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Populations of European Corn Borer, *Ostrinia nubilalis* (Hbn.) in Field Corn, *Zea mays* (L.)

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Populations of European Corn Borer, *Ostrinia nubilalis* (Hbn.) in Field Corn, *Zea mays* (L.)

IN THE NORTH CENTRAL UNITED STATES

Since the introduction of the European corn borer into this country about 1910, it has spread from the eastern states throughout the Great Lakes States, the North Central States, and is now spreading toward the west and south.

The attempt by the U. S. Department of Agriculture in 1927 to eradicate this insect failed because all the corn and many other host plants could not be destroyed. The U. S. Department of Agriculture and various states have surveyed the distribution and abundance of the insect in this country. Information obtained has been useful in warning the growers of the threats of borer infestation in certain localities. But because of the different methods used, the results obtained cannot be compared. Prior to this study the population changes across an extensive area, such as the North Central Region, have not been evaluated.

Within the framework of a North Central Regional Project, NC-20, which was activated in 1953, Dr. F. G. Holdaway of the University of Minnesota proposed a long-range study of the annual changes of borer populations in the North Central Region (Holdaway, 1953). Work on this phase of the NC-20 project was initiated in 1954 in Minnesota, in 1955 in Iowa, Kansas, and Nebraska, and 1956 in Missouri and Ohio. Somewhat similar work had been in progress separately in Minnesota since 1948 (Chiang & Hodson, 1959), in Iowa since 1950, and in Ohio since 1939 (Neiswander, 1952). But never before was a standardized procedure adopted so that the results could be analyzed on a regional basis. The main objectives of the study were as follows:

1. To follow the annual changes in corn borer populations in widely separated localities in the North Central Region for a period of many years.
2. To evaluate the effect of climatic factors on borer populations.
3. To analyze the effect of soil and crop management on the borer populations.
4. To determine the presence, or the lack, of synchronization of the changes of borer populations in these localities.
5. To develop a sampling method which may be adopted for routine borer surveys.

It is realized that to fulfill these objectives would require at least 10 or even 20 years of work. The present publication summarizes the results obtained from 1954 to 1959, inclusive, and therefore represents only the beginning phase of the study.

The results are presented by states. In each of these sections, the factual information obtained in each state is presented, and the analysis of the operation of factors upon the local borer populations are presented by states. The populations in the entire area are then analyzed from a regional viewpoint. This last

Fig. 1—Distribution of the counties studied in the North Central Region of the United States

section represents perhaps the most unique feature of the study, and is made possible by the standardized procedures in all the participating states.

CENSUS PROCEDURES

1. *Counties studied.* A census of the borer population was taken in one or two counties in each of the participating states. The location of the counties is shown in figure 1. The counties and the number of townships in each county are as follows:

Iowa—Boone, 17 townships, but with the area of 16 regular townships
Kansas—Jefferson, 12 townships
Minnesota—Waseca, 12 townships
Missouri—Carroll, 22 townships
New Madrid, 11 townships, but the county was divided into 12 regions for census purposes not necessarily coinciding with townships
Nebraska—Cuming, 12 townships
Hall, 12 townships
Ohio—Van Wert, 12 townships

2. *Selections of fields.* Two fields in each township in a county were used. At the initiation of the study, sections and quarter-sections containing each field were chosen at random. These same quarter-sections were used throughout the years of study. Within the quarter-section picked, the field with the greatest accessibility to an all weather road was then selected; the planting date, variety of

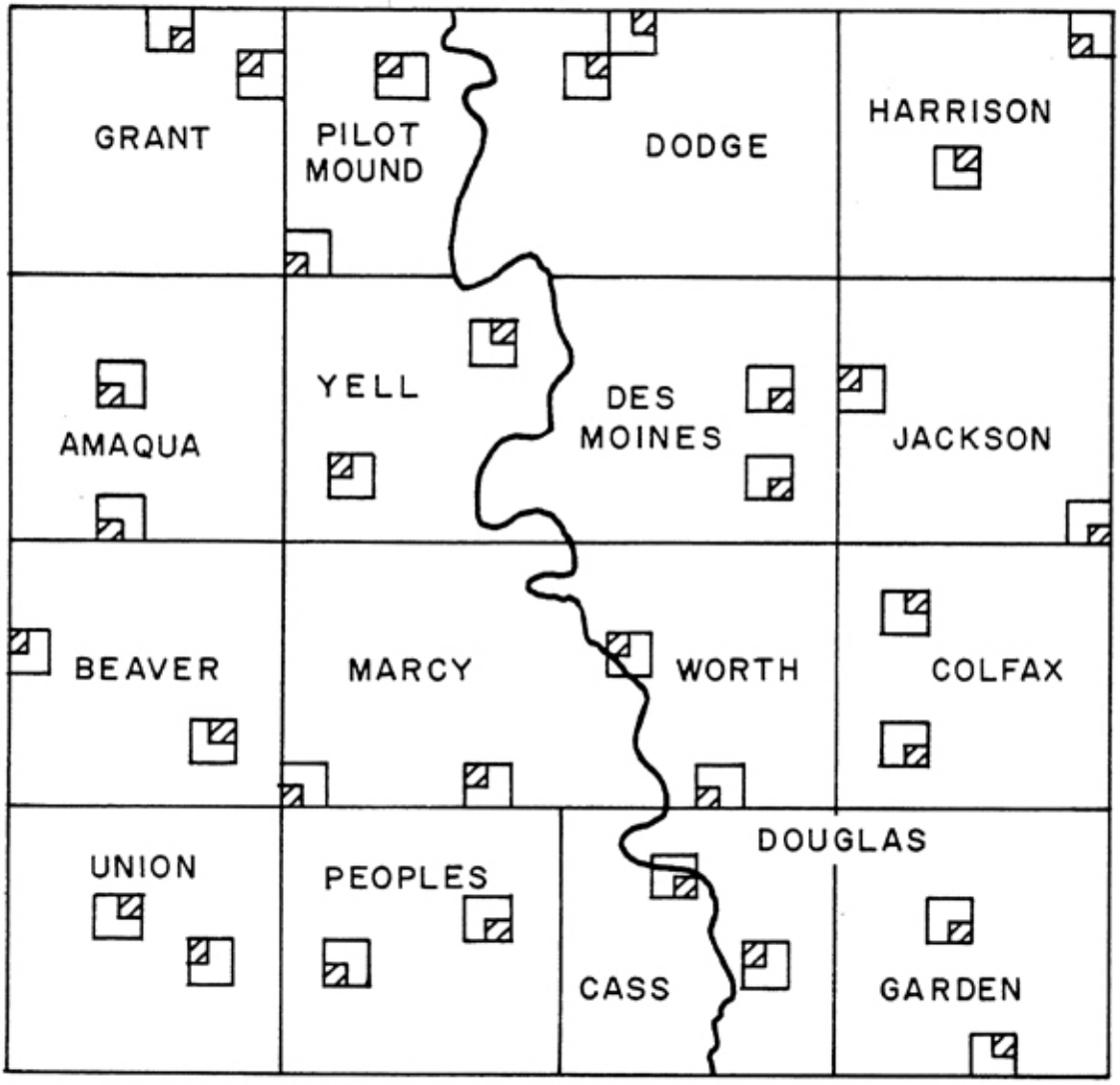

Fig. 2—Approximate locations of fields used in Boone County, Iowa

corn and the method of planting were not factors, determining the selection of fields. Because of crop rotation practices, the actual fields used were often different from year to year. The map of Boone County, Iowa is given as an example showing the distribution of fields within a county (figure 2).

3. *Number and time of annual censuses.* Basically censuses were made three times a year when the populations were relatively stable. (1) Spring censuses, soon after the spring thaw and after a particular field had been prepared for seeding. In Iowa, Kansas, Missouri, and Ohio, in more recent years, two spring censuses were made: (a) An "early spring" census was made before any spring operations began. This was to measure the larval mortality due to natural factors since the crop was harvested the previous fall. (b) The "late spring" census was conducted after all of the fields used had been planted to the current season's

crop. This was to measure the larval mortality due to all factors (natural and cultural). (2) The summer census was made at the end of the first brood, i.e. when the majority of the first brood borers had become full grown, or were starting to emerge as adults. (3) The fall census was made at the time of corn maturity, borer maturity, or first killing frost, whichever came first. In New Madrid County, Missouri a late fall census was conducted in 1959 after the third brood had developed. A post-harvest census was made in Iowa. The variations in procedures are given in the respective state summaries.

4. *Census method.* Three areas were checked in each field. The first was located according to a pre-determined number of paces (a randomly selected number between 30 and 50) from the edge of the field. The second and third were located along a diagonal line across the field and at predetermined distances from the first area and from each other (randomly selected number of paces between 30 and 50).

Each area was 6½ x 6½ feet (for practical purpose, the area was 1/1,000 acre), except in Boone County, Iowa* where the area checked was 1/2,000 acre. All plants in the areas were checked regardless of the method and the rate of planting.

The same fields were checked during the summer and the fall of the same year, and during the spring of the following year. One exception was in Boone County* where the same fields were checked during the late spring if they had been seeded to oats. When a field was not seeded to oats, a substitute field which was in oats was selected in the manner described below.

During the spring census, the plants were down and broken. In such instances, all surface material was dissected and examined for borers.

5. *Field histories.* The following information was obtained regarding each field each year. (1) The method of planting, (2) the variety of corn (complete information is given in the Appendix), (3) the date of planting, (4) crop history during the past 3 years, and (5) fertilizer practices during the past 3 years.

6. *Borer population and plant injury records.* The information secured varied with the time of census. (1) In the spring, the number of living larvae were recorded, (2) in the summer, the number of plants in the sample, the number and stages of living borers, and the number of plants with injury and/or tunnels, (3) in the fall, the number of plants in the area, the number and stages of living borers and the number of plants with tunnels.

7. *Weather conditions* were analyzed on the basis of the official records of the respective counties published by the Weather Bureau.

8. *Quantitative changes* of borer populations from one season to the next are analyzed in terms of "multiple changes." For example, an increase from 100 borers per acre in the summer to 200 borers per acre in the fall represents a multiple change of 2.0, and a decrease from 200 borers per acre in the fall to 100 in the next spring represents a multiple change of –2.0.

*The difference in procedures is due to the fact that the Boone County study was started before the beginning of the present regional project.

BOONE COUNTY, IOWA

General Description of the Area

In Iowa the study was made in Boone County, an area of 576 square miles. The fields under observation were located at random within each of 16 equal 36-square-mile areas within the county. Boone County is divided into 17 townships, one of the 16 equal areas being divided into two townships.

Boone County is located in central Iowa, almost in the center of the state. It lies entirely within the Wisconsin drift soil area and hence its soils are all of glacial origin. As presented in the Soil Survey Report No. 34 of the Iowa Agricultural Experiment Station, the soils of Boone County can be divided into 17 different types. Drift soils cover 93.3 percent of the total area, terrace soils 1.9 percent, and river bottom soils 4.8 percent. Drift soils have been formed in the prairie areas and are characterized by a black color, the result of an accumulation of organic material. Terrace and river bottom soils have been deposited by streams and are found mainly in the valley of the Des Moines River and along Beaver Creek.

The topography of the greater part of Boone County is level to gently rolling. Flat, poorly drained areas with small moraines rising occasionally are common in some areas. The largest stream is the Des Moines River, which flows from north to south almost through the middle of the county. The topography on both sides of the river is rough and broken with steep bluffs extending from 1 to 3 miles back from the river. The river valley itself is about 250 feet below the level of the prairie upland.

The general drainage of the county is toward the south, the Des Moines River and its tributaries affording most of the drainage. In most of Boone County surface drainage is rather poor except in areas adjacent to the Des Moines River, Beaver Creek, and Squaw Creek. In many places tiling is necessary to make the soils satisfactorily productive.

The type of agriculture practiced is mainly cash grain farming and livestock. The most popular crop rotation system used is corn-corn-oats-legume with corn being the most important crop and occupying the most acreage.

General Description of Weather Conditions

The monthly average temperature and monthly total rainfall are presented in Appendix 1A. The deviations of these records from the long-term normal are presented in Appendix 1B. The general weather conditions in the various years may be summarized as follows:

1955—June temperatures cool, July and August above normal. Season deficient in rainfall except July.

1956—June hot, temperatures in July and August below normal. Entire season dry.

1957—Temperatures slightly below normal, rainfall slightly above normal.

1958—Entire summer very cool and wet except August which was deficient in rainfall.

1959—Temperatures near normal except July which was cool. Rainfall deficient during the summer months.

Agronomic Practices

The soils of Boone County are very fertile and as a result the farmers do not heavily fertilize their fields. Over half of the fields checked received no fertilizer application. Corn following leguminous crops is seldom fertilized but fertilizer is commonly used in second and third year corn. Appendix 1C shows fertilizer applications in fields checked in the Boone County study area.

The data on crop history are found in Appendix 1D. Only information on the previous year's crop was obtained. Over 42 percent of all fields examined had been in corn the previous year while 40 percent had been in a leguminous crop. The effects of fertilizers and crop rotation systems upon the borer have not been adequately studied and as a result no conclusions can be drawn at this time.

Planting methods changed considerably during the 5-year period. Wire checked fields have decreased while power checked corn and slightly thicker stands are becoming more popular. No effect of this practice upon the corn borer populations is apparent in the data available. Weekman (1956) found no relation between planting methods and borer populations in Boone County. Corn in central Iowa is normally planted during the first 3 weeks of May and was 90 percent completed by May 20 in the fields surveyed. Planting methods and stand counts are given in Appendix 1E ,and planting dates in table 1.

TABLE 1-PLANTING DATES IN THE FIELDS USED IN BOONE COUNTY, IOWA

Planting dates	Percent of fields					
	1955	1956	1957	1958	1959	Average
April 25-30	3.2	0	0	0	0	0.6
May 1-10	37.4	43.7	65.7	59.4	31.2	47.5
May 11-20	59.4	56.3	6.2	37.4	50.0	41.9
May 21-31	0	0	28.1	0	9.4	7.5
June 1-10	0	0	0	0	9.4	1.9
June 11-21	0	0	0	3.2	0	0.6
Total fields observed	32	32	32	32	32	

The commercial hybrids grown in Boone County are well adapted to the climatic conditions of central Iowa. More than 70 varieties have been used by the farmers in the 5-year period (see Appendix 1F).

Borer Populations

The early spring census was taken during the latter part of March from 1957 through 1959. At this time little farm operation work had begun and the fields have been largely undisturbed since the crop was harvested. The results are presented in table 2. Winter mortality may be determined by comparing these results with the post-harvest census made the previous November. Popu-

TABLE 2-SUMMARY OF BORER POPULATIONS AND INJURY AT VARIOUS TIMES EACH YEAR IN BOONE COUNTY, IOWA

	Average number plants per acre	Total number plants checked	Percent plants with injury	Number of			
				Tunnels per 100 plants	Larvae per 100 plants	Tunnels per acre	Larvae per acre
1955							
Late spring							14,354
Summer	11,250	540			44.2		4,979
Fall	10,479	503			104.4		10,937
1956							
Late spring							895
Summer	11,333	544			45.4		5,146
Fall	10,770	517			188.9		20,354
1957							
Early spring							6,874
Late spring							3,000
Summer	11,187	537	66.6	72.4	45.2	8,104	5,062
Fall	11,750	564	91.6	304.6	186.2	35,791	21,875
Post-harvest							10,375
1958							
Early spring							6,854
Late spring							7,937
Summer	11,646	559	64.3	78.0	62.4	9,083	7,270
Fall	12,020	577	93.5	238.1	106.4	21,437	12,791
Post-harvest							1,958
1959							
Early spring							1,979
Late spring							987
Summer	11,937	573	15.8	5.4	8.9	645	1,020
Fall	12,146	583	25.0	35.8	12.3	4,354	1,562
Post-harvest							520

lations were reduced 33.9 percent during the winter of 1957-58 but no reduction occurred during the winter of 1958-59. The winter of 1957-58 was relatively mild except for a 3-week period in February when minimum temperatures averaged well below zero degree F. The winter of 1958-59 was very severe, with frequent sub-zero temperatures and heavy snows. These data are inconclusive and as a result no definite statement can be made at this time on the effect of winter weather upon corn borer populations in Boone County.

The late spring census was taken each year in April. Only fields which had been in corn the previous year and had been disced and planted to oats were used. The discing of old corn fields and seeding to oats is a common agronomic practice in central Iowa. Fields not planted to oats are plowed and as a result the highest borer populations in the spring are found in oat fields. Oat fiields, which provide ideal conditions for pupating larvae, are the principal source of first generation moths in central Iowa.

Some mortality occurs when the fields are disced. In 1957 and 1959 the late spring populations were approximately half those of the early spring census. In 1958 no apparent reduction occurred. This was because a number of fields used in the early spring census were not planted to oats and the fields substituted

TABLE 3-CHANGES IN BORER POPULATIONS FROM SPRING TO SUMMER TO FALL IN BOONE COUNTY, IOWA, AND CERTAIN WEATHER DATA FOR MONTHS OF JUNE, JULY, AND AUGUST, 1955-59. (T, temperature; R, rainfall)

	1955	1956	1957	1958	1959
No. borers/A - late spring	14,354	895	3,000	7,937	987
- summer	4,979	5,146	5,062	7,270	1,020
Multiple change - spring to summer	-2.8	5.7	1.7	-1.1	1.0
No. borers/A - fall	10,937	20,354	21,875	12,791	1,562
Multiple change - Summer to fall	2.2	3.9	4.3	1.7	1.5
Departure from normal (T) - June	-2.1	4.5	-1.7	-5.2	-0.7
(R) - June	-2.70	-2.10	3.34	1.42	0.72
No. days 90° or more - June	2	15	2	3	7
100° or more - June	0	0	0	0	0
.50" rain - June	2	1	4	5	3
Departure from normal (T) - July	4.7	-2.6	1.3	-6.4	-4.0
(R) - July	1.83	-2.13	1.95	7.05	-1.31
No. days 90° or more - July	19	9	16	0	6
100° or more - July	6	2	3	0	0
.50" rain - July	3	1	4	7	0
Departure from normal (T) - Aug.	4.9	0	-0.5	-1.3	2.6
(R) - Aug.	-3.01	-0.02	-1.34	-3.62	-1.23
No. days 90° or more - Aug.	17	7	8	15	19
100° or more - Aug.	2	0	0	0	0
.50" rain - August	0	1	1	0	3

had high borer populations. The late spring borer population data are shown in table 2.

Summer borer populations are summarized in table 2. Summer populations were not always correlated with spring populations. The highest spring population was found in 1955, yet summer populations that year were not usually high.

Weather conditions throughout June had a great influence upon first generation borer populations (table 3). Everett *et al.* (1958) reported that first generation infestations were reduced in Iowa when June temperatures were below normal and/or rainfall was deficient. In 1955 an over-wintering population was large enough to result in an extremely high first generation infestation. However, oviposition was greatly reduced by a series of cool, windy days shortly after oviposition began. The spring population in 1956 was 1/15 that of 1955 but the summer populations in 1956 were nearly identical to those of 1955. June temperatures in 1956 were considerably higher than in 1955. In 1957, June was characterized by moderately cool temperatures and excessive rainfall. Summer populations were similar to those of 1955 and 1956. The overwintering popula-

tion in 1958 was high. Despite abnormally cool temperatures in June, the summer populations were the highest of the 5-year period. In 1959 a low overwintering population and unfavorable conditions in June resulted in a very low first generation borer population. No measurable rainfall was reported in Boone County during the first 26 days of June. Factors associated with the lack of moisture appear to have had an adverse effect upon the corn borer and resulted in the lowest first generation infestation observed during the census.

The results of the fall census are shown in table 2. Fall populations have always been greater than those found in the summer. Usually a small percentage of the fall population is actually part of the summer population, since all of the first generation borers do not pupate. Summer pupation in Boone County was 83 percent in 1955, 84 percent in 1956, 92 percent in 1957 and 1959, and 62 percent in 1958.

Second generation oviposition in Boone County occurs in late July and August. Weather conditions at this time appear to influence the fall population. In Iowa, Everett *et al.* (1958) found that a high August rainfall or a below normal August mean temperature was associated with a higher borer infestation in the fall. In 1955, August was characterized by a lack of precipitation and excessively high temperatures. Fall populations increased somewhat over those found in the summer. In both 1956 and 1957 the fall populations were approximately four times greater than the summer populations. In both these years, weather conditions in August appeared to be favorable to the corn borer. Normal seasonal temperatures and rainfall were experienced during the period of second generation oviposition in 1958. Conditions at this time were ideal for a large increase in population; however, the fall population was only slightly higher than the summer population. Abnormally cool temperatures which prevailed through June and July and the depressing effect of a high first generation population may have had an adverse effect upon the second generation moths. The fall population in 1959 was the lowest of any of the 5 years involved in this investigation. Despite conditions in August believed to be favorable to the corn borer, the second generation in 1959 failed to increase over the very low population found in the summer.

The post-harvest census was taken in November of 1957, 1958, and 1959 after the corn had been harvested. The results are summarized in table 2. In 1957 picking operations reduced borer populations 52 percent. The 1958 fall population was reduced 85 percent from October to November. This reduction was due to an unexplained high mortality which occurred in the corn borer population in central Iowa in the fall of 1958. Mortality was also high in the fall of 1959 when a 66 percent reduction in population occurred. Bigger and Petty (1953) obtained only a 36 percent reduction in Illinois due to mechanical corn pickers. This would seem to indicate that factors other than mechanical injury were responsible for a large percentage of the 85 percent population reduction which occurred in Boone County in the fall of 1958.

Borer populations in Boone County during the 5-year period ranged from

TABLE 4-QUANTITATIVE CHANGES IN BORER POPULATIONS IN BOONE COUNTY, IOWA

	1955	1956	1957	1958	1959	Average
Multiple changes:						
Summer to fall	2.2	3.9	4.3	1.7	1.5	2.7
Fall to post-harvest						
harvest			-2.1	-6.5	-3.0	-3.9
Post-harvest to early spring				-1.5	1.0	-0.2
Early spring to late spring			-2.3	1.1	-2.0	-1.1
Late spring to summer	-2.5	6.1	1.7	1.1	1.1	1.5
Fall to late spring		-13.0	-6.8	-2.7	-12.9	-8.8
Winter mortality (percent reduction, fall to late spring)		92.4	85.3	63.7	92.3	83.4

520 to 21,875 borers per acre. Table 4 shows quantitative changes in borer populations between different census dates.

The greatest population reductions have always occurred from fall to late spring. Much of this mortality is of mechanical origin, resulting from stalk breakage when the corn is harvested. Additional mortality occurs when fields are plowed or disced in the spring. The extremely low populations in Boone County throughout the 1959 season were the result of a high borer mortality which occurred in the fall of 1958, when many of the borers seemed to "disappear." It is possible that this unexplained mortality among the borer population had some relationship to the failure of the population to increase during the 1959 season. The value of the post-harvest census should be pointed out at this time. In 1958 this census showed that the reduction in borer populations actually occurred in the fall and that no reduction could be attributed to the severe winter of 1958-59.

The greatest population increase occurred from late spring to summer in 1956. June of 1956 was quite warm and conditions were generally favorable to the corn borer. The reduction which occurred from late spring to summer in 1955 was due to cool windy weather in June. In general, only a slight population increase has occurred in Boone County from late spring to summer. The fall populations have always increased over the summer populations, with the greatest increase occurring in 1957. In both 1958 and 1959 conditions were such that a considerable second generation population increase was expected, yet this never occurred. In 1958 cool temperatures, and in 1959 lack of moisture were unfavorable to the first generation (table 3). This may account for the failure of second generation populations to increase despite favorable environmental conditions.

The population range and the average population density over the entire period of study are given in table 5.

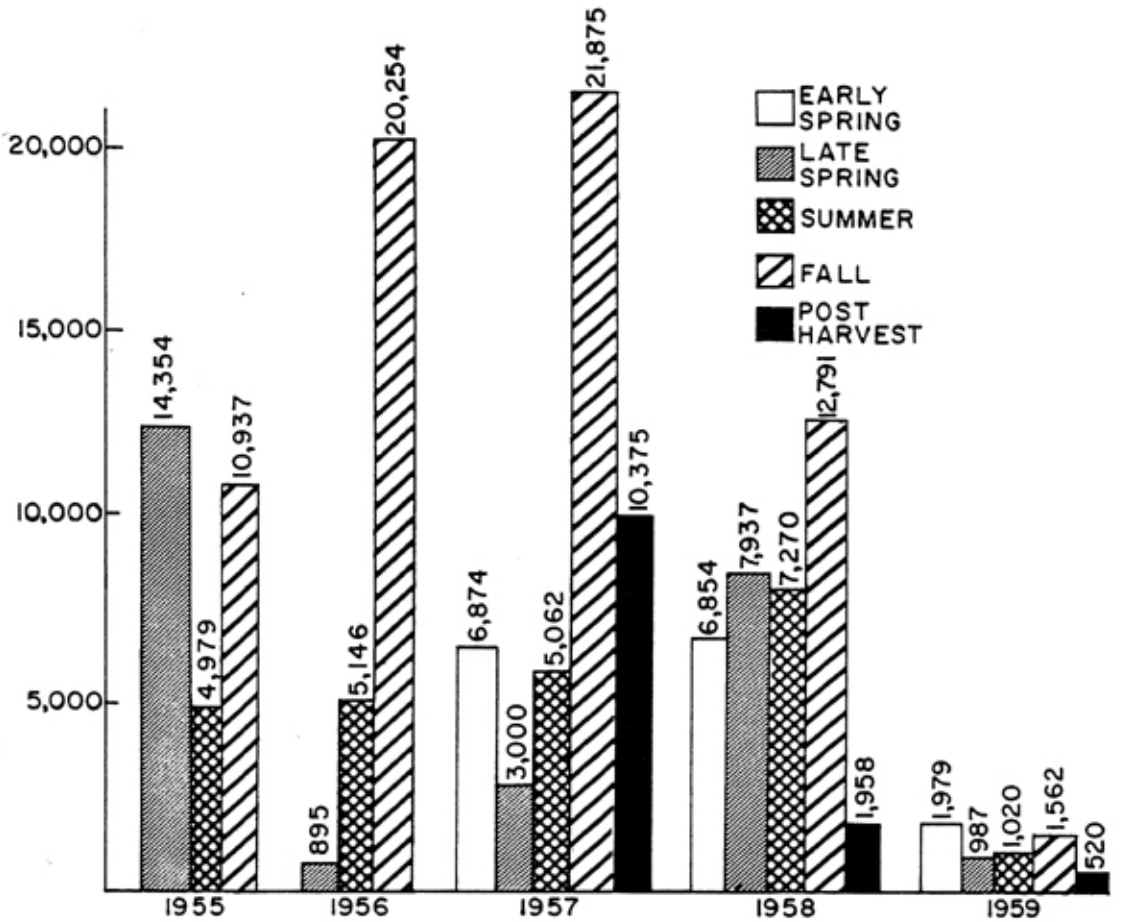

Fig. 3—Number of borers per acre, Boone County, Iowa, 1955-1959

Figure 3 shows borer populations per acre in Boone County at various times of the year. The outstanding features of this graph are the extremely low populations in 1959 and the high fall populations in 1956 and 1957. The change in population from late spring to summer seems to have a definite effect upon the second generation. Note that in 1956 and 1957 summer populations were noticeably higher than the late spring population. In both years the fall populations were much higher than were the summer populations. In 1955 and 1958 summer populations were lower than were the late spring populations and in 1959

TABLE 5-POPULATION RANGE AND AVERAGE NUMBER OF BORERS PER ACRE IN BOONE COUNTY, IOWA, 1955-59

	Number of borers per acre	
	Range	Average
Early spring a/	1,979 - 6,875	5,236
Late spring b/	895 - 14,354	4,911
Summer b/	1,020 - 7,270	4,695
Fall b/	1,562 - 21,875	13,504
Post-harvest a/	520 - 10,375	4,284

a/ Records of 1957-58-59
b/ Records of 1955-59

there was only a very slight population increase in the summer. In these years the second generation failed to show the population gain over the first generation that occurred in 1956 and 1957.

