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European Corn Borer, Ostrinia nubilalis (Hbn.) Populations in Field Corn, Zea mays (L.) in the North Central United States

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CONTENTS

CONTENTS

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European Corn Borer *Ostrinia nubilalis* (HBN.) Populations in Field Corn, *Zea mays* (L.) In the North Central United States

INTRODUCTION

A long-range study of the annual changes in corn borer populations in the North Central States was started in Minnesota, Iowa, Kansas and Nebraska in 1955 and in Missouri and Ohio in 1956. This investigation was a phase of a broader Regional Project, NC-20, entitled "Factors Influencing Corn Borer Populations" and was undertaken to measure by standardized procedures the seasonal changes in abundance of the European corn borer, *Ostrinia nubilalis* (Hbn.), under cropping procedures in different locations within the North Central States.

Much valuable information has been accumulated on the abundance and effects of various physical and biotic factors on corn borer populations. Results obtained from 1955 through 1959 are summarized in a regional publication (Chiang *et al.* 1961). The present compilation and summary is offered as a companion bulletin containing data for the years 1960 through 1964.

Although the primary purpose of the present bulletin is to present results for the 1960 to 1964 period, it seemed pertinent to include statements of comparison with the preceding 5-year's work and to analyze in a rather "gross way" certain aspects of the population changes for the entire 10-year period.

Studies of this nature are long-time projects requiring many years of work in order to evaluate population fluctuations and factors influencing them. Hence the examination of the recent 5-year period becomes more meaningful when compared with the previous 5-year period or when considered as a single 10-year period.

More detailed analyses and short papers dealing with specific aspects of this census study will be forthcoming.

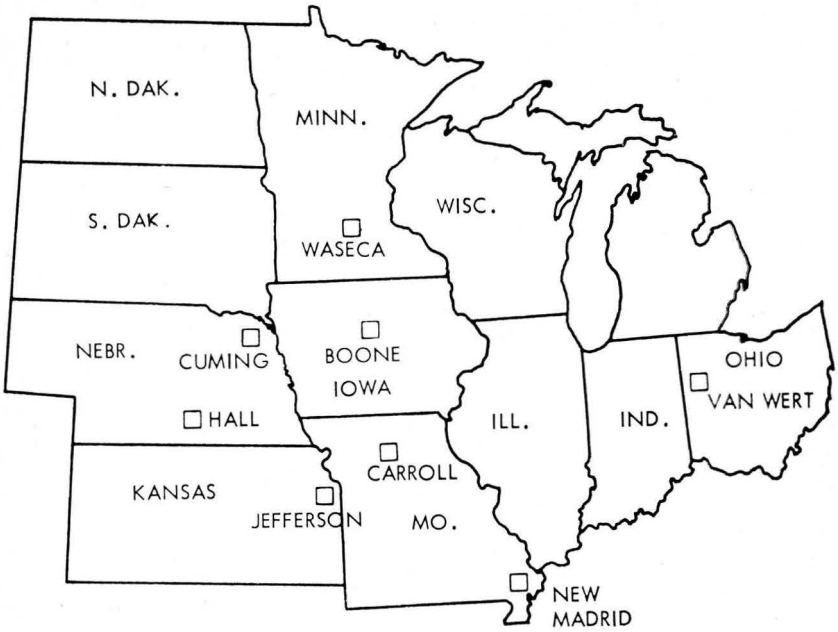

Fig. 1. Distribution of the counties studied in the North Central Region of the United States.

CENSUS PROCEDURES

The most significant feature of this census study is that the procedures followed in each state were standardized. Although these procedures were presented in the previous bulletin (Chiang *et al.* 1961), they are being restated here for the sake of completeness.

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:

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.

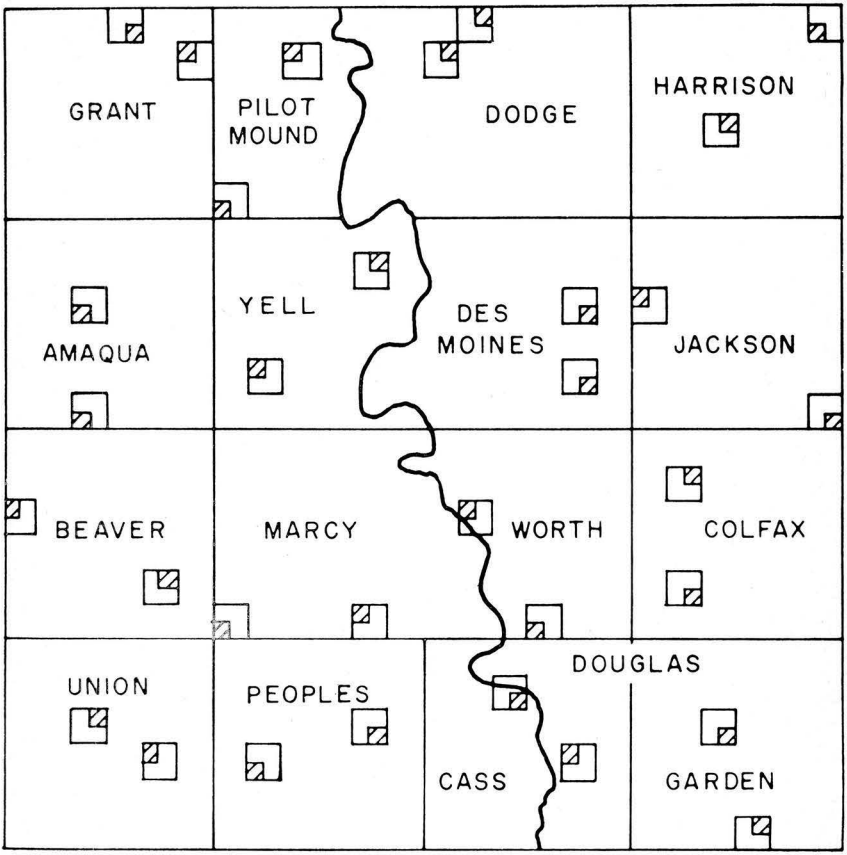

Fig. 2. Approximate locations of fields used in Boone County, Iowa.

2. **Selections of fields.** Two fields in each township in a county were used. At the start 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 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 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 or prepared for 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 Carroll and New Madrid Counties, Missouri a late fall census was conducted after the third brood had developed. A post-harvest census was made in Iowa. 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 predetermined 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[1] 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[1] 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 hybrid 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

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

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 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.

BOONE COUNTY, IOWA

Area Description

In Iowa the study was made in Boone County, an area of 576 square miles. 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 almost in the center of Iowa. It lies entirely within the Wisconsin drift soil area and hence its soils are all of glacial origin. As presented in 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% of the total area, terrace soils 1.9%, and river bottom soils 4.8%. 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 tilling 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.

