses averaging 41 percent more than the predicted numbers of borers on the first planting in 1938.

Inbred U.S.187–2 was compared in single-cross combination with Ill.A and Ia.L317 in 1939 when inbreds Ill.Hy and Ill.R4 were the parents common to the crosses (table 6). The Ia.L317 hybrids averaged 31 percent less, the U.S.187–2 hybrids 24 percent more, and the Ill.A hybrids 41 percent more than the predicted numbers of borers.

In 1939 single-cross U.S.187–2×Ia.1205 and U.S.187–2×Ohio07 had 45 and 12 percent, respectively, more than the predicted numbers of borers. A segregate out of hybrid U.S.187–2×LE23 crossed with inbred Ill.Hy resulted in a single cross with 61 percent more than the predicted number of borers. Two segregates out of U.S.187–2×LE23 crossed with inbred Ohio07 resulted in two single crosses averaging 19 percent more than the predicted numbers of borers, and two segregates out of U.S.187–2×LE23 crossed with inbred Ohio 51A resulted in two single crosses averaging 12 percent more than the predicted numbers of borers.

In three tests given U.S.187–2 as an inbred (table 3) the observed numbers averaged 62 percent more than the predicted numbers of borers.

The inbred and hybrid tests show that inbred U.S.187–2 was susceptible to the borers as an inbred and transmitted this quality to the single crosses and top crosses.

The above inbreds, together with Ill.A, had in tests of inbreds an average of 33 percent more borers than the number predicted, and these were found to transmit their susceptibility to borer survival to hybrid combinations.

RELATIVE BORER RESISTANCE OF SISTER STRAINS

Among the 233 top crosses tested in 1938 there were 39 pairs of hybrids involving sister inbred lines. The "sisters" were separated at the second, third, fourth, or fifth generation of inbreeding. Differences occur between sister strains due to errors in sampling, but if the differences actually found are not much larger than the differences found between the members of pairs of similar-sized samples of the same strains, inherent differences between sisters in borer resistance would not be indicated, and there would be no advantage in testing sister strains individually in future experiments. On the other hand, if the differences between sisters are found to be nearly as large as those between the members of random pairs of unrelated strains and of unknown reaction to the borer, continued segregation for borer resistance among the sisters would be indicated.

With this thought in mind the relative borer resistance of sister strains was studied. The difference between the observed borer populations of sisters was determined for each pair of sisters on the first planting made in 1938. For example, if one sister contained 8 percent more than the number of borers predicted for it and the other sister 6 percent less than the predicted number, the difference was taken as 14 percent. The mean difference between the 39 pairs of sisters was found to be 25.6 ± 3.93 percent.

For studying the difference between samples of the same strains, the data from 62 strains tested with first-generation borers on both plantings of 1938 were available. The 2 plantings were so similar in level of borers and stage of plant development that they could be used safely for this purpose. Also, the strains appeared to react similarly to the borer on both plantings, as is shown by the highly significant correlation coefficient of $+0.5346$ between the deviations of the observed from the predicted borer population on 1 planting and the deviations on the other planting. With 1 sample of each strain coming from the first planting and the other sample coming from the second planting, the mean difference between the 2 samples of the 62 pairs was found to be 23.9 ± 2.55 percent.

For studying the difference between samples from unrelated strains, data from 97 pairs of strains, drawn at random from the first planting, were utilized, the difference being calculated between each odd number drawn and the succeeding even number. As an average of the 97 pairs of strains, the difference was found to be 32.8 ± 2.91 percent.

Although the mean difference between sisters of pairs of sisters may not be considered as significantly different from either the mean

difference between samples of the same strains or the mean difference between members of pairs of unrelated strains, the result from sisters is much closer to the result from samples of the same strains. The difference in the latter comparison is 1.7 percent compared with 7.2 percent in the other. It appears that sisters of pairs of sisters did not differ much in inherent qualities for borer resistance in this experiment and that there would be little advantage in testing sister strains in future experiments.

DISCUSSION

In the preceding presentation of data whenever possible the borer resistance or borer susceptibility contributed to single-cross or top-cross hybrids by an inbred was tested in comparison with the known borer resistance of inbred Ill.R4 or Ia.L317 and the known borer susceptibility of inbred Ill.A. To make the test, inbreds Ill.R4 or Ia.L317 and Ill.A and the inbred under test were all crossed with another inbred common to the crosses.