JEFFERSON COUNTY, KANSAS

General Description of the Area

The Kansas study was conducted in Jefferson County in northeastern Kansas.. The county was chosen as representative of corn production and borer infestation. It is divided into 12 townships and consists of 552 square miles.

The Kansas River bounds the county on the south. The Delaware River crosses it north to south, and several small creeks run north and south in the county. Except for river valleys and creek bottoms, the topography is quite rolling.

Jefferson County has at least seven soil types. Friable, silty to clayey soils (bottomland) covered 45.8 percent of the fields studied. An additional 41.6 percent of the fields represented friable, silty to clayey soils (upland). The remaining 12.6 percent of the fields were located on dark, tight clay and claypan soils, some on bottomland and others on upland.

General Description of Weather Conditions

The monthly average temperature and monthly total rainfall for Jefferson County are given in Appendix IIA. The deviation of these records from the long-term normal are presented in Appendix IIB. The general weather conditions in the various years may be summarized as follows:

1955—Warm and dry. Temperatures from April to October were above normal except slightly below normal in June. This was the third year of a drouth.

1956—Temperatures near normal with a high deficiency in rainfall.

1957—Mean temperatures were slightly below the long-term means, but precipitation was above normal.

1958—Temperatures were below normal with above normal rainfall.

1959—Temperatures were above normal early in the season but cooler than normal in July and about normal in August. Rainfall was deficient in June and ample during July and August.

Agronomic Practices

Corn is the most important crop and occupies the largest acreage. There are numerous two-crop and three-crop rotations in practice, but several of the fields were in corn continuously for many years.

Fertilization practices varied considerably. Data indicated 38.3 percent of the fields received no treatment, 45 percent received commercial fertilizers, 30 percent of which were N-P-K combinations. Appendix IIC shows fertilizer applications in Jefferson County fields. Borer populations were usually higher on heavily fertilized fields than on unfertilized fields.

Data on crop history are given in Appendix IID. Over 60 percent of the fields under study during the 5-year period were in continuous corn for 3 years or more.

Planting methods and plant populations are summarized in Appendix IIE. All fields sampled were drilled. An average of 68.3 percent were listed while 18.3 and 13.2 percent were planted with a furrow opener and surface planter respectively.

Commercial varieties of hybrids were planted in 88.3 percent of the fields (see Appendix IIF).

Planting dates are summarized in table 6. They ranged from April 10 to June 20 but the average date for each year varied little from May 10. Over the 5 years an average of 9.2 percent of the fields was planted before April 20. First generation infestation in these early fields averaged 12.9 percent. Few early plantings harbored second generation borers.

TABLE 6-PLANTING DATES IN JEFFERSON COUNTY, KANSAS

Planting dates	Percent of fields					
	1955	1956	1957	1958	1959	Average
April 1-10	0	8.3	0	0	0	1.7
April 11-20	8.3	12.5	8.3	8.3	8.3	9.2
April 21-30	8.3	12.5	8.3	4.2	12.5	9.2
May 1-10	41.7	20.9	33.3	54.1	33.4	36.7
May 11-20	20.9	33.3	29.2	25.0	33.3	28.3
May 21-31	12.5	4.2	20.9	4.2	12.5	10.8
June 1-10	8.3	8.3	0	0	0	3.3
June 11-20	0	0	0	4.2	0	0.8
Average	May 10	May 10	May 11	May 9	May 10	May 10
Total fields observed	24	24	24	24	24	

Borer Populations

The standard procedure was used for the taking of the census of the borer populations at various times during the year. Results are shown in table 7 and figure 4. The percent of plants with injury by first and second generation borers is also given. During the last three years (1957-59) the census was taken four times a year. An early spring census indicated the percent post-harvest plus winter mortality while a late spring census measured first the amount of "spring farm operation mortality" and secondly the approximate potential available to produce first generation borers.

Percent of plants infested by first generation larvae averaged 12.9 while second generation infestations averaged 44.9 percent. In the falls of 1955 and 1956, percent of plants infested and number of borers per acre were almost identical. The next two years resulted in a higher percent of plants infested and

TABLE 7-SUMMARY OF BORER POPULATIONS AND INJURY AT VARIOUS TIMES EACH YEAR IN JEFFERSON COUNTY, KANSAS

	Average number plants per acre	Total number plants checked	Percent plants with injury	Number of	
				Larvae per 100 plants	Larvae per acre
1955 Fall	16,508	1,199	34.7	30.9	5,483
1956 Spring					1,276
Summer	17,625	1,229	3.8	4.8	846
Fall	16,757	1,157	35.6	31.7	5,230
1957 Early spring					928
Late spring					1
Summer	16,244	975	10.1	13.5	2,193
Fall	12,061	689	59.5	186.3	22,557
1958 Early spring					3,225
Late spring					512
Summer	13,230	1,027	21.3	25.6	3,387
Fall	10,896	654	43.1	111.2	12,568
1959 Early spring					6,677
Late spring					292
Summer	14,904	953	16.4	9.4	1,401
Fall	14,804	1,068	51.9	56.4	8,343

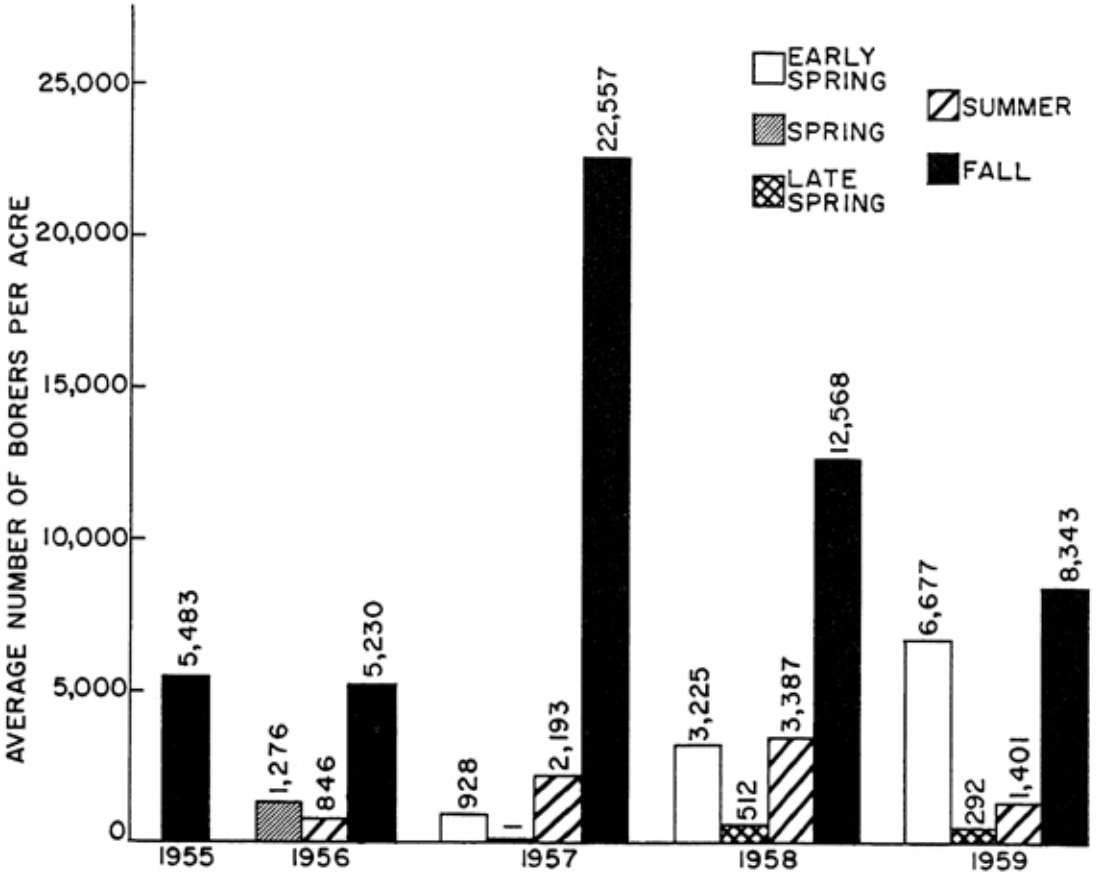

Fig. 4—Number of borers per acre, Jefferson County, Kansas, 1955-1959

an accompanying increase in borer population. However, in the fall of 1959 the percent plants infested was 51.9, intermediate between 1957 and 1958, but borer populations were strikingly lower.

Quantitative changes in borer populations between different censuses are shown in table 8. Borer numbers were always reduced from fall to early spring, with an additional reduction from early spring to late spring. The decrease from fall to early spring has been referred to as winter mortality. It is realized that a considerable amount of this mortality may be caused by mechanical corn pickers at harvest time. The fall-to-early-spring reduction has averaged 73.3 percent during the 4-year period. An average of 26.3 percent additional reduction resulted from spring farm operation mortality. This gave an over-all fall-to-late-spring reduction of 93.1 percent.

TABLE 8-QUANTITATIVE CHANGES IN BORER POPULATIONS IN JEFFERSON COUNTY, KANSAS

	1956	1957	1958	1959	Average
Multiple changes:					
Summer to fall	6.1	10.3	3.7	5.9	6.3
Previous fall to early spring	-4.3	-5.6	-6.9	-1.8	-4.7
Early spring to late spring			-6.2	-22.9	-14.6
Late spring to summer	-1.5		6.6	4.8	3.3
Previous fall to late spring			-44.0	-43.2	-43.6
Winter mortality (%)	76.8	82.3	85.7	48.5	73.3
Spring farm operation mortality (%) [a]	---[a]	17.6	12.1	49.2	26.3[a]
Total mortality (%) (fall to late spring)	76.8[a]	99.9	97.8	97.7	93.1[a]

[a] 1956 spring mortality not measured.

The borer populations in censuses made during the 5-year period ranged from 1 to 22,557 borers per acre, with considerable fluctuations between seasons during most years. However, summer populations were always higher than the late spring populations. The number of borers in the fall was consistently higher than in the summer for each year studied.

There were positive correlations with certain climatic conditions and high first generation borer populations. In Kansas, the weather factors are more important in June than in July. First generation borer populations were strikingly higher in 1957 and 1958, the only 2 years out of five being characterized by a cool-wet June. Temperatures reached 90° F. or more on only 3 and 7 days during June of 1957 and 1958 respectively. The number of days in which 0.50 inch or more of precipitation was received for the same period were 6 and 5 respectively. One inch or more was received on 2 days in June, 1957 and 3 days in June, 1958. A cool-wet June in Kansas has been followed by high first generation borer populations, while a warm-dry June followed by a cool-wet July (1956 and 1959) resulted in considerably lower populations.

Factors other than climatic have had an effect on quantitative changes in borer populations. Populations usually were higher on heavily fertilized fields than on unfertilized fields. During 1959 there was a significant decrease in the number of fields listed with a sharp increase in the number planted with a furrow opener. This trend may account in part for a lower first generation population in 1959 than either of the two previous years. Listing often uncovers stalks that were once plowed under, so moths can emerge more easily.

The population range and average number of borers per acre in Jefferson County, Kansas, throughout the period of study are shown in table 9.

TABLE 9-POPULATION RANGE AND AVERAGE NUMBER OF BORERS PER ACRE IN JEFFERSON COUNTY, KANSAS, 1955-59

	Number borers per acre	
	Range	Average
Early spring	928 - 6,677	3,610
Late spring	1 - 1,276	520
Summer	846 - 3,387	1,957
Fall	5,230 -22,557	10,836

WASECA COUNTY, MINNESOTA

General Description of the Area

Waseca County, located in southern Minnesota, has a land area of approximately 430 square miles, and an elevation of 1,050 to 1,200 feet (Thiel, 1944).

The soils and the surface topography are influenced by what is presently called the Mankato sub-stage of the Late Wisconsin Drift. The topography of the eastern and northern tier of townships is influenced by a moderately rolling end moraine. A small glacial outwash occurs in the southern part of the county. The southwestern part of the county is nearly level lake plain or lake washed till plain. The remainder of the county is a gently undulating ground moraine with the prairies predominating southwest to the LeSueur River. The valley of the LeSueur River is broad and shallow, not exceeding 50 feet in depth, and usually less than 25 feet below the adjoining plain. Wasting of glacial ice left many scattered ice blocks that developed into lakes and potholes.

The majority of the county drains northwestward to the Minnesota River by way of the LeSueur and Cobb Rivers. The northeastern part of the county drains to the Mississippi by way of Crane Creek and tributaries of the Cannon River. The well, moderately well, and somewhat poorly drained soils include Gray-Brown Podzol, Prairies and Prairie-Gray-Brown intergrades. The intergrade soils predominate. The poorly drained soils are predominantly Humic Clays. By capability classes Waseca soils may be grouped as follows: Class I, 7.6 percent; Class II, 59.6 percent; Class III, 25.8 percent; Class IV, 2.8 percent; Class V, 0.3 percent; Class VI, 2.7 percent; Class VII, 1.1 percent.

By capability sub-classes they may be grouped as follows: Erosion problem, 41.8 percent; wetness problem, 55.7 percent; soil problem, 2.5 percent.

A strong shift in types of farming is underway in Waseca County. A diversified type of farming with dairying as the principal enterprise is being replaced by a corn-soybean-hog-beef operation.

Distribution of the annual precipitation of 28.7 inches is such that 70 percent falls during the growing season.

General Description of Weather Conditions

The monthly average temperature and monthly total rainfall are presented in Appendix IIIA. The deviations of these records from the long-term average are presented in Appendix 111B. The general weather conditions in the various years may be summarized as follows:

1954—Both temperature and rainfall near normal.
1955—Entire season warmer than normal, but had deficient rainfall.
1956—Good season in June, poor in July and near normal in August.
1957—Temperature near normal excepting July which was warm, and slightly higher rainfall than normal.
1958—Early season cool and dry, later part of the season near normal.
1959—Near normal in both temperature and rainfall.

Agronomic Practices

Information of the farm practice was not completely available for all fields and all years. Thus it was not possible to correlate the farm practices and borer populations among fields within the county. The information was, however, sufficient to establish the general pattern of farm practice in Waseca County.

The summaries of the different aspects of farming practice are given in Appendix III C, D, E, and F, and figure 5. The following facts are observed: (1) The majority of the farms followed a two- to three-crop rotation. The corn and oats combination was by far the most common type of rotation. (2) Majority of fields received fertilizers and/or manure on one or more crops during a period of 3 years. The great variety of combinations of N-P-K used suggested the variation of soil fertility in the county since the applications were catered to the needs of the soils on individual farms. (3) Commercial varieties of hybrids were used by the Waseca farmers almost exclusively. There was an increase in the number of varieties used by farmers during the years studied. There was also a decrease in the popularity of certain varieties during the period. (4) The majority of the fields adopted wire checked planting. During the first 5 years studied, there was a gradual decrease in the hill-drop type in favor of the drilled planting. In the last year of the study (1959) there was a sharp increase in hill drops, and a corresponding decrease in checked planting. (5) Regardless of the type of planting, the plant population was quite constant, about 13,000 plants per acre. (6) In mid-May 42.7 percent of the fields were planted within a 5-day period, and 69.1 percent in a 10-day period. There were more fields planted prior to the 10-day period (25.0 percent) than after (5.9 percent).

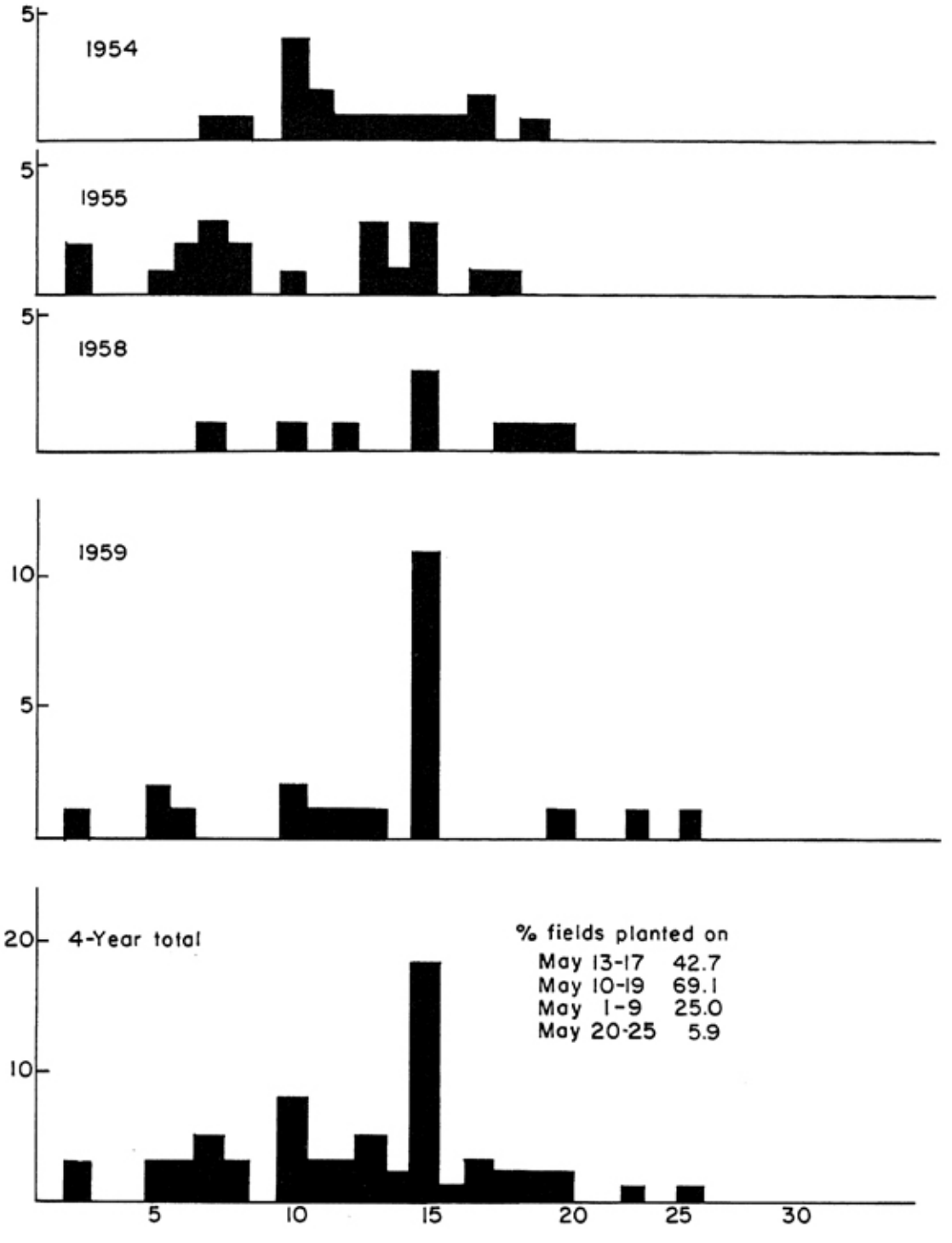

Fig. 5—Dates of planting in Waseca County, Minnesota

TABLE 10-SUMMARY OF THE BORER POPULATIONS AND INJURY AT VARIOUS TIMES IN WASECA COUNTY, MINNESOTA

	Average number plants per acre	Total number plants checked	Percent plants with injury	Number of Tunnels per 100 plants	Number of Larvae per 100 plants	Number of Tunnels per acre	Number of Larvae per acre
1954							
Summer	14,100	679	41.8	26.2	19.9	3,700	2,800
Fall	13,000	625		98.4	14.1	12,800	1,800
1955							
Spring						0	200
Summer	13,800	954	17.1	14.6	7.1	1,900	900
Fall	13,100	908		195.6	73.9	24,400	9,300
1956							
Spring						500	600
Summer	12,500	898	44.9	56.6	35.0	7,000	4,400
Fall	12,400	891		138.2	23.5	17,100	3,200
1957							
Spring						0	100
Summer	13,300	956	29.5	24.6	12.9	3,300	1,700
Fall	15,300	1,003		79.3	50.8	10,400	7,200
1958							
Spring						3,000	500
Summer	14,300	985	10.3	9.6	7.7	1,300	1,100
Fall	14,600	1,011		31.1	9.9	4,200	1,100
1959							
Spring						600	100
Summer	16,300	1,172	9.4	6.3	5.6	11,000	900
Fall	15,500	1,118	29.4	42.2	31.0	6,600	4,800

Borer Populations

Table 10 & Figure 6 give the county averages of the different records. The complete complement of records was taken in the summer. In the fall all except the percent of plants with injury were recorded because the leaf injury was not obvious late in the season. In the spring, only two records were taken, namely, the number of tunnels and the number of borers per acre. It was not possible to express these figures in terms of per 100 plants since only pieces of stalks were present in the sampled field. The results clearly show the following two points. (1) The values of all the records taken varied a great deal throughout the season and throughout the years. This is consistent with the findings by Chiang and Hodson (1959) on the basis of one field in Waseca. (2) the larval population present in the exposed pieces of stalks in the spring was consistently much lower than the larval population in the following summer. Perhaps the increase in number from spring to summer was not any greater than would be expected on the basis of the normal rate of borer survival and fecundity. But it is not impossible that sources of over-wintering population other than that in the corn stalks also contributed to the production of the summer population.

In spite of the high degree of fluctuation, the data show the following:

(1) The number of tunnels in the fall showed a peak in 1955 and gradually decreased until 1958, and then showed some increase in 1959.

TABLE 11-QUANTITATIVE CHANGES IN BORER POPULATIONS IN WASECA COUNTY, MINNESOTA, 1954-59

	1954	1955	1956	1957	1958	1959
Multiple changes:						
Previous fall to spring	----	-9.0	-15.50	-32.0	-14.4	-11.0
Spring to summer	----	4.5	7.33	17.00	2.20	9.00
Summer to fall	-1.41	10.41	- 0.49	3.94	1.08	5.54
Winter mortality (%) a/	----	88.90	93.5	96.9	93.1	90.9

a/ Mortality includes natural mortality and mortality caused by farm operations from harvest to sowing in the next spring.

(2) The number of tunnels in the summer was generally lower and fluctuated less regularly than that in the fall. Furthermore, the peak of the former occurred in a different year, namely, 1956.

(3) The number of borers in the fall was higher than that in the summer in 3 years, lower in 2 years, and about the same in 1 year. Borer populations of both the summer and the fall fluctuated much less regularly than did the number of tunnels.

(4) Borer populations in the spring were extremely low, and were not correlated with the population in the previous fall or the following summer.

The multiple changes of borer populations are also given along with some pertinent weather records in table 12. In general, the multiple changes from spring to summer were correlated with the temperature in June and that from summer to fall was correlated with the temperature in July and August.

NEW MADRID AND CARROLL COUNTIES, MISSOURI

Two counties in Missouri, Carroll and New Madrid, were selected for participation in this investigation. These counties were selected as being representative of the two different types of corn growing areas of the state. Carroll County is located in central Missouri in the Corn Belt while New Madrid County is located in southeastern Missouri in the cotton growing area.

The study was initiated in New Madrid County in 1956. There were nine cooperators in 1956 and in 1957, 1958, and 1959 there were 11, 24, and 24 cooperators, respectively. In general, the study was conducted in a manner similar to that followed by the other cooperating states. However, in New Madrid County there are only 11 townships so the county was divided into 12 districts to agree with the procedure outlined by the NC-20 committee.

The census in Carroll County, Missouri was also initiated in 1956 and contined through 1959. The number of cooperators in 1956, 1957, 1958, and 1959 were 27, 31, 38, and 39, respectively.

The mean and range of the population at each of the three seasons throughout the years studied are given in table 13. The mean population was the highest in the fall and lowest in the spring, but the range of variation throughout the years studied was largest in the fall and smallest in the summer.