Weather Conditions

The average temperatures and total rainfall for each month of the active borer season throughout the 5 years (1960-1964) are presented in Appendix 1A. The monthly deviations of these two factors from the long-term normal are shown in Appendix 1B. The general weather conditions for the various years may be summarized as:

1960—Temperatures below normal throughout growing season. Excessive rainfall in May followed by about half the amount of rain normally expected in June, about average rainfall in July and above average in August.

1961—Temperatures below normal throughout the growing season. Below average rainfall in May and June, about twice the average accumulative rainfall in July, followed by average rainfall in August.

1962—Exceptionally warm May resulted in highest number of accumulated borer-degree days on record by June 1 in Iowa, followed by below average temperatures in June, July and August. Above average rainfall in May, followed by less than average in June, about average in July and less than average in August.

1963—Temperatures were below average in May and July, above average in June and exceptionally cool in August. Rainfall was approximately average in May and July, above average in August but exceptionally low in June.

1964—Above average temperatures in May followed by cooler than average temperatures in June and August. About normal temperatures in July. Approximately normal rainfall in May and August, above average in June and below average in July.

Although several laboratory and field studies have been conducted to examine the effects of portions of weather phenomena on the borer, no study has been able to analyze the gross effect of weather as a unit on borer populations. Such a project, utilizing 15 years' data from Boone County, will be undertaken soon.

Agronomic Practices

The fields in Boone County are fertile and about 10 years ago commercial fertilizers was seldom utilized. However, since the early

1950's there has been a gradual increase in the percentage of fields that receive applications of commercial fertilizers.

Fertility practices in fields checked in the Boone County area for the years 1960-64 are summarized in Appendix 1C. During the years 1955-59, over half of the farms received no commercial fertilizer applications; however, the trend toward utilizing fertilizer has increased each year until over 90% of the fields checked in Boone County in 1963 and 1964 were fertilized with commercial materials. As was expected, there was a more widespread usage of NPK combinations.

Another point worthy of note was the usage of anhydrous ammonia. The first report utilizing this fertilizer in Boone County was in 1957. Since then it has gained in popularity to the point that 68.8% of Boone County fields under study received this particular treatment in 1964.

Crop rotation practices have changed considerably in the past 5 years. The majority of the fields under study still have corn followed by corn; however, this does not necessarily mean continuous corn growing. Many farmers use 2 or 3 years of corn and then start a regular rotation procedure. The major change in recent years was in the usage of soybeans rather than clover to follow corn in a rotation system. The data for rotation practices are presented in Appendix 1D.

The data from Table 1 indicate no major change in date-of-planting practices in the past few years. As a general rule very few fields are planted prior to May 1, about 45% are planted the first 10 days in May, about 45% the second 10 days in May and the remainder are planted sporadically from May 20 to the middle of June.

Planting methods and plant population data are presented in Appendix 1E. The wire checking method is practically non-existent at the present time in Boone County. Although approximately 80% of the corn is planted by power checking, there is a tendency toward increased plant populations and drilling the corn. The data from 1960-64 indicate a wide range of plant populations but the largest

Table 1. Planting dates in the fields used in Boone County, Iowa.

Planting dates	Percent of fields					
	1960	1961	1962	1963	1964	Average
Late April	0	0	9.4	0	0	1.9
May 1-10	6.3	59.4	37.5	62.5	62.5	45.6
May 11-20	62.5	37.5	50.0	34.4	34.4	43.8
May 21-31	21.8	3.1	3.1	3.1	3.1	6.8
June 1-10	3.1	0	0	0	0	0.6
June 11-21	6.3	0	0	0	0	1.3
Total fields observed	32	32	32	32	32	

percentage of the fields under study was in the 14,000 to 15,000 plants per acre category. During 1955-59 the majority of the fields studied had populations of 12,000 to 13,000 plants per acre.

At least 82 different hybrids of corn were grown in the 32 randomly selected fields in the past 5 years. A total of 16 commercial companies provided the hybrids; however, two of the companies cornered approximately 50% of the market. The percent of fields planted to any particular hybrid of corn by years is shown in Appendix 1F.

It seems feasible to surmise that the hybrids of corn utilized in Boone County have had a greater impact on corn borer populations than any other man-manipulated measure. Weekman (1956) found no relationship between method of planting and borer populations in Boone County. Becton (1960), Scott *et al.* (1965) and Cannon and Ortega (1966) reported higher initial survival of first- and second-instar larvae with higher nitrogen fertilization. With increased planting rates and increased usage of fertilizer, it is possible that planting methods could enable more borers to survive simply by providing more surface area upon which the young larvae could crawl and in which to become established.

Borer Populations

Five surveys were taken annually in Boone County. The results of these surveys are indices of borer population fluctuations and in some cases the fluctuations can be related to known factors. The results of all five of the annual surveys are presented in Table 2. Pertinent information concerning weather data and quantitative changes in borer populations are given in Tables 3 and 4. The range in numbers of borers per acre as well as the average size of the population at the time of each survey is presented in Table 5.

The early spring census was taken as soon as weather permitted, generally during the last few days of March or in early April. The fields had been undisturbed since harvest time of the previous year, thus the first census provides an index for calculating overwintering mortality by comparing early spring to the previous season's post-harvest population. For the years 1960-64, winter mortalities of 48.1, 11.7, 16.3, 37.9, and 23.1%, respectively, were recorded. These mortalities could have been caused by one or more of numerous factors, including disease, extremes of temperature, lack of cover, predation by birds, etc.

Stirrett (1930) found that a low temperature of –32°F was required to kill exposed larvae under field conditions. Drought was found to be an unfavorable condition for overwintering larvae by Huber (1941),

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
1960							
Early spring							270
Late spring							162
Summer	12,917	620	25.6	23.7	5.0	3,057	645
Fall	13,166	632	53.3	98.8	45.2	13,041	5,958
Post-harvest							2,666
1961							
Early spring							2,354
Late spring							1,912
Summer	14,040	674	51.3	43.6	17.7	6,121	2,485
Fall	13,584	652	80.1	194.9	81.3	26,467	11,040
Post-harvest							5,354
1962							
Early spring							4,479
Late spring							3,187
Summer	13,062	627	31.4	48.0	10.7	6,269	1,397
Fall	11,354	545	71.0	194.1	92.7	22,030	10,521
Post-harvest							4,857
1963							
Early Spring							3,014
Late Spring							2,050
Summer	13,792	662	25.0	36.1	21.5	4,978	2,965
Fall	13,125	630	79.0	249.5	131.4	32,734	17,240
Post-harvest							9,075
1964							
Early spring							4,228
Late spring							3,250
Summer	14,687	705	47.7	75.7	36.9	11,112	5,416
Fall	15,188	729	70.2	141.7	49.2	21,524	7,473
Post-harvest							2,042

and Barber (1925) reported that birds and mice feed upon overwintering borers in corn stalks.