A group of inbreds was tested as single crosses in 14 comparisons with Ill.R4 or Ia.L317 hybrids. The hybrids involving the inbreds under test averaged 20 percent less than the predicted numbers of borers, as compared with 11 percent less than the predicted in the Ill.R4 or Ia.L317 hybrids. The inbreds under test were classed as borer resistant.

The borer-resistant inbreds when tested in plantings of inbreds had an average of 32 percent less than the predicted numbers of borers in 11 tests. The inbred and hybrid tests showed that the inbreds were not only materially borer-resistant as inbreds but that they transmitted factors for borer resistance to the hybrid combinations.

Another group of inbreds when tested as single crosses or top crosses in 22 comparisons with inbreds Ill.R4 or Ia.L317 and inbred Ill.A resulted in an average borer population equal to the mean number of borers predicted. The Ill.R4 or Ia.L317 hybrids averaged 25 percent less and the Ill.A hybrids contained 28 percent more than the predicted numbers of borers. The inbreds under test were classed as partially resistant.

These partially resistant inbreds when tested in plantings of inbreds averaged 8 percent less than the predicted numbers of borers in 14 tests. The inbred and hybrid tests showed that the inbreds were not only partially borer resistant as inbreds but that they transmitted factors for partial resistance to the hybrid combinations.

Eleven comparisons were made of inbreds that resulted in borer populations averaging 27 percent more than the mean number of borers predicted on the basis of the regression of borers on silking date. The Ill.R4 or Ia.L317 hybrids averaged 26 percent less, and the Ill.A hybrids contained 25 percent more than the predicted numbers of borers. The inbreds under test were classed as borer susceptible.

In addition, these susceptible inbreds were tested in plantings of inbreds. They had on an average 33 percent more than the predicted numbers of borers on the basis of 8 tests. The hybrid and inbred tests showed that the reaction of the inbreds to borer survival in single-cross or top-cross combinations was about the same as when tested as inbreds.

Anticipating the final ranking given to the inbreds, 36 single crosses involving different combinations of resistant, partially resistant, and susceptible inbreds were tested in the 1939 experiment. Four single-cross hybrids each involving 2 resistant inbreds averaged 39 percent less than the predicted numbers of borers; 10 hybrids involving 1 resistant inbred and 1 partially resistant inbred averaged 15 percent less than the predicted number; 4 hybrids involving 2 partially resistant inbreds averaged 2 percent more than the predicted number; 8 hybrids involving 1 resistant and 1 susceptible inbred averaged 8 percent more than the predicted number; 7 hybrids involving 1 partially resistant and 1 susceptible inbred averaged 32 percent more than the predicted; and 3 hybrids involving 2 susceptible inbreds averaged 58 percent more than the predicted numbers of borers. The detailed data are presented in table 11.

TABLE 11.—*Deviation of the observed from the predicted population of the European corn borer in single-cross hybrid field corn whose pedigrees consisted of various combinations of inbred lines shown to have transmitted borer resistance, partial resistance, or susceptibility to hybrid combinations, Toledo, Ohio, 1939*

Group 1, 2 resistant inbred lines		Group 2, 1 resistant and 1 partially resistant inbred line	
Pedigree	Deviation of observed from predicted borer populations	Pedigree	Deviation of observed from predicted borer populations
	Percent		*Percent*
Ill.R4 × Ia.L317	−35	PTE701 × Mich.77	−22
Ill.R4 × Mich.77	−58	PTE701 × Mich.106	−24
Ill.R4 × Mich.106	−36	Ill.R4 × Hy	−5
Mich.77 × 106	−25	Ia.L317 × Ill.Hy	−27
		Ill.R4 × PTE701	−26
		Ill.R4 × Ind.PR	−2
		Ill.R4 × IA.1205	−5
		Ia.L317 × PTE701	−28
		Ia.L317 × Ind.PR	−3
		Ia.L317 × 1205	−12
Mean	−39	Mean	−15

Group 3, 2 partially resistant inbred lines		Group 4, 1 resistant and 1 susceptible inbred line	
Pedigree	Deviation of observed from predicted borer populations	Pedigree	Deviation of observed from predicted borer populations
	Percent		*Percent*
Ia.1205 × PTE701	−6	Ill.A × R4	+39
Ill.Hy × PTE701	+24	Ill.A × Ia. L317	+7
Ill.Hy × Ind.PR	−6	Ill.R4 × 90	+22
Ill.Hy × Ia.1205	−5	Ill.R4 × U.S.187-2	+11
		Ill.R4 × Ind.WF9	+2
		Ia.L317 × Ill.90	−11
		Ia.L317 × U.S.187-2	−15
		Ia L317 × Ind.WF9	+6
Mean	+2	Mean	+8

TABLE 11.—*Deviation of the observed from the predicted population of the European corn borer in single-cross hybrid field corn whose pedigrees consisted of various combinations of inbred lines shown to have transmitted borer resistance, partial resistance, or susceptibility to hybrid combinations, Toledo, Ohio. 1939*—Contd.

