Investigations of Corn Borer Control at Monroe, Michigan
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# Investigations of Corn Borer Control at Monroe, Michigan

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AGRICULTURAL EXPERIMENT STATION

MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

FARM CROPS AND ENTOMOLOGICAL SECTIONS

East Lansing, Michigan

## FOREWORD

In 1921, the European corn borer first made its appearance in Michigan; a few of the larvae were found in some townships on the eastern side of Monroe County. By the spring of 1927, 20 Michigan counties were under federal quarantine to check the spread of this pest. Two years later the corn borer had been found in so many Michigan counties, some even having been found in the Upper Peninsula, that the entire state was placed under federal quarantine and strict regulations are now in effect in an endeavor to prevent the long distance spread of this insect.

The potential destructiveness of the European corn borer was demonstrated in Canada but a few miles from Michigan's leading corn growing counties in 1925, 1926, and 1927, when almost the entire corn crop of Kent and Essex Counties, Ontario, was ruined by borer attack. No such widespread destruction has, as yet, been experienced in Michigan, but the infestation in Michigan, with the possible exception of one or two localities, has steadily increased. In fact, some farmers in Monroe and Lenawee Counties estimated 1929 corn losses due to the ravages of the borer at from 50 to 70 per cent of the crop.

In an endeavor to find out more about this new invader and with the hope of developing more effective means of checking the losses which it causes, the State Board of Agriculture in 1926 leased land near the city of Monroe and established there a branch of the Michigan Experiment Station at which all efforts were to be devoted to a study of corn borer problems.

For one season, the work was carried on through the co-operative efforts of the Michigan State College and the Bureau of Entomology of the United States Department of Agriculture. Subsequently the Bureau of Entomology transferred its activities to the city of Monroe and the entomological work at the station operated by the Michigan State College was all conducted by the Department of Entomology of the latter institution. The work of setting up this sub-station and getting its projects organized was done under the direction of J. F. Cox, dean of agriculture, Michigan State College, who has devoted much effort to the corn borer problem. The investigations which have been carried on thus far are reported in this publication by A. R. Marston of the Farm Crops Section, Superintendent of the corn borer sub-station, and C. B. Dibble of the Entomological Section.

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# Agronomic Investigations at the Michigan State College Corn Borer Experiment Station 1926-1929

A. R. MARSTON

## Corn Planted at Normal Time for Planting Gives Best Results When Corn Borer Infestation is Moderate

Though experiments on time of planting corn at this station have shown that late planting has a tendency to lower corn borer infestation, the advantage of this decrease in infestation is more than offset by the decrease in yield due to late planting under infestation conditions such as have been experienced at Monroe thus far.

In an experiment to determine the best time to plant corn under corn borer conditions, 19 varieties of dent, flint, sweet, and pop corn were planted four different times at intervals of two weeks throughout the planting season. Four plantings were made at each different planting date. The various varieties tested were planted in 19 hill plots three rows wide, checks of the Duncan variety being planted every fourth plot, giving opportunity to correct for any variation in soil that might be found throughout the field. Plant records were kept on all varieties throughout the growing season, and as soon as the various varieties showed maturity they were harvested for yield records and samples were dissected in order to determine the number of borers and the percentage of corn borer infested stalks in each plot. This experiment has been conducted for the past four years and the results are found in the following tables.

Tables 3 and 4 show the results of varieties sent to this station to be tested under corn borer conditions. These tests were not conducted on any variety for more than two years, so no conclusions were drawn, however, these are published for the interest of the growers.

## Relation of Corn Borer Infestation to Time of Planting

Corn planted later than normal planting season showed a marked decrease in corn borer infestation. The records given in Tables 1 and 2, show that a reduction of approximately 30 per cent in the total number of stalks infested with corn borers occurred when corn was planted May 25, rather than May 12, or earlier. It is important to note that all dent varieties considered as suitable for the Monroe locality, except Clement's White Cap, yielded as well planted May 25, as they did planted May 12. With these same varieties, the May 25th plantings also matured with safety.

**Table No. 1.—Time of planting test.**

**Comparison of yield, number corn borers per 100 plants and percentage corn borer infested plants. Average results for four year period, 1926, 1927, 1928, 1929.**

| VARIETY | FIRST PLANTING | | | SECOND PLANTING | | | THIRD PLANTING | | | FOURTH PLANTING | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture |
| DENT CORN | | | | | | | | | | | | |
| Clements White Cap | 80 | 42 | 41.1 | 77 | 53 | 56.8 | 15 | 16 | 49.8 | 2 | 5 | 36.5 |
| Polar Dent | 90 | 53 | 43.0 | 76 | 52 | 41.6 | 8 | 15 | 40.2 | 2 | 4 | 31.7 |
| M. A. C. Yellow Dent | 86 | 58 | 39.3 | 64 | 48 | 44.5 | 13 | 19 | 46.3 | 3 | 4 | 34.8 |
| Duncan | 61 | 45 | 40.2 | 46 | 48 | 44.8 | 12 | 16 | 42.4 | 2 | 4 | 32.9 |
| Wisconsin Cold Resist G. G | 98 | 59 | 31.7 | 69 | 45 | 44.3 | 10 | 12 | 39.4 | 5 | 4 | 33.7 |
| *Golden Glow (P. A. Smith) | 130 | 64 | 33.9 | 82 | 60 | 40.5 | 16 | 16 | 37.8 | 3 | 3 | 29.2 |
| Rustlers White Dent | 56 | 43 | 31.6 | 45 | 41 | 39.3 | 16 | 18 | 32.9 | 3 | 6 | 27.1 |
| Isbell's First Choice | 75 | 44 | 29.9 | 53 | 47 | 36.0 | 13 | 13 | 33.9 | 2 | 4 | 29.3 |
| Wisconsin No. 25 | 142 | 60 | 25.9 | 83 | 52 | 32.4 | 18 | 17 | 29.7 | 1 | 6 | 27.3 |
| Northwestern Red Dent | 86 | 55 | 24.8 | 73 | 52 | 29.4 | 22 | 24 | 24.9 | 1 | 5 | 23.4 |
| *Michigan Yellow Dent | 74 | 58 | 18.4 | 65 | 53 | 28.9 | 8 | 11 | 31.3 | 2 | 2 | 27.3 |
| Red Cob Ensilage | 70 | 44 | 39.8 | 38 | 39 | 45.7 | 8 | 15 | 46.3 | 1 | 4 | 31.5 |
| *Gridley (Ill. Yellow Dent) | 50 | 40 | 46.5 | 48 | 42 | 55.4 | 7 | 10 | 42.7 | 2 | 2 | 27.8 |
| FLINT CORN | | | | | | | | | | | | |
| *Eight Rowed Flint | 79 | 60 | 27.4 | 77 | 48 | 29.8 | 14 | 14 | 26.0 | 3 | 2 | 25.4 |
| King Phillip Flint | 77 | 51 | 22.0 | 42 | 41 | 21.4 | 7 | 14 | 25.9 | 3 | 4 | 21.5 |
| SWEET CORN | | | | | | | | | | | | |
| Country Gentleman | 38 | 37 | 6.0 | 48 | 35 | 7.8 | 1 | 5 | 7.4 | 0 | 1 | 8.6 |
| Crosby | 78 | 44 | 7.1 | 74 | 38 | 6.7 | 16 | 12 | 6.0 | 2 | 4 | 6.3 |
| Golden Bantam | 55 | 28 | 5.2 | 78 | 36 | 7.8 | 15 | 13 | 7.0 | 1 | 2 | 5.0 |
| POP CORN | | | | | | | | | | | | |
| Michigan Hulless Pop Corn | 36 | 37 | 18.0 | 30 | 30 | 19.8 | 21 | 16 | 22.3 | 1 | 2 | 16.8 |

*Tested for years 1927, 1928 and 1929 only.
First Planting—April 28th, 1926, 1927, 1928 and May 8th, 1929.
Second Planting—May 12th, 1926, 1927, 1928 and May 20th, 1929
Third Planting—May 25th, 1926, 1927, 1928 and June 4th, 1929.
Fourth Planting—June 9th, 1926, 1927, 1928 and June 18th, 1929.
Note—Above varieties are not listed in order of yield.

**Table No. 2.—Time of planting test.**

**Comparison of yield, moisture per cent at harvest and number of days of growth to maturity. Average results for four year period, 1926, 1927, 1928, 1929.**

| VARIETY | FIRST PLANTING | | | SECOND PLANTING | | | THIRD PLANTING | | | FOURTH PLANTING | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture |
| DENT CORN | | | | | | | | | | | | |
| Clements White Cap | 134 | 43.8 | 41.1 | 132 | 45.1 | 56.8 | 129 | 46.6 | 49.8 | 124 | 51.9 | 36.5 |
| Polar Dent | 138 | 46.9 | 43.0 | 131 | 50.7 | 41.6 | 128 | 47.5 | 40.2 | 124 | 54.1 | 31.7 |
| M. A. C. Yellow Dent | 137 | 46.8 | 39.3 | 129 | 46.8 | 44.5 | 128 | 45.6 | 46.3 | 114 | 51.1 | 34.8 |
| Duncan | 139 | 41.3 | 40.2 | 131 | 47.7 | 44.8 | 126 | 47.1 | 42.4 | 118 | 51.8 | 32.9 |
| Wisconsin Cold Resist G. G | 137 | 46.3 | 31.7 | 130 | 47.6 | 44.3 | 129 | 44.4 | 39.4 | 117 | 48.9 | 33.7 |
| *Golden Glow (P. A. Smith) | 133 | 46.3 | 33.9 | 125 | 49.8 | 40.5 | 124 | 40.5 | 37.8 | 119 | 34.7 | 29.2 |
| Rustlers White Dent | 133 | 45.6 | 31.6 | 127 | 45.8 | 39.3 | 124 | 42.3 | 32.9 | 120 | 50.4 | 27.1 |
| Isbell's First Choice | 138 | 42.7 | 29.9 | 130 | 40.2 | 36.0 | 125 | 44.5 | 33.9 | 124 | 49.6 | 29.3 |
| Wisconsin No. 25 | 129 | 46.5 | 25.9 | 120 | 48.1 | 32.3 | 119 | 44.5 | 29.7 | 113 | 43.3 | 27.3 |
| Northwestern Red Dent | 131 | 47.9 | 24.8 | 123 | 45.5 | 29.4 | 118 | 47.9 | 24.9 | 115 | 45.8 | 23.4 |
| *Michigan Yellow Dent | 130 | 44.2 | 18.4 | 125 | 44.7 | 28.9 | 129 | 39.6 | 31.3 | 118 | 46.2 | 27.3 |
| Red Cob Ensilage | 148 | 56.7 | 39.8 | 143 | 54.8 | 45.7 | Immature | 57.1 | 46.3 | Immature | 68.8 | 31.5 |
| *Gridley (Ill. Yellow Dent) | 147 | 49.8 | 46.5 | 144 | 45.5 | 55.4 | Immature | 49.4 | 42.7 | Immature | 58.7 | 27.8 |
| FLINT CORN | | | | | | | | | | | | |
| *Eight Rowed Flint | 131 | 45.9 | 27.4 | 123 | 43.1 | 29.8 | 123 | 39.8 | 26.0 | 126 | 48.2 | 25.4 |
| King Phillip Flint | 132 | 43.7 | 22.0 | 123 | 46.9 | 21.4 | 123 | 36.9 | 25.9 | 117 | 44.1 | 21.5 |
| SWEET CORN | | | | | | | | | | | | |
| Country Gentleman | 121 | 83.6 | 6.0 | 112 | 85.8 | 7.8 | 117 | 86.2 | 7.4 | 100 | 75.9 | 8.6 |
| Crosby | 119 | 77.9 | 7.1 | 108 | 84.3 | 6.7 | 98 | 84.4 | 6.0 | 95 | 78.0 | 6.3 |
| Golden Bantam | 121 | 74.4 | 5.2 | 108 | 76.6 | 7.8 | 89 | 78.1 | 7.0 | 91 | 82.8 | 5.0 |
| POP CORN | | | | | | | | | | | | |
| Michigan Hulless Pop Corn | 139 | 40.2 | 18.0 | 131 | 37.2 | 19.8 | 126 | 36.5 | 22.3 | 120 | 42.1 | 16.8 |

*Tested for years 1927, 1928 and 1929 only.
First Planting—April 28th, 1926, 1927, 1928 and May 8th, 1929.
Second Planting—May 12th, 1926, 1927, 1928 and May 20th, 1929.
Third Planting—May 25th, 1926, 1927, 1928 and June 4th, 1929.
Fourth Planting—June 9th, 1926, 1927, 1928 and June 18th, 1929.
Note—Above varieties are not listed in order of yield.