TABLE 12-CHANGES IN BORER POPULATIONS FROM SPRING TO SUMMER IN WASECA COUNTY, MINNESOTA, AND CERTAIN WEATHER DATA FOR MONTHS OF JUNE, JULY, AND AUGUST, 1954-59. (T, temperature; R, rainfall)

	1954	1955	1956	1957	1958	1959
No. borers/A - spring	----	200	600	100	500	100
- summer	2,800	900	4,400	1,700	1,100	900
Multiple change - spring to summer	----	4.5	7.3	17.0	2.2	9.0
No. borers/A - fall	1,800	4,300	3,100	7,200	1,100	4,800
Multiple change - summer to fall	-1.4	10.4	-0.5	3.9	1.0	5.5
Departure from normal (T) - June	3.0	-1.0	4.0	-0.9	-5.4	1.8
(R) - June	0.98	-0.18	4.22	-1.53	-1.93	-0.91
No. days 90° or more - June	3	1	8	1	3	5
100° or more - June	0	0	0	0	0	0
.50" rain - June	3	4	5	1	1	1
Departure from normal (T)-July	0.8	4.1	-4.7	2.1	-4.0	-1.9
(R)-July	-1.20	-0.01	-1.14	3.70	-0.80	-0.63
No. days 90° or more - July	7	13	0	10	2	3
100° or more - July	0	0	0	0	0	0
.50" rain - July	1	2	1	3	2	1
Departure from normal (T) - August	-1.3	4.9	-1.1	-1.0	0.6	4.2
(R) - August	0.06	-1.79	-0.43	0.84	0.16	1. 39
No. days 90° or more - August	1	12	1	2	8	11
100° or more - August	0	0	0	0	0	0
.50" rain - August	3	0	2	3	2	4

TABLE 13-POPULATION RANGE AND AVERAGE NUMBER OF BORERS PER ACRE IN WASECA COUNTY, MINNESOTA, 1954-59

	Years	Number borers per acre	
		Range	Mean
Spring	1955-59	100 - 600	300
Summer	1954-59	900 - 4,400	1,960
Fall	1954-59	1,100 - 9,300	4,560

In conclusion, the borer population in Waseca County from 1954 to 1959 fluctuated a great deal. The fluctuations of borer population in the three seasons of the same year did not show clear and simple correlations. In view of the recent findings by Chiang and Hodson (1959) on the relationship between summer population and fall population, the lack of a simple correlation was to be expected. It is to be concluded further that the period studied was not long enough to determine the presence or absence of a cyclic fluctuation in the borer population in Waseca County.

NEW MADRID COUNTY

General Description of the Area

New Madrid County is located in southeastern Missouri on the fertile Mississippi Delta, about 35 miles southwest of Cairo, Illinois. The county consists

of almost 700 square miles of land divided among 11 townships. Cotton, soybeans, and corn are the most important crops in this area with a small amount of wheat in certain areas.

General Description of Weather Conditions

The monthly average temperature and the total monthly rainfall are given in the Appendix IV A. The deviations of these readings from long-term normal are given in the Appendix IV B. The general weather conditions during the 4 years may be summarized as follows:

1956—Temperatures were below normal in April and September and slightly above normal the remainder of the season. Entire season dry.

1957—Through June the rainfall was very heavy. The remainder of the year the rainfall was normal and the temperatures were below normal.

1958—Entire season slightly cooler than normal with the monthly rainfall alternately fluctuating above and below normal.

1959—Over-all season slightly warmer than normal with deficient rainfall.

Agronomic Practices

The fertilizer treatments used in New Madrid County are summarized in Appendix IV C. An average of 76 percent of the fields received various combinations of N-P-K. About 40 and 36 percent of the fields were treated with anhydrous ammonia and starter fertilizer, respectively. Only two fields failed to get at least some type of fertilization over the 4-year period.

The information on crop rotations in New Madrid County is summarized in Appendix IV D by the previous crop grown in each field for the 4 years. According to the 4-year average, 40 percent of the fields were planted to corn for the second year. Approximately 18 percent and 16 percent of the fields were on ground used for cotton and small grains the previous year. About 11 percent of the fields were on soybean ground but the soybean acreage varied considerably over the 4-year period. The remainder of the corn followed small acreages of clover, pasture, sorghum, rye, and vetch.

Stand counts were taken in each field and are summarized in Appendix IV E. The stand counts ranged from 8,300 to over 18,000 plants per acre. The 4-year average was 12,523 plants per acre.

The dates of planting are summarized in table 14. In 1956 the dates varied from March 26 to May 10. In 1957, it was very wet in southeast Missouri and as a consequence the earliest corn was planted March 23 while the latest corn was not planted until June 6. The planting dates in 1958 generally agree with 1956. However, in 1959 all of the fields had been planted by April 25.

Over 40 different hybrids were planted over the 4-year period 1956-1959. No trend in the choice of hybrid was shown. The hybrids used are listed in Appendix IV F.

TABLE 14-PLANTING DATE IN NEW MADRID COUNTY, MISSOURI

Planting date	Percent of fields				
	1956	1957	1958	1959	Average
Before March 31	10	8.3	0	10.5	6.7
April 1-10		8.3	5.3	42.1	16.7
April 11-20	30	25.0	31.6	36.8	31.7
April 21-30	50	8.3	26.3	10.5	21.7
May 1-10	10	33.3	21.1	0	15.0
May 11-20		0	15.8	0	5.0
May 21-31		8.3	0	0	1.7
After June 1		8.3	0	0	1.7
Total fields observed	10	12	19	19	

Borer Populations

Table 15 is a summary of the borer populations in New Madrid County. The borer populations are also shown in figure 7. In 1956 and 1957, only two censuses (one summer and one early fall) were conducted. A spring census was added in 1958 and a late fall census was added in 1959 to measure the borer population after the third generation had developed. The heaviest infestation was encountered in 1956. However, the summer infestations were never severe during the 4-year period.

It is very difficult to get a valid late fall census in New Madrid County as much of the early corn is picked and the ground is worked before the third generation has developed in that area. However, since there is a third generation it is essential that some check on the late fall population be made.

TABLE 15-SUMMARY OF BORER POPULATIONS AT VARIOUS TIMES EACH YEAR IN NEW MADRID COUNTY, MISSOURI. NUMBER PER ACRE

	Spring	Summer	Early fall	Late fall
1956 Larvae		947	5,478	
Tunnels		2,792	14,535	
1957 Larvae		692	2,116	
Tunnels		1,516	5,949	
1958 Larvae	567	1,013	1,280	
Tunnels		2,089	3,154	
1959 Larvae	145	300	1,022	236
Tunnels		726	3,043	
Average				
Larvae	356	730	2,474	236
Tunnels		1,781	6,670	

Table 16 shows the quantitative changes in the borer populations from time to time each year. There was an average multiple change of 1.93 in the population from the spring census to the end of the summer census. The multiple change from summer to early fall was 3.39 over the 4 years. A late fall census in 1959, made after the third generation had developed, indicated that there was

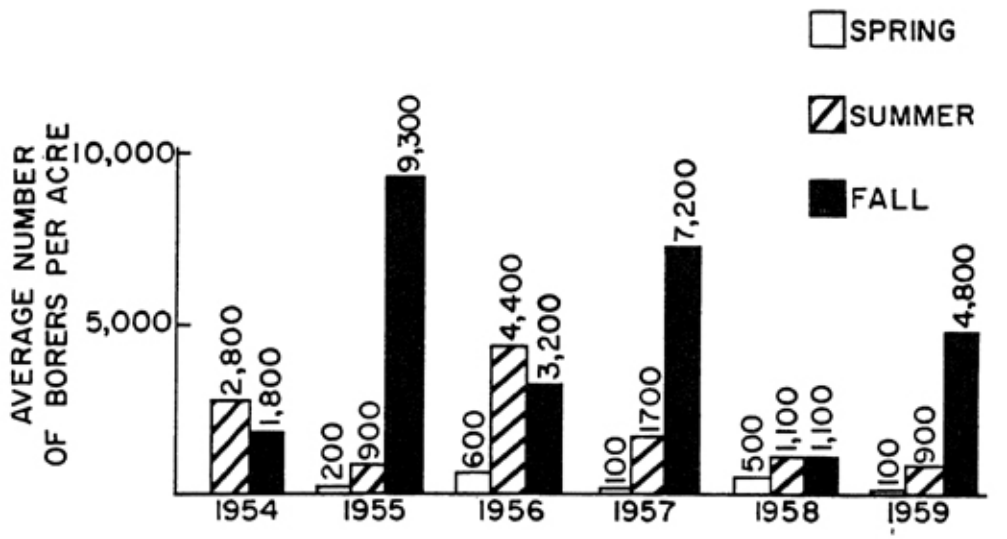

Fig. 6—Number of borers per acre, Waseca County, Minnesota, 1954-1959.

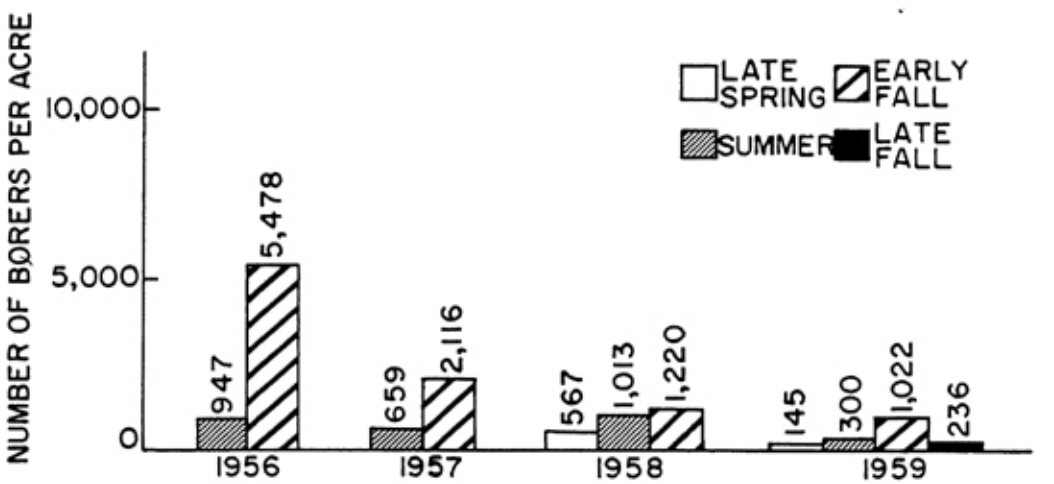

Fig. 7—Number of borers per acre, New Madrid County, Missouri, 1956-1959

a drastic drop in the borer population between the early fall and late fall censuses. There are two reasons for this decline: (1) The agronomic practices previously discussed, and (2) only late corn would be susceptible to the third generation and all of the fields in which the late fall census was taken were planted early in 1959.

TABLE 16-QUANTITATIVE CHANGES IN BORER POPULATIONS IN NEW MADRID COUNTY, MISSOURI

Multiple changes	1956	1957	1958	1959	Average
Spring to summer			1.79	2.07	1.93
Summer to early fall	5.78	3.21	1.15	3.41	3.39
Early fall to late fall				-4.33	-4.33

Table 17 is a summary of the borer populations in relation to date of planting. As expected, in general the earlier corn had the highest first generation infestations while the corn planted later in the season received higher second generation infestations. However, apparently the earliest planted corn still was susceptible to a limited second generation infestation.

Temperature and rainfall are important in regulating the borer population. The borer populations at different times of the year and various weather records are summarized in table 18. However, in New Madrid County, the borer populations have been low all 4 years and it is difficult to interpret the effect of weather on the borer.

TABLE 18-CHANGES IN BORER POPULATIONS FROM SPRING TO SUMMER IN NEW MADRID COUNTY, MISSOURI AND CERTAIN WEATHER DATA FOR MONTHS OF JUNE AND JULY, 1956-59. (T, temperature; R, rainfall)

	1956	1957	1958	1959
No. borers/A - spring	----	----	568	149
- summer	947	659	1,013	
Multiple change - spring to summer	----	----	1.79	2.07
Departure from normal (T) - June	1.3	1.2	-0.2	- a/
(R) - June	-0.33	6.37	-1.44	- a/
No. days 90° or more - June	10	10	10	6
100° or more - June	3	0	0	0
.50" rain - June	2	3	1	4
Departure from normal (T) - July	0.1	-1.3	-0.5	- a/
(R) - July	-1.37	0.10	1.97	- a/
No. days 90° or more - July	17	14	10	11
100° or more - July	4	0	0	0
.50" rain - July	2	3	3	3
Departure from normal (T) - August	1.3	-1.3	-0.6	- a/
(R) - August	-1.94	0	-0.55	- a/
No. days 90° or more - August	21	11	13	17
100° or more - August	3	0	0	0
.50" rain - August	1	3	1	2

a/ No records available.

TABLE 17-SUMMARY OF BORER POPULATIONS BY PLANTING DATES IN NEW MADRID COUNTY, MISSOURI
NUMBER PER ACRE

Date of planting	1956		1957		1958		1959			Average		
	Summer	Early fall	Summer	Early fall	Summer	Early fall	Summer	Early fall	Late fall	Summer	Early fall	Late fall
Before 3/31	0	326	0	663			333	639	0	83	407	0
4/1-5							0	2,247	167	0	562	167
4/6-10			0	0	0	588	303	1,142	611	76	433	611
4/11-15	2,384	8,393			1,550	184	398	0	167	1,083	2,144	167
4/16-20	1,958	0	1,921	329	124	2,405	375	696	0	1,094	857	0
4/21-25	762	3,273			3,405	501	162	703	333	1,082	1,119	333
4/26-30	406	2,392	0	0	0	856				101	812	
5/1-5	0	23,947	663	4,861	2,649	378				828	7,297	
5/6-10			0	0	648	1,032				162	258	
5/11-15					0	996				0	249	
5/16-20					0	4,343					1,086	
5/21-25												
5/26-31			0	0							0	
After 6/1			0	9,163							2,291	

CARROLL COUNTY

General Description of the Area

Carroll County is located in the north central part of the state on the Missouri River. The southern quarter of the county is a fertile, flat area in the Missouri River bottomland while most of the remainder of the county is located in poorer upland soil. The county consists of over 700 square miles of land divided among 22 townships. Corn, soybeans and a small amount of wheat are the principal crops grown.

General Description of Weather Conditions

The monthly average temperature and the total monthly rainfall are given in Appendix V A. The deviations of average temperature and rainfall from long-term normal are given in Appendix V B. The general weather conditions during the 4 years studied may be summarized as follows:

1956—Entire season hot and dry except for July when the rainfall was above normal.

1957—Near normal rainfall and temperature throughout the growing season.

1958—Temperature slightly below normal through July then near normal the remainder of the season while the rainfall was above normal through July followed by below normal rainfall the remainder of the season.

1959—With the exception of July, which was wet and cooler than normal, 1959 was hot and dry.

Agronomic Practices

The various fertilizer treatments used in Carroll County are summarized in Appendix V C. Twenty percent of the fields received no fertilizer treatment. N-P-K combinations were used in 36 percent of the fields while nitrogen was used on 26 percent of the fields. Ammonium nitrate was applied to 16 percent of the fields and the remaining fertilizers used were anhydrous ammonia, starter fertilizer, and manure.

Appendix V D is a summary of the crop rotations in Carroll County with the percent of the fields following the various crops. About 51 percent of the fields were planted to second year corn. Approximately 11, 12, and 13 percent of the corn followed soybeans, clover, and small grains, respectively. A small number of the fields were used for sorghum, alfalfa, and oats in the previous years.

The plant populations ranged from 8,333 to over 16,000 plants per acre. The 4-year average for rate of planting was 11,289 plants per acre. A summary of the stand counts for the 4 years is given in Appendix VE.

Table 19 summarizes the date of planting in Carroll County. With the exception of 1958, corn planting started during the latter part of April and was completed before June 1. A majority of the corn was planted between May 1 and 10.

TABLE 19-PLANTING DATES IN CARROLL COUNTY, MISSOURI

Planting date	Percent of fields				
	1956	1957	1958	1959	Average
Before March 31	4.2	3.2			1.7
April 21-30	8.3	12.9		5.9	6.7
May 1-10	54.2	58.1	51.6	47.1	51.7
May 11-20	33.3	16.1	22.6	44.1	29.2
May 21-31		9.7	12.9	2.9	6.7
After June 1			12.9		3.3
Total fields observed	24	31	31	34	

As in New Madrid County, many different hybrids were planted in Carroll County. Over 50 different hybrids were grown in the census fields from 1956 to 1959. The hybrids used are summarized in Appendix V F.

Borer Populations

The same censuses were taken in Carroll County as in New Madrid County except two spring census were conducted in 1959. The first spring census was made before spring work had been completed. These two censuses were made to determine the borer mortality due to spring work. There was an 85 percent reduction in the borer populations between these two censuses. The 1957 infestation was the heaviest recorded in that county and the 1959 infestation was the lowest. Table 20 is a summary of the borer populations over the 4 years. The populations are also shown in figure 8.

TABLE 20-SUMMARY OF BORER POPULATIONS AT VARIOUS TIMES EACH YEAR FOR CARROLL COUNTY, MISSOURI. NUMBER PER ACRE

	Early spring	Late spring	Summer	Early fall	Late fall
1956 Larvae			1,123	2,523	
Tunnels			3,297	8,962	
1957 Larvae			5,143	23,557	
Tunnels			10,258	37,827	
1958 Larvae		1,729	1,994	4,775	
Tunnels			4,995	15,395	
1959 Larvae		174	409	632	272
Tunnels			943	2,302	2,184
Average					
Larvae	1,206	952	2,167	7,871	272
Tunnels			4,873	16,121	2,184

The quantitative changes in borer populations in Carroll County are given in table 21. There was an average multiple change of 2.69 from the summer census to the early fall census. The greatest change was 4.58 in 1957, when the borer infestation was also the heaviest. There was a great decrease in the borer population over the winter. The borer reductions from the early fall census to the late spring census were 96 percent in both 1958 and 1959.

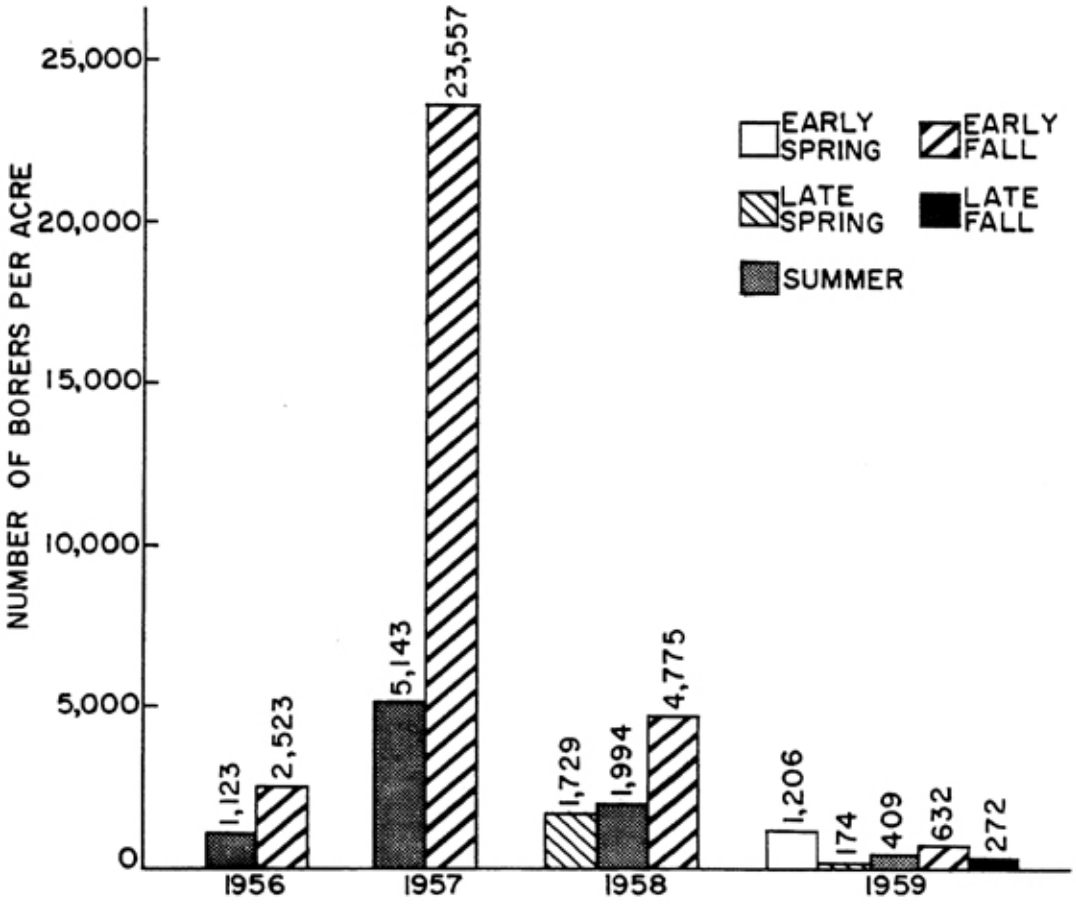

Fig. 8—Number of borers per acre, Carroll County, Missouri, 1956-1959

Table 22 is a summary of the borer populations in relation to the date of planting. There appears to be definite relationship between date of planting and borer infestation. The earlier planted corn was most attractive to the first generation while the later corn was more susceptible to the second generation infestation.

TABLE 21-QUANTITATIVE CHANGES IN BORER POPULATIONS IN CARROLL COUNTY, MISSOURI

Multiple changes	1956	1957	1958	1959	Average
Early to late spring				-6.93	-6.92
Late spring to summer			1.15	2.35	1.75
Summer to early fall	2.25	4.58	2.39	1.55	2.69
Early fall to late fall				-2.32	-2.32
Early fall to late spring			-13.62	-27.33	-20.53

TABLE 22-SUMMARY OF BORER POPULATIONS BY PLANTING DATE FOR CARROLL COUNTY, MISSOURI. NUMBER PER ACRE

Date of planting	1956		1957		1958		1959		Average	
	Summer	Early fall	Summer	Early fall	Summer	Early fall	Summer	Early fall	Summer	Early fall
Before 4/20	4,000	5,075	9,666	12,769					3,717	4,461
4/21-25			15,985	12,456					3,996	3,114
4/26-30	3,833	1,221	10,720	19,805			2,000	0	4,138	5,257
5/1-5	1,667	2,082	6,510	17,568	1,024	4,206	778	333	2,495	6,047
5/6-10	733	1,965	3,427	25,062	4,229	4,207	533	143	2,230	7,844
5/11-15	67	3,056	1,230	26,661	2,713	6,409	242	242	1,063	9,092
5/16-20	333	3,676			1,436	8,364	0	83	442	3,031
5/21-25					841	3,329	0	667	210	999
5/26-31			0	41,654		3,682			0	11,334
After 6/1					638				159	0

The borer populations at various times are summarized in table 23 with different weather records. It should be mentioned that in 1957 when the highest borer populations were recorded, the temperatures were about normal for that locality with slightly more than average rainfall.

TABLE 23-CHANGES IN BORER POPULATIONS FROM SPRING TO SUMMER IN CARROLL COUNTY, MISSOURI AND CERTAIN WEATHER DATA FOR MONTHS OF JUNE AND AUGUST, 1956-59

	1956	1957	1958	1959
No. borers/A - spring	---	---	1,729	174
- summer	1,123	5,143	1,994	409
Multiple change - spring to early fall	---	---	1.5	2.35
No. days 90° or more - June	16	8	5	12
100° or more - June	.3	0	0	0
.50" rain - June	0	3	5	0
No. days 90° or more - July	17	22	6	9
100° or more - July	4	4	0	0
.50" rain - July	5	2	5	2
No. days 90° or more - August	22	17	20	20
100° or more - August	1	1	0	0
.50" rain - August	4	2	4	2

Comparison of Borer Populations in New Madrid and Carroll Counties

Since the two counties under study in Missouri are so widely separated, they have been discussed separately. However, for comparison, table 24 shows the range and average borer populations at various times of the year for the period 1956 to 1959. The borer population in Carroll County has consistently been higher than in New Madrid County. The average borer populations were about three times as high in Carroll County. It should be pointed out that the late fall census in New Madrid County did not include any late fields which were attractive to third generation borers. However, there were very few fields of late corn, which possibly would not be too great a factor in influencing the potential population.

TABLE 24-POPULATION RANGE AND AVERAGE NUMBER OF BORERS PER ACRE IN NEW MADRID AND CARROLL COUNTIES, MISSOURI, 1956-59

	New Madrid County No. borers per acre		Carroll County No. borers per acre	
	Range	Average	Range	Average
Early spring	---	---	---	1,206a/
Late spring	145 - 567	356 b/	174 - 1,729	952b/
Summer	300 - 1,013	730	409 - 5,143	2,167
Early fall	1,022 - 5,478	2,474	632 -23,557	7,871
Late fall	---	236a/	---	272a/

a/ Records of 1959 only
b/ Records of 1958 and 1959 only

CUMING AND HALL COUNTIES, NEBRASKA

The information included in this report has been gathered over the period of June 1955 to November 1959. All of the observations on corn borer populations were collected by members of the Department of Entomology of the University of Nebraska. Information on planting dates, crop rotations and fertilizer application was obtained through use of questionnaires sent to each of the cooperators soon after the completion of each fall survey. Spring populations were checked between May 8 and June 5 in all years since 1956. Summer populations were checked between July 17 and August 4, and fall populations between September 26 and November 5 since 1955. Populations in all cases have been estimated from three areas 1/1000 acre in size from each field.

CUMING COUNTY

General Description of the Area

Cuming County is located in the northeastern part of Nebraska in the second tier of counties west of the Missouri River. This county is in a hilly region that was once smooth upland which has been thoroughly dissected by the drainage system of the Elkhorn River. Cuming County consists of 570 square miles, or 364,000 acres. The drainage of the county is toward the south by the Elkhorn River. Logan, Plum, and Cuming creeks are the main tributaries in the county.

The topography of the county may be described as varying from steeply rolling along the more deeply entrenched water-ways to nearly flat on the portions of undissected prairie upland. Flood plains in the county are generally narrow but do expand to 1¼ miles along the larger streams. Terrace or bench lands form a considerable portion of the tillable land and occur at several distinct levels, some as high as 60 feet above the adjoining flood plains.

The soils that make up Cuming County are divided among 18 different types which are all of glacial origin and are described as Nebraska loess. Marshall silt loam comprises 69.0 percent of the soil, Wabash silt loam 8.8 percent, with the remainder of the soils divided among silt and very fine sandy loams.

Corn is the major grain crop of the county and grain not fed to livestock is sold for cash. Irrigation plays only a minor role in the agriculture of the county.

General Description of Weather Conditions

The average temperatures and total rainfall for the months of the growing season at West Point, Nebraska, are shown in Appendix VI A. Deviations from long-term means are shown in Appendix VI B. In general the weather conditions for Cuming County, Nebraska, may be summarized as follows:

1955—May warm, June cool, July and August above normal in temperature. Season deficient in rainfall except for July.