Group 5, 1 partially resistant and 1 susceptible inbred line		Group 6, 2 susceptible inbred lines	
Pedigree	Deviation of observed from predicted borer populations	Pedigree	Deviation of observed from predicted borer populations
	Percent		*Percent*
Ill.A × Ind.TR	+32	Ill.A × 99	+43
Ill.A × ITE701	+42	Ill.A × U.S.187-2	+74
Ill.A × Ia.1205	+12	Ill.A × Ind.WF9	+57
Ill.A × Hy	+42		
Ill.Hy × 99	+42		
Ill.Hy × U.S.187-2	+30		
Ill.Hy × Ind.WF9	+21		
Mean	+32	Mean	+58

The double-cross hybrids tested during 6 seasons were also grouped according to different combinations of the inbreds. Hybrid Ill. (R4 × Hy) × (Ill.R4 × Ia.L317), involving 3 resistant and 1 partially resistant parent, averaged 42 percent less than the predicted numbers of borers in 2 tests; 13 tests of hybrids with 2 resistant and 2 partially resistant or 1 resistant and 3 partially resistant inbreds in their pedigrees gave an average of 19 percent less than the predicted; 7 tests of hybrids with 2 resistant, 1 partially resistant, and 1 susceptible inbred in their pedigrees gave an average of 4 percent more than the predicted; and 14 tests of hybrids with 1 resistant, 2 partially resistant, and 1 susceptible inbred or 1 resistant, 1 partially resistant, and 2 susceptible inbreds in their pedigrees gave an average of 8 percent more than the predicted numbers of borers. While the numbers of tests for some of the groups are small, and data for some of the possible groupings are not available, especially separate groupings involving 2, 3, and 4 susceptible inbreds, nevertheless a trend of decreasing borer resistance with increasing numbers of partially resistant and susceptible inbreds in the pedigrees is suggested. The detailed data are presented in table 12.

It has been shown that the different inbred lines of field corn vary in their inherent resistance to survival of the corn borer, and that the factors responsible for this resistance are transmitted to the hybrids into which these inbreds enter as parents. From present knowledge it appears that resistance is the result of an undetermined number of multiple factors, and that strains showing the greatest degree of resistance contain the largest number of these factors, whether dominant or recessive, and, conversely, the inbreds showing susceptibility or the least degree of resistance to the borer contain the smallest number of these factors, and between these two extremes there is a wide range of inbreds exhibiting various degrees of resistance.

TABLE 12.—*Deviation of the observed from the predicted population of the European corn borer in double-cross hybrid field corn whose pedigrees consisted of various combinations of inbred lines shown to have transmitted borer resistance, partial resistance, or susceptibility to hybrid combinations, Toledo, Ohio, 1933–37 and 1939*

Pedigree of hybrids	Mean of group	1933	1934	1935	1936	1937	1939
3 resistant and 1 partially borer resistant inbred lines	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Ill.(R4 × Hy) × (Ill.R4 × Ia.L317)	−42						
2 resistant and 2 partially borer resistant inbred lines or 1 resistant and 3 partially borer resistant inbred lines				−61		−22	
Ill.(R4 × Hy) × (Ia.L317 × Ind.TR)	−19						
Ill.(R4 × Hy) × (Ia.L317 × U.S.540)				−25	−17	−15	
Ill.(R4 × Hy) × (Ia.L317 × Ill.A48)				−28	−32	+2	−34
(Ill.R4 × U.S.540) × (Ia.L317 × Ind.TR)				−25		+10	
Ill.(R4 × Hy) × (Ill.A48 × U.S.540)				−18			
(Ill.Hy × U.S.540) × (Ill.A48 × Ia.L317)					−42		
(Ill.Hy × U.S.540) × (Ind.TR × Ia.L317)				−16			
2 resistant, 1 partially resistant and 1 susceptible inbred lines				−1			
Ill.(R4 × Hy) × (Ia.L317 × Ill.A)	+4						
Ill.(R4 × Hy) × (Ia.L317 × Ill.90)				−2	+10	−11	
Ill.(R4 × Hy) × (Ia.L317 × Ind.WF9)				−3		+26	
(Ill.R4 × Ind.TR) × (Ia.L317 × Ind.WF9)						−9	
1 resistant, 2 partially resistant and 1 susceptible inbred lines or 1 resistant, 1 partially resistant and 2 susceptible inbred lines					+20		
Ill.(R4 × Hy) × (Ill.A × Ind.TR)	+8						
Ill.(R4 × Hy) × (Ill.A × U.S.540)			−13	+45		+35	
Ill.(R4 × Hy) × Ind.(WF9 × TR)		−6	−16	+14	−22		
Ill.(A × Hy) × (Ia.L317 × Ind.TR)				+7			
(Ill.Hy × Ind.TR) × (Ia.L317 × Ill.90)			−4	+58			
Ill.(R4 × Hy) × (Ill.A × Ind.WF9)					+15		
Ill.(A × Hy) × (Ia.L317 × Ill.90)			0		+7		
					−9		