**Table No. 3.—Time of planting test.**

**Comparison of yield, number corn borers per 100 plants, and percentage corn borer infested plants. Average results for one to two year test.**

| VARIETY | Years Tested | FIRST PLANTING | | | SECOND PLANTING | | | THIRD PLANTING | | | FOURTH PLANTING | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture | No. Corn Borers Per 100 Plants | Percentage Corn Borer Infested Plants | Yield Bu. Per Acre at 14% Moisture |
| DENT CORN | | | | | | | | | | | | | |
| Special Golden Glow | 1926 | ..... | 36 | 59.2 | ..... | 17 | 64.3 | ..... | 22 | 67.6 | ..... | 6 | 37.8 |
| Laughlin Yellow Dent | 1926 | ..... | 38 | 46.2 | ..... | 21 | 47.1 | ..... | 15 | 50.7 | ..... | 9 | 47.3 |
| Luce's Favorite | 1926 | ..... | 24 | 45.1 | ..... | 26 | 47.0 | ..... | 12 | 34.6 | ..... | 5 | 36.9 |
| Funk's Cross | 1928–29 | 13 | 20 | 39.4 | 49 | 49 | 45.6 | 7 | 9 | 44.8 | 3 | 1 | 25.9 |
| Clarage | 1928–29 | 36 | 38 | 30.3 | 55 | 48 | 37.2 | 12 | 19 | 43.7 | 4 | 2 | 35.7 |
| Minn. No. 13 | 1928–29 | 23 | 33 | 26.6 | 50 | 48 | 30.6 | 6 | 13 | 34.1 | 3 | 2 | 29.5 |
| Wilk's Yellow Dent | 1929 | 47 | 49 | 32.8 | 21 | 46 | 39.1 | 0 | 5 | 31.7 | 0 | 0 | 21.0 |
| Ferden's Yellow Dent | 1929 | 49 | 56 | 25.4 | 50 | 62 | 25.0 | 2 | 3 | 25.3 | 0 | 1 | 21.7 |
| Perrines Yellow Dent | 1929 | 16 | 42 | 23.7 | 25 | 37 | 23.3 | 1 | 2 | 25.9 | 1 | 2 | 19.5 |
| FLINT CORN | | | | | | | | | | | | | |
| Smut Nose Flint | 1926 | ..... | 29 | 28.1 | ..... | 34 | 29.8 | ..... | 23 | 35.3 | ..... | 6 | 32.7 |
| SWEET CORN | | | | | | | | | | | | | |
| Earliest of All | 1927 | 56 | 60 | 4.6 | 38 | 80 | 4.0 | 23 | 46 | 4.2 | 0 | 0 | 4.0 |

First Planting—April 28th, 1926, 1927, 1928, May 8th, 1929.
Second Planting—May 12th, 1926, 1927, 1928, May 20th, 1929.
Third Planting—May 25th, 1926, 1927, 1928, June 4th, 1929.
Fourth Planting—June 9th, 1926, 1927, 1928, June 18th, 1929.
Note—Above varieties are not listed in order of yield.

**Table No. 4—Time of planting test.**

**Comparison of yield, moisture per cent at harvest and number of days growth to maturity. Average results for one to two year test.**

| VARIETY | Years Tested | FIRST PLANTING | | | SECOND PLANTING | | | THIRD PLANTING | | | FOURTH PLANTING | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture | No. Days Growth to Harvest | Moisture Per Cent at Harvest | Yield Bu. Per Acre at 14% Moisture |
| DENT CORN | | | | | | | | | | | | | |
| Special Golden Glow | 1926 | 141 | 46.0 | 59.2 | 130 | 44.2 | 64.3 | 136 | 40.5 | 67.6 | 124 | 52.4 | 37.8 |
| Laughlin Yellow Dent | 1926 | 141 | 43.5 | 46.2 | 135 | 51.3 | 47.1 | 131 | 39.6 | 50.7 | 124 | 52.0 | 47.3 |
| Luce's Favorite | 1926 | 150 | 48.0 | 45.1 | 136 | 52.0 | 47.0 | 136 | 49.4 | 34.6 | 124 | 48.7 | 36.9 |
| Funk's Cross | 1928–29 | 144 | 59.2 | 39.4 | 135 | 54.3 | 45.6 | Immature | 55.4 | 44.8 | Immature | 65.2 | 25.9 |
| Clarage | 1928–29 | 135 | 50.4 | 30.3 | 124 | 44.6 | 37.2 | Immature | 43.9 | 43.7 | Immature | 50.1 | 35.7 |
| Minn. No. 13 | 1928–29 | 131 | 46.6 | 26.6 | 121 | 49.1 | 30.6 | 117 | 43.7 | 34.1 | 110 | 50.6 | 29.5 |
| Wilk's Yellow Dent | 1929 | 129 | 44.8 | 32.8 | 122 | 44.6 | 34.1 | 119 | 54.9 | 31.7 | Immature | 58.0 | 21.0 |
| Ferden's Yellow Dent | 1929 | 124 | 41.4 | 25.4 | 117 | 47.7 | 25.0 | 117 | 47.5 | 25.3 | Immature | 58.2 | 21.7 |
| Perrines Yellow Dent | 1929 | 127 | 48.1 | 23.7 | 119 | 47.7 | 23.3 | 117 | 54.0 | 25.9 | Immature | 57.2 | 19.5 |
| FLINT CORN | | | | | | | | | | | | | |
| Smut Nose Flint | 1926 | 135 | 47.6 | 28.1 | 122 | 48.4 | 29.8 | 125 | 40.1 | 35.3 | 117 | 52.5 | 32.7 |
| SWEET CORN | | | | | | | | | | | | | |
| Earliest of All | 1927 | 118 | 74.5 | 4.6 | 104 | 83.5 | 4.0 | 97 | 76.8 | 4.2 | 85 | 77.6 | 4.0 |

First Planting—April 28th, 1926, 1927, 1928, May 8th, 1929.
Second Planting—May 12th, 1926, 1927, 1928, May 20th, 1929.
Third Planting—May 25th, 1926, 1927, 1928, June 4th, 1929.
Fourth Planting—June 9th, 1926, 1927, 1928, June 18th, 1929.
Note—Above varieties are not listed in order of yield.

Plantings later than May 25, experienced another marked reduction in infestation but these later plantings, June 9, also suffered a severe loss in yield and many of the varieties did not mature properly.

Real early planting, April 28, proved disadvantageous to all dent varieties except Polar Dent, a frost resistant corn bred by J. R. Duncan of the Michigan Experiment Station at East Lansing. Polar dent yielded well at all planting dates from April 28 to May 25. However, Clement's White Cap, bred in Monroe County by Paul Clement of Britton, was the highest yielding variety in the experiment.

Other dependable varieties for this locality, as shown by their yields in these tests, are M. A. C. Yellow Dent, Duncan, and Golden Glow. The Gridley corn, an Illinois variety, yielded well but did not mature except in the case of the real early plantings.

Fig. 1.—Counting corn borers and taking yield on corn plats.

Very early corn, such as Wisconsin No. 25, Northwestern Red Dent, Eight-rowed Flint, and King Philip Flint, were not materially affected by time of planting at Monroe so far as yield is concerned. However, their yield was way below that of Clement's White Cap, M. A. C. Yellow Dent, and other varieties adapted to Southern Michigan and they have no place in this part of the State except when June plantings are a necessity or where yield may be sacrificed for maturity to provide for early hogging off operations.

This experiment was conducted for the purpose of finding the best time to plant corn under corn borer conditions, but other interesting results showed up. For example, it was found that earlier silking corn varieties were likely to have a heavier corn borer infestation.* These early silking varieties also gave lower yields of corn to the acre than did the better adapted though moderately later corns. When all dent

* Correlation — .654 ± .097 showing the fewer days from planting to 50% silk the higher the percentage of infestation.

varieties used in this experiment were compared for yield and infestation when planted at the different dates, there was indication that the higher yielding varieties of corn were inclined to carry a lower borer infestation. This tendency is illustrated in the charts on this page.

The lessons to be learned from these experiments may prove to be of real importance. This work points out that a planting time ranging from May 12 to May 25 is most desirable for Southeastern Michigan,

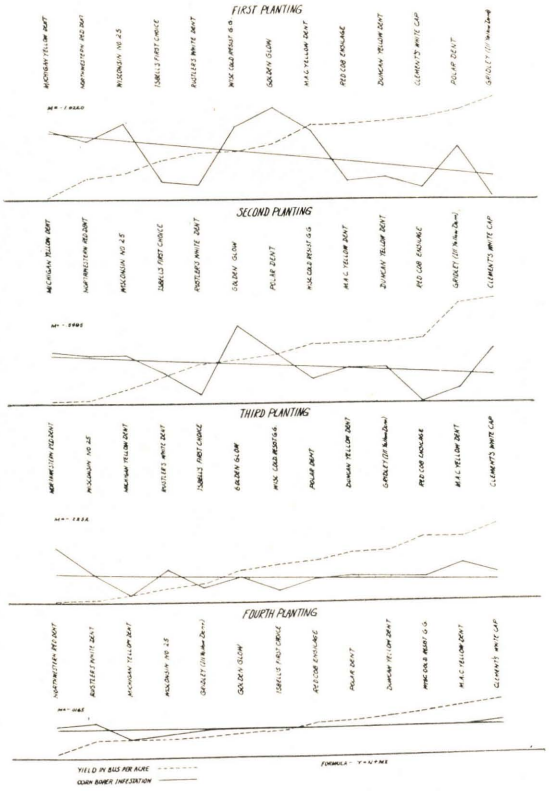


Fig. 2.—Comparison of yield and corn borer infestation when corn varieties were planted at different times.

with plantings toward the latter part of this period likely to suffer somewhat less from corn borer attack than those made earlier.

Though plantings during the second week in June have greatly reduced corn borer infestation, these late plantings as a means of corn borer control under present conditions of infestation have proved impractical and have resulted in materially lower yields of immature corn.

## Do Corn Borer Moths Prefer to Lay Their Eggs on the Highest Corn

In conjunction with the experiments to determine the effect of the time of planting, several different types of corn were planted in small plots six feet square. A screened cage was placed over the plots and corn borer moths were liberated in the cages. A similar plot was left uncovered as a check. As each of these plots contained the same variety of corn planted at four different dates, the corn borer moths had opportunity to choose the corn in any stage of growth which they might prefer. All plants in all of the plots were observed daily during the moth flight season, and, when the corn was mature, all corn borers in the plants were counted. This experiment was carried on by W. F Russow, an agricultural student at the Michigan State College.

**Table No. 5.—Preference for date of planting. Total of both caged and open planting.**

| Planting | Date | No. Corn Borer Egg Masses | No. Corn Borer Eggs | Corn Borer Population* | Survival |
|---|---|---|---|---|---|
| First | May 1, 1928 | 40 | 740 | 207 | 27.9% |
| Second | May 15, 1928 | 20 | 516 | 196 | 37.9% |
| Third | May 29, 1928 | 11 | 228 | 141 | 61.9% |
| Fourth | June 12, 1928 | 0 | 0 | 69 | 0 % |

*A greater number of borers than eggs is found in some cases due to migration.

| | |
|---|---|
| Total Number Egg Masses | 71 |
| Total Number Eggs | 1,484 |
| Average Egg Mass Open Planting | 12.7 Eggs |
| Average Egg Mass Closed Planting | 23.4 Eggs |

By studying the foregoing tables, it is evident that the corn borer moth is attracted to the earliest planted corn, within a given variety, consequently to the tallest corn of that variety. Whether or not this attraction is due to the greater height and vigor that the earlier planted corn has attained, to an aroma given off by the corn planted early, or to some other characters has not yet been learned. It is quite evident

**Table No. 6.—Corn borer survival. Total of all dates of planting.**

| Variety | OPEN PLANTING | | | CAGED PLANTING | | |
|---|---|---|---|---|---|---|
| | Eggs | Borers* | Survival | Eggs | Borers* | Survival |
| DENT CORN | | | | | | |
| Duncan | 0 | 4 | 0% | 137 | 47 | 34.3% |
| FLINT CORN | | | | | | |
| Maize Amargo | 0 | 2 | 0% | 0 | 1 | 0 % |
| Longfellow | 50 | 36 | 72.0% | 430 | 221 | 51.3% |
| Argentine | 17 | 3 | 17.6% | 42 | 10 | 23.7% |
| SWEET CORN | | | | | | |
| Golden Bantam | 13 | 33 | 0 % | 166 | 75 | 45.1% |
| POP CORN | | | | | | |
| Mich. Hulless Pop | 32 | 16 | 50 % | 177 | 45 | 25.4% |

*A greater number of borers than eggs is found in some cases due to migration.

that the borers are able to survive equally as well on the late planted corn as on the early planted corn after the eggs have once been laid.

Table 6, shows there is possibly a host preference. The common Michigan varieties and types of corn are about equally susceptible to corn borer infestation but the South American Maize Amargo variety shows repellant characteristics. Corn borer eggs were laid in large numbers on the cage structure rather than on the plants where Maize Amargo was planted in a cage and an attempt made to force infestation.