1956—May with above normal temperatures, June warm, and July cool, August "normal." Entire season dry.

1957—Cool May, cool—wet June followed by a warm—wet July.

1958—Warm May, cool—dry June followed by cool—wet July and a wet August.

1959—Warm—dry June followed by a cool—dry July and a warmer—wet August.

Agronomic Practices

Cuming County, which follows the general trend of most of the Corn Belt, used some form of crop rotation which may include a leguminous crop to build soil fertility. Commercial fertilizers were used in 15.28 percent of the fields checked in the county (Appendix VI C). Crop rotations (Appendix VI D) were primarily two-crop plans with 75.9 percent of the sampled fields involved; corn-oats rotations were the most common, being found in 38.8 percent of the fields. Three-crop rotations were found in 3.8 percent of the fields and the remaining 16.25 percent of the fields were in continuous corn. In this county, as in most corn growing counties in the state, drill planting was used almost exclusively, with 85.0 percent of the fields surface planted and 9.2 percent lister planted (Appendix VI E). There has been a tendency for plant populations to gradually increase since the inception of this study.

Planting dates through the years that this study has been active have remained quite constant with 55.0 percent of the fields planted during the period from May 11 to 20. Date of planting (Table 25) is controlled almost entirely by the weather conditions prevalent during each spring season, although there is considerable reluctance on the part of the individual growers to plant prior to May 5 irrespective of weather conditions. A summary of planting information for Cuming County appears in table VI E of the Appendix.

TABLE 25-PLANTING DATES IN CUMING COUNTY, NEBRASKA

Planting date	Percent of fields					
	1955	1956	1957	1958	1959	Average
May 1-10	12.5	12.5	8.3	16.7	8.3	11.7
May 11-20	54.2	66.7	41.7	54.2	58.3	55.0
May 21-31	16.7	16.7	41.7	29.2	20.8	25.0
June 1-10	8.3	---	4.2	---	8.3	4.2
Unknown	8.3	4.2	4.2	---	4.2	4.2
Average date of planting	May 19	May 17	May 21	May 17	May 19	May 19
Total fields observed	24	24	24	24	24	

Borer Populations

Spring populations in Cuming County have averaged 2,581 live borers per acre since 1956. Summer populations have averaged 6,244 borers per acre and fall populations averaged 36,957 borers per acre. Table 26 and figure 9 summarize the borer populations in Cuming County. The magnitude of the population changes in Cuming County for 4 years is shown in table 27. In two of the

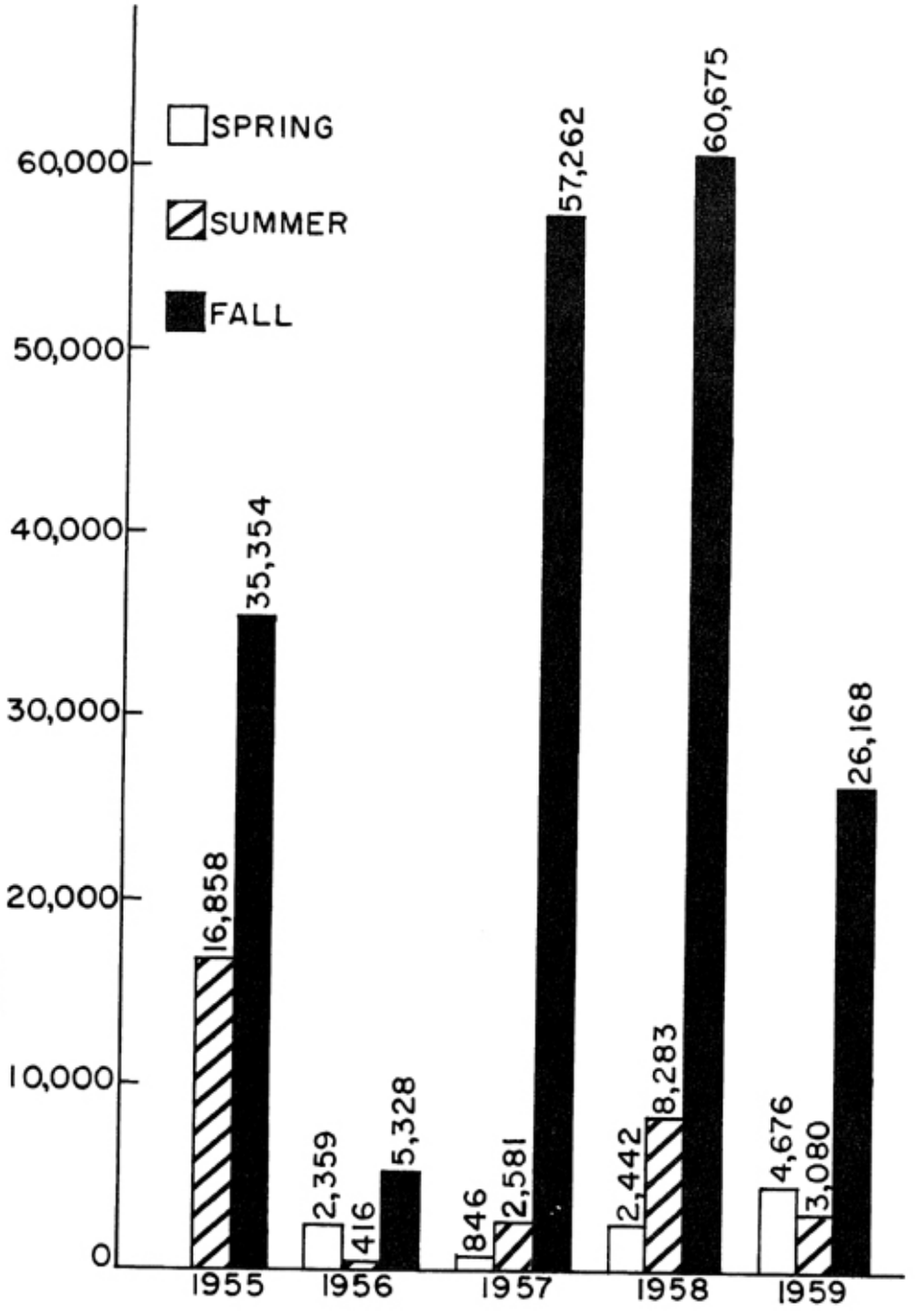

Fig. 9—Number of borers per acre, Cuming County, Nebaska, 1955-1959

TABLE 26-SUMMARY OF BORER POPULATIONS AND INJURY AT VARIOUS TIMES EACH YEAR IN CUMING COUNTY, NEBRASKA

		Average number plants per acre	Total number plants checked	Percent plants with injury	Number of Borers per 100 plants	Number of Borers per acre
1955	Late spring					
	Late summer	10,698	771		157.6	16,858
	Fall	10,878	784	99.4	325.0	35,354
1956	Late spring					2,359
	Late summer	11,322	816		0.1	416
	Fall	10,836	781		0.5	5,328
1957	Late spring					846
	Late summer	11,322	816	32.8	22.8	2,581
	Fall	10,462	754	97.3	547.3	57,262
1958	Late spring					2,442
	Late summer	11,461	826	66.1	72.3	8,283
	Fall	12,793	922	99.9	474.3	60,675
1959	Late spring					4,676
	Late summer	11,100	800	36.9	27.8	3,080
	Fall	11,613	837	86.5	225.3	26,168

TABLE 27-QUANTITATIVE CHANGES IN BORER POPULATIONS IN CUMING COUNTY, NEBRASKA

	1955	1956	1957	1958	1959
Multiple changes:					
Summer to fall	2.1	12.8	22.2	7.3	8.5
Fall to spring	---	-15.0	-6.3	-23.4	-13.0
Spring to summer	---	-5.7	3.0	3.4	-1.5
Winter mortality (%)	---	93.3	84.1	95.7	92.3

TABLE 28-CHANGES IN BORER POPULATIONS FROM SPRING TO SUMMER IN CUMING COUNTY, NEBRASKA, AND CERTAIN WEATHER DATA FOR MONTHS OF JUNE AND JULY, 1956-59. (T, temperature; R, rainfall).

	1956	1957	1958	1959
No. borers/A - spring	2,359	846	2,442	4,676
- summer	416	2,581	8,283	3,080
Multiple change - spring to summer	-5.7	3.0	3.4	-1.5
Departure from normal (T) - June	5.0	-1.6	-3.2	2.1
(R) - June	-0.89	1.45	-3.41	-0.88
No. days 90° or more - June	21	6	7	15
100° or more - June	4	0	2	2
.50" rain - June	4	7	0	5
Departure from normal (T) - July	-2.9	2.7	-6.1	-4.4
(R) - July	-0.35	2.20	7.19	-1.03
No. days 90° or more - July	13	25	3	11
100° or more - July	3	8	0	0
.50" rain - July	2	4	6	2

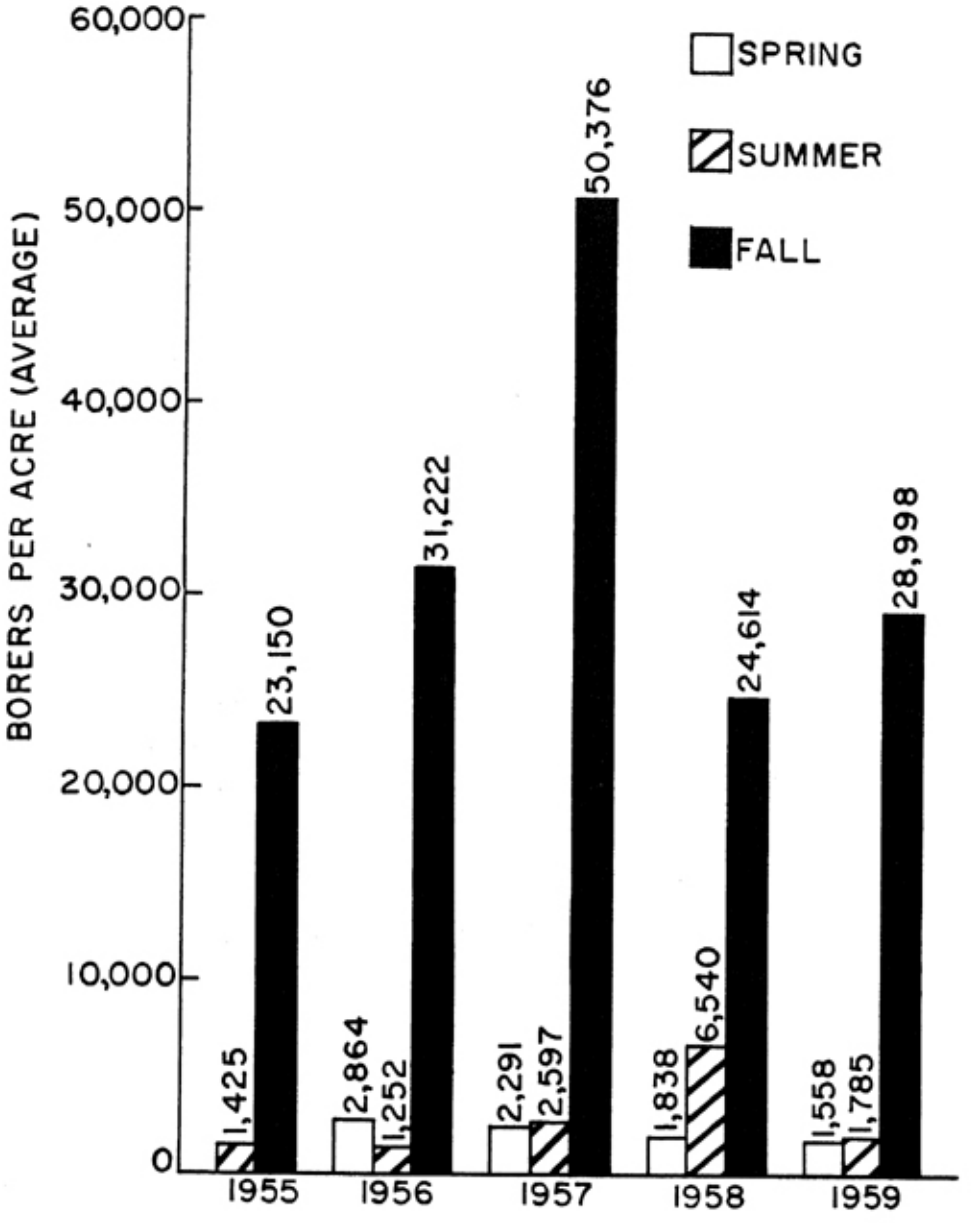

Fig. 10—Number of borers per acre, Hall County, Nebraska, 1955-1959

4 years there was a net population decrease between the spring and summer census periods. This population decrease could be due to weather conditions. In the years in which there was a decrease in the spring to summer populations, a warm dry June was followed by cool dry July (table 28). Corn borer populations have always increased from summer to fall in Cuming County. This multiple increase has averaged 10.6 times over the 5 years of this study. Winter mortality of the corn borer has averaged 91.4 percent. Figure 10 summarizes borer populations in Cuming County since 1955.

A definite relationship is shown between planting date and borer populations in table 29. First generation populations decrease with late planting and

TABLE 29-RELATIONSHIP OF CORN BORER POPULATIONS TO DATE OF PLANTING IN CUMING COUNTY, NEBRASKA, 1955-59

Date	Average number borers per acre	
	Summer	Fall
May 1-10	8,111	27,924
May 11-20	7,505	35,343
May 21-31	2,533	47,952
June 1-10	222	42,291
Unknown	12,121	15,917
Total	6,244	36,957

the second generation populations increase with lateness of planting. A positive relationship is shown (table 30) between the number of years of commercial fertilizer use and borer populations; the longer the use of fertilizer the higher the average corn borer populations.

TABLE 30-RELATIONSHIP OF CORN BORER POPULATIONS TO FERTILIZER APPLICATIONS IN CUMING COUNTY, NEBRASKA, 1955-59

Number years fertilizer applied	Average number borers per acre	
	Summer	Fall
None	4,474	26,811
1	5,161	41,514
2	6,450	49,272
3	10,674	41,978
Unknown	7,992	21,354
Total	6,244	36,957

HALL COUNTY

General Description of Area

Hall County is located in the north central part of the state. The Platte River crosses the county in a northeasterly direction through a shallow valley 12 to 15 miles wide. Hall County is composed of 528 square miles or 337,920 acres. The drainage of the county is supplied by the Platte River except for an area of approximately 6 square miles in the northwestern corner, which is drained by the South Loup River. The Wood River and Prairie, Silver, Dry, and Moore Creeks, all flowing in a northeasterly direction, contribute to the drainage of the county.

The upland areas of the county lie 50 to 150 feet above the floor of the Platte Valley and the topography varies from nearly flat to slightly rolling. A small area along the northern border of the county is covered with a layer of loosely piled sand in dunes or low irregular hills shaped by wind action.

The soils found in Hall County are all glacial in origin and are divided into 26 different types; 20.2 percent of the soils are Hall silt loam, 8.6 percent Hall very fine sandy loam, 8.5 percent Valentine sand, 7.0 percent Cass very fine sandy loam, and 6.9 percent Grundy silt loam. The remainder of the soils are divided among various sandy and silt loams. Practically all of the soil types in the county are under cultivation although some of the poorly drained low river-bottom areas are maintained as native grass meadows and pasture. Irrigation has had a tremendous effect upon the agriculture of the county in the last decade and most of the areas level enough to permit efficient use of water are devoted to cash grain or crop farming with little or no crop rotation. Other more poorly adapted areas are devoted to cattle raising and to some extent general farming.

General Description of Weather Conditions

The average temperatures and total rainfall for the months of the growing season at Grand Island, Nebraska, are shown in Appendix VII A. Deviations from long-term means are presented in Appendix VII B. In general the weather conditions for Hall County, Nebraska, may be summarized as follows:

1955—May warm, June cool, July and August above normal in temperature. Season deficient in rainfall except for June.

1956—May with above normal temperature, June warm, July cool, August slightly cool. Entire season dry.

1957—Cool-wet May and June followed by a warm-dry July and a wet August.

1958—Warm-dry May, cool-dry June followed by a cool-wet July and dry August.

1959—Wet May, warm-wet June followed by a cool-dry July and a warmer-wet August.

Agronomic Practices

In Hall County the trend toward deep well irrigation with nearly all of the commercially grown corn raised on irrigated land has led to a practice of continuous corn season after season. This continuous cropping has been followed by a wider use of commercial fertilizer than would be expected under normal Corn Belt conditions. Commercial fertilizers are used in 77.87 percent of the survey fields in Hall County (Appendix VII C). Crop rotations (Appendix VII D) are generally of the two-crop plans and were found in 36.6 percent of the fields. Three-crop rotations are rare and appear in only 0.8 percent of the fields. Of the remaining fields, 59.5 percent were in continuous corn with a small number of fields having corn following summer fallow.

The planting method in Hall County is drill with 53.6 percent of the fields surface planted and 35.2 percent lister planted. Plant populations have shown a tendency to increase since 1955 and have averaged yearly between 11,960 and 14,480 plants per acre (Appendix VII E).

In Hall County the planting dates (table 31) have varied little from one year to the next with 55.0 percent of the fields planted during the period of May 11 to 20.

TABLE 31-PLANTING DATES IN HALL COUNTY, NEBRASKA

Planting date	Percent of fields					
	1955	1956	1957	1958	1959	Average
May 1-10	4.0	8.0	---	4.0	---	3.2
May 11-20	56.0	68.0	48.0	64.0	56.0	58.4
May 21-31	32.0	24.0	40.0	24.0	32.0	30.4
June 1-10	4.0	---	12.0	4.0	4.0	4.8
July 1-10	---	---	---	---	8.0	1.6
Unknown	4.0	---	---	4.0	---	1.6
Average date of planting	May 20	May 18	May 23	May 19	May 24	May 21
Total fields observed	25	25	25	25	25	

Borer Populations

Spring populations in Hall County have averaged 2,138 live borers per acre since 1956 and summer populations have averaged 2,719 live borers per acre

since 1955. Fall populations have averaged 31,475 borers per acre over the last 5 years. A summary of the borer populations since 1955 appears in table 32. The magnitude of the population changes in Hall County from one census period to the next is compared in tables 33 and 34, and in figure 10. There has, with one exception, always been a population increase from spring to summer and from summer to fall in Hall County since 1955. The 16.1 multiple increase average for summer to fall populations is relatively high, indicating favorable conditions for second generation borer establishment and survival. The influence that irrigation has had upon borer establishment and survival is as yet undetermined and any comment would be pure speculation.

Winter mortality or a comparison of a fall population with the following spring populations has averaged 92.6 percent over the 5 years.

A comparison of planting date and corn borer populations in Hall County (table 35) illustrates a decrease in first generation population with lateness of planting. However, planting date appears to have little effect upon second generation populations. When fertilizer use is compared with borer populations (table 36), a strong positive correlation is shown as the number of fertilizer applications increase.

TABLE 32-SUMMARY OF BORER POPULATIONS AND INJURY AT VARIOUS TIMES EACH YEAR IN HALL COUNTY, NEBRASKA

	Average number plants per acre	Total number plants checked	Percent plants with injury	Number of Borers per 100 plants	Number of Borers per acre
1955 Late spring					
Late summer	11,908	894		12.0	1,425
Fall	12,521	940	78.2	184.9	23,150
1956 Late spring					2,864
Late summer	13,773	1,034		9.1	1,252
Fall	14,412	1,082	85.2	216.6	31,222
1957 Late spring					2,291
Late summer	15,278	1,147	30.3	17.0	2,597
Fall	13,573	1,019	98.0	371.1	50,376
1958 Late spring					1,838
Late summer	15,824	1,188	40.2	41.3	6,540
Fall	12,934	971	100.0	182.7	23,630
1959 Late spring					1,558
Late summer	14,173	1,064	20.8	12.6	1,785
Fall	14,679	1,102	85.0	197.5	28,998

TABLE 33-QUANTITATIVE CHANGES IN BORER POPULATIONS IN HALL COUNTY, NEBRASKA

	1955	1956	1957	1958	1959
Multiple changes:					
Summer to fall	16.2	24.9	19.4	3.8	16.2
Fall to spring	---	-8.2	-13.6	-27.4	-15.8
Spring to summer	---	-2.3	1.1	3.6	1.1
Winter mortality (%)	---	87.7	92.7	96.4	93.4

TABLE 34-CHANGES IN BORER POPULATIONS FROM SPRING TO SUMMER IN HALL COUNTY, NEBRASKA, AND CERTAIN WEATHER DATA FOR MONTHS OF JUNE AND JULY, 1956-59. (T, temperature; R, rainfall)

	1956	1957	1958	1959
No. borers/A - spring	2,864	2,291	1,838	1,558
- summer	1,252	2,597	6,540	1,785
Multiple change - spring to summer	-2.3	1.1	3.6	1.1
Departure from normal (T) - June	4.7	-2.2	-3.3	1.5
(R) - June	-0.15	0.65	-0.94	0.43
No. days 90° or more - June	15	3	6	8
100° or more - June	0	0	0	0
.50" rain - June	5	5	3	4
Departure from normal (T) - July	-3.4	0.4	-7.1	-5.7
(R) - July	-1.69	-0.95	4.46	-1.68
No. d ays 90° or more - July	11	18	1	9
100° or more - July	2	5	0	0
.50" rain - July	0	2	8	0

TABLE 35-THE RELATIONSHIP OF CORN BORER POPULATIONS TO DATE OF PLANTING IN HALL COUNTY, NEBRASKA, 1955-59

Date	Average number borers per acre	
	Summer	Fall
May 1-10	3,330	24,559
May 11-20	3,490	31,548
May 21-31	1,814	27,891
June 1-10	388	63,103
July 3	0	47,785
Unknown	333	13,486
Total	2,720	31,729

TABLE 36-RELATIONSHIP OF CORN BORER POPULATIONS TO FERTILIZER APPLICATIONS IN HALL COUNTY, NEBRASKA, 1955-59

Number years fertilizer applied	Average number borers per acre	
	Summer	Fall
None	777	18,458
1	388	34,822
2	2,220	28,046
3	3,187	33,922
Unknown	2,301	23,014
Total	2,720	31,475

Comparison of Borer Populations in Cuming and Hall Counties

Cuming and Hall counties are located within 100 miles of one another in what could be considered the western Corn Belt. Cuming County follows the typical Corn Belt agronomic practices based on the maintenance of soil fertility through the use of crop rotation supplemented with commercial fertilizers. In Hall County, with the recent emphasis in deep well irrigation, continuous cropping with corn has become the rule rather than the exception. Commercial fer-

tilizers are used freely and crop rotation is seldom seen. In the fields checked in Hall County, 77.87 percent were commercially fertilized while only 15.28 percent of the fields in Cuming County were so treated. A comparison of the two counties based on principal crops raised, fertilizer used and acres irrigated is shown in table 37.

TABLE 37-FIVE PRINCIPAL CROPS HARVESTED, AMOUNT OF LAND IRRIGATED, AND TONS OF FERTILIZER USED IN CUMING AND HALL COUNTIES, NEBRASKA IN 1957*.

Five principal crops:			
Cuming County		Hall County	
Crop	Harvested acres	Crops	Harvested acre
Corn	126,080	Corn	98,250
Oats	57,250	Hay	36,590
Hay	46,820	Sorghum (grain)	34,240
Sorghum (grain)	11,840	Winter wheat	23,760
Soybeans	5,180	Oats	10,490
Extent of irrigation:		Cuming County No. acres	Hall County No. acres
Total land irrigated		4,600	135,700
Irrigated corn		1,640	83,840
Non-irrigated corn		124,440	14,410
Fertilizer used:			
Tons fertilizer used		610	8,570
Total acres fertilized		8,700	108,500

*Data from the Nebraska Agricultural Statistics Annual Report for 1957.

Planting rates when compared in the two counties illustrate an additional difference in the agriculture of the two areas. Planting rates are on the average higher in Hall County and surface planting is the dominant type in both counties.

The corn borer populations over the last 5 years in the two counties (table 38) show the effects of the different agronomic practices on corn borer establishment and survival. Spring populations in Hall County have been on the average lower than in Cuming County, but the seasonal variation in these spring populations has been greater (2.9 times) in Cuming than in Hall County. Summer populations in Cuming County have been on the average much larger than in Hall, but again the seasonal variation has been greater (3.1 times) in Cuming

TABLE 38-POPULATION RANGE AND AVERAGE NUMBER OF BORERS PER ACRE IN CUMING AND HALL COUNTIES, NEBRASKA, 1955-59

	Cuming County No. borers per acre		Hall County No. borers per acre	
	Range	Average	Range	Average
Spring	846 - 4,676	2,581	1,558 - 2,864	2,138
Summer	416 - 16,858	6,244	1,252 - 6,540	2,719
Fall	5,328 - 60,675	36,957	23,150 - 50,376	31,475

County. The fall populations in Cuming County on the average are larger than in Hall County but the variation from year to year is less in Hall County. These figures demonstrate the stabilizing effects that irrigation has on corn borer populations.

It is too early to fully evaluate the effects that spring plowing will have on a county wide basis, surely a reduction in potential of the corn borer is in operation. Increased stand counts may influence borer oviposition and survival, high nitrogen levels may increase borer establishment, and the increased vitality of the corn plant during periods of second generation oviposition should influence corn borer survival.

VAN WERT COUNTY, OHIO

General Description of the Area

Van Wert County, 406 square miles in area, is located in the northwestern quarter of the state along the Indiana line. Topographically, it is flat over the northern half and flat to undulating over the remainder. Drainage is through numerous small creeks which flow northeastwardly into the Auglaize River, excepting a small area in the southwestern corner which is crossed by the St. Marys River. The soils of the county are all of glacial origin. In the northern part a heavy clay (Clyde or Fulton) predominates and south of this the soil, although still black, is more loamy and is classified as Clyde clay loam, with small areas of the yellow Miami clay loam.

General Description of Weather Conditions

The monthly average temperatures and total monthly rainfall are given in Appendix VIII A. The deviations of the average temperature and rainfall from the long-term normal are given in Appendix VIII B. In general, the weather conditions for Van Wert County, Ohio, may be summarized as follows:

1956—Cool-wet June followed by cool-dry July.
1957—Cool-wet June followed by cool-dry July.
1958—Cool-wet June followed by cool-wet July.
1959—Warm-dry June followed by cool-dry July.