SUMMARY

The problem of the control of the European corn borer through the use of borer-resistant strains of corn was investigated by the authors from 1930 to 1939.

From 24 to 36 strains were tested each year in the earlier years, each strain being tested at several levels of borer population. Certain hybrids showed a decided resistance to borer survival, whereas others exhibited a marked susceptibility to the borer. These were later used as standards for comparison. Over 200 top-cross strains were tested in 1938 and more than 100 single and top crosses in 1939.

The test plots contained 6 plants each which were manually infested with from 120 to 180 eggs per plant. The numbers of eggs placed on the plants by hand were far in excess of any possible differences between the strains in the numbers of eggs laid by free moths, and hence it is believed that a reliable comparison among the strains of the number of borers surviving was assured.

The inbreds under test were compared with the inbreds of known borer resistance and susceptibility after allowing for the regression of the number of borers per plant on stage of plant development as measured by silking date. The number of borers predicted for any strain was the average number expected for its date of silking calculated on the basis of the regression of the observed number of borers on silking dates.

Ten open-pollinated varieties were tested during six seasons with borer populations ranging from 7 to 98 percent, and averaging 25 percent, more than the predicted number.

Three of the inbred strains were pronounced enough in their influence in crosses to serve as examples of three classes—Ill.R4 as an outstanding resistant inbred, Ill.Hy as a partially resistant, and Ill.A as a decidedly susceptible inbred.

Inbreds Ill.R4, Ia.L317, Wis.CC5, Mich.77, and Mich. 106 averaged 32 percent less than the predicted numbers of borers, and on the basis of tests in hybrid combinations were classed as transmitting borer resistance to the hybrids.

Inbreds Ill.Hy, Ind.TR, U.S.540, Ia.I205, Wis.CC1, Ill.A48, and Ill.L averaged 8 percent less than the predicted numbers of borers, and on the basis of tests in hybrid combination were classed as transmitting partial borer resistance to the hybrids.

Inbreds Ill.A, Ill.90, Ind.WF9, and U.S.187–2 averaged 33 percent more than the predicted numbers of borers in plantings of inbreds and on the basis of tests in hybrid combinations were classed as being borer susceptible.

A comparison of sister inbred lines, separated at the second to the fifth generation of inbreeding, showed that the difference between sisters of pairs of sisters in transmitting borer resistance to hybrids averaged not much larger than the difference found between the members of pairs of samples of the same hybrids, indicating little advantage in testing sister strains in future experiments.

In the 1939 experiment single-cross hybrids involving two resistant inbreds averaged 39 percent less than the predicted numbers of borers. Hybrids involving one resistant and one partially resistant inbred averaged 15 percent less than the predicted numbers. Hybrids involving two partially resistant inbreds and one resistant and one susceptible inbred averaged 2 percent more and 8 percent more, respectively, than the predicted numbers. Hybrids involving one partially resistant and one susceptible inbred averaged 32 percent more than the predicted numbers. Hybrids involving two susceptible inbreds averaged 58 percent more than the predicted numbers of borers.

Double-cross hybrids tested during six seasons also showed a trend from pronounced borer resistance toward borer susceptibility, when the number of partially resistant and susceptible inbreds used in the pedigrees was increased.

The cumulative effect of an undetermined number of multiple factors in inbred lines in producing borer resistance in hybrids is clearly indicated.

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This bulletin is a contribution from

Bureau of Entomology and Plant Quarantine	P. N. ANNAND, *Chief.*
Division of Cereal and Forage Insect Investigations.	C. M. PACKARD, *Principal Entomologist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1942

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