### Increased Breakage Adds to Corn Borer Difficulties When Corn Harvest Is Delayed

Corn left standing after it has matured will suffer more damage from the European Corn Borer under infestation conditions such as were experienced at Monroe during 1927, 1928, and 1929 than will corn harvested at maturity. The tests in which this condition was evident

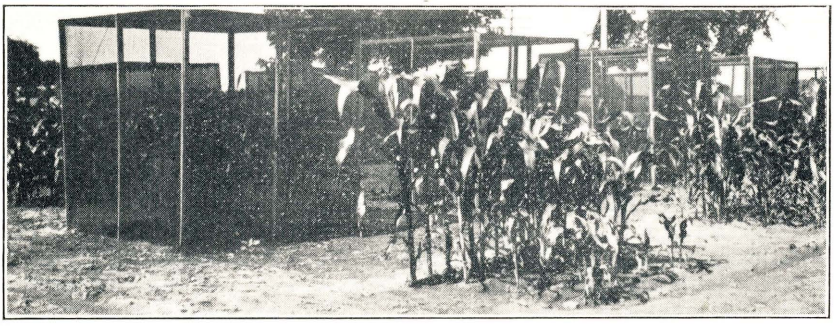

Fig. 3.—Testing corn borer attack on corn in different stages of maturity in open and under caged conditions.

indicated that there was greater breakage of corn below the ear, when harvesting was delayed, due to weakening of the stalks by the corn borer. Premature harvesting further to overcome such losses did not prove practical since this practice greatly reduced the yield, as may well be expected. No important losses in yield of grain resulted when the corn was permitted to stand uncut for some time after maturity, but the breakage in stalks did cause considerable inconvenience in handling the corn.

In the experiment to determine the influence of the time of harvest on corn borer damage, corn was harvested at five different dates. In 1927, plots which were 16 hills long and four rows wide with no checks were used; but, in 1928 and 1929, the 64 hills in each plot came from an area two rows wide and 32 hills long and every other plot was cut at the same date as a check on infestation, damage, and yield.

Conditions of the experiment varied each season. In 1927 and 1929, the infestation was light, probably due to late planting since the corn used was planted June 1 in 1927 and May 31 in 1929. Because of this light infestation, no breakage records were taken these years. However, in 1928, an early planting, May 1, was used and the plots in this

season had well over 100 borers per 100 stalks and breakage due to the work of the borer was important.

The increase in this breakage of corn stalks below the ear in 1928 directly caused by the corn borer is shown in Table 7.

**Table No. 7.—Showing increase in percentage of stalks broken below the ear by the European corn borer when harvest was delayed beyond maturity.**

| Date of Harvest | Per Cent Stalks broken below ear by borer | |
|---|---|---|
| | Duncan Corn | Golden Glow Corn |
| August 8 | 8.8% | 12.0% |
| September 14 | 7.3% | 11.5% |
| September 28 (Check) | 9.8% | 15.1% |
| October 15 | 12.5% | 25.5% |

Breakage of stalks below the ear was not significantly different in corn cut September 14 and in that cut in August. Much of the early work of the borer is in the top of the plant and, while there were more broken tassels in September than in August, breakage below the ear did not increase materially until later. In the case of both varieties, there is a steady increase in stalk breakage caused by the corn borer after September 14, this breakage was greater in the lighter stalked Golden Glow corn. The Golden Glow corn was down to 32.7 per cent moisture September 14, while the Duncan was not that mature for another two weeks.

From the standpoint of yield of grain, it is usually desirable to allow corn to stand until quite mature. Severe frost, or the use of corn for silage purposes, would, of course, alter the case. During all three years of this experiment, there were more bushels of sound corn per

Fig. 4.—Corn borer infested corn field, Monroe County, 1929.

acre produced when the corn was allowed to ripen fully. Both varieties were ripe by mid-September in 1927. In 1928, the Golden Glow corn was again well down in moisture by this date with the Duncan still containing 46 per cent moisture. In 1929, Golden Glow was not safe until early October and Duncan until nearly November. These statements may be amplified further by a study of Tables 8, 9, and 10 which show the yield and moisture content of corn at the different harvest dates and also the corn borer infestation.

## Time of Harvest Tests

**Table No. 8.—Average of two cuttings—1927.**

| Cutting | Date | Variety | No. Corn Borers Per 100 Plants | Per Cent Infestation* | Moisture Content at Harvest | Yield Bu. Marketable Corn at 14% Moisture |
|---|---|---|---|---|---|---|
| First Cutting | Sept. 20, 1927 | Duncan | 1 | 5 | 32.2% | 30.2 |
| Second Cutting | Sept. 27, 1927 | Duncan | 27 | 45 | 29.8% | 46.5 |
| Third Cutting | Oct. 11, 1927 | Duncan | 19 | 24 | 30.3% | 47.1 |
| Fourth Cutting | Oct. 24, 1927 | Duncan | 24 | 24 | 27.5% | 45.9 |
| Fifth Cutting | Nov. 25, 1927 | Duncan | 11 | 26 | 24.8% | 53.0 |
| First Cutting | Sept. 20, 1927 | Golden Glow | 16 | 16 | 39.6% | 30.2 |
| Second Cutting | Sept. 27, 1927 | Golden Glow | 32 | 55 | 32.4% | 45.5 |
| Third Cutting | Oct. 11, 1927 | Golden Glow | 15 | 27 | 29.5% | 47.5 |
| Fourth Cutting | Oct. 24, 1927 | Golden Glow | 23 | 36 | 26.8% | 46.8 |
| Fifth Cutting | Nov. 25, 1927 | Golden Glow | 38 | 35 | 28.4% | 50.1 |

*This indicates per cent of plants in which the borer had evidently worked though in some cases no borers were found.

**Table No. 9.—Average of two cuttings—1928.**

| Cutting | Date | Variety | No. Corn Borers Per 100 Plants | Per cent Infestation | Moisture Content at Harvest | Yield Bu. Marketable Corn at 14% Moisture |
|---|---|---|---|---|---|---|
| First Cutting | Aug. 8, 1928 | Duncan | 104 | 56 | 46.2% | 45.9 |
| Second Cutting | Sept. 14, 1928 | Duncan | 170 | 82 | 46.9% | 38.2 |
| Third Cutting | Oct. 15, 1928 | Duncan | 114 | 84 | 21.4% | 58.2 |
| Fourth Cutting | Apr. 22, 1929 | Duncan | 27 | 72 | 18.0% | 54.6 |
| Check (Average) | Sept. 28, 1928 | Duncan | 111 | 77 | 40.4% | 53.3 |
| First Cutting | Aug. 8, 1928 | Golden Glow | 184 | 84 | 40.0% | 40.3 |
| Second Cutting | Sept. 14, 1928 | Golden Glow | 124 | 90 | 32.7% | 44.8 |
| Third Cutting | Oct. 15, 1928 | Golden Glow | 175 | 86 | 26.6% | 38.6 |
| Fourth Cutting | Apr. 22, 1929 | Golden Glow | 45 | 67 | 17.4% | 46.2 |
| Check (Average) | Sept. 28, 1928 | Golden Glow | 142 | 80 | 34.7% | 46.2 |

**Table No. 10.—Average of two cuttings—1929.**

| Cutting | Date | Variety | No. Corn Borers Per 100 Plants | Per cent Infestation | Moisture Content at Harvest | Yield Bu. Marketable Corn at 14% Moisture |
|---|---|---|---|---|---|---|
| First Cutting | Sept. 20, 1929 | Duncan | 12 | 12 | 74.0% | 14.3 |
| Second Cutting | Oct. 3, 1929 | Duncan | 12 | 14 | 50.5% | 35.8 |
| Third Cutting | Nov. 5, 1929 | Duncan | 14 | 26 | 25.6% | 38.9 |
| Fourth Cutting | Nov. 23, 1929 | Duncan | 10 | 18 | 30.9% | 30.9 |
| Fifth Cutting | Dec. 6, 1929 | Duncan | 10 | 8 | 28.9% | 27.3 |
| Check (Average) | Oct. 3, 1929 | Duncan | 9 | 13 | 48.5% | 32.9 |
| First Cutting | Sept. 20, 1929 | Golden Glow | 12 | 10 | 58.0% | 19.4 |
| Second Cutting | Oct. 3, 1929 | Golden Glow | 4 | 6 | 41.2% | 29.6 |
| Third Cutting | Nov. 5, 1929 | Golden Glow | 18 | 26 | 33.7% | 27.2 |
| Fourth Cutting | Nov. 23, 1929 | Golden Glow | 8 | 16 | 40.5% | 29.7 |
| Fifth Cutting | Dec. 6, 1929 | Golden Glow | 16 | 14 | 22.7% | 23.4 |
| Check (Average) | Oct. 3, 1929 | Golden Glow | 12 | 14 | 42.8% | 28.1 |

The results of this experiment emphasize the importance of growing a variety of corn that will mature in good season so that, under conditions of heavy infestation, it may be harvested reasonably early before serious breakage of the stalks greatly adds to the inconvenience of handling the crop.

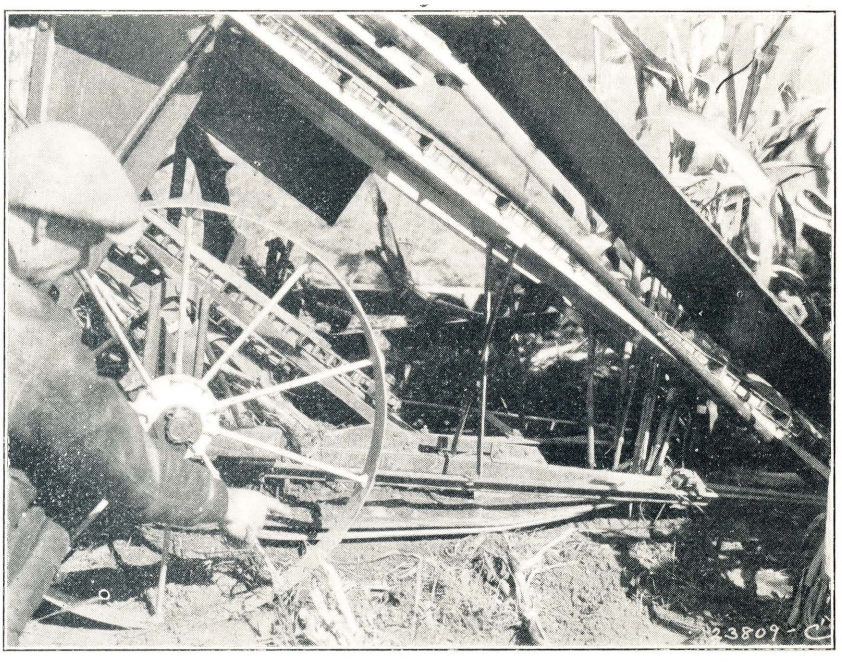

Fig. 5.—Low cutting attachments for corn binders leave very few borers in the short stubble.

## Rate and Spacing of Corn

Corn was planted by hilling and drilling to determine whether any particular rate of planting would influence the attack of the corn borer. The following rates were used in the drilled corn: one kernel every 3½, 7, 14, 21 and 42 inches with the rows 42 inches apart. In the hilled corn which was planted with three kernels per hill, the hills were 7, 14, 21 and 42 inches apart and the rows were 42 inches apart. When six kernels per hill were planted, the hills and rows were 84 inches apart. Results over a period of four years, 1926, 1927, 1928, 1929 did not show any important differences in infestation.

## Cutting Corn at Different Heights

The number of European corn borers remaining in the field is greatly reduced when corn is cut low. This is substantiated by the results of an experiment conducted at the Monroe Corn Borer Station over a period of three years.

### Method

The corn was cut with a corn harvester in the "Date of Planting" project, where the same varieties had been planted at four different dates, April 28th, May 12th, May 25th, and June 9th. Each date of planting included 20 varieties of corn, with a standard variety as check every fourth plot. The corn was cut with the corn harvester set at the following heights: Surface, 4, 10 and 15 inches respectively. The remaining stubble was dissected and the presence or absence and number of borers were recorded. The data taken are shown in Table 11.

For various reasons the corn binder did not always leave stubble of the exact height planned. The actual height of stubble remaining in the field was determined by measurements on several hundred stubble in the four respective cutting heights, and it differs slightly from the height at which the harvester was set. A total of 30,028 stubble was examined and a total of 2,527 corn borers was found.

**Table No. 11.—Number of borers per acre remaining in stubble of various heights. Average for 1926, 1927, 1928.**

| Height at which machine was set to cut | Actual average height of stubble left (inches) | No. of borers per acre for each planting date | | | | Average for different stubble heights |
|---|---|---|---|---|---|---|
| | | April 28 | May 12 | May 26 | June 9 | |
| Ground surface | 2.9 | 764.0 | 552.9 | 130.4 | 37.6 | 371.2 |
| 4 inches | 4.8 | 1411.1 | 659.5 | 437.3 | 83.7 | 647.9 |
| 10 inches | 10.4 | 2783.2 | 1816.8 | 913.3 | 281.9 | 1448.8 |
| 15 inches | 13.7 | 2890.8 | 1950.1 | 1372.9 | 267.9 | 1620.4 |

Table No. 11 shows the marked difference in the number of corn borers left in the field when the corn was cut at various heights. Stubble which averaged 2.9 inches in height harbored 371.2 borers per acre as compared to 647.9 borers left in 4.8 inch stubble, 1448.8 borers left in 10.4 inch stubble, and 1620.4 borers in stubble 13.7 inches in height. In

the field studied, the average number of borers per acre before cutting was approximately 6,696 in 1927, while only 1,517 borers per acre were found under similar conditions in 1928. Approximately 20.6 per cent of all corn borers found in the stubble were below the ground, according to records obtained in 1928.