Agronomic Practices

The farming procedures in Van Wert County may be characterized as follows (table 39, and Appendix VIII C, D, E, and F): (1) Regular 3-5 year rotations are followed, seldom following corn with corn at present, (2) heavy applications of fertilizers are made annually with little or no barnyard manure, (3) plant populations have gradually increased over the years the census has been taken, (4) practically no insecticides have been used on field corn, and (5) resistant hybrids have been ignored because of low borer populations in recent years.

TABLE 39-PLANTING DATES IN THE FIELDS USED IN VAN WERT COUNTY, OHIO

Planting date	1958	1959	Average
May 1-10	30.43	12.50	21.47
May 11-20	60.87	75.00	67.93
May 21-31	8.70	12.50	10.60
Average date of planting	May 13	May 16	
No. fields observed	24	24	

Borer Populations

The records on borer populations were not as complete as desired (tables 40, 41, 42, and 43, and figure 11). However, two trends were observed to date:

1. Resistant hybrids (C54 and K62) have low first generation population even when planted early. The second generation is usually higher than the first on these hybrids when they are planted late.

2. Susceptible hybrids (Ind. 620 and Iowa 4249) demonstrate that early planting contributes to higher first generation build-up with a corresponding decrease in second generation population; late plantings largely escape first generation damage but usually have higher second generation populations.

VALIDITY OF SAMPLING METHODS

An analysis of variance was computed for each borer population samplied. Estimates of the respective components of variance were computed as well as the relative percent variation due to each component. The results of the individual analyses are too lengthy to present; however, the following generalizations can be made. (1) In all but a few cases the least amount of variation occurred between townships, indicating an evenly distributed population per township throughout each county. In other words, variation between fields was due to the condition of the fields themselves rather than to their location within a county. (2) Counties with low population means were uniformly low, and had little variation between fields; but a considerable amount of variation occurred between sites within fields. (3) Counties with high population means showed much more variation between fields, but less variation between sites.

The adequacy of the sample mean was measured by two methods. For each population sample the 95 percent confidence interval of the mean and an "index of variation" were computed. These data are shown in table 44. The confidence interval may be interpreted as meaning that, if it is stated that the confidence interval includes the true population mean, this statement will be correct on the average 95 percent of the time.

The "index of variation" is defined as the variance of a county mean divided by the sample county mean multiplied by 100 percent. This was used rather than the coefficient of variation. In this type of data the variance, not the standard deviation, is a function of the mean. In addition, the same sample sizes were not used consistently throughout the course of this study. For these reasons, it appeared best to use the above defined "index of variation" rather than the coefficient of variation.

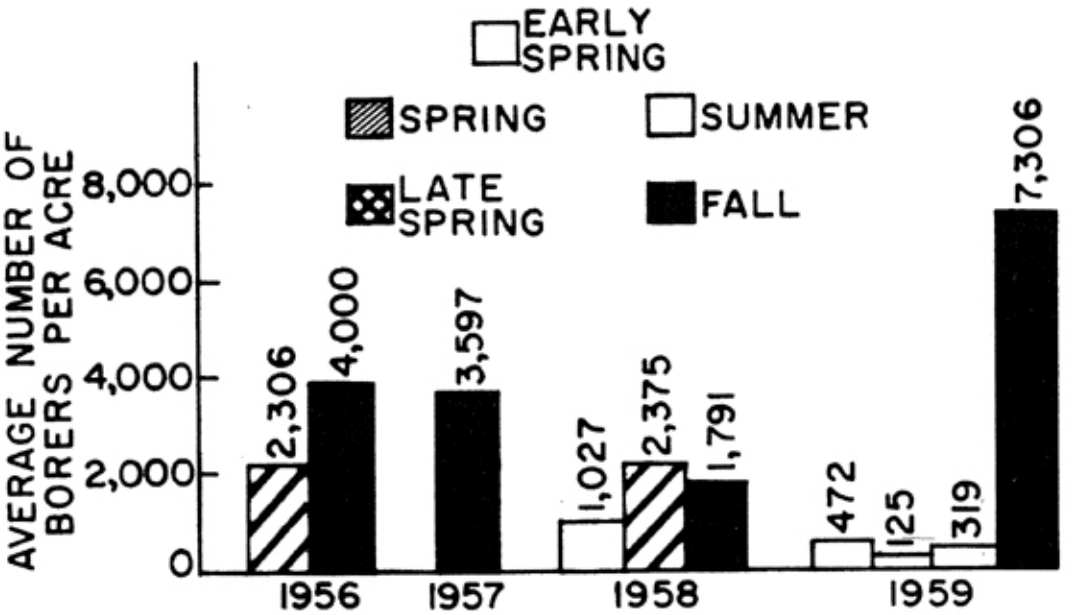

Fig. 11—Number of borers per acre, Van Wert County, Ohio, 1956-1959

TABLE 40-SUMMARY OF BORER POPULATIONS AND INJURY AT VARIOUS TIMES EACH YEAR FOR VAN WERT COUNTY, OHIO

	Average No. plants per acre	Total plants checked	Percent plants with injury	No. larvae per 100 plants	No. larvae per acre
1956[a]					
Summer	10,000	364	41.8	22.8	2,306
Fall	12,806	461	51.6	31.2	4,000
1957					
Fall	13,900	1,001	36.1	25.9	3,597
1958					
Early spring					1,027
Summer	13,666	984	18.6	17.4	2,375
Fall	13,056	940	19.5	13.7	1,791
1959					
Early spring					472
Late spring					125
Summer	14,472	1,042	6.3	2.2	319
Fall	14,680	1,057	34.8	49.8	7,306

a/ Only 12 fields observed in 1956.

TABLE 41-QUANTITATIVE CHANGES IN BORER POPULATIONS IN VAN WERT COUNTY, OHIO

	1956	1957	1958	1959	Average
Multiple changes:					
Summer to fall	1.73		-1.32	22.90	10.79
Fall to early spring			-3.50	-3.79	-3.65
Early spring to late spring				-3.77	
Late spring to summer				2.55	
Early spring to summer			2.31		
Winter mortality (%)			71.44	73.65	72.55
Spring farm operations mortality (%)				73.52	

TABLE 42-CHANGES IN BORER POPULATIONS FROM SPRING TO SUMMER IN VAN WERT COUNTY, OHIO, AND CERTAIN WEATHER DATA FOR MONTHS OF JUNE AND JULY, 1956-59. (T, temperature; R, rainfall)

	1956	1957	1958	1959
No. borers/A - spring	----	----	1,027	472
- summer	2,306	----	2,375	319
Multiple change - spring to summer	----	----	2.3	-1.47
Departure from normal (T) - June	-0.5	-1.7	-6.4	-0.5
(R) - June	0.49	2.51	5.02	-2.48
No. days 90° or over - June	4	1	0	6
100° or over - June	0	0	0	0
.50" rain - June	3	3	6	1
Departure from normal (T) - July	-2.5	-2.6	-2.6	-1.5
(R) - July	0.20	-0.20	3.4	-0.57
No. days 90° or over - July	3	4	2	6
100° or over - July	0	0	0	0
.50" rain - July	2	3	5	3

TABLE 43-POPULATION RANGE AND AVERAGE NUMBER OF BORERS PER ACRE IN VAN WERT COUNTY, OHIO, 1956-59

	No. borers per acre	
	Range	Average
Early spring	472 - 1,027	750
Late spring a/	125	125
Summer	319 - 2,375	1,667
Fall	1,791 - 7,306	4,174

a/ 1959 data only

TABLE 44-SAMPLE MEANS, VARIANCE, 95 PERCENT CONFIDENCE INTERVALS, AND "INDEX OF VARIATION" FOR ALL COUNTIES STUDIED

Year		Mean No. of borers per site	Variance of the mean	95 percent confidence interval of mean		Index of variation
				Lower limit	Upper limit	Percent
		Boone County, Iowa [a]				
1955	Late spring	7.18	0.4489	5.87	8.49	6.25
	Midseason	2.49	0.1593	1.71	3.72	6.40
	Fall	5.47	0.8378	3.68	7.26	15.32
1956	Late spring	0.45	0.0087	0.27	0.63	1.93
	Midseason	2.57	0.3143	1.47	3.67	12.23
	Fall	10.18	1.7640	7.58	12.78	17.33
1957	Early spring	3.59	0.2724	2.57	4.61	7.59
	Late spring	1.50	0.1046	0.87	2.13	6.97
	Midseason	2.54	0.1920	1.68	3.40	7.56
	Fall	10.92	2.9632	7.55	14.29	27.13
	Post harvest	5.19	0.5142	3.79	6.59	9.91
1958	Early spring	3.43	0.1852	2.59	4.27	5.40
	Late spring	3.97	0.2581	2.98	4.96	6.50
	Midseason	3.61	0.3524	2.45	4.77	9.76
	Fall	6.39	0.6773	4.78	8.00	10.60
	Post harvest	1.01	0.0214	0.73	1.29	2.19
1959	Early spring	0.99	0.0401	0.60	1.38	4.05
	Late spring	0.49	0.0116	0.28	0.70	23.67
	Midseason	0.51	0.0102	0.33	0.69	20.00
	Fall	0.78	0.0208	0.50	1.06	26.67
	Post harvest	0.26	0.0023	0.17	0.35	8.85
		Jefferson County, Kansas [b]				
1955	Fall	5.49	1.2128	3.33	7.65	22.09
1956	Late spring	1.28	0.6081	less than	2.81	47.51
	Midseason	0.85	0.2490	less than	1.83	29.29
	Fall	5.23	2.4464	2.17	8.29	46.78
1957	Early spring	0.93	0.1164	0.26	1.60	12.52
	Late spring	0	-------	-------	-------	------
	Midseason	2.19	1.2221	0.03	4.35	55.80
	Fall	22.56	16.1487	14.69	30.43	71.58
1958	Early spring	3.23	0.3903	2.01	4.45	12.08
	Late spring	0.51	0.0319	0.16	0.86	6.25
	Midseason	3.40	0.8411	1.60	5.20	24.74
	Fall	12.55	23.5169	3.05	22.05	187.38
1959	Early spring	6.68	1.0301	4.69	8.67	15.42
	Late spring	0.29	0.0156	0.05	0.53	5.38
	Midseason	1.40	0.4324	0.11	2.69	30.88
	Fall	8.35	1.8514	5.69	11.01	22.17
		Waseca County, Minnesota [b]				
1954	Midseason	4.00	0.1856	3.16	4.84	4.64
	Fall	2.27	0.1046	1.64	2.90	4.61
1955	Late spring	0.02	0.0060	less than	0.17	30.00
	Midseason	1.04	0.0363	0.67	1.41	3.49
	Fall	9.39	2.1671	6.51	12.27	23.08

TABLE 44--(CONTINUED)

Year		Mean No. of borers per site	Variance of the mean	95 percent confidence interval of mean		Index of variation
				Lower limit	Upper limit	Percent
1956	Late spring	0.61	0.0464	0.19	1.03	7.61
	Midseason	4.97	1.0348	2.98	6.96	20.82
	Fall	4.10	0.8878	2.25	5.95	21.65
1957	Late spring	0.12	0.0034	0.01	0.23	2.83
	Midseason	1.71	0.1237	1.02	2.40	7.23
	Fall	7.08	1.7860	4.46	9.70	25.22
1958	Late spring	0.49	0.0170	0.24	0.74	3.47
	Midseason	1.05	0.1424	0.31	1.79	13.56
	Fall	1.42	0.1101	0.77	2.07	7.75
1959	Late spring	0.17	0.0032	0.06	0.28	1.88
	Midseason	1.29	0.0444	0.88	1.70	3.44
	Fall	4.71	0.8725	2.88	6.54	18.52
		New Madrid County, Missouri [b]				
1956	1st brood	1.03	0.1405	0.30	1.76	13.64
	2nd brood	5.17	3.7200	1.96	8.38	71.95
1957	1st brood	0.27	0.0246	less than	0.57	9.11
	2nd brood	1.22	0.3264	0.11	2.33	26.75
1958	1st brood	0.92	0.0867	0.34	1.50	9.42
	2nd brood	1.45	0.3079	0.37	2.53	21.23
1959	Spring	0.06	0.0026	less than	0.17	4.33
	1st brood	0.36	0.0103	0.16	0.56	2.86
	2nd brood	1.07	0.0475	0.65	1.49	4.44
	Fall	0.19	0.0126	less than	0.41	6.63
		Carroll County, Missouri [b]				
1956	1st brood	1.02	0.0623	0.53	1.51	6.11
	2nd brood	1.65	0.1882	0.80	2.50	11.41
1957	1st brood	5.62	1.1329	3.54	7.70	20.16
	2nd brood	21.68	9.6742	15.59	27.70	44.62
1958	1st brood	2.00	0.1317	1.29	2.71	6.58
	2nd brood	4.68	0.8993	2.82	6.54	19.21
1959	Spring	0.17	0.0095	less than	0.36	5.58
	1st brood	0.37	0.0060	0.22	0.52	1.62
	2nd brood	0.64	0.0272	0.32	0.96	4.25
	Fall	0.26	0.0039	0.14	0.38	1.50
		Cuming County, Nebraska [b]				
1955	Midseason	16.49	12.0273	9.70	23.28	72.94
	Fall	35.39	33.8924	23.98	46.80	95.77
1956	Midseason	0.42	0.0116	0.21	0.63	2.76
	Fall	5.33	3.3704	1.73	8.93	63.23
1957	Late spring	0.85	0.1349	0.13	1.57	15.87
	Midseason	2.58	0.6837	0.96	4.20	26.50
	Fall	57.32	27.5107	47.04	67.60	47.99

TABLE 44--(CONTINUED)

Year		Mean No. of borers per site	Variance of the mean	95 percent confidence interval of mean		Index of variation Percent
				Lower limit	Upper limit	
1958	Late spring	2.44	0.2013	1.56	3.32	8.25
	Midseason	8.29	2.8504	4.98	11.60	34.38
	Fall	60.73	25.5364	50.83	70.63	42.05
1959	Late spring	4.68	0.9913	2.73	6.63	21.18
	Midseason	2.57	0.2199	1.65	3.49	8.56
	Fall	26.18	12.3929	19.28	30.08	47.34
		Hall County, Nebraska[b/]				
1955	Midseason	1.03	0.0387	0.65	1.41	3.76
	Fall	23.44	20.1197	14.65	32.23	85.83
1956	Midseason	1.28	0.1087	0.64	1.92	8.49
	Fall	30.22	5.1617	25.77	34.67	17.08
1957	Late spring	2.39	0.1862	1.55	3.23	7.79
	Midseason	2.67	0.5460	1.22	4.12	20.45
	Fall	50.83	44.0148	37.83	63.83	86.59
1958	Late spring	1.87	0.3813	0.66	3.08	20.39
	Midseason	6.32	5.9315	1.55	11.09	93.85
	Fall	23.24	12.5995	16.29	30.19	54.21
1959	Late spring	1.62	0.8587	less than	3.43	53.01
	Midseason	1.19	0.2222	0.27	2.11	18.67
	Fall	29.29	11.5122	22.65	35.93	39.30
		Van Wert County, Ohio[b/]				
1956	Midseason	2.39	0.7907	0.67	3.66	33.08
	Fall	4.00	0.3073	2.92	5.08	7.68
1957	Fall	3.60	0.5900	2.10	5.10	16.39
1958	Midseason	2.37	0.1473	1.62	3.12	6.21
	Fall	1.79	0.0754	1.25	2.33	4.21
1959	Early spring	0.47	0.0163	0.23	0.71	3.47
	Late spring	0.07	0.0011	0.22	0.34	1.57
	Midseason	0.32	0.0056	0.18	0.46	1.75
	Fall	7.30	4.9462	2.94	11.66	67.75

[a/] Each sampling unit 1/2000 acre in size
[b/] Each sampling unit 1/1000 acre in size

As the population mean increased, so did the variance, and as a result, the width of the confidence interval also increased. It should be pointed out at this time that the accurate estimation of a very high population is not as critical as the accurate estimation of a low or moderate population. The widest confidence interval calculated occurred in the 1957 fall population sample in Hall County, Nebraska. This confidence interval (37.83 to 63.83 borers per site) represents a high population at both the lower and upper limits of the interval. If an interval of similar width should occur when the point estimate of the mean is much lower, the value of the point estimate would be considerably less. This occurred only once during the course of this study, in Jefferson County, Kansas in the

fall of 1958. Here, the lower limit of the 95 percent confidence interval (3.05 borers per site) represents a rather low population while the upper limit (22.05 borers per site) represents a high population. This was the only instance in which the confidence interval included both a low and a high population. Note that the lowest populations are generally associated with a narrow confidence interval while the highest populations are associated with a wider confidence interval.

The "index of variation" is a second method of measuring the adequacy of the sampling method as regards numbers of townships, fields, and sites taken. The lower the index, the better the sample. The index obtained for Jefferson County in the fall of 1958 was nearly twice as large as the second largest index. Four other population samples (Hall County, fall of 1955, 1957, and 1958, Cuming County, fall of 1957) produced wider confidence intervals yet the indices were considerably lower than in Jefferson County in the fall of 1958. The "index of variation" tends to be higher when the population mean is higher, although no definite relationship is apparent. The index appears to be somewhat higher in Kansas and Nebraska than in the other states.

When the population is low there is no apparent justification in increasing the number of fields sampled, due to the low amount of variation between fields. Increasing the number of sites within fields beyond five is of doubtful value. In the late spring census in New Madrid County, Missouri in 1959, five sites were checked from each of 24 fields. The population mean at this time was only 0.06 borer per site. In 19 of these fields no borers were found and so an additional five sites were checked in these 19 fields. No borers were found in any of the 19 fields in which ten sites were checked. This would seem to indicate that if no borers are found in five sites, the chances of finding any borers in an additional five sites is rather small. When populations are high, little would be gained by checking more than three sites per field. However, sampling more fields would somewhat reduce the width of the confidence interval, because of the greater variation between fields when the population mean is high.

The present scheme of two fields per township and three sites per field (five sites per field in the late spring census) appears to be adequate and no changes are recommended. In most cases the "index of variation" was sufficiently low. If the sample size should be changed in the future, in no case should less than two fields per township and/or two sites per field be checked.

GENERAL DISCUSSIONS

Fluctuations in Borer Populations in the Region

Although the counties used in the present study were selected separately by each state, their distribution throughout the region shows a definite pattern. One county is located in Ohio where the borer has been established for the longest time in the region. The other counties are located along an arc covering the newer portions of the borer distribution. Since Ohio is considered the origin

of the initial borer populations in the region, the distribution of the older counties enables us to analyze first the westward expansion of the borer populations, and secondly, the borer populations along the periphery extending from the north to the south. In addition, in one of the fringe areas of spread of the borer (Nebraska), two entirely different farming operations are studied, the one with extensive irrigation (Hall County), the other with little irrigation (Cuming County).

For the convenience of comparison, the borer populations (in terms of number of borers per acre) at three seasons of each of the 5 years are extracted from tables presented earlier and are depicted in their respective locations in the region as shown in figure 1. The population fluctuations in the entire region will be discussed as follows:

1. Relation between the populations of the three seasons. It has been mentioned that the spring census dealt with the overwintering larvae, the summer census dealt with the mature first generation larvae, and the fall census dealt with the larvae entering hibernation. It is to be expected that the population will show increases at the successive census during a given year. This relationship was generally true throughout the region. But exceptions also occurred when the population was lower in the summer than in the spring (Boone, 1955 and 1958, Cuming, 1956 and 1959, and Hall, 1956), or lower in the fall than in the summer (Waseca, 1956, Van Wert, 1958, Carroll, 1959, and New Madrid, 1959). That exceptional cases were found in different years and different locations suggests that they resulted from independent and varied causes.

2. Population peaks within a locality. One of the purposes of this study is to determine if the fluctuations of borer population are cyclic, i.e., have a regularity in the occurrence of population peaks. Chiang and Hodson (1959) studied the fluctuations of borer population in Waseca County on the basis of one field each year for a period of 10 years. They observed no cyclic fluctuations. Because of the multitude of factors which affected the populations, the authors suggested that it is doubtful that the population peaks will occur at any regular intervals more often than by chance. In the present study, records have been kept for too few years to permit us to draw any conclusions.

3. Population peaks within the region. Another main objective of the study is to determine if the fluctuations in the different parts of the region were synchronized. In order to examine this point, the years in which peak populations occurred in each of the three times of census taking (spring, summer, and fall) in each locality are shown in table 45. As mentioned earlier, the populations in the three seasons of a given year were not necessarily correlated with each other. Thus it is not surprising to find that the peaks of the three populations occurred in different years in a given locality. It is again interesting to note that the peak years for any one of the three populations were different in the different localities. In other words, the available records showed no synchronization of population fluctuations in different parts of the North Central States. This lack of synchronization conforms with the general conclusions by Odum (1959) that

TABLE 45-THE YEARS WITH PEAK POPULATIONS DURING THE THREE SEASONS OF THE YEAR

County	Spring	Summer	Fall
Boone	1955	1958	1957
Carroll	----	1957	----
Cuming	1959	1955	1958
Hall	1956	1958	1957
New Madrid	----	1956	----
Van Wert	1958	1956	1956
Waseca	1956	1956	1955

regular cycles of abundance of animal populations in complex communities are not pronounced, and that peaks of abundance of the same animal species in different regions do not always coincide.

Attention is here called to the extremely high multiple increase of the populations from summer to fall in Van Wert, Ohio in 1959. The 23-fold increase was the highest recorded during the course of the study. The warm and dry weather in August in 1959 might have brought about a high oviposition and high survival of eggs and larvae.

Geographical Distribution of Borer Populations in the Region

Figure 12 gives the general trends of the population changes over the entire region. Comparisons will now be made along the line of counties running from Van Wert westward through Boone, Cuming to Hall, a line from Van Wert southwestward through Carroll to Jefferson, and a line running from Waseca southward through Boone, Carroll to New Madrid.

1. East-west distribution. Along the line of counties from Van Wert, Ohio westward to Hall, Nebraska, the *spring* populations were, on the average, higher in the central part, represented by Boone, Iowa, than in either end. These high populations might be due partly to the use of only fields seeded to oats. The *summer* populations showed a similar trend. The *fall* populations, however, were progressively higher toward the west. These facts suggest the following relations: (a) The overwintering survival was higher in the central part than in either the east or the west. This was particularly true in view of the fact that the fall population which entered the winter was much higher in the west than in the central part. (b) The increase from the spring to the summer was about the same in the counties along this east-west line. (c) In most of the years, the multiple increase was the highest in the west and the lowest in the east. In summary, the seasonal populations within a year were rather stable in the east, but fluctuated greatly in the west. These differences are reflections of more favorable conditions during the growing season in the west than in the east.

In a study of borer populations in a smaller area (Minnesota and South Dakota) but with more closely distributed points (by the counties), Chiang (1961) observed that populations at the western fringe of borer distribution were higher than those in the eastern portion of the area. This observation is confirmed in the present study which covers a larger area.

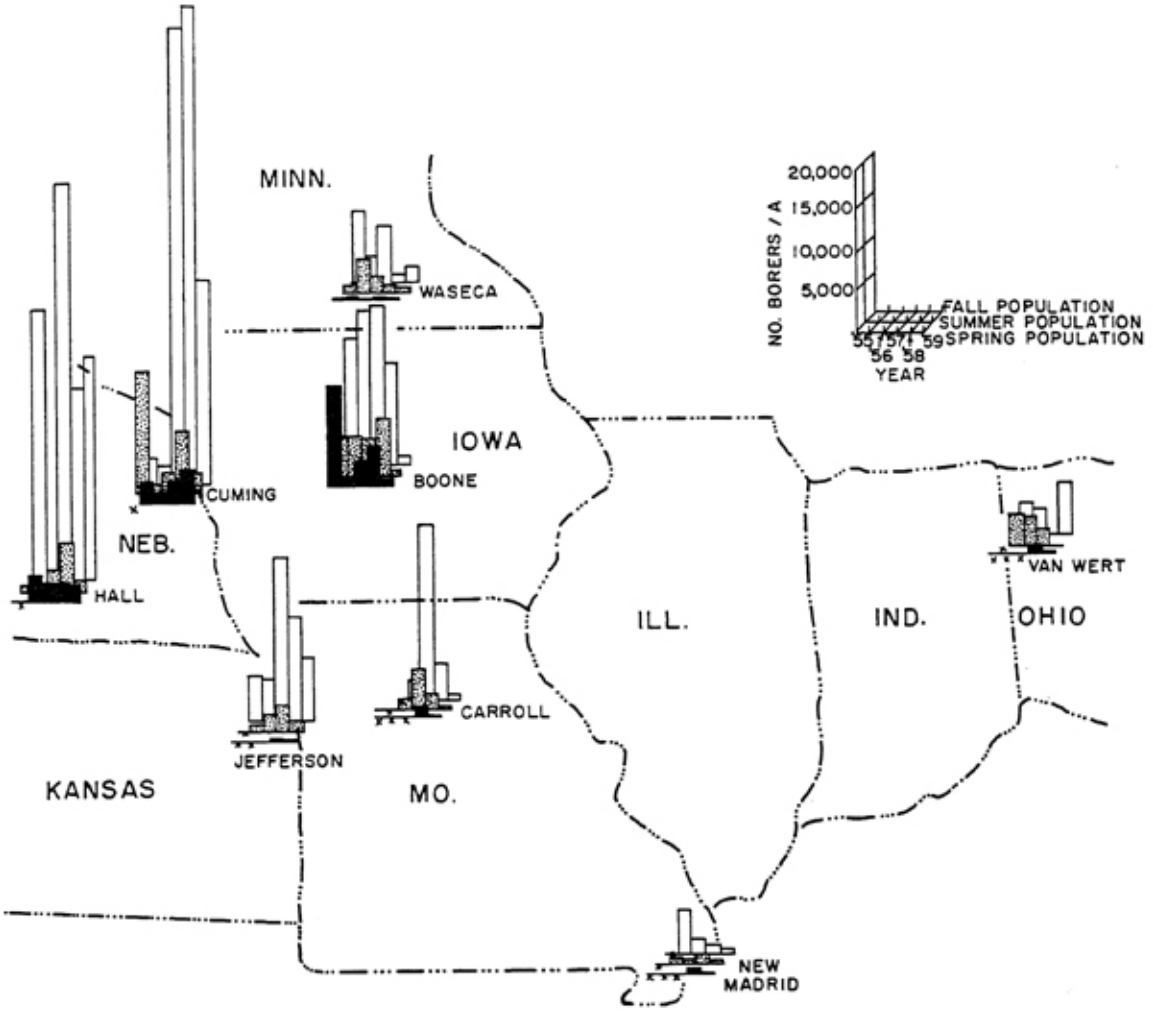

Fig. 12—Number of borers per acre in eight counties in the North Central United States, 1955-1959

2. Southwestward distribution. Along the line of three counties from Van Wert, Ohio, through Carroll, Missouri to Jefferson, Kansas, the *spring* populations differed only slightly. The *summer* populations were again similar in Van Wert and in Jefferson. In 1957, the summer population in Carroll was the highest recorded in the entire region for the 5-year period. The high build-up of summer population might have been due to, among other things, the presence of a partial third brood. The *fall* population and also the multiple increase from summer to fall were highest in Jefferson. But the central part (Carroll) showed the lowest fall population. This feature is different from the trend shown by the fall populations along the east-west line where the increase toward the west was progressive.