Wall and Whitcomb (1964) in Arkansas studied overwintering mortality of larvae in corn stalks caused by birds and rodents. They made observations on species of birds and mortality to southwestern and European corn borer larvae. They reported 1.7 to 24.6% and 5.5 to 54.6% reductions in larval populations caused by birds in the winters of 1961-62 and 1962-63, respectively. Five species of rodents were taken in the fields and dissected but none appeared to be feeding on these larvae. They found the downy woodpecker to be the most important bird predator of the European corn borer, a conclusion in agreement with experiences expressed by entomologists working on the corn borer in central Iowa.

Although creditable work has been carried out in this area, more

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, 1960–64. (T, temperature; R, rainfall)

	1960	1961	1962	1963	1964
No. borers/A—late spring	162	1,912	3,187	2,050	3,250
—summer	645	2,485	1,397	2,965	5,416
Multiple change—spring to summer	4.0	1.3	–2.3	1.4	1.7
No. borers/A—fall	5,958	11,040	10,521	17,240	7,473
Multiple change—summer to fall	9.2	4.4	7.5	5.8	1.4
June weather					
Departure of mean (T) from normal	–3.9	–1.6	–1.7	+1.8	–1.2
Departure of mean (R) from normal	–2.69	–1.12	–2.82	–4.2	+2.75
No. days 90° or more	0	5	0	10	0
No. days 100° or more	0	0	0	0	0
No. days with .50″ rainfall	2	2	1	0	6
July weather					
Departure of mean (T) from normal	–4.4	–3.4	–4.8	–2.6	+0.4
Departure of mean (R) from normal	–0.26	+4.31	–0.68	+0.74	+1.81
No. days 90° or more	6	9	2	4	12
No. days 100° or more	0	0	0	0	0
No. days with .50″ rainfall	3	6	2	3	3
August weather					
Departure of mean (T) from normal	–1.3	–2.1	–1.4	–4.9	–3.9
Departure of mean (R) from normal	+1.75	+0.15	–1.76	+0.82	–0.14
No. days 90° or more	5	5	4	3	2
No. days 100° or more	0	0	0	0	0
No. days with .50″ rainfall	6	3	2	2	5

Table 4. Quantitative changes in borer populations in Boone County, Iowa.

	1960	1961	1962	1963	1964	Average
Multiple changes:						
Summer to fall	+9.2	+4.4	+7.5	+5.8	+1.4	+5.7
Fall to post-harvest	–2.2	–2.1	–2.1	–1.9	–3.7	–2.4
Post-harvest to early spring	–1.9	–1.1	–1.4	–1.5	–2.1	–1.6
Early spring to late spring	–1.7	–1.1	–1.4	–1.5	–1.3	–1.4
Late spring to summer	+4.0	+1.3	–2.3	+1.4	+1.7	+1.4
Fall to late spring	–9.6	–3.1	–3.4	–5.1	–5.3	–5.3
Inactive season mortality (percent reduction, fall to late spring)	90.3	67.9	71.1	80.5	81.1	78.2

Table 5. Population range and average number of borers per acre in Boone County, Iowa, 1960–64.

Survey	Number of borers per acre	
	Range	Average
Early spring	270 - 4,479	2,869
Late spring	162 - 3,250	2,112
Summer	645 - 5,416	2,581
Fall	5,958 - 17,240	10,446
Post-harvest	2,042 - 9,075	4,599

facts need to be established before definite statements can be made relating to the cause of winter mortality or before predictions of winter mortality can be made.

When the ground thaws in the spring in Iowa, a common practice followed by many Iowa farmers is to disc the previous year's corn field and sow oats. Fields treated in such a manner are the primary source of first-brood corn borer infestations (Chiang 1961). The late spring survey was taken in the 32 fields utilized in the previous year's study and sown to oats as described previously. If oats were not seeded in some fields, a randomly selected field in the same vicinity was sampled.

The results of the late spring survey indicate the mortality caused primarily by the mechanics of oat seeding. They also show the numbers of larvae present to initiate first brood infestations. The average population change in corn borers from early- to late-spring indicate that early spring population is about 140% of the late spring population in Iowa. The quantitative changes (Table 4) consistently indicate a negative-fold change in population from early- to late-spring.

Bigger and Petty (1953) reported that discing and oat seeding killed 69% of the remaining borers in their study. The range of kill attributable to these factors in Boone County from 1960 through 1964 was 19 to 40%, with an average population decrease of 29%. Differences in seeding techniques, plus the fact that some fields sampled in the late spring survey in Boone County were substitute fields, could account for these differences.

Summer borer populations are estimated from a survey conducted in the latter part of July after all first brood eggs have hatched and prior to the beginning of the second brood oviposition period. An examination of Table 2 and Figure 3 will illustrate that late spring and summer populations are not consistently correlated.

Positive correlations between date of planting and first brood populations have been reported by several workers [Goleman (1954), Weekman (1957) and Everett *et al.* (1958)]. For the years 1960-64 planting dates and first brood populations were correlated in only

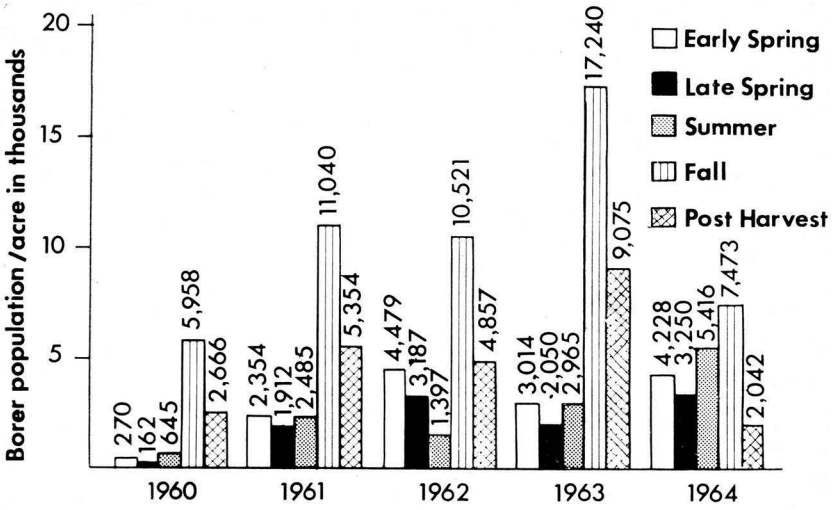

Fig. 3. Average number of borers per acre, Boone County, Iowa, 1960–64.

two of the years, 1961 and 1963. Everett *et al.* (1958) reported that first brood infestations were reduced in Iowa when June temperatures were below normal and/or rainfall was deficient. Both temperature and rainfall were below that expected when compared to long-term normals for 1960, 1961 and 1962. From Table 6 the data show that the percent survival, based on total eggs oviposited per acre versus the numbers of borers per acre found at midseason dissections, is much lower for those years than the survival found in 1963 and 1964.