### Low Cutting Is Best in All Dates of Planting

Corn cut low, irrespective of the date of planting, left fewer borers in the field than corn cut high. The earlier planted corn had many more borers to begin with, but low cutting caused approximately the same proportionate reduction of borer population in the corn field regardless of the planting date. This is shown in Table 11.

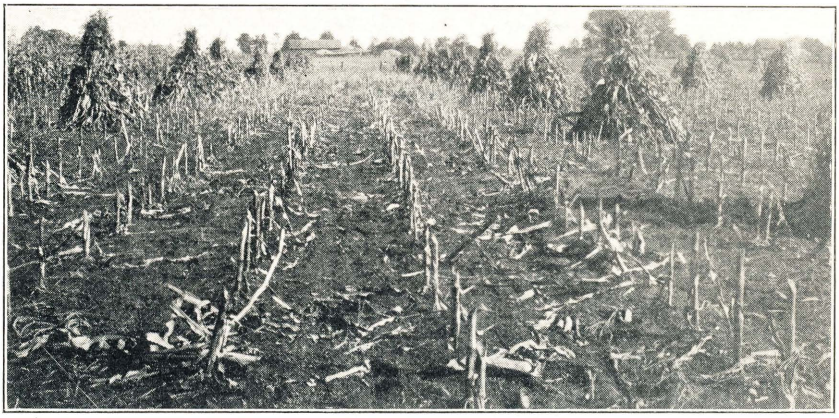

Fig. 6.—Fields of high stubble harbor many corn borers.

### Farm Machinery Properly Handled Will Kill Corn Borers

As the corn borer harbors for approximately nine months of the year in the corn fodder, experiments were conducted to test the effectiveness of commonly used farm machinery in killing these borers.

The husker-shredder, corn ensilage cutter, and roughage mill were tested with samples of 100 stalks of corn which were passed through and the resulting material examined for dead or live borers. The stalks used came from a 66.4 per cent infested field. All machinery tests were supervised by the Agricultural Engineering Department of the Michigan State College, and determinations of the borer kill were made under the supervision of Dr. Phillip Luginbill, Bureau of Entomology, United States Department of Agriculture.

The following tables give the results obtained.

Table No. 13 shows that the husker-shredder was able to destroy practicall 99.6 per cent of all corn borers in the corn fodder in all three tests conducted. Corn shelled by the husking rolls contained the greatest number of live corn borers and should be utilized as soon as possible after it comes from the machine.

**Table No. 13.—Husker-shredder.**

| Samples | Percentage Borers Killed | | |
|---|---|---|---|
| | No. 1 (Per cent) | No. 2 (Per cent) | No. 3 (Per cent) |
| Shredded fodder from blower | 99.51 | 100.00 | 100.00 |
| Ears husked | 99.02 | 99.51 | 99.51 |
| Shelled corn caught on grain screen | 99.02 | 99.02 | 99.02 |
| Canvas placed under machine | 100.00 | 100.00 | 100.00 |
| Total percentage of borers killed | 99.4 | 99.6 | 99.6 |

Table 14 shows that when the ensilage cutter was adjusted so that the fodder was cut less than one inch in length approximately 100 per cent of all corn borers were killed.

**Table No. 14.—Ensilage cutter.**

| Length of Cut | Percentage of Borers Killed |
|---|---|
| | (Per cent) |
| 3/8 inch | 100 |
| 5/8 inch | 100 |
| 3/4 inch | 100 |
| 1 and 3/8 inches | 99.6 |

Corn cut within the length of one inch will contain practically no live borers.

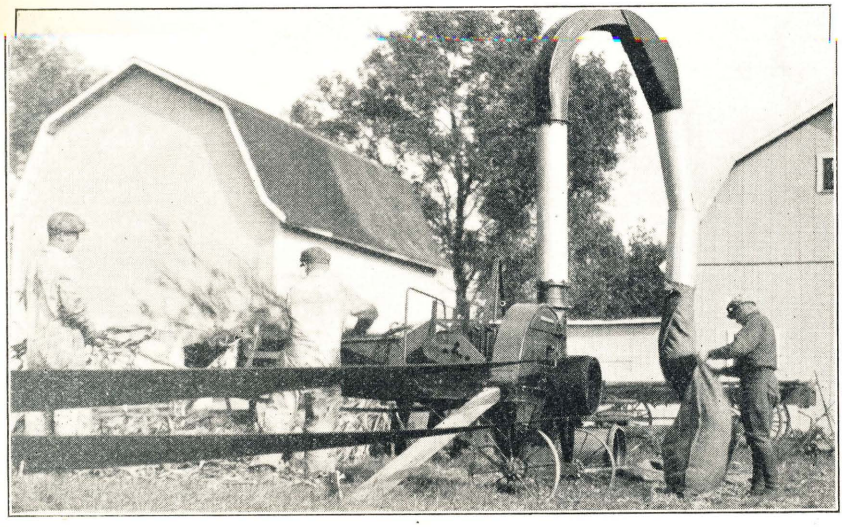

Fig. 7.—Testing ensilage cutter for corn borer kill.

### Roughage Mill

The grinding action of the roughage mill eliminates any possibility of the corn borers going through it alive. Corn fodder passed through this machine was so finely ground that not even small portions of the corn borer could be found.

### Topping Corn Not a Practical Means of Reducing Corn Borer Losses

Early in the season, many young corn borers establish themselves in the upper parts of the corn plant. The upper parts of the plant being young growing tissue, possibly carry more succulent food for the young borers than do the more mature lower sections of the plant. Growers have suggested that the removal of the corn tops might reduce the corn borer damage. Because of this possibility, experimental work was carried on to determine the influence of topping corn on corn borer infestation and the yield of the crop. The work was conducted under field conditions over a period of three years, 1926, 1927, and 1928.

Fig. 8.—Husker-shredder showing corn and corn fodder after passing through machine.

### Methods

In 1927, single row plots 19 hills long were used. These were topped at three different heights; just above the ear, midway between the ear and the tassel, and just below the tassel. Each topping treatment was conducted on three different plots. This resulted in cutting off the stalks approximately four, five, and six feet from the ground. The M. A. C. Yellow Dent variety of corn was used throughout this experiment.

Topping was done immediately after pollinization of the corn had taken place and the silks had turned brown. In 1927, single row plots were used and some migration undoubtedly took place between plots of different heights. Probably for this reason, the final count in the case of topped rows did not show any reduction in number of borers.

However, the yield of corn was decreased proportionately to the amount of the plant that was removed by topping.

In 1928 and 1929, a different arrangement of plots was adopted for the purpose of avoiding migration of borers. These plots consisted of 12 rows, 19 hills long; each plot being topped at one of the three heights previously mentioned. The check plots which were not topped were also 12 rows wide as described above. All plots were duplicated and the same variety of corn was again used. Corn borer counts in the tops which were removed as well as in the remainder of the plants were made at harvest and records of the yields of corn were also taken. Table 15 gives the average results obtained for the three years.

**Table No. 15.—Corn topping test. Average results for three years, 1927, 1928, 1929.**

| Treatment | No. corn borers removed per 100 plants when topped | | | No. corn borers per 100 plants at harvest | | | Percentage Infestation | | | Yield in bu. per acre at 14% moisture | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1927 | 1928 | 1929 | 1927 | 1928 | 1929 | 1927 | 1928 | 1929 | 1927 | 1928 | 1929 |
| No treatment (Check ave.) | ..... | ..... | ..... | 26 | 124 | 6 | 24 | 73 | 7 | 57.2 | 66.5 | 33.7 |
| Topped below tassel | 20 | 50 | 0 | 29 | 93 | 3 | 31 | 69 | 4 | 54.2 | 63.3 | 27.8 |
| Topped between tassel and ear | 44 | 34 | 0 | 30 | 86 | 4 | 22 | 51 | 3 | 49.0 | 59.2 | 25.7 |
| Topped above ear | 44 | 58 | 1 | 32 | 40 | 2 | 30 | 47 | 3 | 32.6 | 41.4 | 24.1 |

When migration is eliminated, as in the case of the 1928 and 1929 experiments, there is a decided decrease in corn borer population when corn is topped, this decrease increasing with an increase in the amount of plant removed. The increase in the number of borers in the topped corn in the 1927 experiment was evidently due to migration of borers into the dryer, topped plants for winter quarters.

Fig. 9.—Topped corn plots.

### Reduction in Corn Borers

The number of corn borers per 100 plants was reduced by the topping practice in the 1928 and 1929 experiments by approximately 11 per cent when tassels only were removed, 31 per cent when the plant was topped between the tassel and the ear, and 68 per cent when all the plant above the ear was removed.

### Effect of Topping on the Corn Plant

While topping reduces the number of borers remaining in the corn plant this practice did not prove desirable. After the corn plants were topped, they stopped growing. Measurements indicated no increase in height of topped corn while the check plots of untopped corn continued to grow for sometime. The corn in the topped plots dried out quicker than that which was not topped and it also suffered a decided decrease in yield. This reduction in yield was very nearly proportionate to the

Fig. 10.—Trap strip on right and main crop on left. The more vigorous corn in the trap strip attracts corn borer moths.

amount of plant removed by topping. When the plants had only tassels removed, there was an average decrease of 8 per cent in yield for the three years, when topped between the tassel and the ear the loss in yield was 13 per cent, and when all the plant above the ear was removed the yield was reduced about 38 per cent. This reduction in yield obviously makes topping impractical as a means of checking corn borer losses.

### An Experiment With Trap Crops

As corn planted early evidently possesses greater attraction for corn borer moths, Professor R. H. Pettit of the Entomology Department of the Michigan State College suggested that experiments be conducted to test the use of an early planted trap strip of corn as a control measure.

In 1928, such experiments were started under a co-operative arrangement with some farmers in Monroe County. Duncan corn was drilled in an eight-rowed strip across the ends of one field, while a similar strip was drilled completely around another, the main crop of corn of the

same variety being planted inside these trap strips about two weeks later. In 1929, the experiment was continued but in all cases the eight-rowed strip which was used as the trap was drilled the full length of either side of the field, thus leaving the ends unobstructed for the planting of the main crop in the center.

**Table No. 18.—Trap tests, 1928. Comparison between number borers per 100 plants and the percentage of infestation in trap strips and in main crop.**

| Crop | Date planted | Variety of corn | No. borers per 100 plants | Percentage infestation |
|---|---|---|---|---|
| | | | | (Per cent) |
| Field No. 1 | | | | |
| Trap crop | May 12, 1928 | Duncan | 68 | 30 |
| Main crop (First planting) | May 28, 1928 | Duncan | 70 | 30 |
| Main crop (Second planting) | June 9, 1928 | Duncan | 5 | 5 |
| Field No. 2 | | | | |
| Trap crop around field | May 8, 1928 | Duncan | 200 | 52 |
| Main crop | May 23, 1928 | Duncan | 40 | 22 |

Results as given in Table No. 18, seem to indicate a possible value of the trap strip of early planted corn when the trap is planted completely around the field, as is the case in Field No. 2. The trap strip carried a much heavier infestation than the main field. Possibly, the main part of the field would have carried an infestation as light as it did, without any trap strip, simply because of the comparatively late planting date. However, the main crop had an infestation of only 40 borers per 100 plants, much lower than some other corn fields in that locality planted on the same date, while the relatively heavy infestation of the trap strip, 200 borers per 100 plants, indicates that it may have attracted a fair portion of the corn borer moths which would ordinarily have deposited their eggs throughout the main crop.

In Field No. 1, where the trap was drilled across the end of the field, no difference in infestation resulted when part of the main crop was planted two weeks later. However, there was a very marked reduction in infestation in the balance of the main crop which was planted four weeks later than the trap. No doubt, this very late planting had

**Table No. 19.—Trap tests, 1929. Comparison of number borers per 100 plants and percentage infestation in trap crop to main crop.**

| Crop | Date planted | Variety of corn | No. borers per 100 plants | Percentage infestation |
|---|---|---|---|---|
| | | | | (Per cent) |
| Field No. 1 | | | | |
| Trap crop | May 27, 1929 | Duncan | 23 | 30 |
| Main crop | June 6, 1929 | Duncan | 12 | 14 |
| Field No. 2 | | | | |
| Trap crop | May 25, 1929 | Common yellow dent | 23 | 5 |
| Main crop | June 10, 1929 | Golden bantam | 2 | 2 |
| Field No. 3 | | | | |
| Trap crop | May 25, 1929 | Argentine flint | 3 | 5 |
| Main crop | June 10, 1929 | Argentine flint | 0 | 0 |

much to do with the light infestation in this part of the field regardless of the trap.