3. Along the north-south line from Waseca through Boone, Carroll to New Madrid, the *spring* population was again the highest in the central part (Boone). The *summer* population increased from Waseca to Carroll, then decreased toward the very south (New Madrid). The *fall* population in these counties showed an increase from Waseca to Boone, but toward the south it decreased drastically in Carroll and New Madrid. The size of borer populations is influenced by several aspects of the life cycle of this insect, as well as by physical factors. Among these biological aspects are, in general, the size of the overwintering population,the number of broods per year, the percent pupation in each brood, and the survival of the second brood. Chiang and Hodson (1959) showed that in Waseca County there was a partial second brood, and that the percent of pupation of the first brood mature borers and the percentage of survival of the second brood borers in the fall varied from year to year. While the records on the percent of pupation of the first brood borers in the present study were not complete, it is not unlikely that these biological factors also influenced the borer populations in the region.

New Madrid County presented a unique situation, namely, a third brood. It was not determined what percent of the second brood larvae pupated and gave rise to a third brood; but it is known that this percentage varied with, among other things, the proportion of fields plowed before the development of the third brood. The latter aspect could be very variable. The survival and reproduction of the second brood moths and the survival of the eggs and larvae of the third brood were dependent upon the proportion of late planted fields which was again variable. Furthermore, these moths might have turned to other host plants for oviposition when few corn fields in the suitable condition were present. In this case, the survival of third brood individuals might be higher than what was found in the corn fields alone.

Some of the population changes along the southwestern line and the north-south line could be due to the above variables. More detailed records are needed in order to analyze the population dynamics adequately.

The fall data in Carroll and New Madrid Counties are rather scanty. But the general picture suggests a further point of significance. In these counties the build-up of the population during a given season has been great in spite of the low population in the previous fall. Assuming that a given year had an excep-

tionally long growing season, and that a greater proportion of the third brood did reach maturity, the fall population would be unusually high. If the conditions in the year which follows were as favorable as the average of the area of Missouri, as extraordinarily high population would be expected in late planted fields, such as has never been experienced in any two-brooded areas.

Another point regarding the geographic distribution of borer population is worthy of mention, namely, its relation to crop combinations. Huber, Neiswander and Salter (1928) pointed out that borer population is related to the vegetation types of the locality. Their emphasis was that the general ecological conditions favorable for a certain type of vegetation are also favorable for corn borers. Iowa workers have observed that the moths which initiated the first brood larval population came principally from oat fields which provided an ideal environment for pupating larvae. This observation suggests that the cultural practices associated with a particular vegetation, favored the increase of borer populations; oats fields usually have a higher percentage of corn stalks on the surface of the soil. Weaver (1954) mapped the distribution of various crop combinations in the North Central Region. Examinations of these maps and the distribution of borer populations show that the heavy first brood borer populations coincided, in a general way, with the areas which had a corn-oats combination in 1949. It will be interesting to follow and compare the changes of borer populations and the changes in farming practices in the future.

SUMMARY

The study was conducted in eight counties in six states in the north central United States from 1955 to 1959, inclusive. Standardized procedures were followed in gathering data. This report includes three aspects: information regarding the cultural procedures and borer populations, the analyses of the effects of various factors on borer populations, and a discussion of the borer population throughout the region. The results are summarized in the following paragraphs.

1. Effect of weather conditions on borer populations. Weather conditions greatly influenced borer populations, both favorable and unfavorable. In Boone County in 1956, the increase of the population from spring to summer was the result of favorable weather conditions. In the same county in 1955, however, the population decreased from spring to summer. This decrease was due to cool windy weather in June. On the other hand, the warm and dry weather in Van Wert County in August of 1959 brought about an extremely high multiple increase in borer populations in the summer.

The effects of weather conditions in the winter on the survival of the overwintering larvae also varied. Thus the average multiple changes from fall to early spring of the following year varied from -0.2 in Boone County to -5.6 in Jefferson County.

The effect of rainfall during the growing season was analyzed in various reports. In Nebraska the borer population showed an increase during years with an above normal rainfall. A similar response was shown in Jefferson County,

Kansas. In Boone County in 1959, no measurable rainfall was reported during the first 26 days of June. It was suggested that factors associated with the lack of moisture had an adverse effect upon the borers, and resulted in the lowest first brood infestation observed during the study.

2. Effect of cultural procedures on borer populations. The effect of planting date was analyzed in the reports of Missouri, Nebraska, and Iowa. In Missouri and Nebraska the earlier corn had the highest first generation infestation while the corn planted later in the season received higher second generation infestation. In Missouri, the very late plantings had heavier third brood infestation.

The effects of two methods of planting, listing and furrow opening, were discussed in the Jefferson County report. A decrease in the first generation population was found to be associated with a decrease in the number of fields listed and with an increase in the number of fields planted with a furrow opener. It was suggested that listing often brings stalks that were plowed under back to the surface thereby making emergence of moths easier.

The effect of crop sequence was analyzed in the Nebraska report. The spring population in a field varied with the crop which followed corn. It was shown that the spring population was higher in fields sowed to oats than those planted to corn. This reduction in borer populations in the fields planted to corn was perhaps due to the plowing which was associated with planting of corn. The effect of spring operation was also emphasized in the reports of Boone and Jefferson Counties. In Boone County in 1957 and 1959, the spring operation resulted in about 50 percent mortality, while in Jefferson County the 3-year average was 26 percent.

The effect of mechanical harvesting was discussed in both Boone and Jefferson County reports. Boone County reported 52 percent mortality for 1957 while Jefferson County reported an average of 73 percent winter mortality, a considerable amount of which may have been caused by mechanical corn pickers at harvest time.

Irrigation was practiced in Nebraska. It was reported that the influence of irrigation on borer population was especially profound during the dry summers, and, on the average, irrigation provided the most favorable environment for summer to fall population increases in Hall County.

Nebraska showed a direct relationship between first generation borer population and the number of years of fertilizer application.

3. Borer populations in the North Central region. Two aspects of the borer populations were analyzed from a regional viewpoint: the distribution of the peaks, and the geographical shifts.

Data collected showed little correlation between the borers found in the spring with either the population of the preceding fall or the following summer. In most locations, the peaks of the three populations (spring, summer, and fall) fell in different years. Furthermore, the peaks of any one of the three populations in the different locations in the region fell in many different years. In other words, the available data showed no synchronization of population fluctua-

tions in the North Central region, and showed no indication of a cyclic fluctuation.

The distribution of borer populations throughout the region was analyzed geographically by comparing the populations along three transacts: east-west from Van Wert to Hall, north-south from Waseca to New Madrid, and southwestward from Van Wert to Jefferson.

Along the east-west line counties, spring and summer populations were higher in the central part than either the east or the west. The fall population was progressively higher toward the west. Along the north-south line, the spring population was the highest in the central part. The summer population increased from Waseca to Carroll, then decreased toward the very south (New Madrid). The fall population showed an increase from Waseca to Boone, but decreased drastically farther south (Carroll and New Madrid). In the southwest, Carroll County in the middle showed the highest summer population and the lowest fall population.

The concentration points of borer populations were found to coincide with the areas having a corn-oats crop combination.

In conclusion, the data showed certain patterns in the geographic distribution of borers, but the reasons which brought about these patterns were rather complex.

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APPENDIX I

APPENDIX I A-WEATHER CONDITIONS IN BOONE COUNTY IOWA DURING THE GROWING SEASON

	1955	1956	1957	1958	1959
	Average temperature for the month (° F.)				
May	64.6	62.8	60.0	63.0	63.1
June	67.9	74.5	69.5	66.0	71.9
July	80.7	73.4	77.9	70.2	72.6
August	77.9	73.0	73.2	72.4	76.3
	Total rainfall for the month (inches)				
May	4.44	5.19	3.63	1.55	8.69
June	1.91	2.51	8.71	6.79	3.21
July	5.59	1.63	5.68	10.78	1.48
August	0.93	3.92	1.64	0.44	2.83

APPENDIX I B-WEATHER CONDITIONS IN BOONE COUNTY, IOWA; DEVIATION FROM LONG-TERM NORMAL

	1955	1956	1957	1958	1959
	Monthly temperature				
May	3.4	1.6	-1.2	1.7	1.9
June	-3.3	3.3	-1.7	-5.2	0.7
July	4.1	-3.2	1.3	-6.4	-4.0
August	4.2	-0.7	-0.5	-1.3	2.6
	Monthly rainfall				
May	0.44	1.07	-0.49	-2.57	4.57
June	-3.46	-2.51	3.34	1.42	-2.16
July	1.86	-2.10	0.31	7.05	-2.25
August	-3.13	-0.14	-2.42	-3.62	-1.23

APPENDIX I C-FERTILIZER TREATMENTS IN THE FIELDS USED IN BOONE COUNTY, IOWA

Fertilizer application	Percent of fields					
	1955	1956	1957	1958	1959	Average
N-P-K combinations	31.2	21.9	9.3	18.8	28.2	21.9
Anhydrous ammonia	0	0	3.1	0	0	0.6
Nitrogen	0	0	0	3.1	6.2	1.9
Textopa/	0	3.1	0	0	0	0.6
Manure	12.5	15.6	18.8	25.0	18.8	18.1
No application	56.3	59.4	68.8	53.1	46.8	56.9
Total fields checked	32	32	32	32	32	

a/ A commercial fertilizer containing a number of trace elements.

APPENDIX I D-PREVIOUS YEAR'S CROP IN THE FIELDS USED IN BOONE COUNTY, IOWA

Previous crop	Percent of fields					
	1955	1956	1957	1958	1959	Average
Corn	40.6	50.0	37.5	40.5	43.7	42.5
Clover	34.3	25.0	9.4	6.3	12.5	17.5
Soybeans	12.5	12.5	21.8	9.4	15.6	14.4
Oats	3.1	6.3	18.8	15.6	9.4	10.6
Alfalfa	0	3.1	3.1	18.8	18.8	8.8
Sod	9.4	3.1	6.3	9.4	0	5.6
Sorghum	0	0	3.1	0	0	0.6
Total fields observed	32	32	32	32	32	

APPENDIX I E-PLANTING METHODS AND PLANT POPULATION IN THE FIELDS USED IN BOONE COUNTY, IOWA

	Percent of fields					
	1955	1956	1957	1958	1959	Average
Type of planting						
Power checked	25.0	40.6	56.2	68.7	81.2	54.4
Wire checked	68.7	53.1	37.5	28.1	12.5	39.9
Drilled	6.3	6.3	6.3	3.2	6.3	5.7
Total fields observed	32	32	32	32	32	
Plants per acre						
Less than 10,000	25.0	28.1	9.5	6.2	6.2	15.0
10,000-10,999	31.3	9.4	18.7	37.5	6.2	20.7
11,000-11,999	9.4	12.5	18.7	3.1	28.2	14.2
12,000-12,999	6.2	25.0	15.6	25.0	37.7	21.9
13,000-13,999	15.7	9.4	9.5	12.5	6.2	10.7
14,000-14,999	3.1	12.5	18.7	9.5	6.2	10.0
15,000-15,999	3.1	3.1	6.2	3.1	3.1	3.8
16,000-16,999	6.2	0	3.1	3.1	0	2.5
Over 17,000	0	0	0	0	6.2	1.2
Average	11,250	11,340	11,750	12,020	12,145	11,700
Total fields observed	32	32	32	32	32	

APPENDIX I F-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN BOONE COUNTY, IOWA

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Bergstrom 5470	0	0	0	3.1	0	0.6
Bergstrom unknown	0	3.1	3.1	0	0	1.2
Total	0	3.1	3.1	3.1	0	1.9
Blacks 24	0	0	3.1	0	3.1	1.2
Blacks DeKalb	3.1	0	0	0	0	0.6
Blacks Funks	3.1	0	0	0	0	0.6
Blacks unknown	0	3.1	0	0	0	0.6
Total	6.2	3.1	3.1	0	3.1	3.1
Cargill 250A	3.1	0	0	0	0	0.6
Cargill 300AA	3.1	0	0	0	0	0.6
Cargill 333	3.1	0	0	0	0	0.6
Cargill DeKalb	0	3.1	0	0	0	0.6
Cargill Pioneer	0	3.1	3.1	0	0	1.2
Total	9.3	9.3	3.1	0	0	3.7
Crows 407	0	0	0	3.1	3.1	1.2
Crows 495	0	0	3.1	0	0	0.6
Total	0	0	3.1	3.1	3.1	1.9
DeKalb 3x1	0	0	0	0	3.1	0.6
DeKalb 3x2	0	0	0	0	3.1	0.6
DeKalb 3x2,3x3	0	0	0	3.1	0	0.6
DeKalb 627	6.2	0	6.2	0	0	2.5
DeKalb 630	0	0	0	0	3.1	0.6
DeKalb 635	3.1	0	0	0	0	0.6
DeKalb 627, Cargill 250A	3.1	0	0	0	0	0.6
DeKalb 800A,666	3.1	0	0	0	0	0.6
DeKalb unknown	6.2	18.8	6.2	0	0	6.2
Total	21.7	18.8	12.4	3.1	9.3	13.1
Farmers 427A	0	0	3.1	0	0	0.6
Farmers 537	0	0	0	3.1	0	0.6
Farmers 427A,527	0	0	0	3.1	3.1	1.2
Farmers unknown	3.1	3.1	0	0	0	1.2
Total	3.1	3.1	3.1	6.2	3.1	3.7
Funks 16	0	0	6.2	0	0	1.2
Funks G75	0	0	0	3.1	0	0.6
Funks 78	0	0	0	3.1	0	0.6
Funks unknown	3.1	0	0	0	0	0.6
Total	3.1	0	6.2	6.2	0	3.1
Iowa 504	3.1	0	0	0	0	0.6
Iowa 4376	3.1	0	0	3.1	0	1.2
Total	6.2	0	0	3.1	0	1.9
Iowa State Certified	0	0	0	0	3.1	0.6
Lynks 27, 40A,40B	0	0	0	3.1	0	0.6
Lynks 52	0	0	0	0	3.1	0.6
Total	0	0	0	3.1	3.1	1.2
Moews 500A	0	0	0	0	3.1	0.6
Moews 14	3.1	0	0	0	0	0.6
Moews 96	0	0	3.1	0	3.1	1.2

APPENDIX I F--(CONTINUED)

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Moews 524,500A	0	0	0	3.1	0	0.6
Moews 524,520, 535,65A	0	0	0	3.1	0	0.6
Moews unknown	0	0	3.1	0	3.1	1.2
Total	3.1	3.1	3.1	6.2	9.3	5.0
Northrup King	0	0	0	3.1	0	0.6
Pfister 227	0	0	3.1	3.1	0	1.2
Pfister 303	0	0	0	0	3.1	0.6
Pfister 331	0	0	0	3.1	0	0.6
Pfister 343	3.1	0	0	0	0	0.6
Pfister 370	0	0	3.1	0	3.1	1.2
Pfister unknown	0	12.4	6.2	3.1	3.1	5.0
Total	3.1	12.4	12.4	9.3	9.3	9.3
Pioneer, Pfister	0	3.1	0	0	0	0.6
Pioneer, 255	0	0	3.1	0	0	0.6
Pioneer, 288	0	0	0	3.1	0	0.6
Pioneer, 301B	0	0	0	3.1	3.1	1.2
Pioneer 301B, 309	0	0	3.1	0	0	0.6
Pioneer 301B,354	3.1	0	0	0	0	0.6
Pioneer 305B	0	0	0	0	3.1	0.6
Pioneer 325	3.1	0	0	0	0	0.6
Pioneer 325,318	3.1	0	0	0	0	0.6
Pioneer 329	0	0	9.4	0	0	1.9
Pioneer 329,354	0	0	3.1	0	0	0.6
Pioneer 335, Tomco 7B	3.1	0	0	0	0	0.6
Pioneer 345	0	0	6.2	0	0	1.2
Pioneer 347	3.1	0	0	0	0	0.6
Pioneer 350	0	0	0	3.1	0	0.6
Pioneer 350B	3.1	0	0	0	0	0.6
Pioneer 352	0	0	0	0	9.4	1.9
Pioneer 352B	0	0	3.1	0	0	0.6
Pioneer 354	9.4	0	0	12.5	15.6	7.5
Pioneer 371	0	0	0	0	3.1	0.6
Pioneer 800,806	0	0	3.1	0	0	0.6
Pioneer x 5709	0	0	0	0	3.1	0.6
Pioneer unknown	9.4	37.5	6.2	12.5	0	13.1
Total	37.4	40.6	37.3	34.3	37.4	37.4
Raymond Eveland 101	0	0	3.1	0	0	0.6
Raymond Eveland unknown	0	0	0	0	3.1	0.6
Total	0	0	3.1	0	3.1	1.2
Steckleys Genetic Giant	0	0	0	3.1	0	0.6
Tomco	0	3.1	0	0	0	0.6
Turners 14A	0	0	3.1	0	0	0.6
United Hagie 41A	0	0	0	3.1	0	0.6
Webster 475	0	0	3.1	0	0	0.6
Webster unknown	0	3.1	0	0	0	0.6
Total	0	3.1	3.1	0	0	1.2

APPENDIX I F--(CONTINUED)

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Unknown	6.2	0	3.1	6.2	3.1	3.7
Total number fields observed	32	32	32	32	32	32
Total number of varieties	24	13	24	23	22	21.2

APPENDIX II

APPENDIX II A-WEATHER CONDITIONS IN JEFFERSON COUNTY, KANSAS DURING THE GROWING SEASON

	1955	1956	1957	1958	1959
	Average temperature for the month (^{O} F.)				
May	66.1	68.9	63.7	66.5	67.4
June	69.8	75.8	73.0	72.3	75.3
July	83.8	79.0	81.5	75.6	75.3
August	79.1	80.0	79.2	76.8	80.1
	Total rainfall for the month (inches)				
May	4.43	3.64	6.04	2.93	5.01
June	3.19	4.52	6.87	6.55	1.62
July	2.89	5.10	2.60	12.45	6.29
August	2.42	2.3	1.30	1.54	4.04

APPENDIX II B-WEATHER CONDITIONS IN JEFFERSON COUNTY, KANSAS; DEVIATION FROM LONG-TERM NORMAL

	Monthly temperature				
May	2.0	3.8	-1.7	1.0	2.1
June	-3.8	0.8	-1.9	-2.7	0.7
July	4.3	-1.1	1.4	-4.4	-4.5
August	2.9	1. 3	0.7	-2.1	2.5
	Monthly rainfall				
May	-0.91	-1.98	2.17	-1.71	2.49
June	-1.10	-1.13	2.39	1.61	-3.65
July	-0.28	1.60	-0.85	9.92	3.12
August	-1.53	-3.15	-2.70	-3.39	-2.41

APPENDIX II C-FERTILIZER TREATMENTS IN THE FIELDS USED IN JEFFERSON COUNTY, KANSAS

Fertilizer application	Percent of fields					
	1955	1956	1957	1958	1959	Average
N-P-K combinationsa/	20.9	20.8	33.3	33.3	41.6	30.0
Ammonium nitrate	20.8	16.6	8.3	8.3	8.3	12.5
Starter fertilizer	4.2	4.2	0	4.2	0	2.5
Green manure	12.5	4.2	0	4.2	0	4.2
Barnyard manure	8.3	4.2	20.9	8.3	20.8	12.5
No treatment	33.3	50.0	37.5	41.7	29.3	38.3
Total fields checked	24	24	24	24	24	

a/ The N-P-K combinations included the following:

8-24-8	12-12-12	10-20-0	16-5-5
9-20-20	16-20-0	10-20-10	16-16-0
15-15-0	19-38-0	16-24-0	16-8-0
8-32-0	13-39-0	0-45-0	

APPENDIX II D-CROP HISTORY IN THE FIELDS USED IN JEFFERSON COUNTY, KANSAS

Type of rotation	Percent of fields					
	1955	1956	1957	1958	1959	Average
Continuous corn	41.7	62.5	66.7	75.0	54.2	60.0
Two-crop rotations						
Corn-wheat	12.5	25.0	4.2	4.2	12.5	11.7
Corn-clover	12.5	0	4.2	4.2	4.2	5.0
Corn-alfalfa	0	4.2	0	0	0	0.8
Corn-soybeans	0	4.1	0	4.1	0	1.7
Corn-oats	0	0	4.1	4.1	4.2	2.5
Corn-pasture	0	0	8.4	0	4.1	2.5
Corn-sorghum	0	0	4.1	0	4.1	1.6
Total	25.0	33.3	25.0	16.6	29.1	25.8
Three-crop rotations						
Corn-wheat-clover	12.5	0	0	0	0	2.5
Corn-wheat-wheat	4.1	0	0	0	4.2	1.7
Corn-alfalfa-clover	4.1	0	0	0	0	0.8
Corn-wheat-oats	4.2	0	0	0	0	0.8
Corn-soybeans-sorghum	4.2	0	0	0	0	0.8
Corn-soybeans-soybeans	4.2	0	0	0	0	0.8
Corn-clover-wheat	0	4.2	4.2	0	0	1.7
Corn-rye-wheat	0	0	4.1	4.2	0	1.7
Corn-alfalfa-alfalfa	0	0	0	4.2	12.5	3.4
Total	33.3	4.2	8.3	8.4	16.7	14.2
Total number fields checked	24	24	24	24	24	

APPENDIX II E-PLANTING METHODS AND PLANT POPULATIONS IN THE FIELDS USED IN JEFFERSON COUNTY, KANSAS

	Percent of fields					
	1955	1956	1957	1958	1959	Average
Type of planting						
Drilled						
Listed	75.0	70.8	79.2	66.7	50.0	68.4
Furrow opened	8.3	16.7	8.3	20.8	37.5	18.3
Surface planted	16.7	12.5	12.5	12.5	12.5	13.3
Total fields observed	24	24	24	24	24	
Plants per acre						
Less than 10,000	0	0	26.3	30.0	0	11.1
10,000-10,999	0	0	15.8	5.0	0	4.0
11,000-11,999	4.2	4.2	26.3	35.0	0	13.6
12,000-12,999	8.3	8.3	0	15.0	4.2	7.0
13,000-13,999	4.2	12.5	5.3	10.0	20.8	12.4
14,000-14,999	16.7	16.7	10.5	0	41.7	17.0
15,000-15,999	12.5	8.3	5.3	0	12.5	7.4
16,000-16,999	0	8.3	10.5	5.0	8.3	6.2
17,000-17,999	20.8	12.5	0	0	4.2	7.3
Over 18,000	33.3	29.2	0	0	8.3	14.0
Average	16,508	16,757	12,061	10,896	14,804	14,205
Total fields observed	24	24	19	20	24	

APPENDIX II F-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN JEFFERSON COUNTY, KANSAS

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Commercial						
Pioneer 300	20.87	16.74	25.00	8.34	12.50	16.69
Pioneer 302	0	8.34	8.36	4.16	8.34	5.84
Pioneer 332	0	4.16	0	0	0	0.83
Pioneer 339	0	0	0	0	4.16	0.83
Pioneer 312A	0	0	0	0	4.16	0.83
Total	20.87	29.24	33.36	12.50	29.16	
DeKalb 3x2	0	0	0	4.16	16.74	4.18
DeKalb 3x1	0	0	8.36	4.16	0	2.50
DeKalb 802	0	0	0	8.34	0	1.67
DeKalb 925	0	4.16	0	0	4.16	1.67
DeKalb 832	0	4.16	0	0	0	0.83
DeKalb 910	4.16	0	0	0	0	0.83
DeKalb unknown	8.33	4.16	12.50	20.88	4.16	10.04
Total	12.49	12.48	20.86	37.54	25.06	
United-Hagie 65A	12.50	8.34	4.16	0	4.16	5.83
United-Hagie 60	0	0	0	4.16	4.16	1.67
United-Hagie 37A	0	0	0	4.16	0	0.83
United-Hagie W50	0	0	0	0	4.16	0.83
United-Hagie 66	0	0	0	0	4.16	0.83
Total	12.50	8.34	4.16	8.32	16.64	
Kansas Champion Blend	4.16	4.16	4.16	4.16	4.16	4.16
Steckley	8.33	4.16	0	0	4.16	3.33
Standard 813	4.16	0	12.50	0	0	3.33
Funks 94	4.16	0	0	0	0	0.83
Funks 95A	0	0	0	4.16	0	0.83
Funks 96	0	0	0	4.16	0	0.83
Funks 144	0	0	0	0	4.16	0.83
Funks unknown	0	4.16	0	8.34	0	2.50
Total	4.16	4.16	0	16.66	4.16	
KFU 523W	0	0	0	8.34	4.16	2.50
KFU 150	0	0	0	4.16	0	0.83
Total	0	0	0	12.50	4.16	
Cornhusker L1B2	0	4.16	0	0	0	0.83
Cornhusker 2x1	0	4.16	0	0	0	0.83
Cornhusker unknown	8.33	0	0	0	0	1.67
Total	8.33	8.32	0.	0	0	
Commercial						
American	0	0	4.16	0	0	0.83
Carlsons	0	0	4.16	0	0	0.83
Cargill	0	0	4.16	0	0	0.83
Crows 607	0	4.16	0	0	0	0.83
Crows Premium 825	4.16	0	0	0	0	0.83
Total	4.16	4.16	0	0	0	