Table 6. Survival of European corn borer based on estimates of number of eggs per acre versus number of borers per acre in Boone County, Iowa, first and second brood, 1960–64.

Year	Egg masses per 100 plants	Average size of mass	Average No. eggs per 100 plants	Average No. eggs per acre	Average No. borers per acre	Percent survival borers per acre / eggs per acre
			First brood			
1960	8	13.0	104	13,433	645	4.80
1961	47	14.7	691	97,016	2,485	2.56
1962	28	11.4	319	41,667	1,397	3.35
1963	28	11.9	333	45,927	2,965	6.46
1964	34	14.1	479	70,307	5,416	7.70
			Second brood			
1960	12	18.2	218	28,702	5,958	20.76
1961	45	15.6	702	95,360	11,040	11.58
1962	49	12.7	622	70,622	10,521	14.89
1963	74	21.2	1,569	205,931	17,240	8.37
1964	115	15.1	1,736	263,663	7,473	2.83

June of 1963 was warmer than normal but rainfall was far less than what is normally expected. June of 1964 was cooler but received a sizeable increase in rainfall over the amount normally expected. These data indicate that the effect of the interaction between June rainfall and temperature may exceed the effect of either factor considered alone.

According to Polivka and Huber (1931) larval survival is inversely proportional to the number of total eggs laid. The Boone County data do not agree with these findings. The second highest oviposition per acre and the highest percent survival for the 5-year period were recorded in 1964 (Table 6). In 1962 and 1963 the number of eggs laid per acre was similar; however, survival in 1963 was almost twice that of 1962.

Various workers have reported significant contributions of egg and larval parasites and predators toward keeping corn borer populations in check [Baker *et al.* (1949), Froeschner (1950) and Chiang and Holdaway (1955)]. Sparks *et al.* (1965) reported the results of predator evaluation studies conducted under caged conditions by workers in five states over a period of years. They concluded that although predators make a significant contribution to lowering corn borer populations in some areas during some years, they cannot be depended upon to significantly influence a borer population at any given site in any given year. Blickenstaff (1953) summarized the status of the corn borer in Iowa and concluded that the two most important parasites were *Lydella thompsoni* Herting and *Sympiesis viridula* (Thoms.)

The fall survey is taken as late as possible but prior to the beginning of harvesting. Data in Tables 2 and 4 indicate the fall populations increased an average of 5.7 times over summer populations. Borers that entered diapause in July were included in fall populations. Summer diapause was estimated at 6, 24, 8, 4 and 6% for 1960-64, respectively.

Oviposition and survival data for the second brood are given in Table 6. Everett *et al.* (1958) found that second brood oviposition was inversely proportional to mean August temperatures. Utilizing figures of larvae per 100 plants at midseason, and egg masses per 100 plants during second brood, the females averaged 4.8, 5.0, 9.2, 6.8 and 6.2 egg masses per female for 1960-64, respectively.

Immediately, one sees that the year of highest egg production per female was also the year in which the second hottest and most rainfall-deficient August occurred. However, a second look indicates that the year in which the second highest oviposition rate occurred was also the year with the coolest August and most abundant rainfall. These data are contradictory to the reports of Everett *et al.* (1958) and in-

dicative of the complexities associated with predicting borer populations.

Another factor that probably is of importance in corn borer populations is the incidence of an infection caused by a protozoan, *Perezia pyraustae* Paillot. Zimmack *et al.* (1954) reported that corn borer collections from several Midwestern states were infected. Later, Zimmack (1956) reported that the protozoan caused slower growth, lower larval survival, depressed oviposition rates by diseased females, and showed the pathogen to be egg transmitted. Available information on the incidence of *Perezia* infection as it occurred in Boone County at designated dates is presented in Table 7. Data concerning this protozoan and its effects on the borer are not sufficient to reach any decisive conclusions at the present time.

The post-harvest survey is taken in late fall after all fields have been harvested. The original idea behind this survey was to obtain an estimate of the size of reduction in borer populations due to mechanical harvesting. Bigger and Petty (1953) reported a 36% kill of the fall population by mechanical corn pickers in Illinois. The figures for percent reductions based on post-harvest populations in Iowa for the years 1960-64 read 54, 50, 61, 47 and 73%, respectively, for an average yearly reduction of 57% (Table 2). This average mortality figure certainly differs from that reported by Bigger and Petty; however, the probability that this reduction is caused by something other than mechanical picking is great.

For example, the greatest reduction in populations of corn borers from early fall to post-harvest occurred in 1964. The protozoan infection was found to be 82% in midseason and 70% in the fall. Consider the findings of Kramer (1959) who reported that cold of winter and heat of summer were factors of stress which interact with the protozoan disease to cause mortality in European corn borer populations. It is also important to recall the report of Zimmack (1956) indicating that the infection results in slower larval growth.

With these factors in mind, the data for the latter part of the 1964 season present circumstantial evidence indicating that *Perezia pyraustae* could have been influential in the high mortality of the

Table 7. Percent of Boone County, Iowa borer population infected with *Perezia pyraustae* at designated survey times.

	Spring	Summer	Fall	Post harvest
1959	–	–	24	–
1960	18	–	–	–
1961	12	17	–	–
1962	–	–	52	–
1963	–	–	68	–
1964	72	82	70	50

corn borer population occurring in a 6-week period between fall and post-harvest survey times. With an infection of 82% in the midseason population and a mean August temperature 3.9°F lower than the long-term normal, it is possible that the combined effect of lower temperature and high infection rate put the population under stressed conditions. The low temperatures dropped into the 30's for three nights in late September and this plus the mechanical damage caused by picking could be highly effective in reducing the borer population.

Borer populations in Boone County ranged from 162 to 17,240 borers per acre (Table 5). The greatest population reductions consistently occurred during the inactive season of the borer, i.e., fall to late spring (Table 4). During this time the population is reduced by mechanical picking, predators, discing and seeding of oats and—perhaps of more importance than formerly expected—the combined effect of adverse weather and the protozoan infection, *Perezia pyraustae*.