In the fields reported in Table No. 19, covering the 1929 work, many more borers were found in the trap strips than in the main crop of corn in every instance. From these experiences, it seems likely that trap strips of earlier planted corn may find a place as an aid in checking corn borer in case infestation is high enough to make those losses of commercial importance.

### Handling Trap Strips

When trap strips of corn are planted it is advisable to harvest these more heavily infested strips just before maturity and put them in the silo, thereby destroying all the borers contained therein. Cutting the trap corn green and feeding it to livestock would also destroy many of the borers. If the trap strip is not properly disposed of, it might prove a detriment rather than a benefit since the leaving of this strip undestroyed might well increase rather than diminish the number of borers living through the winter and starting a new generation the next season.

### Experiments in Breeding Corn For Borer Resistance

A major project of this station has been the plant breeding work carried on since 1926 in an effort to secure varieties of corn which in some manner might prove resistant, repellant, or distasteful to the corn borer. Varieties of plants which are very resistant and in some instances essentially immune to plant diseases may be numbered among the definite contributions of the science of plant breeding. Nor is the idea entirely fanciful that plant varieties can be developed which are not subject to attack or at least to severe injury by insect enemies.

That other investigators forsee this possibility is indicated by a report by Raubaud,[1] of the Pasteur Institute, Paris, telling of studies in 1927 which indicate seemingly complete immunity of the corn variety Dent de Cheval and partial immunity of the variety Hatif d'Auxonne to infestation by the corn borer.

Hase,[2] of the German Biological Institute of Agriculture, has also noted the practical immunity of the variety Pferdezahn under conditions very favorable to corn borer attack.

The hope of the plant breeding work at this station is to breed a variety of corn which will be resistant, or at least partially resistant, to attack by the European corn borer and at the same time a variety that will be at least as high in yield, as early in maturity, and as desirable in every other respect as our standard Michigan varieties of corn.

In one instance, selections have been made from a large number of inbred strains and crosses of common corn varieties from Michigan, Ohio, Wisconsin, Minnesota, Indiana, and Illinois. This work has included studies of physiological and chemical characteristics of the different strains in an effort to learn possible reasons for any preference which the borer might show. Data were taken on fibro vascular bundle counts, epidermal hardness and thickness, size of the stalk in relation

[1]International Corn Borer Investigations. Scientific Investigations, 1927-28.
[2]International Corn Borer Investigations. Scientific Investigations, Volume II.

to its height, width, and number of leaves, and acidity of the corn plants at various stages of development.

In all of the native corn strains which were tested, there were found no significant differences in infestation which might justify a belief that any of these strains were markedly resistant to corn borer attack.

However, more promising results were secured from work with a South American type of corn called Maize Amargo, seed of which was furnished to this station in 1926 by Dr. D. W. Jones of the Federal corn borer station at Arlington, Massachusetts, upon the suggestion of Dr. D. J. Caffrey of the U. S. Bureau of Entomology.

Fig. 11.—Inbreeding by hand pollinization Duncan x Maize Amargo, 1927.

This variety indicated probable resistance to corn borer attack in trials at the Arlington station but to make sure that this resistance would show itself under Michigan conditions a small cage was placed over one hill of Maize Amargo and 20 to 25 mature corn borers were liberated in this cage. Later, observations were made by Dr. Phillip Luginbill, of the U. S. Bureau of Entomology, then with this station, to see if the borers had established themselves on the plants but he was unable to find a single borer.

In 1927, a large cage was placed over several of the Maize Amargo plants and a large number of corn borer moths were introduced. These moths laid many of their eggs on the cage but only about 150 eggs were

deposited on the Maize Amargo plants and when this corn was mature only one live corn borer could be found. Under similar caged conditions, corn borer moths deposited great numbers of eggs on native corn plants and these plants were completely destroyed.

In 1926, the corn, Maize Amargo, was crossed with three strains commonly used in Michigan, Duncan, Golden Glow, and Red Cob Ensilage. The Maize Amargo, being a very late corn entirely unadapted to the northern part of the United States, presented the difficulty of different pollen and silking dates from those of the Michigan varieties. Other breeders in attempting this cross used Maize Amargo as the female plant and these plants took so long to mature that no viable seed was produced. In making the crosses at this station, Maize Amargo was used as the male parent and a few kernels of crosses with Duncan, Golden Glow and Red Cob Ensilage were secured.

In 1927, this seed was planted. Only two plants of the Duncan, four plants of the Golden Glow, and nine plants of the Red Cob Ensilage crosses with Maize Amargo grew. This being the first generation of the cross and there being such a limited number of plants, most of them were covered with screen cages to protect them from corn borer attack. The plants left unprotected suffered considerable corn borer injury.

In 1928, all of the seed harvested from the 1927 plots was planted and a large number of plants was secured for further studies. This second ($F_2$) generation was planted along with a few rows of each of the parent varieties. Practically all of the $F_2$ plants grew to a normal height. The Michigan parent showed a fairly high infestation but the $F_2$ progenies of the Duncan x Maize Amargo cross and the Maize Amargo itself carried a much lighter infestation. See Table 20.

**Table No. 20.—Percentage of corn borer infestation of Duncan corn, Maize Amargo and Duncan x Maige Amargo $F_2$ hybrids in 1928.**

| Plot number | Variety | Infestation |
|---|---|---|
| | | (Per cent) |
| 1 | Duncan yellow dent | 68 |
| 2 | Maize amargo | 5 |
| 3 | Duncan x Maize amargo $F_2$ | 18 |
| 4 | Duncan x Maize amargo $F_2$ | 8 |

Counts of the infestation, shown in Table 20, are based on the number of plants which were found infested and not infested in each plot.

To continue this work, all of the $F_2$ plants were inbred by hand pollination to be used the following year in growing each family in a

**Table No. 21.—Segregation of resistance and susceptability to corn borer attack showing up in $F_3$ Duncan x Maize Amargo hybrids.**

| Plot number | Variety | Infestation |
|---|---|---|
| | | (Per cent) |
| 90633 | Duncan x Maize amargo $F_3$ | 29 |
| 90634 | Duncan x Maize amargo $F_3$ | 0 |
| 90635 | Duncan x Maize amargo $F_3$ | 26 |

separate row. In the third ($F_3$) generation, such plantings were made, and, on many of these individual plant rows scattered throughout the field, no corn borer infestation was ever found though adjacent rows frequently carried quite a high infestation. Records of infestation in three adjacent plots shown in Table 21 illustrate this condition.

There was nothing about the external appearance of the non-infested rows which in any way offered explanation for their freedom from attack. Some were earlier than adjacent infested rows; others were later. Some were taller; some shorter. All had been planted at the


Fig. 12.—A.—Inbred strains of Duncan x Maize Amargo. Left.—0% infested. Right—29% infested.

B.—Inbred strains of Duncan x Maize Amargo. Left—0% infested. Right—37% infested.

Note: A shows the 0% infested plat higher than the 29% infested, while B shows the 37% infested plat the higher, and the 0% infested plat was the shorter, thus showing that resistance to the corn borer was not influenced by stage of growth or maturity of the corn plants, in these instances.

same time, yet along with the rows of no infestation were some in which 50 per cent of the plants showed evidence of corn borer attack.

One group of Golden Glow x Maize Amargo crosses for some unknown reason never possessed the vigor of the rest of the $F_3$ strains. The stand was not as good, the plants developed slowly and few of them ever attained a height of more than three feet. Possibly because of this lack of vigor there was hardly any infestation in this area. If, because of its abnormalities we may exclude this one group from con-

sideration, the balance of the field of $F_3$ plantings offers an interesting possibility.

The remainder of the $F_3$ inbreds of the Duncan, Golden Glow, and Red Cob Ensilage crosses with Maize Amargo numbered 935 families. Of these 708 families were found to have corn borers present and 227 were without any borers. In the $F_1$ generation, all crosses between Maize Amargo and Michigan corn varieties carried a relatively high

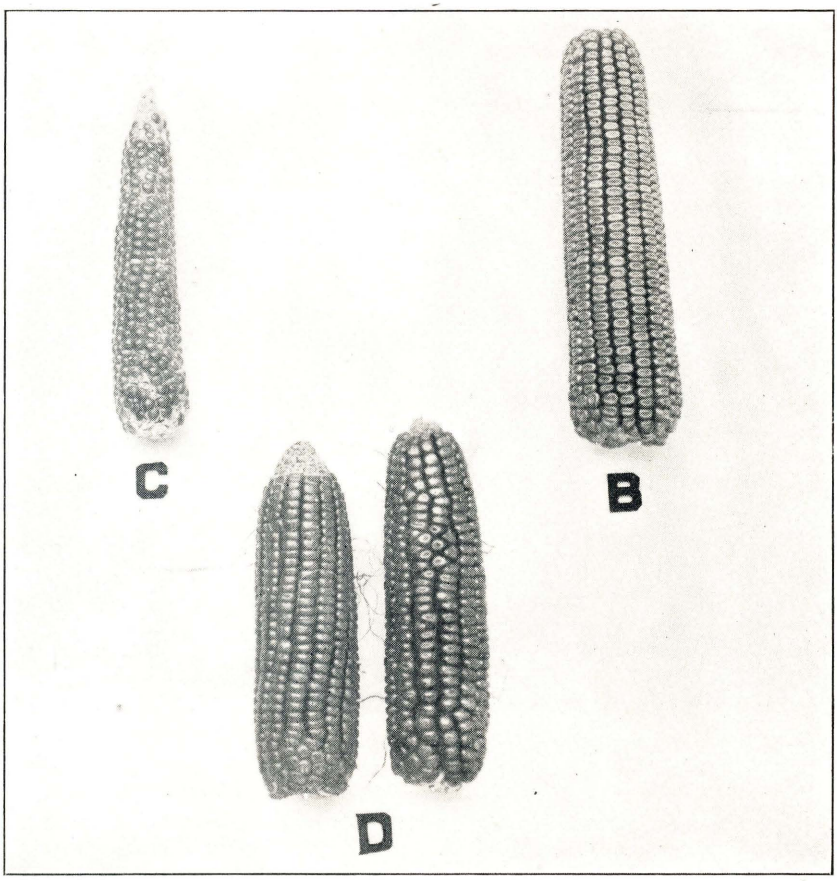


Fig. 13.—C—Maize Amargo, B—Golden Glow, D—Golden Glow x Maize Amargo.

infestation, it being approximately the same as that found in the native Michigan varieties. In the $F_2$ generation, a lighter infestation was found in the crosses (See Table 20) than in the Michigan parents but since these strains were not on a row basis and since even the Michigan corns did not have 100 per cent infestation it was impossible to distinguish between plants which were resistant to borer attack and those which carried no infestation merely through chance.

However, in the $F_3$ generation, plantings were on a plant-row basis

and it is unlikely that entire rows would be uninfested from chance when adjacent rows were attacked. It will be noted that 708 families infested to 227 not infested is a ratio of 3.1 :1. Though further work is necessary the evidence accumulated thus far indicates that the resistance of Maize Amargo to attack by the European Corn Borer is a simple genetic character recessive to that characteristic of standard

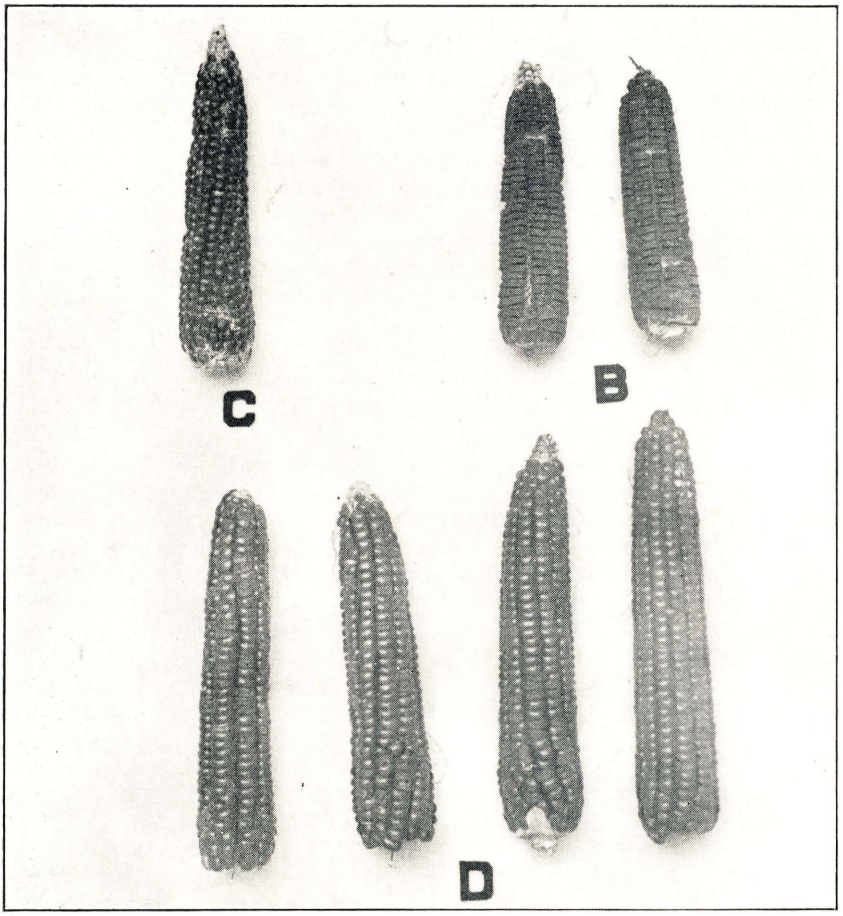


Fig. 14.—C—Maize Amargo, B—Golden Bantam Sweet Corn, D—Golden Bantam x Maize Amargo.