APPENDIX II F--(CONTINUED)

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Embryo	0	0	0	4.16	0	0.83
Maygold	0	0	4.16	0	0	0.83
Old Nick	0	4.16	0	0	0	0.83
Pfister	0	0	4.16	0	0	0.83
Tomson	0	4.16	0	0	0	0.83
Experiment Station and U.S.						
Kansas 1859	16.68	8.34	0	4.16	4.16	6.67
Kansas 1639	0	4.16	0	0	8.34	2.50
Total	16.68	12.50	0	4.16	12.50	
U.S. 13	4.16	4.16	4.16	0	0	2.50
Total number fields observed	24	24	24	24	24	24
Total number of varieties	12	18	13	16	17	15.2

APPENDIX III

APPENDIX III A-WEATHER CONDITIONS IN WASECA COUNTY, MINNESOTA DURING THE GROWING SEASON

	1954	1955	1956	1957	1958	1959
	Average temperature for the month (^{O} F.)					
May	53.1	63.3	58.7	57.2	61.1	61.4
June	70.4	66.4	72.2	67.3	62.8	70.0
July	73.6	76.9	68.6	75.4	69.3	71.4
August	68.7	74.9	69.7	69.8	71.4	75.0
	Total rainfall for the month (inches)					
May	4.51	1.15	2.24	4.98	1.20	5.06
June	5.27	4.11	8.79	3.04	2.64	3.66
July	2.10	3.29	2.11	6.95	2.45	2.60
August	3.58	1.85	3.83	4.24	3.65	4.79

APPENDIX III B-WEATHER CONDITIONS IN WASECA COUNTY, MINNESOTA; DEVIATION FROM LONG-TERM NORMAL

	1954	1955	1956	1957	1958	1959
				Monthly temperature		
May	-5.2	5.0	0.1	-1.4	2.5	2.8
June	3.0	-1.0	4.0	-0.9	-5.4	1.8
July	0.8	4.1	-4.7	2.1	-4.0	-1.9
August	-1.3	4.9	-1.1	-1.0	0.6	4.2
				Monthly rainfall		
May	1.11	-2.25	-1.35	1.39	-2.39	1.47
June	0.98	-0.18	4.22	-1.53	-1.93	-0.91
July	-1.20	-0.01	-1.14	3.70	-0.80	-0.63
August	0.06	-1.79	0.43	0.84	0.16	1.39

APPENDIX III C.-FERTILIZER TREATMENTS IN THE FIELDS USED IN WASECA COUNTY, MINNESOTA

Fertilizer application	Percent of fields				
	1954	1955	1958	1959	Average
N-P-K combinations[a]	28.6	34.8	53.6	38.9	38.9
Ammonia nitrate	12.5	2.2	14.3	5.6	8.7
Starter fertilizer	3.6	8.7			3.1
Green manure	14.3	6.5			5.2
Barnyard manure	23.2	23.9	7.1	22.2	19.1
No treatment	17.8	23.9	25.0	33.3	25.0
Total number of field units	56	46	28	18	

[a] The N-P-K combinations included the following:

8-23-0	6-24-12	9-26-0
5-20-10	0-20-20	0-0-60
4-12-10	0-20-0	6-24-24
4-12-12	8-16-16	6-12-24
5-20-20	0-46-0	

APPENDIX III D.-CROP HISTORY IN THE FIELDS USED IN WASECA COUNTY, MINNESOTA

Type of rotation	Percent of fields		
	1955	1959	2-year average
Continuous corn	10	20	15
Two-crop rotations			
Corn-oats	40	15	
Corn-soybeans	5	15	
Corn-pasture	5	25	
Total	50	55	52.5
Three-crop rotations			
Corn-oats-soybeans	20	5	
Corn-oats-pasture	15	5	
Corn-soybeans-wheat		5	
Corn-soybeans-peas		5	
Total	35	20	27.5
Four-crop rotation			
Corn-soybeans-oats-pasture	5	5	5
Total number fields checked	20	20	

APPENDIX III E-PLANTING METHODS AND PLANT POPULATION IN THE FIELDS USED IN WASECA COUNTY, MINNESOTA

	Percent of fields						
	1954	1955	1956	1957	1958	1959	Average
Type of planting							
Checked	54.1	50.0	54.5	---	55.5	25.0	47.9
Hill drops	25.0	29.1	18.1	---	16.7	45.8	26.9
Drilled	20.9	20.9	37.4	---	37.8	29.2	25.2
Total fields observed	24	24	22	---	18	24	
Plants per acre							
Average	13,550	13,450	12,450	14,300	14,450	15,900	14,010
Total fields observed	24	23	24	24	23	24	

APPENDIX III F-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN WASECA COUNTY, MINNESOTA

Variety	Percent of fields				
	1954	1955	1958	1959	Average
Cargill 110	0	0	0	3.03	0.76
Cargill unknown	10.7	0	0	0	2.67
Total	10.71	0	0	3.03	3.43
Carlson	4.17	0	0	0	1.04
DeKalb 65	4.17	0	0	0	1.04
DeKalb 239	0	3.57	0	0	0.89
DeKalb 240	4.17	3.57	0	0	1.94
DeKalb 248	4.17	3.57	0	0	1.94
DeKalb 401	0	3.57	0	3.03	1.65
DeKalb 404	0	0	0	3.03	0.76
DeKalb 406	0	0	6.25	0	1.56
DeKalb 411	0	0	0	3.03	0.76
DeKalb unknown	8.32	7.15	6.25	3.03	6.19
Total	20.8	21.4	12.5	12.1	16.73
Farmer's Seeds 85	0	0	6.25	0	1.56
Farmer's Seeds 101	0	0	0	3.03	0.76
Total	0	0	6.25	3.03	2.32
Funks G1A	4.17	3.57	0	0	1.94
Funks G6	0	0	6.25	0	1.56
Funks G20	0	0	0	3.03	0.76
Funks G21	4.17	0	0	0	1.04
Funks G26	4.17	3.57	0	0	1.94
Funks G68	0	3.57	0	0	0.89
Funks unknown	4.17	0	0	0	1.04
Total	16.8	10.71	6.25	3.03	9.2
Genetic Giants	0	0	0	3.03	0.76
Hagas 201	0	0	6.25	0	1.56
Hopola 252	0	0	6.25	3.03	2.32
Hopola unknown	00	0	0	3.03	0.76
Total	0	0	6.25	6.06	3.13
Jacques 1005J	0	0	0	3.03	0.76
Jacques 1158	0	0	0	3.03	0.76
Jacques unknown	0	0	6.25	3.03	2.32
Total	0	0	6.25	9.09	3.84
Kingscrost K05	12.5	0	0	0	3.13
Kingscrost KS4	0	0	6.25	0	1.56
Kingscrost KS5	0	0	0	3.03	0.76
Kingscrost unknown	0	3.57	0	3.03	1.65
Total	12.5	3.57	6.25	6.06	7.1
Master T-75	4.17	0	0	0	1.04
Minhybrid 608	4.17	0	0	0	1.04
Minhybrid 3647	0	0	0	3.03	0.76
Minhybrid unknown	0	3.57	18.75	6.06	7.09
Total	4.17	3.57	18.75	9.09	8.9
Naeve	4.17	0	0	0	1.04
Pfister 108	0	0	0	3.03	0.76
Pfister 112	0	0	0	3.03	0.76
Pfister 277	0	0	0	3.03	0.76
Total	0	0	0	9.09	2.27

APPENDIX III F--(CONTINUED)

Variety	Percent of fields				
	1954	1955	1958	1959	Average
Pioneer 253	0	0	0	3.03	0.76
Pioneer 349	8.32	21.43	6.25	3.03	9.76
Pioneer 352	4.17	7.15	6.25	0	4.39
Pioneer 371	0	0	6.25	0	1.56
Pioneer 373	4.17	0	0	3.03	1.80
Pioneer 373A	0	3.57	0	0	0.89
Pioneer 376	0	0	6.25	0	1.56
Pioneer 377	0	0	0	3.03	0.76
Pioneer 377A	0	0	0	9.09	2.27
Pioneer 379	4.17	3.57	0	0	1.94
Pioneer 383	0	0	6.25	3.03	2.32
Pioneer silo blend	0	3.57	0	0	0.89
Pioneer unknown	8.32	7.15	0	6.06	5.38
Total	29.2	46.4	31.3	30.3	34.3
Pride 55	0	0	0	3.03	0.76
Tomahawk 209	0	0	0	3.03	0.76
Tomahawk 263	0	0	0	3.03	0.76
Total	0	0	0	6.06	1.52
Unknown	4.17	3.57	0	0	1.94
Total number fields observed	24	28	16	33	
Total number of varieties	19	18	14	29	20

APPENDIX IV

APPENDIX IV A-WEATHER CONDITIONS IN NEW MADRID COUNTY, MISSOURI DURING THE GROWING SEASON

	1956	1957	1958	1959
	Average temperature for the month (°F.)			
April	56.1	59.8	56.7	59.0
May	68.5	66.2	65.7	71.3
June	75.6	75.5	74.1	74.5
July	78.7	77.3	78.1	76.9
August	78.9	76.3	77.0	78.7
September	68.1	68.8	70.4	72.1
October	61.7	55.7	58.4	59.8
	Total rainfall for the month (inches)			
April	4.17	7.86	4.28	2.02
May	4.58	11.5	4.41	4.77
June	3.86	10.56	2.75	2.75
July	2.35	3.82	5.69	3.20
August	1.86	3.80	3.25	3.44
September	2.94	3.32	4.86	3.94
October	1.41	6.52	0.85	4.42

APPENDIX IV B.-WEATHER CONDITIONS IN NEW MADRID COUNTY, MISSOURI; DEVIATIONS FROM LONG-TERM NORMAL

	1956	1957	1958	1959
		Monthly temperature		
April	-2.0	1.7	-1.4	0.6
May	0	-2.3	-2.8	2.8
June	1.3	1.2	-0.2	0.2
July	0.1	-1.3	-0.5	-1.7
August	1.3	-1.3	-0.6	1.1
September	-3.0	-2.3	-0.7	1.0
October	2.4	-3.6	-0.9	0.5
		Monthly rainfall		
April	-0.45	3.24	-0.34	-2.38
May	0.34	7.26	0.17	1.53
June	-0.33	6.37	-1.44	-1.44
July	-1.37	0.10	1.97	-0.52
August	-1.94	0	-0.55	-0.36
September	-0.94	-0.56	0.98	0.06
October	-1.86	3.25	-2.42	1.15

APPENDIX IV C.-FERTILIZER TREATMENTS IN THE FIELDS USED IN NEW MADRID COUNTY, MISSOURI

Fertilizer applications	Percent of fields				
	1956	1957	1958	1959	Average
N-P-K combinations	100.0	90.9	69.5	63.2	76.2
Ammonium Nitrate	30.0	18.2	21.7	5.3	17.5
Anhydrous Ammonia	30.0	27.3	39.1	52.6	39.7
Nitrogen	0	9.1	8.7	36.8	15.9
Starter fertilizer	30.0	72.2	52.2	0	36.5
Manure	10.0	0	0	0	1.6
No application	0	9.1	0	5.3	3.2
Total fields checked	10	11	23	19	

APPENDIX IV D.-CROP HISTORY IN THE FIELDS USED IN NEW MADRID COUNTY. MISSOURI

Previous crop	Percent of fields				
	1956	1957	1958	1959	Average
Clover	0	0	0	5.3	1.6
Corn	40.0	40.0	30.4	52.6	40.3
Cotton	10.0	0	21.7	26.3	17.7
Pasture	0	0	4.3	0	1.6
Small grain[a/]	40.0	20.0	8.7	10.5	16.1
Sorghum	0	0	8.7	0	3.2
Soybeans	0	30.0	13.0	5.3	11.3
Rye and vetch	10.0	10.0	13.0	0	8.1
Total fields observed	10	10	23	19	

a/ Mainly wheat with scattered fields of rye and barley.

APPENDIX IV E.-PLANT POPULATION IN THE FIELDS USED IN NEW MADRID COUNTY, MISSOURI

	Percent of fields				
	1956	1957	1958	1959	Average
Plants per acre					
8,000 - 8,999	10				1.4
9,000 - 9,999		8.3	16.7		7.1
10,000 - 10,999	20	25.0	25.0	8.3	18.6
11,000 - 11,999	10	41.7	12.5	12.5	17.1
12,000 - 12,999		8.3	16.7	25.0	15.7
13,000 - 13,999		16.7	8.3	20.8	12.9
14,000 - 14,999	20		4.2	20.8	11.4
15,000 - 15,999	30		8.3	12.5	11.4
17,000 - 17,999	10				1.4
Over 18,000			8.3		1.4
Average	13,433	11,416	12,142	13,103	12,523
Total fields observed	10	12	24	24	

APPENDIX IV F.-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN NEW MADRID COUNTY, MISSOURI

Variety	Percent of fields				
	1956	1957	1958	1959	Average
Pfister 147	0	0	0	4.5	1.3
Pfister 170	7.7	0	0	0	1.3
Pfister 270	0	0	0	4.5	1.3
Pfister 300	0	0	0	4.5	1.3
Pfister 347	0	31.6	20.8	4.5	15.4
Pfister 351	0	0	0	4.5	1.3
Pfister 374	7.7	0	0	0	1.3
Pfister 387	0	0	4.2	0	1.3
Pfister 403	0	0	0	4.5	1.3
Pfister 444	7.7	0	0	0	1.3
Pfister 631	7.7	0	0	0	1.3
Pfister White	0	0	0	4.5	1.3
Pfister unknown	7.7	10.5	8.3	4.5	7.7
Total	38.5	42.1	33.3	36.0	37.2
Pioneer 300	7.7	15.8	4.2	0	6.4
Pioneer 312	0	5.3	0	0	1.3
Pioneer 313	0	0	4.2	4.5	2.6
Pioneer 333	0	10.5	0	0	2.6
Pioneer 336	15.4	5.3	0	0	3.8
Total	23.1	36.9	8.4	4.5	16.7
Funks 77	7.7	0	0	0	1.3
Funks 77A	0	5.3	0	0	1.3
Funks G-91	0	0	0	4.5	1.3
Funks G-134	0	0	4.2	0	1.3
Funks 193	0	0	4.2	4.5	2.6
Funks White	0	0	4.2	0	1.3
Total	7.7	5.3	12.6	9.0	9.0
DeKalb 3x2	0	0	4.2	0	1.3
DeKalb 803	0	0	4.2	0	1.3
DeKalb 803A	0	0	4.2	0	1.3
DeKalb 847	0	0	4.2	0	1.3
DeKalb unknown	0	5.3	0	0	1.3
Total	0	5.3	16.8	0	6.4
M.F.A. 120	0	5.3	0	0	1.3
M.F.A. unknown	0	0	0	4.5	1.3
Total	0	5.3	0	4.5	2.6
McMullin 148	0	0	4.2	4.5	2.6
Zimmerman 909	0	0	4.2	0	1.3
Indiana 9	0	0	4.2	0	1.3
Indiana 501	0	0	0	4.5	1.3
Indiana 909	0	0	4.2	9.1	3.8
Indiana 909A	0	0	0	4.5	1.3
c Total	0	0	8.4	18.1	7.7
U.S. 13	15.4	5.3	0	4.5	5.1
U.S. 13 Dwarf	0	0	0	4.5	1.3
U.S. 523W	7.7	0	12.5	4.5	6.4
U.S. 880	0	0	0	9.1	2.6
Total	23.1	5.3	12.5	22.6	15.4
Illinois 200	7.7	0	0	0	1.3
Total number of fields observed	9	11	24	24	
Total number of varieties	11	10	17	20	

APPENDIX V

APPENDIX V A-WEATHER CONDITIONS IN CARROLL COUNTY, MISSOURI DURING THE GROWING SEASON

	1956	1957	1958	1959
	Average temperature for the month (°F.)			
April	53.3	54.6	54.4	55.0
May	69.6	64.7	65.9	68.2
June	76.4	73.7	71.1	75.1
July	78.2	80.6	75.2	75.5
August	78.2	77.5	76.8	79.6
September	69.9	65.3	68.3	69.6
October	63.0	52.9	57.2	53.6
	Total rainfall for the month (inches)			
April	2.26	2.74	2.88	2.23
May	2.33	6.14	3.72	3.75
June	1.33	5.26	6.09	0.49
July	7.13	3.74	7.02	5.64
August	2.67	3.13	1.90	2.31
September	0.30	4.82	4.22	3.29
October	0.81	5.58	1.49	4.02

APPENDIX V B-WEATHER CONDITIONS IN CARROLL COUNTY, MISSOURI; DEVIATION FROM LONG-TERM NORMAL [a/]

	1956	1957	1958	1959
	Monthly temperature			
April	0.2	1.5	1.3	1.9
May	6.0	1.1	2.3	4.6
June	3.2	0.5	-2.1	1.9
July	1.6	4.0	-1.4	-1.1
August	3.3	2.6	1.9	4.6
September	2.6	-2.0	1.0	2.3
October	8.8	-1.3	3.0	-0.6
	Monthly rainfall			
April	-1.27	-0.79	-0.65	-1.30
May	-2.02	1.79	-0.63	-0.60
June	-3.59	0.34	1.17	-4.43
July	3.36	-0.03	3.25	1.87
August	-1.28	-0.82	-2.05	1.64
September	-4.50	0.02	-0.58	-1.51
October	-2.26	2.51	-1.58	0.95

a/ Long-term normal temperature and rainfall records are not available for the county. The mean of the long-term normal readings of two neighboring stations was used in the calculation of the deviations.

APPENDIX V C.-FERTILIZER TREATMENTS IN THE FIELDS USED IN CARROLL COUNTY, MISSOURI

Fertilizer application	Percent of fields				
	1956	1957	1958	1959	Average
N-P-K combinations	31.0	36.6	35.2	38.9	35.7
Ammonium Nitrate	20.7	16.7	8.8	19.4	16.3
Anhydrous Ammonium Nitrogen	6.9	6.7	2.9	11.1	7.0
Starter fertilizer	20.7	33.3	32.4	19.4	26.4
Manure	6.9	0	5.9	2.9	3.9
No application	3.4	0	0	2.9	1.6
Total fields checked	24.1	16.7	20.6	19.4	20.2
	29	30	34	36	

APPENDIX V D.-CROP HISTORY IN THE FIELDS USED IN CARROLL COUNTY, MISSOURI

Previous crop	Percent of fields				
	1956	1957	1958	1959	Average
Clover	3.5	10.7	4.3	25.8	11.7
Corn	46.4	53.6	65.2	41.9	50.9
Oats	10.7	7.1	4.3	0	5.5
Pasture	3.5	0	4.3	3.2	2.7
Small grain[a/]	10.7	14.3	13.0	12.9	12.7
Sorghum	0	0	4.3	6.5	2.7
Soybeans	17.9	14.3	4.3	6.5	10.9
Alfalfa	7.1	0	0	3.2	2.7
Total fields observed	28	28	28	31	

[a/] Mainly wheat, with scattered fields of rye and barley.

APPENDIX V E.-PLANT POPULATION IN THE FIELDS USED IN CARROLL COUNTY, MISSOURI

	Percent of Fields				
	1956	1957	1958	1959	Average
Plants per acre					
8,000 - 8,999	11.1	19.4	12.9	7.7	12.5
9,000 - 9,999	14.8	12.9	19.4	17.9	16.4
10,000 - 10,999	29.6	22.6	9.7	15.4	18.8
11,000 - 11,999	7.4	12.9	19.4	23.1	16.4
12,000 - 12,999	14.8	6.5	9.7	15.4	11.7
13,000 - 13,999	3.7	12.9	16.1	10.3	10.9
14,000 - 14,999	11.1	9.7	12.9	7.7	10.2
15,000 - 15,999	7.4			2.6	2.3
16,000 - 16,999		3.2			0.8
Average	11,345	11,075	11,430	11,307	11,289
Total fields observed	27	31	31	39	

APPENDIX V F.-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN CARROLL COUNTY, MISSOURI

Variety	Percent of fields				
	1956	1957	1958	1959	Average
DeKalb 3x1	0	2.7	0	2.6	1.5
DeKalb 3x2	0	2.7	17.9	13.2	8.5
DeKalb 3x22	0	0	0	2.6	0.8
DeKalb 661	0	0	3.6	0	0.8
DeKalb 801	3.7	0	0	0	0.8
DeKalb 820	0	0	3.6	0	0.8
DeKalb 821	3.7	0	0	0	0.8
DeKalb 825	3.7	2.7	0	0	1.5
DeKalb 847	3.7	0	0	0	0.8
DeKalb 852	0	0	3.6	0	0.8
DeKalb unknown	0	2.7	3.6	10.5	4.6
Total	14.8	10.8	32.3	28.9	21.5
Pioneer 300	0	2.7	0	0	0.8
Pioneer 302	11.1	13.5	7.1	0	7.7
Pioneer 305	3.7	0	0	0	0.8
Pioneer 312A	0	2.7	3.6	7.9	3.8
Pioneer 318	7.4	0	0	0	1.5
Pioneer 329	0	0	7.1	0	1.5
Pioneer 335	0	2.7	0	2.6	1.5
Pioneer 352	0	2.7	0	0	0.8
Pioneer unknown	3.7	2.7	3.6	10.5	5.4
Total	25.9	27.0	21.4	21.0	23.8
Pfister 170	0	5.4	0	5.3	3.1
Pfister 347	3.7	2.7	0	2.6	2.3
Pfister 383	0	5.4	0	0	1.5
Pfister 401	0	2.7	0	0	0.8
Pfister 403	7.4	5.4	3.6	2.6	4.6
Pfister 444	0	0	0	2.6	0.8
Pfister 484	0	2.7	0	0	0.8
Pfister unknown	0	0	10.7	10.5	5.4
Total	11.1	24.3	14.3	23.6	19.2
Funks G-91	0	0	0	2.6	0.8
Funks G-134	0	0	0	2.6	0.8
Funks G-144	0	2.7	3.6	2.6	2.3
Funks G-704	3.7	2.7	0	0	1.5
Funks G-711	0	2.7	0	0	0.8
Gunks G-711B	0	2.7	0	0	0.8
Total	3.7	10.8	3.6	7.8	6.9
M.F.A. 118	0	0	3.6	0	0.8
M.F.A. 120A	7.4	2.7	3.6	0	3.1
M.F.A. 2120	0	2.7	0	0	0.8
Total	7.4	5.4	7.2	0	4.6
Maygold 47	0	2.7	0	0	0.8
Maygold 59A	7.4	8.1	3.6	5.3	6.2
Total	7.4	10.8	3.6	5.3	6.9
Gargil 349	3.7	0	0	0	0.8
Gargil unknown	3.7	0	0	2.6	1.5
Total	7.4	0	0	2.6	2.3

APPENDIX V F--(CONTINUED)

Variety	Percent of fields				
	1956	1957	1958	1959	Average
Monier M-24	0	2.7	0	0	0.8
Monier unknown	0	0	3.6	0	0.8
Total	0	2.7	3.6	0	1.5
Kings Krost unknown	0	0	3.6	2.6	1.5
McCurdy 987	3.7	2.7	0	0	1.5
Plymouth 37	0	0	3.6	2.6	1.5
Steckley's unknown	0	0	3.6	2.6	1.5
Carlson 3-25	3.7	0	0	0	0.8
Corn Husker 2x3	3.7	0	0	0	0.8
Embro unknown	3.7	0	0	0	0.8
Morgan unknown	0	0	0	2.6	0.8
Standard 813	0	2.7	0	0	0.8
Mo. 843 873	3.7	2.7	3.6	0	2.3
WF9 x 07A x KP1 x C103	3.7	0	0	0	0.8
Total number fields observed	27	31	38	39	
Total number of varieities	21	28	20	21	22.5

APPENDIX VI

APPENDIX VI A-WEATHER CONDITIONS IN CUMING COUNTY, NEBRASKA DURING THE GROWING SEASON

	1955	1956	1957	1958	1959
	Average temperature for the month (° F.)				
May	65.7	64.2	60.6	65.7	61.9
June	69.0	77.6	71.0	69.4	74.7
July	82.9	75.8	81.4	72.6	74.3
August	81.9	76.5	76.9	75.4	77.5
	Total rainfall for the month (inches)				
May	1.39	3.56	2.20	3.50	8.40
June	4.40	3.66	6.00	1.14	3.67
July	3.84	2.65	5.20	10.19	1.97
August	0.78	2.67	2.57	4.70	4.47

APPENDIX VI B-WEATHER CONDITIONS IN CUMING COUNTY, NEBRASKA; DEVIATIONS FROM LONG-TERM NORMAL

	1955	1956	1957	1958	1959
			Monthly temperatures		
May	4.4	2.1	-1.5	3.6	-0.2
June	-2.0	5.0	-1.6	-3.2	2.1
July	5.9	-2.9	2.7	-6.1	-4.4
August	7.2	0.4	0.8	-0.7	1.4
			Monthly rainfall		
May	-2.51	0.15	-0.21	0.09	4.99
June	-0.15	-0.89	1.45	-3.41	-0.88
July	0.84	-0.35	2.20	7.19	-1.03
August	-2.37	-0.48	-0.58	1.55	1.32

APPENDIX VI C-FERTILIZER TREATMENTS IN THE FIELDS USED IN CUMING COUNTY, NEBRASKA

Fertilizer application	Percent of fields					
	1955	1956	1957	1958	1959	Average
N-P-K combinations	12.5	8.3	9.7	5.6	15.3	10.3
Ammonia nitrate	2.8	1.4	4.2	---	---	1.7
Anhydrous ammonia (PV82)	2.8	1.4	2.8	1.4	---	1.7
Nitrogen gas	1.4	---	---	1.4	1.4	0.8
Lime	---	2.8	---	1.4	---	0.8
Total fields checked	14	10	12	7	12	
Manure applications						
Green manure	1.4	1.4	1.4	2.8	1.4	1.7
Barnyard manure	22.2	18.1	23.6	26.4	16.7	21.4
Both	1.4	1.4	---	1.4	---	0.8
Total fields checked	18	15	18	22	13	
No treatment	44.4	56.9	54.2	59.7	61.1	55.3
Treatment unknown	11.1	8.3	4.2	---	4.2	5.6
Total number field units observed	72	72	72	72	72	