The summer-to-fall population increase exceeded the late-spring-to-summer increase in 4 of the 5 years. In each of those 4 years, the mean July and August temperatures were below normal and July rainfall was near the long-term normal. The one exception during the 5-year period, 1964, had near normal July temperatures and was deficient in rainfall. These facts establish reasons for high increases in summer-to-fall populations.

According to Everett *et al.* (1958) low increases in late-spring-to-summer populations are to be expected with cool June temperatures and/or deficient rainfall. One or both of these factors occurred in all 5 years.

Finally, a graphic representation of borer populations at the time of each survey each year is shown in Figure 3. The most outstanding features of this graph are the reduced 1962 summer populations compared to the late spring, the high fall population of 1963 compared to the summer population, and the apparent inability of the 1964 population to significantly increase its numbers throughout its active season along with its "quick disappearance" in numbers in late fall.

The 1962 and 1963 data can be explained by unfavorable and favorable weather conditions, respectively. The 1964 data cannot be explained by weather conditions alone. Perhaps these data give clues as to where more emphasis should be placed in future studies.

JEFFERSON COUNTY, KANSAS

Area Description

The Kansas study was conducted in Jefferson County in northeastern Kansas. The county was chosen as representative of corn pro-

duction 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% of the fields studied. An additional 41.6% of the fields represented friable, silty to clayey soils (upland). The remaining 12.6% of the fields are on dark, tight clay and claypan soils, some on bottomland and others on upland.

Weather Conditions

The average temperature and total rainfall for each month of the active borer seasons during 1960-64 for Jefferson County are given in Appendix IIA. The deviation of these records from the long-term normal are presented in Appendix IIB. General weather conditions in the various years may be summarized as follows:

1960—Cool and dry. Average temperatures were below normal from May through July and slightly above in August. Total rainfall was below normal for each month.

1961—Temperatures were quite below normal while rainfall was slightly above normal in May, below in June and August but well above normal in July.

1962—Warm May with subnormal June-August temperatures. Rainfall above normal except for June.

1963—Mean temperatures above long-term mean, while rainfall was below normal except for May.

1964—Cool June and August, with slightly above normal May and July temperatures. Rainfall below normal in May and July but above during June and August.

Agronomic Practices

Corn is still the most important crop in Jefferson County and occupies the largest acreage. There are numerous two-crop and three-crop rotations in practice but several fields used in this study were in corn continuously for many years.

Fertilizer practices varied considerably. Data indicate 24.2% of the fields received no treatment, 73.3% received commercial fertilizer, 55.0% of which were N-P-K combinations (Appendix IIC). Borer populations were usually higher on heavily fertilized fields than on unfertilized fields.

Table 8. Planting dates in Jefferson County, Kansas.

Planting dates	Percent of fields					
	1960	1961	1962	1963	1964	Average
April 1-10	0	0	0	0	8.3	1.7
April 11-20	0	4.2	0	8.3	0	2.5
April 21-30	16.7	0	8.3	4.2	0	5.8
May 1-10	33.3	25.0	33.3	37.5	50.0	35.9
May 11-20	37.5	25.0	37.5	33.4	20.8	30.8
May 21-31	12.5	37.4	16.7	8.3	12.5	17.5
June 1-10	0	4.2	4.2	8.3	4.2	4.2
June 11-20	0	0	0	0	4.2	.8
June 21-30	0	4.2	0	0	0	.8
Average Date of Planting	May 7	May 18	May 17	May 12	May 11	May 13
Total fields observed	24	24	24	24	24	

Data on crop history are given in Appendix IID. Over 77% of the fields under study during the 5-year period (1960-64) were in continuous corn for 3 years or more.

Planting methods and plant populations are summarized in Appendix IIE. An average of 37.5% were listed while 45.8 and 16.7% were planted with a furrow opener and surface planter respectively.

Commercial hybrids were planted in 79.9% of the fields (Appendix IIF).

Planting dates are summarized in Table 8. They range from April 1 to June 30 but the average date for each year varied little from the overall average date of May 13. Over the 5 years an average of 4.2% of the fields were planted before April 20.

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 9 and Figure 4. The percent of the plants with injury by first and second generation borers is also given. During the last eight years (1957-64) the census was taken four times a year. An early spring census indicated the percent post-harvest plus winter mortality whereas a late spring census measured first the amount of "spring farm operating mortality" and secondly the approximate potential available to produce first generation borers.

During the 1960-64 period the number of plants infested by first generation larvae averaged 7.7% whereas second generation infestation averaged 34.8%.

Following a high in the borer population in 1957 (Chiang *et al.* 1961) there was a sharp decline until a low was hit in 1961. Since

Table 9. 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
1960	Early spring					1,802
	Late spring					125
	Summer	11,194	806	10.0	7.0	777
	Fall	10,416	750	27.0	19.0	1,985
1961	Early spring					250
	Late spring					25
	Summer	12,750	918	8.0	3.8	458
	Fall	11,180	805	26.0	14.5	1,611
1962	Early spring					403
	Late spring					17
	Summer	11,222	808	3.0	0.3	28
	Fall	11,236	809	30.0	29.9	3,871
1963	Early spring					458
	Late spring					42
	Summer	11,013	793	7.0	2.3	277
	Fall	9,916	714	45.0	75.4	7,180
1964	Early spring					1,403
	Late spring					84
	Summer	9,349	589	9.6	3.1	292
	Fall	10,666	768	45.6	70.8	7,305

1961 there has been a gradual increase in the borer population as shown in Table 9 and Figure 4.

Quantitative changes in borer populations between different cen-

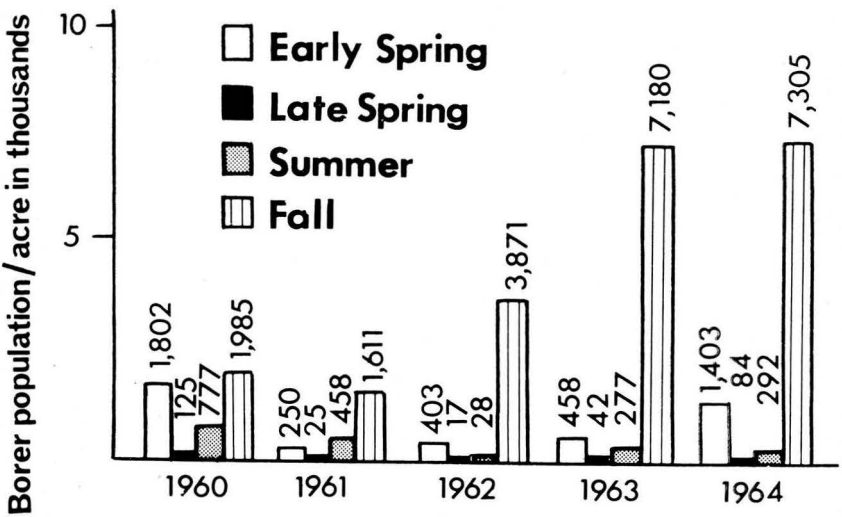

Fig. 4. Average number of borers per acre, Jefferson County, Kansas, 1960–64.