Michigan varieties of corn which makes them susceptible to attack. What this character may be furnishes a very interesting problem for further studies. The material resulting from the 1926 crosses will not only be used in such studies but it will also be used in an attempt to produce a strain of corn resistant to borer attack and carrying characteristics of quality and productivity in order that it may be grown profitably in corn borer infested areas.

Since 1926, successful crosses have been made between Maize Amargo and several other varieties of corn and these are being carried along in the same manner as described previously. One of the crosses of interest was that made in 1928 between Maize Amargo and Golden Bantam sweet corn. In 1929, the $F_1$ of this cross grew to an average height of about eight feet, had very few suckers and showed a definite segregation on the ear of a 3:1 ratio of flint and sweet corn kernels, proof that the cross was successful. Maize Amargo crosses have been made with eight-rowed flint and Northwestern Dent, which are earlier types of corn adapted to Northern Michigan, and also with Michigan Hulless pop corn. The cross pop corns produced nine kernels as a foundation for future work.

While the breeding work described herewith has been significant, it will undoubtedly take many years to prove or disprove the practicability of developing a type of corn resistant or immune to European corn borer injury. However, the results, thus far, have been so promising that corn breeding will be a major project at this station in the future and it is hoped that this work will result in types of corn which can be grown profitably in infested areas despite the European corn borer.

## SUMMARY OF AGRONOMIC INVESTIGATIONS

Though infestation of corn by the European corn borer is materially reduced by late planting, this practice is not recommended as a control measure under present conditions of infestation in Michigan. Planting May 12th to May 25th at the Monroe substation has given the highest yield of mature corn regardless of infestation. Planting in June has greatly reduced the borer infestation but has resulted in poor yields and immature corn. The infestation has been noticeably lighter in the case of May 25th plantings than in the case of those plots planted April 28th or May 12th.

The heavier corn borer infestation found in early planted corn is apparently due to the greater attraction which the taller and more vigorous corn possesses for corn borer moths, since more eggs are deposited and more borers are found on corn of this character.

The planting of a variety that will mature in good season and the harvesting of the crop as soon as it is mature avoids some of the loss caused by breakage of the stalks due to the work of the borer. Harvest before such breakage occurs greatly adds to the convenience of handling the crop.

Cutting of the corn crop as close to the ground as possible left fewer borers remaining in the field to be destroyed by subsequent operations.

In trials supervised by the Agricultural Engineering section of the Michigan Experiment Station conducted at Monroe, the husker-shredder was able to destroy 99 per cent of all corn borers in the corn fodder put through the machine. When the ensilage cutter was adjusted so that the fodder was cut less than one inch in length, all corn borers were killed. When corn was passed through a roughage mill, it was so finely ground that not even small portions of corn borers could be found.

Topping corn shortly after pollinization had taken place reduced the number of borers remaining in the standing corn but so greatly reduced the yield of the corn that this cannot be considered a practical means of lowering corn borer losses.

The planting of a trap strip of corn considerably earlier than the main field offers promise as a means of reducing corn borer losses. The trap strips of early planted corn attract the corn borer moths and carry the heavier infestation. Such strips may be harvested early for silage, in which case practically all of the borers carried from the field in the corn will be destroyed. In the experiments conducted thus far, the later planted corn in the main body of the field has carried a much lighter infestation than the trap strips. Part of the reduction in infestation may be due to the later planting, regardless of the traps, but there is some evidence to indicate that fields having trap strips carried a lighter infestation than other fields in the same locality planted at the same date without trap strips.

Maize Amargo, a very late maturing South American corn, has thus far proved markedly resistant to borer attacks. Maize Amargo has been crossed successfully at this station with several strains of Michigan corn. The earliest crosses were in the third generation in the season of 1929 and selfed strains of these crosses segregated in the proportion of 3.1 susceptible strains to one resistant. The continuation of the work in breeding corn in an endeavor to secure varieties of merit which are resistant to borer attacks will be the major project at this station in the immediate future.

## ACKNOWLEDGMENTS

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All of the entomological data given in the foregoing reports were obtained under the direction of Mr. C. B. Dibble of the Entomological Section of the Michigan Experiment Station except for the season of 1926 when such data were obtained by Dr. Phillip Luginbill, Bureau of Entomology, United States Department of Agriculture. Valuable suggestions in planning and conducting the work have been received from Dr. D. J. Caffrey of the Bureau of Entomology, United States Department of Agriculture. Professor H. H. Musselman, Agricultural Engineering Section of the Michigan Experiment Station, directed the machinery trials. Appreciation is expressed to these men for their co-operation and assistance.

# ENTOMOLOGICAL INVESTIGATIONS

## At The Michigan State College Corn Borer Experiment Station 1927-1929

C. B. Dibble

In order to determine the number of borers that may escape after having been buried by plowing to a depth of six to eight inches, large cages open at the bottom, were placed over quantities of corn refuse which had been plowed under in infested farm corn fields. These cages measured four feet by eight feet and were eleven inches high. They were made of boards with the top closed in with 12-mesh wire screen. In 1927, 30 such trap cages were used. Sets of five cages were placed on six different sites just before the time for the larvae to pupate. The cages were examined at one or two day intervals dur-

Fig. 15.—Cleanly plowing under all corn refuse is an effective corn borer control measure.

ing the period of moth flight, from July 1st to August 1st inclusive. During this test, no moths were found to have emerged in the trap cages.

In 1928, the experiment was repeated, using 20 trap cages, which were arranged on two sites in two series of 10 traps each. From these cages, three adult moths were taken July 10th from traps located on the Edward Vogel farm.

Immediately following the period of moth flight, the refuse which had previously been plowed down was exhumed and carefully gone over. No evidence of corn borer life was detected.

### Number of Borers Escaping From Buried Material

In 1928, two groups of five traps each were placed over corn stalks containing a known number of larvae which had been buried with the

plow in furrows eight inches deep. Five traps were used over fall plowed material and five over spring plowed material.

Twelve stalks were placed beneath each trap and each stalk contained two borers. There were 24 borers beneath each trap. These traps were fitted with oilcloth barriers around their tops, and corrugated paper strips were used to provide the larvae a place to hide. The traps were visited daily and the corrugated paper strips were examined. The fall plowed material was placed in the ground on November 15th and the spring plowing was done April 19th. In the case of the material buried in the fall, 11 borers were recovered. The material buried in the spring yielded 47 borers; or respectively 9.1 per cent and 39.1 per cent of the total number of larvae buried.

Following the period of the flight of the moths, the stalk refuse which had been buried, was exhumed and dissected for possible borer remains. None were found.

### Borers Escaping From Stalks Buried at Known Depths

As a further study and in order to obtain evidence on the efficiency of plowing at various depths, the following experiments were conducted. Four pieces of stalk were selected for each trial and each piece contained five borers. These pieces of stalks were buried at five different depths, 4 inches, 6 inches, 8 inches, 12 inches, and 16 inches; and, in addition, 20 borers were placed on the surface of the soil in a separate cage to serve as a check. A trap or cage was placed over each separate lot of 20 borers. The traps measured four feet by four feet in area and were 11 inches high. These board frames were set into the soil about 2 inches and the top was fitted with an oilcloth barrier four inches wide. The recoveries of the larvae were made in corrugated paper strips placed on the soil surface, the borers being removed from the corrugated paper strips daily.

The following table records the recoveries of larvae both in actual numbers and in percentages, for the season of 1928.

**Recoveries from material buried in spring of 1928.**

| Depth buried | Larvae recovered | Per cent recovered |
|---|---|---|
| 4 inches | 4 | 20 |
| 6 inches | 6 | 30 |
| 8 inches | 6 | 30 |
| 12 inches | 2 | 10 |
| 16 inches | 8 | 40 |
| Check (Surface) | 18 | 90 |

The cages failed to capture any adult moths. After the period of moth flight, the material was exhumed and dissected. No borer remains were found.

Late in the fall of 1928 similar burials were made for recovery counts to be made during the spring of 1929. No larvae were recovered from these burials.

Following the plan outlined, spring burials were made in 1929 and in this case temperature records were kept throughout the period of

observation. A summary of the data taken is given below in tabular form.

**Recoveries from Material buried in spring of 1929.**

| Depth buried | Larvae recovered | Per cent recovered | Average Temp. |
|---|---|---|---|
| | | | (Degrees) |
| 4 inches | 1 | 5 | 19.1 |
| 6 inches | 1 | 5 | 18.4 |
| 8 inches | 4 | 20 | 18.7 |
| 12 inches | 3 | 15 | 18.2 |
| 16 inches | 0 | — | 18.4 |
| Check surface | No borers | ..... | 20.7 |

Fig. 16.—The work of the European corn borer at its worst.

## SUMMARY

Apparently very few moths emerged from plowed fields where no refuse was left on the surface. Many borers leave the soil to hide in debris before pupation takes place. Some larvae are able to reach the surface from a considerable depth, at least 16 inches. Many borers perish in the soil and never reach the surface. Fall plowing seems to be more effective than spring plowing.

## SEASONAL DEVELOPMENT

The following calendar records the principal events in the development of the corn borer in Monroe County, Michigan, for the seasons of 1927, 1928, and 1929.

**Record of development of corn borer**

| Date | Observations, 1927 | Observations, 1928 | Observations, 1929 |
|---|---|---|---|
| May 2 | | Larvae observed on the soil in a plowed field. | |
| May 4 | | Larvae observed as previously. | |
| June 1 | | | Larvae observed on the soil of a recently plowed field. |
| June 3 | | | First pupae. Outside. |
| June 14 | | Pupae. First outside | |
| June 16 | Pupae and larvae collected in Ontario. | | |
| June 19 | | | Adults. First outside. |
| June 21 | Pupation 75% at Monroe | | |
| June 24 | | | Eggs. First outside. |
| June 28 | Moths taken at lights at Station. | | |
| June 29 | Moths at lights | | |
| June 30 | Moths at lights | Adults emerge | |
| July 1 | Eggs. First found | | Moths abundant. |
| July 2 | | Moths abundant. Eggs. First outside. | |
| July 5 | | | Moth flight near peak. |
| July 7 | Larvae. Newly hatched | Moth flight near peak. Eggs abundant. | |
| July 8 | Eggs abundant | | Peak of flight probably previous to now. |
| July 11 | | Eggs less numerous. Many hatching. | |
| July 14 | Eggs less abundant. Many hatched. | | |
| July 16 | | Egg masses scarce | |
| July 24 | | | Last moths in cages. |
| July 25 | | | Last eggs observed in the egg plats. |
| July 29 | Some eggs remain | | |
| July 30 | | Moth flight ended | |
| Aug. 2 | No eggs left | | |
| Aug. 11 | | Larvae growing rapidly. Many full grown. | Preliminary counts in farm fields indicate the presence of the borer in larger numbers than usual. |
| Aug. 13 | Borer work quite noticeable | | |

Young larvae often drop and hang suspended by silken threads either before entering the stalk or after having eaten their way out from inside the stalk. Some redistribution may take place at this time, due to the effects of wind or to the larvae attaching themselves to passing animals.

It often happens that young larvae work into the developing tassel before it appears in the open. Such mutilated tassels, on completing their growth, often break over soon after appearing. This accounts, in part, for the breakage of tassels early in the season.

For winter quarters, the borers seem to favor dry stalks rather than the juicy stalks of immature plants. They search out dry stems with soft pith in which to spend the winter. This tendency is shown only after the feeding period is finished. For food, larvae prefer juicy plants and linger in such green, juicy plants until time for seeking winter quarters.

## Deposition of Eggs

Throughout the period of egg deposition, counts were made on the number of egg masses deposited on plants in representative plats. Counts were also made of the number of eggs in a mass.

In 1927, six varieties of corn were selected for this purpose, Duncan Yellow Dent, Clements White Cap Yellow Dent, Crosby Sweet corn, Michigan Hulless Popcorn, and King Phillip Flint. Observations were made and egg masses counted at six day intervals. The egg masses found in each count and the number of eggs in each mass was recorded and the location on the plant marked with a ticket punch. Following is a tabular record of these counts.