APPENDIX VI D-CROP HISTORY OF THE FIELDS USED IN CUMING COUNTY, NEBRASKA

Type of rotation	Percent of fields					
	1955	1956	1957	1958	1959	Average
Continuous corn	8.3	10.4	29.2	16.7	16.7	16.3
Two-crop rotations						
Corn-oats	41.7	52.1	37.5	33.3	29.2	38.8
Corn-wheat	---	2.1	---	---	---	0.4
Corn-barley	---	4.2	4.2	4.2	8.3	4.2
Corn-alfalfa	9.4	14.6	---	8.3	20.8	10.6
Corn-soybeans	6.3	---	---	4.2	4.2	2.9
Corn-oats+clover	13.5	8.3	16.7	16.7	8.3	12.7
Corn-oats+alfalfa	---	---	4.2	---	---	0.8
Corn-sorghum	---	---	---	---	4.2	0.8
Corn-sudan grass	4.2	---	---	---	---	0.8
Corn-pasture	6.2	4.2	4.2	4.2	---	3.8
Total	81.3	85.5	66.8	70.9	75.0	75.9
Three-crop rotations						
Corn-oats-alfalfa	2.1	---	---	---	---	0.4
Corn-wheat-sorghum	---	---	---	4.2	---	0.8
Corn-alfalfa-soybeans	---	---	---	---	4.2	0.8
Corn-oats-fallow	---	---	---	4.2	---	0.8
Corn-sorghum-pasture	---	---	---	4.2	---	0.8
Total	2.1	---	---	12.6	4.2	3.8
Unknown	8.3	4.2	4.2	---	4.2	4.2
Total number fields checked	24	24	24	24	24	

APPENDIX VI E-PLANTING METHODS AND PLANT POPULATIONS IN THE FIELDS USED IN CUMING COUNTY, NEBRASKA

	Percent of fields					
	1955	1956	1957	1958	1959	Average
Type of planting						
Checked		4.2				0.8
Hill drop			4.2			0.8
Drilled	83.3	87.5	83.3	87.5	83.3	85.0
Listed	8.3	4.2	8.3	12.5	12.5	9.2
Unknown	8.3	4.2	4.2	---	4.2	4.2
Total fields observed	24	24	24	24	24	
Plants per acre						
10,000 or less	62.5	58.3	62.5	29.2	41.7	50.8
11,000	20.8	20.8	16.7	20.8	25.0	20.8
12,000	8.3	12.5	8.3	16.7	20.8	13.3
13,000		4.2	4.2	12.5	4.2	5.0
14,000	8.3	---	4.2	4.2	---	3.3
15,000	---	---	4.2	8.3	4.2	3.3
16,000	---	---	---	4.2	4.2	1.7
17,000	---	4.2	---	---	---	0.8
19,000	---	---	---	4.2	---	0.8
Total fields observed	24	24	24	24	24	
Average	10,708	10,875	10,833	12,125	11,250	11,158

APPENDIX VI F-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN CUMING COUNTY, NEBRASKA

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
DeKalb 3x1	0	0	6.6	0.4	7.1	2.8
DeKalb 3x2	0	0	5.2	0.4	6.2	2.4
DeKalb 3x3	0	0	0	10.1	9.2	3.8
DeKalb 3x4	0	0	0	0	0.8	0.2
DeKalb 450	0.8	0	0	0	0	0.2
DeKalb 455	4.2	0	0	0	0	0.8
DeKalb 458	0	0.6	0	0	4.2	0.9
DeKalb 459	0.8	0.6	0	0	0	0.3
DeKalb 488	0	0	0	4.2	4.2	1.7
DeKalb 627	2.9	2.7	2.1	0	0	1.5
DeKalb 628	0	0	2.1	0	0	0.4
DeKalb 630	0	0	1.4	0	0	0.3
DeKalb 631	0	2.1	1.4	1.4	0	1.0
DeKalb 631A	0	0	2.1	0	0	0.4
DeKalb 635	1.9	0	1.0	0	0	0.6
DeKalb 636	0	0	0	3.5	0	0.8
DeKalb 666	1.0	0	0	0	0	0.2
DeKalb 680	0.8	0	2.1	4.2	0	1.4
DeKalb 800	0	0	2.1	0	0	0.4
DeKalb 800A	4.2	4.2	0	0	0	1.7
DeKalb 820	4.2	0.7	0	0	0	1.0
DeKalb 825	0	0	0	0.4	0	0.1
DeKalb 847	0	0	2.1	0	0	0.4
DeKalb unknown	6.2	7.6	12.5	8.3	11.5	9.2
Total	27.1	18.4	40.6	32.9	43.1	32.4
Funks G16A	0	0.6	0	0.8	0	0.3
Funks G29	0	0.6	0	0	0	0.1
Funks G30A	0	0	4.2	0	0	0.8
Funks G50	0	0	0	0	0.8	0.2
Funks G54	0	0.6	0	8.3	0	1.8
Funks G75A	0	0	0	0	4.2	0.8
Funks G77	0	0.6	1.0	0	0	0.3
Funks G77A	0	2.1	0	0	4.2	1.2
Funks G95A	0	2.1	0	0	0	0.4
Funks unknown	4.2	0	2.1	9.7	1.0	3.4
Total	4.2	6.5	7.3	18.9	10.2	9.4
Cargill 300	0	0	2.8	0	0	0.6
Cargill 310	0	0	1.4	2.1	0.8	0.9
Cargill 320	0	0	0	3.5	0	0.7
Cargill 335	0	0	0	0.8	0	0.2
Cargill unknown	8.3	9.0	7.3	0.8	9.7	7.0
Total	8.3	9.0	11.5	7.2	10.5	9.3
Pioneer 301	0	0.7	0	0	0	0.1
Pioneer 318A	0	0	0	0	2.1	0.4
Pioneer 329	0	2.1	4.2	4.2	4.2	2.9
Pioneer 335	0	4.2	0	0	0	0.8
Pioneer 339	0	0.7	0	0	0	0.1
Pioneer 349	4.2	2.1	0	0	0	1.2
Pioneer unknown	2.1	0	0	6.2	1.0	1.9
Total	6.2	9.7	4.2	10.4	7.3	7.6

APPENDIX VI F--(CONTINUED)

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Pfister 347	4.2	4.2	1.0	8.3	0	3.5
Pfister 403	0	0	0	1.4	0	0.3
Pfister unknown	4.2	1.4	2.1	4.2	1.0	2.6
Total	8.3	5.5	3.1	13.9	1.0	6.4
Nebraska 501	1.0	0	1.4	0	4.2	1.3
Nebraska 802	0	2.1	1.4	0	0	0.5
Nebraska 803	0	2.1	0	0	2.1	0.8
Nebraska 806	1.0	0	0	2.1	0	0.6
Total	2.1	4.2	2.8	2.1	6.2	3.5
Tekseed 63	0	0	0	1.4	0	0.3
Tekseed 115	0	2.1	0	0	0	0.4
Tekseed unknown	2.1	1.4	2.1	5.5	2.4	2.7
Total	2.1	3.5	2.1	6.9	2.4	3.4
United Hagie 42A	4.2	0	0	0	0	0.8
United Hagie 428	0	0	1.0	0	0	0.2
United Hagie unknown	4.2	1.4	4.2	0.4	0	2.0
Total	8.3	1.4	5.2	0.4	0	3.1
Cornhusker 3x1	0	3.5	0	0	0	0.7
Cornhusker 3x2	0	1.4	0	0	0	0.3
Cornhusker 75	0	2.1	0	0	0	0.4
Cornhusker unknown	6.2	0	0	0.4	0	1.3
Total	6.2	7.0	0	0.4	0	2.7
Steckley 13	0	0	1.0	0	0	0.2
Steckley 14	0	0	0	0.8	0	0.2
Steckley 15	0	2.1	2.4	0.8	0	1.1
Steckley 20	0	0	1.0	0	0	0.2
Steckley unknown	1.4	2.8	0	0	2.1	1.2
Total	1.4	4.9	4.5	1.7	2.1	2.9
Thompson's Tomahawk 81	4.2	0	0	0	0	0.8
Thompson's Tomahawk unknown unknown	1.4	6.9	0	0	0	1.7
Total	5.6	6.9	0	0	0	2.5
Kansas Farmer Union 150	0	1.4	0	0.4	0	0.4
Kansas Farmer Union 625	0	0	0	0.4	0	0.1
Kansas Farmer Union 800	0	0	1.0	0	0	0.2
Kansas Farmer Union 825	0	0	1.0	0.4	0	0.3
Kansas Farmer Union unknown	1.4	1.4	0	0	1.4	0.8
Total	1.4	2.8	2.1	1.2	1.4	1.8
Iowa 306	4.2	0	0	0	0	0.8
Iowa 309	0	0	4.2	0	0	0.8
Total	4.2	0	4.2	0	0	1.7

APPENDIX VI F--(CONTINUED)

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Hulting	0	2.1	0	2.5	0	0.9
Clarks	0	0	4.2	0	0	0.8
Hagemeyer's 180	0	4.2	0	0	0	0.8
McCurdy	0	1.4	0	0	0	0.5
Moews	2.1	0	0	0	0	0.4
King Cross	0	0	0	1.4	0	0.3
Tomco	0	0	0	0	1.0	0.2
Pride	0	0	0	0	1.0	0.2
Unknown	12.5	12.5	8.3	0	12.5	9.2
Total number fields observed	24	24	24	24	24	
Total number of varieties	29	24	34	33	26	

APPENDIX VII

APPENDIX VII A-WEATHER CONDITIONS IN HALL COUNTY, NEBRASKA DURING THE GROWING SEASON

	1955	1956	1957	1958	1959
	Average temperature for the month (^{O} F.)				
May	64.7	62.2	57.9	62.7	61.0
June	67.0	76.2	69.4	68.3	73.1
July	82.0	75.5	79.3	71.8	73.2
August	79.7	75.3	75.9	75.4	78.8
	Total rainfall for the month (inches)				
May	1.91	2.43	5.64	2.24	6.69
June	4.65	3.51	4.31	2.72	4.09
July	1.30	0.94	1.68	7.09	0.95
August	0.78	0.77	4.08	1.38	3.11

APPENDIX VII B-WEATHER CONDITIONS IN HALL COUNTY, NEBRASKA; DEVIATION FROM LONG-TERM NORMAL

	1955	1956	1957	1958	1959
	Monthly temperature				
May	3.6	1.1	-3.2	1.6	-0.1
June	-4.6	4.7	-2.2	-3.3	1.5
July	3.1	-3.4	0.4	-7.1	-5.7
August	3.5	-0.9	-0.3	-0.8	2.6
	Monthly rainfall				
May	-1.96	-1.44	1.77	-1.63	2.82
June	0.99	-0.15	0.65	-0.94	0.43
July	-1.33	-1.69	-0.95	4.46	-1.68
August	-1.61	-1162	1.69	-1.01	0.72

APPENDIX VII C-FERTILIZER TREATMENTS IN THE FIELDS USED IN HALL COUNTY, NEBRASKA

Fertilizer Application	Percent of fields					
	1955	1956	1957	1958	1959	Average
N-P-K combinations	46.7	49.3	50.7	56.0	46.7	49.87
Ammonia nitrate	4.0	4.0	2.7	2.7	4.0	3.47
Anhydrous ammonia (PV82)	13.3	16.0	22.7	21.3	38.7	22.40
Nitrogen (gas)	5.3	2.7	2.7	---	---	2.13
Total fields checked	52	54	59	60	67	
Manure applications						
Green manure	---	1.3	---	---	---	0.27
Barnyard manure	4.0	1.3	4.0	6.7	4.0	4.00
Total fields checked	3	2	3	5	3	
No treatment	17.3	25.3	13.3	10.7	2.7	13.87
Treatment unknown	9.3	---	4.0	2.7	4.0	4.00
Total number field units observed	75	75	75	75	75	

APPENDIX VII D-CROP HISTORY OF THE FIELDS USED IN HALL COUNTY, NEBRASKA

Type of rotation	Percent of fields					
	1955	1956	1957	1958	1959	Average
Continuous corn	54.5	59.3	64.0	51.9	68.0	59.5
Corn-fallow	0	3.7	4.0	3.7	4.0	3.2
Two-crop rotations						
Corn-oats	4.5	11.1	4.0	0	0	4.0
Corn-oats+ clover	13.6	3.7	8.0	7.4	0	6.3
Corn-alfalfa	9.1	11.1	4.0	0	4.0	5.6
Corn-soybeans	4.5	3.7	0	7.4	4.0	4.0
Corn-sugar beets	4.5	0	4.0	3.7	4.0	3.2
Corn-wheat	0	3.7	4.0	3.7	4.0	3.2
Corn-potatoes	4.5	0	0	0	4.0	1.6
Corn-sorghum	0	0	8.0	18.5	8.0	7.1
Corn-pasture	4.5	3.7	0	0	0	1.6
Total	45.2	37.0	32.0	40.7	28.0	36.6
Three-crop rotations Corn-sorghum-alfalfa	0	0	0	3.7	0	0.8
Total number fields checked	22	27	25	27	25	

APPENDIX VII E-PLANTING METHODS AND PLANT POPULATION IN THE FIELDS USED IN HALL COUNTY, NEBRASKA

	Percent of fields					
	1955	1956	1957	1958	1959	Average
Type of planting						
Hill drop	---	---	4.0	8.0	4.0	3.2
Drilled	52.0	60.0	48.0	48.0	60.0	53.6
Listed	40.0	28.0	40.0	36.0	32.0	35.2
Unknown	8.0	12.0	8.0	8.0	4.0	8.0
Total fields observed	25	25	25	25	25	
Plants per acre						
10,000 or less	32.0	16.0	8.0	12.0	16.0	16.8
11,000	24.0	4.0	8.0	12.0	4.0	10.4
12,000	4.0	12.0	8.0	---	4.0	5.6
13,000	20.0	20.0	12.0	16.0	12.0	16.0
14,000	12.0	16.0	12.0	16.0	16.0	14.4
15,000	---	8.0	20.0	8.0	16.0	10.4
16,000	4.0	12.0	20.0	16.0	8.0	12.0
17,000	---	---	8.0	4.0	4.0	3.2
18,000	4.0	4.0	4.0	4.0	8.0	4.8
19,000	---	---	---	---	4.0	0.8
20,000	---	4.0	---	8.0	8.0	4.0
21,000	---	4.0	---	4.0	---	1.6
Total fields observed	25	25	25	25	25	
Average	11,960	13,800	14,160	14,440	14,480	13,768

APPRENDIX VII F-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN HALL COUNTY, NEBRASKA

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
DeKalb 3x1	0	0	12.7	11.3	19.3	8.7
DeKalb 3x2	0	0	5.3	5.3	7.3	3.6
DeKalb 3x3	0	0	0	3.3	4.0	1.5
DeKalb 56	0	0	1.0	0	0	0.2
DeKalb 57	0	0	1.0	0	0	0.2
DeKalb 627	5.3	0	0	0	0	1.1
DeKalb 628A	7.3	0	0	0	0	1.5
DeKalb 630	0	0	4.0	2.0	0	1.2
DeKalb 800A	4.0	0	4.0	4.0	0	2.4
DeKalb 820	0	4.0	0	0	0	0.8
DeKalb 826	0	4.0	0	0	0	0.8
DeKalb 837	2.0	0	0	0	0	0.4
DeKalb 847	4.0	4.0	2.3	0	0	2.1
DeKalb unknown	8.0	12.0	4.0	11.3	4.0	7.9
Total	30.7	24.0	34.3	37.3	34.7	32.2
Funks G75A	0	0	0	0	4.0	0.8
Funks G76	0	2.0	2.0	1.3	2.0	1.5
Funks G77A	2.0	0	0	0	0	0.4
Funks G80	2.0	0	0	0	0	0.4
Funks G91	0	4.0	2.0	2.0	0	1.6
Funks G94	2.0	2.0	0	0	0	0.8
Funks G95A	0	0	0	1.3	0	0.3
Funks G144	0	0	0	1.3	4.0	1.1
Funks unknown	1.0	2.0	10.0	9.3	12.0	6.9
Total	7.0	10.0	14.0	15.3	22.0	13.7
Pioneer 300	9.0	8.0	4.0	0	0	4.2
Pioneer 312A	0	0	0	0	4.0	0.8
Pioneer 318	0	0	0	12.0	0	2.4
Pioneer 334	4.0	0	0	0	0	0.8
Pioneer 335	1.0	4.0	0	0	0	1.0
Pioneer 339	0	0	4.0	0	0	0.8
Pioneer unknown	0	4.0	0	0	4.0	1.6
Total	14.0	16.0	8.0	12.0	8.0	11.6
Steckley 15	2.0	4.0	0	0	0	1.2
Steckley 20	0	0	4.0	2.0	4.0	2.0
Steckley unknown	5.3	6.0	10.0	7.3	4.0	6.5
Total	7.3	10.0	14.0	9.3	8.0	9.7
Cornhusker 3x1	6.0	8.0	0	0	0	2.8
Cornhusker 3x2	0	4.0	0	0	0	0.8
Cornhusker 148	3.0	0	0	0	0	0.6
Cornhusker unknown	4.0	4.0	0	0	0	1.6
Total	13.0	16.0	0	0	0	5.8
Tekseed 43A	0	0	1.3	0	0	0.3
Tekseed 63	0	0	0	4.0	0	0.8
Tekseed 81A	0	0	0	0	2.0	0.4
Tekseed 111A	0	0	0	4.0	0	0.8
Tekseed 115	0	0	1.3	0	0	0.3
Tekseed 892	0	4.0	1.3	0	0	1.1
Tekseed unknown	2.0	4.0	---	2.0	8.0	3.2
Total	2.0	8.0	4.0	10.0	10.0	6.8

APPENDIX VII F--(CONTINUED)

Variety	Percent of fields					
	1955	1956	1957	1958	1959	Average
Cargill 310	0	0	0	2.0	4.0	1.2
Cargill 333	4.0	2.0	0	0	0	1.2
Cargill unknown	6.0	4.0	0	0	0	2.0
Total	10.0	6.0	0	2.0	4.0	4.4
Nebraska 401	0	0	1.0	0	0	0.2
Nebraska 402	0	0.8	1.0	0	0	0.4
Nebraska 501D	0	0	0	2.0	2.7	0.9
Nebraska 502	0	0.8	0	0	0	0.2
Nebraska 503	0	0.8	0	0	0	0.2
Nebraska 703	0	0.8	1.0	0	1.3	0.6
Nebraska 806	4.0	0.8	1.0	2.0	1.3	1.8
Total	4.0	4.0	4.0	4.0	5.3	4.3
Pfister 170	2.0	0	0	0	0	0.4
Pfister 347	0	0	2.0	0	4.0	1.2
Total	2.0	0	2.0	0	4.0	1.6
Thompson's Tomahawk 78	4.0	4.0	0	0	0	1.6
Tomco 78	0	0	2.0	2.0	0	0.8
Tomco 278	0	0	2.0	0	0	0.4
Tomco unknown	0	0	0	2.0	0	0.4
Total	0	0	4.0	4.0	0	1.6
Pride 86	0	0	4.0	0	0	0.8
Pride unknown	0	0	4.0	2.0	0	1.2
Total	0	0	8.0	2.0	0	2.0
Clark 57	0	0	2.0	0	0	0.4
McCurdy's 825	2.0	0	0	0	0	0.4
McCurdy's unknown	0	2.0	0	0	0	0.4
Total	2.0	2.0	0	0	0	0.8
Prairie Valley 660	0	0	2.0	0	0	0.4
Prairie Valley AAA	0	0	0	0	2.0	0.4
Total	0	0	2.0	0	2.0	0.8
Farmer's Hydrid 537	0	0	0	0	2.0	0.4
Unknown	4.0	0	4.0	4.0	0	2.4
Total number fields observed	25	25	25	25	25	
Total number of varieties	26	27	30	24	21	25.6

APPENDIX VIII

APPENDIX VIII A.-WEATHER CONDITIONS IN VAN WERT COUNTY, OHIO DURING GROWING SEASON

	1956	1957	1958	1959
	Average temperature for the month (°F.)			
May	60.2	60.1	59.6	65.1
June	70.1	69.5	64.8	70.7
July	71.9	72.4	72.4	73.5
August	72.0	71.2	70.8	77.1
September	63.0	64.5	64.8	67.9
	Total rainfall for the month (inches)			
May	5.59	5.19	2.87	2.36
June	4.45	6.70	9.21	1.71
July	3.48	3.27	6.87	2.90
August	2.64	1.18	2.33	2.07
September	0.52	4.15	4.06	2.24

APPENDIX VIII B.-WEATHER CONDITIONS IN VAN WERT COUNTY, OHIO DEVIATION FROM LONG-TERM NORMAL

	1956	1957	1958	1959
		Monthly temperature		
May	9	-0.8	-1.3	4.2
June	-0.4	-1.7	-6.4	-0.5
July	-0.25	-2.6	-2.6	-1.5
August	-0.5	-1.6	-2.0	4.3
September	-3.4	-1.5	-1.2	-1.9
		Monthly rainfall		
May	1.61	1.14	-1.18	-1.69
June	0.49	2.51	5.02	-2.48
July	0.20	-0.2	3.40	-0.57
August	0.10	-1.42	-0.27	-0.53
September	-2.57	1.08	0.99	-0.83

APPENDIX VIII C.-FERTILIZER TREATMENTS IN THE FIELDS USED IN VAN WERT COUNTY, OHIO

Application	Percent of fields		
	1958	1959	Average
N-P-K combinations[a/]	95.90	100.00	98.00
Ammonium nitrate[b/]	25.00	41.67	33.33
Barnyard manure in combination with other fertilizer	4.17	---	2.00
No fertilizer	4.17	---	2.09
Total number fields observed	24	24	

a/ N-P-K combinations included the following:

3-12-12	6-12-12		8-24-12	15-10-0
5-10-10	6-18-6	1	10-10-10	16-20-0
5-12-12	6-24-12		12-12-12	
5-20-10	6-40-0	1	13-13-13	
5-20-20	7-28-14		14-14-14	

b/ Always in combination with other fertilizer applications.

APPENDIX VIII D.-CROP HISTORY IN THE FIELDS USED IN VAN WERT COUNTY, OHIO

Type of rotation	Percent of fields		
	1958	1959	Average
Continuous corn [a]	16.67	8.70	12.69
Two-crop rotations			
Corn-beans	4.17	13.04	8.61
Three-crop rotations			
Corn-soybeans-legume	20.83	8.70	14.77
Corn-soybeans-small grain	4.17	4.35	4.26
Corn-small grain-beans	4.17	---	2.09
Corn-small grain-legume	---	8.70	4.35
Four-crop rotations			
Corn-legume-soybeans-soybeans	---	4.35	2.18
Corn-soybeans-small grain-legume	33.33	30.43	31.88
Corn-small grain-legume-small grain	4.17	8.70	6.44
Corn-small grain-small grain-legume	---	4.35	2.18
Corn-legume-soybeans-small grain	---	4.35	2.18
Five-crop rotations			
Corn-soybeans-small grain-small grain-legume	8.33	---	4.17
Corn-soybeans-small grain-legume-small grain	4.17	4.35	4.26
Total	9	11	
Total number fields checked	24	23	

[a] Never more than three consecutive years in fields observed.

APPENDIX VIII E.-PLANTING METHODS AND PLANT POPULATION IN THE FIELDS USED IN VAN WERT COUNTY, OHIO

	Percent of Fields				
	1956	1957	1958	1959	Average
Type of planting					
Drilled	100	100	100	100	100
No. fields observed	12	24	24	24	
Plants per acre					
10,000 or less	16.67	---	---	---	4.17
11,000	25.00	---	12.50	4.17	10.42
12,000	16.67	16.67	12.50	8.33	13.54
13,000	8.33	29.17	12.50	16.67	16.67
14,000	33.33	12.50	20.83	16.67	20.83
15,000	---	16.67	16.67	12.50	11.46
16,000	---	12.50	20.83	12.50	11.46
17,000	---	---	---	16.67	4.17
18,000	---	12.50	4.17	4.17	5.21
19,000	---	---	---	---	---
20,000 or more	---	---	---	8.33	2.08
Average	11,458	13,902	13,666	14,638	13,416
No. fields observed	12	24	24	24	

APPENDIX VIII F.-CORN VARIETIES USED IN THE FIELDS FOR THE STUDY IN VAN WERT COUNTY, OHIO

Variety	Percent of fields			
	1957	1958	1959	Average
Funks 670-500A	16.7	0	0	5.6
Funks 850	0	4.3	0	1.4
Funks unknown	0	4.3	0	1.4
Total	16.7	8.6	0	8.4
Pfister 777	16.7	0	0	5.6
Pfister 187	16.7	4.3	4.2	8.4
Pfister unknown	0	0	4.2	1.4
Pfister 323	0	0	4.2	1.4
Pfister 299	0	0	4.2	1.4
Total	33.4	4.3	16.8	18.2
Pioneer 371	0	4.3	4.2	2.8
DeKalb 630	16.7	4.3	0	7.0
DeKalb 450	16.7	0	0	5.6
Total	33.4	4.3	0	12.6
Greenleaf 870	0	4.3	0	1.4
Greenleaf 62	0	4.3	0	1.4
Total	0	8.6	0	2.8
Parker 49	0	4.3	0	1.4
Tiemann 72	0	0	4.2	1.4
Lowe's Golden Goliath	0	0	4.2	1.4
Experiment station and U.S. varieties				
Indiana 620	16.7	34.8	41.7	31.1
Indiana 621	0	0	8.3	2.8
Indiana 607	0	4.3	4.2	2.8
Indiana 608	0	4.3	0	1.4
Total	16.7	43.4	54.2	38.1
Iowa 4249	0	8.7	4.2	4.3
Ohio K62	0	4.3	4.2	2.8
Ohio C54	0	4.3	4.2	2.8
Total	0	8.6	8.4	5.6
Indiana 450	0	0	4.2	1.4
Penn. 602	0	4.3	0	1.4
Total number fields observed	6	24	23	
Total number of varieties	6	15	14	11.7