Table 10. Quantitative changes in borer populations in Jefferson County, Kansas.

	1960	1961	1962	1963	1964	Average
Multiple changes (per 1/1,000 acre):						
Summer to fall	1.25	1.15	3.85	6.90	6.99	4.02
Previous fall to early spring	−6.29	−1.73	−1.35	−3.42	−5.81	−3.72
Early spring to late spring	−1.93	−0.22	−0.24	−0.43	−1.32	−0.82
Late spring to summer	.60	.43	.01	.25	.24	.31
Previous fall to late spring	−8.22	−1.95	−1.59	−3.85	−7.13	−4.54
Winter mortality (%)	75.3	87.4	75.0	88.1	83.3	81.8
Spring farm operation mortality (%)	22.2	9.7	23.3	10.8	15.5	16.3
Total mortality (%) (fall to late spring)	97.5	97.1	98.3	98.9	98.8	98.1

Table 11. Population range and average number of borers per acre in Jefferson County, Kansas, 1960–1964.

	Number borers per acre	
	Range	Average
Early spring	250 – 1,802	863
Late spring	17 – 125	58
Summer	28 – 777	365
Fall	1,611 – 7,305	3,990

suses are shown in Table 10. 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 81.8% during the past 5-year period as compared to only 73.3 during 1956-1959. An average of 16.3% additional reduction resulted from spring farm operation mortality. This is considerably lower than the 26.3% average during the preceding 5-year period. However, the overall fall-to-late-spring reduction 98.1 is higher than the 93.1% of the previous 5 years.

The borer populations in censuses made during the past five years range from 17 to 7,305 borers per acre (Table 11) which is less than the 1 to 22,551 range of the previous 5-year period. Considerable seasonable fluctuations can be observed during the past 9 years. In all instances the average summer populations were higher than the late spring populations. Also, the number of borers in the fall was consistently higher than in the summer for *each year studied.*

The highest second brood borer population during the 1955-1959 study occurred in 1957, a year in which June was quite cool and wet. During the 1960-1964 period, the same correlation existed between high borer population and a cool-wet June in 1964. These two high population peaks during the two 5-year periods respectively were associated with the two coolest-wettest Junes in the entire period of study.

WASECA COUNTY, MINNESOTA

Area Description

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

Soils and 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. 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%; Class II, 59.6%; Class III, 25.8%; Class IV, 2.8%; Class V, 0.3%; Class VI, 2.7%; Class VII, 1.1%.

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

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

Weather Conditions

The monthly average temperature and monthly total rainfall for years 1960 to 1964 are presented in Appendix III A. The deviations of these records from the long-term average are presented in Appendix III B. The general weather conditions in the various years may be summarized as follows:

1960—Relatively cool. Rainfall in July and August slightly subnormal. Above normal rainfall occurred in May and June.

1961—Relatively cool. Rainfall above normal in May, July and August. Although precipitation was below normal in June, the amount for the entire growing season was much above normal.

1962—Very cool during June, July and August. Rainfall near normal except August which was rather wet.

1963—Temperature below normal in May, July and August. Rainfall was below normal in May and August and above normal in June and July. The total for the season was near normal.

1964—August very cool, other months near normal. Rainfall somewhat below normal in June and July but the total for the season was near normal.

Agronomic Practices

Over the period of 1960-64, about 43% of the fields in Waseca County were planted to corn continuously, about 42% were in two-crop rotation and 14% in three-crop rotation (Appendix III C). The corresponding figures for the period of 1954-59, as reported in an earlier publication of this study (Chiang *et al.* 1961), were 15, 52 and 27%, respectively. Thus there has been an increase in continuous corn planting and a decrease in crop rotation, particularly in three-crop rotations. Among the two-crop rotations, 11% of the fields were in the corn-oats sequence. This represents a very notable decrease from the earlier period when 26% of the fields were in the corn-oats sequence.

A great variety of combinations of N-P-K were used by the farmers (Appendix III D). This situation was the same as in the early period. There were only 5.6% of the fields which did not receive any fertilizers. This represents a drastic decrease comparing to 25% for the period of 1954-59. This situation is probably related to the increase in the planting of continuous corn.

In the present 5-year period, 8.7% of fields were check-planted (Appendix III E). The comparable figure for the previous 5-year period was 47.9%. Correspondingly, the percentages of hill drop and drilled planting showed increases.

Table 12. Planting dates in the fields used in Waseca County, Waseca, Minnesota.

Planting dates	Percent of fields					
	1960	1961	1962	1963	1964	Average
May 1–10	8.3	33.3	25.0	57.1	29.1	29.9
May 11–20	25.0	50.0	54.2	42.9	58.3	47.9
May 21–31	16.7	16.7	8.3		12.6	9.4
June 1–10	33.3		8.3			8.5
June 11–20	12.5		4.3			4.3
June 21–30	4.2					
Total fields observed	24	24	24	21[a]	24	

[a] Records of three fields not available.

The average plant density for the 5-year period was approximately 15,400 which is 1,400 more than that of the previous 5-year period (Appendix III E). This fact is undoubtedly related to the increase in the drilled planting.