**Tabular record of egg counts, 1927.**

| Variety | Plat No. | Egg Masses Found on All Plants | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Row 1A April 28 | Row 2A May 12 | Row 3A May 26 | Row 4A June 9 | Row 1B April 28 | Row 2B May 12 | Row 3B May 26 | Row 4B June 9 |
| Duncan | 2700 | 10 | 21 | 2 | 4 | 16 | 3 | 5 | 0 |
| Clements White Cap | 2703 | 23 | 99 | 2 | 0 | 20 | 8 | 1 | 4 |
| Golden Glow | 2707 | 9 | 11 | 7 | 1 | 29 | 9 | 5 | 2 |
| King Phillip | 2714 | 20 | 10 | 7 | 0 | 9 | 9 | 5 | 0 |
| Michigan Hulless Popcorn | 2715 | ..... | 2 | 4 | 0 | 8 | 9 | 1 | 0 |
| Crosby Sweet | 2718 | 15 | 5 | 1 | 2 | 19 | 6 | 1 | 0 |

It would seem that the moths prefer the plants which are most advanced in growth for egg deposition.

Such plants in the two earlier plantings generally receive the greatest number of egg masses.

## Egg Counts in 1928 and 1929

In 1928 and in 1929, egg counts were made on separate plats. Three row plats with two guard rows on either side were used. Unplanted rows were left between the several groups of the series. In 1928, the first eggs were found on these plats on July 2 and the last ones on

July 23. In 1929, the first eggs were found on June 26 and the last on July 25. A tabular record of these counts follows.

**Tabular record of egg counts, 1928.**

| Row | Group 1 | | | Group 2 | | | Group 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. Masses | No. Plants | No. Eggs | No. Masses | No. Plants | No. Eggs | No. Masses | No. Plants | No. Eggs |
| 1 | 2 | 28 | 18 | 2 | 28 | 21 | 7 | 32 | 97 |
| 2 | 3 | 31 | 35 | 9 | 33 | 121 | 6 | 30 | 68 |
| 3 | 5 | 30 | 65 | 3 | 28 | 47 | 8 | 29 | 109 |
| Total | 10 | 89 | 118 | 14 | 89 | 189 | 21 | 91 | 274 |

**Analysis of 1928 egg count record.**

| Group | No. Plants | No. Masses | No. Eggs | No. Masses per Plant | No. Eggs per Plant |
|---|---|---|---|---|---|
| 1 | 89 | 10 | 118 | .11 | 1.32 |
| 2 | 89 | 14 | 189 | .16 | 2.12 |
| 3 | 91 | 21 | 274 | .23 | 3.01 |
| Average | | | | .16 | 2.15 |

**Tabular record of egg counts, 1929.**

| Row | Group 1 | | | Group 2 | | | Group 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. Masses | No. Plants | No. Eggs | No. Masses | No. Plants | No. Eggs | No. Masses | No. Plants | No. Eggs |
| 1 | 6 | 25 | 119 | 10 | 26 | 149 | 2 | 29 | 33 |
| 2 | 6 | 25 | 109 | 3 | 23 | 35 | 0 | 17 | 0 |
| 3 | 3 | 26 | 45 | 2 | 26 | 32 | 5 | 26 | 54 |
| Totals | 15 | 76 | 273 | 15 | 75 | 216 | 7 | 71 | 87 |

**Analysis of 1929 egg count record.**

| Group | No. Masses | No. Plants | No. Eggs | No. Masses per Plant | No. Eggs per Plant |
|---|---|---|---|---|---|
| 1 | 15 | 76 | 273 | .2 | 3.6 |
| 2 | 15 | 75 | 216 | .2 | 2.9 |
| 3 | 7 | 71 | 87 | .1 | 1.2 |
| Average | | | | .16 | 2.5 |

in the field during the summer of 1929 but beetles caged with egg masses were seen to feed freely on such masses.

### Relative Attractiveness of Corn Plants at Various Stages

In view of the extreme sensitiveness of insects to odors, attempts were made to determine the relative attractiveness of plants of different sizes and varieties preferred by the moths as places on which to lay their eggs. In carrying on this inquiry, use was made of a series of chambers, known as olfactometers, so arranged as to give the moths a choice between the two samples to be compared.

This apparatus consists of three darkened chambers connected by a Y-shaped piece of two and one-half inch tubing. One chamber was attached to the stem of the Y and moths were placed in this chamber during the egg-laying season. Each fork of the Y connected with a separate chamber and in these were placed samples of corn plants to be compared. It will readily be seen that moths placed in the first chamber which contained no plant material, would be attracted to one or the other of the chambers which contained samples of corn. In order to cause the odors from the two samples to be carried into the reception chamber, a faint current of air was maintained from the two chambers containing the samples of plant material into the one in which the moths had been placed.

During the season of 1927, it was possible to carry on a few experiments which clearly demonstrated the fact that samples of the more mature corn plants were more attractive than those of smaller size, also, it was found that unmutilated plants were more attractive than those that had been chopped up into fine pieces. During 1928, trials of the attractiveness of corn plants of varying size were made. Samples 2 inches in height and those of 8 inches, 24 inches, 36 inches, and 48 inches, respectively, were compared one with another and samples of the common mugwort, **Artemesia vulgaris,** were included. As a result of these tests, the greatest attractiveness was found in corn from 24 inches to 36 inches in height. No preference was shown for the mugwort, although a very few moths did enter the mugwort chamber. This preference for corn about 24 inches to 36 inches high corresponds very closely to the relative attractiveness of various sizes of corn as observed in the field. In other words, plants ranging from 24 inches to 36 inches high seemed to have reached a stage of development which was selected in preference to that of a smaller or of a greater size.

### Migration of Borer Larvae and Moth Emergence from Shocked Corn

In October, 1927, a recovery trap was arranged to capture any migrating borers that might attempt to leave a single shock of corn. The square trap measured four feet on the side and was eleven inches high. It was fitted with an oilcloth barrier tacked around the top edge of the frame, and corrugated paper strips were tacked inside the frame to furnish retreats for such larvae as might leave. The shock consisted of 50 stalks and contained approximately 100 borers.

On November 19th, one borer was removed from the recovery trap.

**Percentage of borer larvae surviving, 1927 data.**

| Plat No. | Planting | No. of Masses | No. of Eggs (Apx) | No. of Stalks | Population | No. of Borers | Survival Per cent | Mortality Per cent |
|---|---|---|---|---|---|---|---|---|
| 2700 A—Duncan Check. | 1 | 10 | 135 | 53 | .6 | 32 | 23 | 77 |
| | 2 | 21 | 284 | ..... | 1.28 | 68 | 24 | 76 |
| | 3 | 2 | 27 | ..... | .00 | 0 | 0 | 100 |
| | 4 | 4 | 54 | ..... | .08 | 4 | 16 | 84 |
| 2704 B—Duncan Check. | 1 | 16 | 216 | 53 | 1.25 | 66 | 30 | 70 |
| | 2 | 3 | 41 | ..... | .76 | 40 | 98 | 2 |
| | 3 | 5 | 68 | ..... | .16 | 9 | 13 | 87 |
| | 4 | 0 | 0 | ..... | .0 | 0 | — | — |
| 2703 A—Clements White Cap..... | 1 | 23 | 310 | 54 | 2.04 | 110 | 35 | 65 |
| | 2 | 9 | 122 | ..... | 2.54 | 138 | 113 | −13 |
| | 3 | 2 | 27 | ..... | .08 | 4 | 16 | 84 |
| | 4 | 0 | 0 | ..... | .0 | 0 | — | — |
| 2703 B—Clements White Cap..... | 1 | 20 | 170 | 54 | 1.80 | 97 | 57 | 43 |
| | 2 | 8 | 108 | ..... | .64 | 35 | 22 | 88 |
| | 3 | 1 | 14 | ..... | .28 | 15 | 108 | −8 |
| | 4 | 2 | 27 | ..... | .00 | 0 | 0 | 100 |
| 2707 A—Golden Glow.. | 1 | 9 | 122 | 53 | 1.36 | 72 | 59 | 41 |
| | 2 | 11 | 149 | ..... | .48 | 25 | 17 | 83 |
| | 3 | 2 | 27 | ..... | .28 | 15 | 55 | 45 |
| | 4 | 1 | 14 | ..... | .12 | 6 | 35 | 65 |
| 2707 B—Golden Glow.. | 1 | 29 | 392 | 53 | 2.50 | 133 | 34 | 66 |
| | 2 | 9 | 122 | ..... | .92 | 49 | 39 | 61 |
| | 3 | 5 | 68 | ..... | .28 | 15 | 32 | 88 |
| | 4 | 0 | 27 | ..... | .04 | 2 | 8 | 92 |

The Mean Average Survival According to this Table is — 34.4%

**Percentage of borer larvae surviving, 1928 data.**

| Group | Row | No. Plants | No. Eggs | No. Larvae | Mortality Per cent | Survival Per cent |
|---|---|---|---|---|---|---|
| 1..... | 1 | 28 | 18 | 4 | ..... | 22 |
| | 2 | 31 | 35 | 19 | ..... | 54 |
| | 3 | 30 | 65 | 29 | ..... | 45 |
| 2..... | 1 | 28 | 21 | 13 | ..... | 62 |
| | 2 | 33 | 121 | 33 | ..... | 27 |
| | 3 | 28 | 47 | 22 | ..... | 47 |
| 3..... | 1 | 32 | 97 | 27 | ..... | 28 |
| | 2 | 30 | 68 | 29 | ..... | 43 |
| | 3 | 29 | 109 | 34 | ..... | 31 |
| Totals..... | ..... | 269 | 581 | 210 | ..... | ..... |
| Average..... | ..... | ..... | 64.5 | 23.3 | 64 | 36 |

**Survival of larvae, 1929 data.**

| Group | Row | No. Plants | No. Eggs | No. Larvae | Mortality Per cent | Survival Per cent |
|---|---|---|---|---|---|---|
| A | 1 | 25 | 119 | 16 | ..... | 13.4 |
| | 2 | 26 | 149 | 11 | ..... | 8 |
| | 3 | 29 | 33 | 10 | ..... | 30 |
| B | 1 | 25 | 109 | 8 | ..... | 7 |
| | 2 | 23 | 35 | 5 | ..... | 14 |
| | 3 | 17 | 0 | 0 | ..... | — |
| C | 1 | 26 | 45 | 2 | ..... | 4 |
| | 2 | 26 | 32 | 9 | ..... | 28 |
| | 3 | 26 | 54 | 6 | ..... | 11 |
| Total | | 233 Plants | 574 Eggs | 67 Larvae | ..... | ..... |
| Average | | ..... | ..... | ..... | 88 | 12 |

To summarize these data briefly, we find that in 1927 an average survival of 34.4 per cent prevailed. In 1928 the average survival was 36.0 per cent and in 1929, 12.0 per cent. This sharp drop in the number of individuals surviving through the season, may possibly be accounted for by the presence of a ladybird, **Megilla maculata,** which was very plentiful during 1929 and which was seen to feed on the eggs freely.

## Miscellaneous Host Plant Record

During 1927, a variety of plants that might possibly serve as host plants for the corn borer were kept under observation. A list of the plants under observation during 1927 is given. Those starred were the only ones in which corn borers established themselves. Some of the others showed slight leaf injury just after the time of hatching but subsequent dissections of the plants failed to reveal the borers:

Early Amber Cane*
Feterita*
Kaffir Corn*
Milo Maize*
Western Hulless Kaffir
Pink Kaffir
Sunflower
Artichoke
Cotton
Cowpeas
Peanuts
Cabbage
Carrots
Cucumbers
String Beans
Peas
Tomatoes
Beets
Potatoes
Field Beans

## Host Plant Observations in 1928

During the season of 1928, a total of 60 different species and varieties of plants were under observation. Some were placed under screened cages into which moths were introduced in order to force, if possible, the larvae to attack these plants. Their egg deposition, larval establishment, and total population were observed on both the caged plants and on those grown in the open. The plants under observation are listed.

## Miscellaneous Plant Records for 1928

### Ornamentals

Sunflower
Stocks
Dahlia* Eoc, Boc
Zinnia* Eoc, Boc
Marigold* Eoc, Boc
Aster* Eoc, Boc
Tulip
Carnation
Pink * Ec, Bc
Galliardia
Poppies, Garden
Rose of Heaven
Gladiolus* Eco, Boc
Sweet Pea
Canna
Salvia
Dusty Miller, Artemesia
Nasturtium
Pansy

### Farm Crops

Cow-peas
Soybeans*
Peanuts*
Oats*
Barley*
Buckwheat*
Rye*
Potatoes*
Beans, Robust*
Sugar Beets*
Cotton*
Chicory*
Kaffir Corn
Millet, Wh. Wonder
Sudan Grass
Sorghum
Mangels
Rape
Millet, Japanese
Alfalfa*
Sweet Clover* Ec

### Garden Crops

Artichokes, Jerusalem* Ec
Turnips*
Red Beets
Tomatoes*
Celery* Ec
Onions*
Cabbage* Ec
Cauliflower
Beans, String* Ec
Carrots
Cucumbers
Watermelon
Muskmelon
Radish
Swiss Chard
Lettuce

Key—

*—Cage used
E—Eggs
B—Larvae
o—Not under cage
c—Under cage

In 1929, the list was reduced somewhat and no caged material was used. The following list indicates the plants under observation in 1929. No borer work was found during the growing season, and none was found in the final inspection on November 22. This material was all planted very late, due to adverse weather, and was quite small at the time the moth flight occurred.

### Plants Observed in 1929

Cosmos
Zinnia
Marigold
Dahlia
Amber Cane
Sunflower
Kaffir Corn
Feterita
Sudan Grass
Millet, Common
Millet, German
Millet, Wh. Wonder
Cotton
Artichoke, Jerusalem
Soybeans
Cow-peas
Long Beets
Mangels
Rape
Carrot
Wax-bean
Tomato
Potato

### A Comparison Between Corn and Mugwort as Host Plants For the Corn Borer

The fact that in France the common mugwort, **Artemesia vulgaris,** is said to be very attractive to the corn borer led us, during 1928 and 1929, to grow mugwort and corn in close proximity to each other in order to determine the relative attractiveness of the two plants as host plants for the corn borer. The mugwort seed was obtained in Canada* and the corn used was Duncan, a standard Michigan variety. The mugwort was grown in a row with a row of corn on each side. Part of the series of three rows was covered by two screened cages and moths were introduced into these to supply an abundance of borers. Following, in tabular form, are the data taken in 1928. No eggs were found on the mugwort, and the borers which were found very likely migrated from the corn plants. This behavior is not indicative of any particular preference on the part of the borer for mugwort, since the same thing often happens in corn fields where rank weed growth is to be found.

**Corn borer attack on Mugwort compared to that on corn, 1928 data. Natural conditions.**

| | No. of Plants | No. of Eggs | No. of Borers | No. of points of attact |
|---|---|---|---|---|
| Corn | 80 | 50 | 23 | 17 |
| Mugwort | 37 Stems | 0 | 3 | 3 |
| | Caged Material | | (Moths Introduced) | |
| Cage No. 1 | | | | |
| Corn | 14 | 184 | 24 | 48 |
| Mugwort | 22 Stems | 0 | 6 | 14 |
| Cage No. 2 | | | | |
| Corn | 14 | 60 | 22 | 24 |
| Mugwort | 12 Stems | 0 | 23 | 23 |

*The mugwort seed was furnished by the Botany Department, Central Experimental Farm, Ottawa, Ontario, Canada.

## Corn and Mugwort Compared as Hosts For the Corn Borer During 1929

During 1929 the corn made a very poor growth and was considerably outgrown by the mugwort both beneath the cages and in the open. During this season the plants not caged showed no evidence of borer work either in the corn plants or in the mugwort. Late in the fall, 43 stems of mugwort which had been grown in the open, were dissected and no borers found.

In the case of mugwort and corn grown side by side inside of a cage, 10 female and five male moths were introduced at the time of flight. The following table gives the results of this test.

**Data 1929**

| | No. of Plants | No. of points of injury | No. of Borers |
|---|---|---|---|
| Corn (very small) | 6 Stems | 0 | 0 |
| Mugwort (**A. vulgaris**) (Rank growth) | 31 Stems | 3 | 3 |

This experiment indicates, first, that the corn borer prefers corn to common mugwort as a host plant under Michigan conditions; second, that corn in the presence of mugwort is not protected by the latter from corn borer attack; and third, that a migration of the corn borer from corn to mugwort is possible after the eggs have been deposited on the corn but this migration does not necessarily indicate a preference on the part of the corn borer for common mugwort as a host.

Fig. 17.—Mugwort plants *(Artemesia vulgaris)*.

## Farm Field Infestation Survey for 1929

A survey of fields and infestation counts over a limited part of the state, was made in 1929. Owners of fields were interviewed in each case and infestation counts were made in each field. In selecting fields for examination, the attempt was made to make use of the more heavily infested fields in each locality. The counties visited were Monroe, Lenawee, Hillsdale, Washtenaw, Wayne, Macomb, St. Clair, and Sanilac. Counts were made in fields in all of these counties except Sanilac. The accompanying table gives the names of the farms visited in each county, with the borer population in each field as determined by the counts.

During this survey, the most heavily infested field visited and that most severely damaged was on the Weeman farm in Monroe county. In this field, 99.9 per cent of the plants showed borer work, with an average of 11 borers to a plant. No count of breakage was taken in this particular field because the corn was cut before such a count could be taken. It is believed that this field carried more borers per acre than any other field found in the state at this time.

In general, the infestations were much higher, in Monroe county at least, than ever before, the earlier planted corn suffering severely throughout the county. In Lenawee county, some fields were found where severe losses occurred. The eastern and southern parts of the county showed a considerable increase in borer population over that of previous years. In Hillsdale county, farm owners noticed an increase in the amount of corn borer work over that of previous seasons, although the county seems to be just outside of the area in which notable commercial loss has occurred. Some fields in Wayne county carried high infestations, and in Macomb county there was an increase in the number of borers, although the infestation did not appear to be so serious as in the other counties mentioned. Apparently a decrease has taken place in the borer population in St. Clair and Sanilac counties.

In these counties, considerable sweet corn is grown for canning purposes and the officials at the canneries are convinced that the number of infested ears received, up to the time of this survey, was very much smaller than in the past.

Farmers throughout the area covered by this survey are, with very few exceptions, anxious to practice control measures for the handling of corn borer. They are convinced that clean cultural practice and careful plowing will control the borer or at least aid materially in doing so. Wherever large increases of infestation have occurred, it was in districts where corn stalk residues were carelessly disposed of before the time of moth flight. To summarize, it would appear that Monroe, Lenawee, and Wayne counties have suffered increases in corn borer attack up to the point of commercial damage. Hillsdale, Macomb, and Washtenaw counties have noticeable increases in their corn borer population but have experienced only slight losses. Sanilac and St. Clair counties apparently show decreases in the corn borer population.

Following is a list of farms visited in the course of making this survey, together with the per cent of infestation, the borer population per plant, and in some cases the breakage of stalks given in percentage.

## Farm Survey of Borer Infestation

| Field | Address | Infestation Per cent | Borer Population | Breakage Per cent |
|---|---|---|---|---|
| Monroe County | | | | |
| Curtis Drillard | Erie | 100 | 6.15 | |
| A. Weeman | Monroe | 99.9 | 11 | |
| W. F. Carter | Monroe | 99.9 | 7.22 | 81 |
| G. A. Custer | Monroe | 99 | 4.5 | |
| Martin Miller | Monroe | 98 | 7.6 | 77 |
| A. Kipf | Monroe | 98 | 4.6 | |
| Ben Cousino | Newport | 97 | 4.7 | |
| Bert Rathke | Monroe | 97 | 4.2 | |
| Joe Coutcher | Monroe | 97 | 4 | |
| R. R. Kirtland | Erie | 96.8 | 4.68 | 48 |
| W. Krauss | Monroe Co. Farm | 96.3 | 5.6 | |
| J. W. Hobbs | Flat Rock | 96.5 | 4.3 | |
| Chas. Baker | Monroe | 96.2 | 5.3 | |
| Wm. Kipf | Monroe | 96 | 6.4 | |
| Wm. Fox | Newport | 96 | 5.0 | |
| Geo. Happy | Monroe | 96 | 3.8 | 61 |
| John Outher | Newport | 95.2 | 2.4 | |
| James Kelley | Carlton | 93 | N.T. | |
| Earl Stowell | Dundee | 92.2 | 5.2 | 45 |
| M. Huffman | Newport | 92 | 4.3 | |
| Geo. Hoppert | Newport | 92 | 4.2 | |
| Irving Knapp | Monroe | 90 | 2.4 | |
| J. D. Ladian | Flat Rock | 89 | 3.1 | |
| Peter Ganallis | Monroe | 86.8 | 3.26 | 40 |
| Geo. J. Godfried | Monroe | 86.6 | 1.92 | |
| Everett Vanriper | Ida | 85.4 | 3.5 | 35.8 |
| Gordon Wagar | Carlton | 83.9 | 2.8 | |
| Bert Knapp | Monroe | 83.8 | 2.34 | 28 |
| Ed. Vogel | Monroe | 83.3 | 2.0 | |
| Joe Morrin | Erie | 83 | 3.2 | |
| Paul Clement | Britton | 71.6 | 1.5 | 2.8 |
| H. T. Stinley | Monroe | 70 | 1.9 | |
| Ben Dusseau | Monroe | 54 | 1.36 | .09 |
| Miller Farms | Monroe | 47 | 1.00 | |
| Lenawee County | | | | |
| Geo. Brablic | Britton | 95.4 | 2.7 | 53.7 |
| Si. Sheldron | Blissfield | 94 | N.T. | 40 |
| Earnest Gricmohm | Riga | 45.6 | .98 | 3.4 |
| Hillsdale County | | | | |
| Roscoe Masters | Waldron | 50.2 | .78 | 9.8 |
| Earnest Gilbert | Waldron | 47.2 | 1.5 | 5.8 |
| I. K. Maystead | Osseo | 5.2 | .22 | 1.6 |
| Wayne County | | | | |
| W. M. Bristow | Flat Rock | 96.8 | | |
| J. M. Sweglis | Plymouth | 39.6 | .8 | 6.8 |
| E. F. Truesdale | Wayne | 35.8 | 2.6 | 11.2 |
| Grennan Farms | Northville | 7.6 | .12 | 2.0 |
| Washtenaw County | | | | |
| Louis Scherdt | Saline | 31 | .35 | 4 |
| A. J. Lutz | Saline | 29 | 5.6 | 68 |
| Clarence Feldknap | Saline | 13.6 | .3 | 2.4 |
| Macomb County | | | | |
| John Ganfield | Richmond | 75. | | 16. |
| John Gamm | Armada | 33.8 | 1.26 | 11.4 |
| Roy Weeks | Richmond | 32.6 | 1.22 | 10.2 |
| Henry Gamm | Romeo | 21.8 | 1.16 | 9.6 |
| C. A. Denison | Romeo | 20.8 | .52 | 6.4 |
| Alice Kling | Mt. Clemens | 20.6 | .42 | 38. |
| St. Clair County | | | | |
| Joe Dietlin | Marine City | 56.4 | 1.55 | 17 |
| Joe Dietlin | Marine City | 34.8 | .62 | 7. |
| T. J. Theison | St. Clair | 27.2 | .92 | 7.4 |
| Frank Loyle | St. Clair | 24.8 | .72 | 5.6 |
| | | 24.4 | .26 | 3.6 |
| Joe Zweng | Marine City | 26.2 | .8 | |

## SUMMARY OF ENTOMOLOGICAL INVESTIGATIONS

Screened traps were placed in several nearby farm corn fields where cornstalks had been plowed under to a depth of 6 to 8 inches. These were allowed to remain in the fields until after the period of moth flight. No moths were found to have emerged in these trap cages, supporting the contention that clean plowing, leaving no debris on the surface of the ground in which the borer may hide, is a very effective control measure.

A similar experiment was conducted whereby a known number of corn borer larvae were buried in cornstalks in a furrow 8 inches deep. In the case of larvae buried in the fall 9.1 per cent were recovered in corrugated paper strips at the surface of the ground inside the trap. In the case of material buried in the spring 39.1 per cent of the buried larvae were recovered in the paper strips. The remaining borers evidently perished, as no moth recoveries were made, and upon exhuming and inspecting the buried material no borers were found.

That many borers which are buried by plowing or by other means come to the surface was indicated by the fact that some borers buried to a depth of 4, 6, 8, 12 and 16 inches were recovered in corrugated paper strips placed on the soil surface.

Studies of egg deposition indicated that the corn borer moths preferred to lay their eggs on the larger and more advanced plants.

Some borers were recovered from corn stored in an open crib, emergence of these corn borer moths followed that of field collected material very closely, being slightly later. The peak of the emergence from the crib came about ten days later than the peak of general moth flight.

The relative attractiveness of corn plants at different stages of development to corn borer moths was studied with an olfactometer. Plants ranging from 24 inches to 36 inches high seemed to have reached a stage of development which was selected by the borer moths in preference to plants of a smaller or greater size.

In a field in which the corn stubbles averaged 9 inches high 9.2 per cent of the total population of borers before harvest were found in the stubble, and .4 per cent of the total population were found below the ground.

For two years corn and mugwort were compared as food for the corn borer. These experiments indicated that the corn borer under Michigan conditions preferred corn to common mugwort as a host plant. Corn in the presence of mugwort was not protected by the mugwort from corn borer attack.

Counts made in a number of corn fields in southeastern Michigan and growers' estimates of the damage done by the borer point out rather severe losses which many farmers in this section of the state experienced in the season of 1929. The most heavily infested field carried a 99.9 per cent infestation and an average borer population of 11 borers per plant.

## CONCLUSION

The most satisfactory and effective means of controlling the European corn borer available at this time is the destruction of borer larvae between the time of corn harvest and moth emergence the following spring. This can be accomplished by:

I. Low cutting, to take the maximum percentage of borers from the field in the corn stalks.
II. Ensiling, shredding, or grinding the stalks.
III. Plowing under, burning, or otherwise destroying all corn stubble, waste and refuse before June 1st.