For the 5-year period, about 22 hybrids were used each year in the 24 fields (Appendix III F). During the early period, 20 hybrids were used each year on the same farms. The hybrids used in the two

Table 13. 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	Larvae per 100 plants	Tunnels per acre	Larvae per acre
1960							
Early spring							441
Late spring							67
Summer	13,350	961	21.1	19.3	7.4	2,500	1,000
Fall	12,800	919	50.7	91.7	39.9	11,700	5,097
1961							
Early spring							83
Late spring							75
Summer	16,200	1,165	21.6	11.3	10.0	1,833	1,468
Fall	15,400	1,108	31.0	54.9	8.4	8,450	1,380
1962							
Early spring							190
Late spring							–
Summer	15,100	1,815	17.8	27.3	5.7	4,100	900
Fall	14,500	1,743	32.5	54.2	5.9	7,700	800
1963							
Early spring							50
Late spring							–
Summer	18,200	2,181	20.2	17.1	3.8	3,100	700
Fall	15,500	1,864	48.3	80.4	21.9	12,500	3,400
1964							
Early spring							–
Late spring							216
Summer	14,500	1,744	26.2	28.8	3.1	4,100	600
Fall	15,900	1,909	37.2	58.7	7.7	9,300	1,200

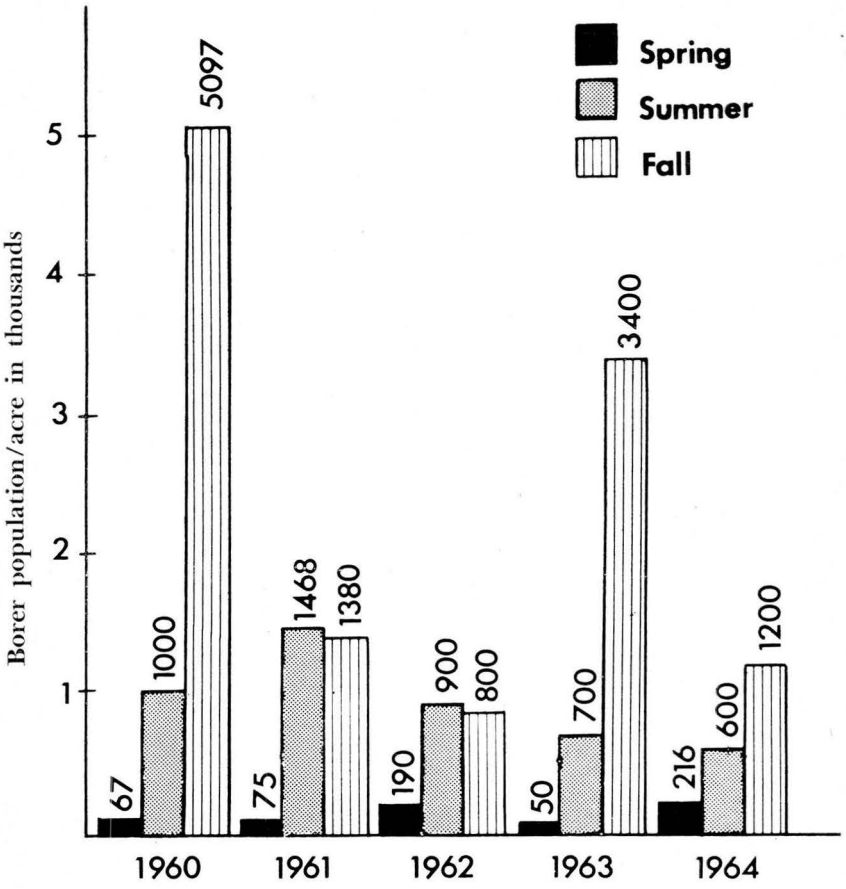

Fig. 5. Average number of borers per acre, Waseca County, Minnesota, 1960–64.

periods differed considerably. This comparison indicates that over the country, the degree of diversity of the farmers' choices ran about the same over the 10-year period but the hybrids chosen changed from year to year. The Agricultural Experiment Station hybrids did not gain popularity.

Corn in southern Minnesota is usually planted during the first 3 weeks of May. Unusually late plantings in 1960 were due to excessive rainfall in May and June. The planting dates in the fields used in Waseca County are given in Table 12.

Borer Populations

The summaries of borer populations and damage ratings are given in Table 13 and Figure 5. The percent of plants injured in the sum-

Table 14. Quantitative changes in borer populations in Waseca County, Minnesota.

	1960	1961	1962	1963	1964
Multiple changes:					
Previous fall to early spring	−10.8	−61.4	−7.3	−16.0	
Previous fall to late spring				−15.7	
Early spring to late spring	−6.6	−1.1			
Early spring to summer			+4.7	+14.0	
Late spring to summer	+14.9	+19.6			+2.8
Summer to fall	+5.1	−1.1	−1.1	+4.9	+2.0
Winter mortality (%)[a]	90.8	98.4	86.2	92.5	93.6

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

mer varied from 17.8 to 26.2 through the 5-year period. The comparable values in the fall varied from 31.0 to 50.7. In all the five years, the number of injured plants recorded in the fall was larger than that in the summer. A similar relation was shown in the number of tunnels per acre.

The number of borers per acre was checked in spring, summer and fall. The numbers varied greatly from year to year. There was a considerable decrease from early spring to late spring. And, as to be expected, the summer population was always higher than the spring population. But the fall population was not always higher than the summer population. In two of the 5 years, it was lower (Table 14). As discussed by Chiang and Hodson (1959), a low fall survival among second brood larvae may result in reduced fall populations, particularly striking if the summer pupation rate was high.

Recent studies in Minnesota indicate that (1) 26% of the moths in the spring came not from the stalks in the fields but from the ears in storage cribs on the farms (Chiang 1964). This source would increase the differential between the spring population which was determined on the basis of plant material left in the fields and the summer populations as indicated earlier. (2) During the flight of the summer brood moths, some moths may be carried by winds from points south into Minnesota (Chiang, Sisson and Ewert, 1965). This relation may contribute to a higher second brood population.

The borer populations in the present 5-year period showed great reductions compared to those of the previous 5-year period. The spring population and the summer population were about half, and the fall population about 1/5 (Table 16). This is even more significant when we consider that the plant density had actually increased, as mentioned earlier.

The temperature in the present 5-year period (Table 15) showed many months below the long-term averages. Out of the 15 monthly

Table 15. Changes in borer populations from spring to summer to fall in Waseca County, Minnesota, and certain weather data for June, July and August, 1960–64. (T, temperature; R, rainfall)

	1960	1961	1962	1963	1964
No. borers/A – early spring	441	83	190	50	—
– late spring	67	75	—	—	216
– summer	986	1,468	900	700	600
Multiple change – early spring to summer	+2.2	+17.7	+4.7	+14.0	—
Multiple change – late spring to summer	+14.9	+19.6	—	—	+2.8
No. borers/A – fall	5,097	1,380	800	3,400	1,200
Multiple change – summer to fall	+5.1	–1.1	–1.1	+4.9	+2.0
June weather					
Departure of mean (T) from normal	–2.8	–0.1	–2.4	2.2	–1.5
Departure of mean (R) from normal	.52	–3.59	–1.09	.83	–2.65
No. days 90° or more	0	4	0	3	3
No. days 100° or more	0	0	0	0	0
No. days with .50″ rainfall	4	0	3	6	1
July weather					
Departure of mean (T) from normal	–2.0	–3.5	–5.3	–1.1	.7
Departure of mean (R) from normal	– .99	3.48	1.85	1.92	– .58
No. days 90° or more	7	1	0	1	10
No. days 100° or more	0	0	0	0	0
No. days with .50″ rainfall	1	4	2	4	1
August weather					
Departure of mean (T) from normal	0.8	–0.2	–2.3	–2.8	–6.1
Departure of mean (R) from normal	– .81	2.25	5.06	–1.20	1.06
No. days 90° or more	3	0	0	0	4
No. days 100° or more	0	0	0	0	0
No. days with .50″ rainfall	1	3	3	2	2

values (for June, July and August of the five years), 12 were negative. In the previous period, out of 18 monthly values (June, July and August of six years), only 9 were negative. Furthermore, in the present 5-year period, summation of all monthly departures showed a negative value of 24.4, whereas in the previous period, the corresponding value was a positive 4.2. Thus, it is likely that generally cooler seasons were responsible for lower borer populations recorded from 1960 through 1964.

In the first bulletin of this study (Chiang *et al.* 1961), it was re-

Table 16. Population range and average number of borers per acre in Waseca County, Minnesota, 1960–64.

	Number borers per acre	
	Range	Mean
Early spring	50 - 441	245.5
Late spring	67 – 216	141.5
Summer	600 – 1468	1034
Fall	800 – 1380	1090

ported that the heavy first brood borer populations coincided, in a general way, with the area which had a corn-oats crop sequence. It was further pointed out that a comparison of the changes of borer populations and the changes in farm practices in the future would be significant. With the extension of the second 5-year period, the study has a span of 10 years. It is possible now to conclude that reduced borer populations concurred with a reduction in corn-oats crop sequence in Minnesota.

The Minnesota data may be briefly summarized as follows:

(1) Borer populations (in terms of number of borers per acre) were lower in the period 1960-64 than in the preceding 5-year period, 1954-59. This was true even though more farmers drill planted their corn at higher plant densities in 1960-64 than in 1954-59.

(2) The weather during the months of June, July and August in the 5-year period (1960-64) was cooler than the long-term average. This condition is considered partially responsible for generally lower borer populations comparing to those in the preceding 5-year period.

(3) More farmers adopted continuous corn planting in 1960-64 than in 1954-59 and considerably fewer fields were in the corn-oats crop sequence. This gradual decrease in corn-oats planting over the 10-year period may also have been responsible for some of the decrease in borer populations.

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, 11 in 1957, and 24 in 1958, 1959, 1960, 1961, 1962, 1963 and 1964. 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 was also initiated in 1956. There were 27 cooperators in 1956, 31 in 1957, 38 in 1958, 39 in 1959 and 24 in 1960, 1961, 1962, 1963 and 1964. Since there are more than 12 townships in Carroll County, an attempt was made to select fields in townships which were representative of larger areas.

Table 17. Summary of corn yield and production in New Madrid County, Missouri, for 1956–1963.

Year	Acreage	Bu / A yield	Production bushels
1956	53,000	49.8	2,638,000
1957	60,000	40.6	2,433,700
1958	45,400	50.8	2,305,700
1959	45,400	58.5	2,655,800
1960	47,600	59.4	2,827,000
1961	38,200	67.0	2,559,400
1962	41,700	58.2	2,428,200
1963	50,300	68.1	3,424,900

New Madrid County

Area Description

New Madrid County is in southeastern Missouri in the fertile Mississippi Delta, about 35 miles southwest of Cairo, Ill. 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. A summary of the corn production in the area during the NC-20 census study period is given in Table 17.

Weather Conditions

The average monthly temperature and the total monthly rainfall are given in Appendix IV A. The deviations of these readings from the long-term normal are given in Appendix IV B. The general weather conditions for the year 1960-1964 may be summarized as follows:

1960—Temperatures were above normal in April and September and below normal the rest of the season. Most of the season was dry.

1961—Temperatures were considerably below normal except for September and October. Early part of the season was wet and late season dry.

1962—Temperature in May considerably above normal, cool rest of season. Early part of season was dry and later part wet.

1963—Above normal temperatures early and in October, remainder below normal. Most of season dry but July and August wetter than normal.

1964—Early part of season warm, later part cooler. Entire season dry.

Agronomic Practices

Fertilizer treatments used in New Madrid County are summarized in Appendix IV C. Approximately 83% of fields received combina-

Table 18. Planting dates in New Madrid County, Missouri.

Planting dates	Percent of fields					
	1960	1961	1962	1963	1964	Average
Before March 31	0	0	0	0	0	0
April 1–10	13.6	9.1	4.1	26.0	14.2	13.3
April 11–20	63.6	13.6	29.1	43.4	47.6	39.3
April 21–30	18.1	13.6	29.1	13.0	28.5	20.3
May 1–10	0	18.2	29.1	17.3	9.5	15.5
May 11–20	4.5	18.2	8.3	0	0	6.0
May 21–31	0	13.6	0	0	0	2.6
After June 1	0	13.6	0	0	0	2.6
Total fields observed	22	22	24	23	21	

tions of N.P.K. as a starter fertilizer. Over 84% of fields were treated with anhydrous ammonia. During the period 1960 to 1964 all fields received some type of commercial fertilizer but no fields received barnyard manure.

Information on crop rotations in New Madrid County is summarized in Appendix IV D. According to the 5-year average, 49.5% of fields were planted to corn for the second year. Approximately 19% and 21% of the fields were on ground used for cotton and soybeans the previous year. The remainder of the corn followed small acreages of clover, pasture, small grain, sorghum, rye and vetch.

Stand counts taken in each field are summarized in Appendix IV E. Stand counts ranged from 8,000 to over 18,000 plants per acre with the majority falling in the 12,000 to 17,000 plants per acre range.

The dates of planting for the cooperator fields are summarized in Table 18. Over 50% of the fields were planted by April 20 and approximately 90% were planted by May 10. Because of excessive rain-

Table 19. Summary of borer populations at various times each year in New Madrid County, Missouri. Number per acre.

	Early spring	Late spring	Suummer	Early fall	Late fall
1960 Larvae	92	8	145	3,500	2,417
Tunnels			666.6	6,903	
1961 Larvae	1,420	44	403	3,500	1,694
Tunnels			638.8	5,277	
1962 Larvae	2,110	142	208	2,000	2,431
Tunnels			597.1	6,639	
1963 Larvae	1,211	145	181	3,611	3,431
Tunnels			847.3	6,972	
1964 Larvae	1,017	167	1,653	11,722	2,683
Tunnels			4,069	25,514	
Average					
Larvae	1,170	101	518	4,867	2,531
Tunnels			1,364	10,261	

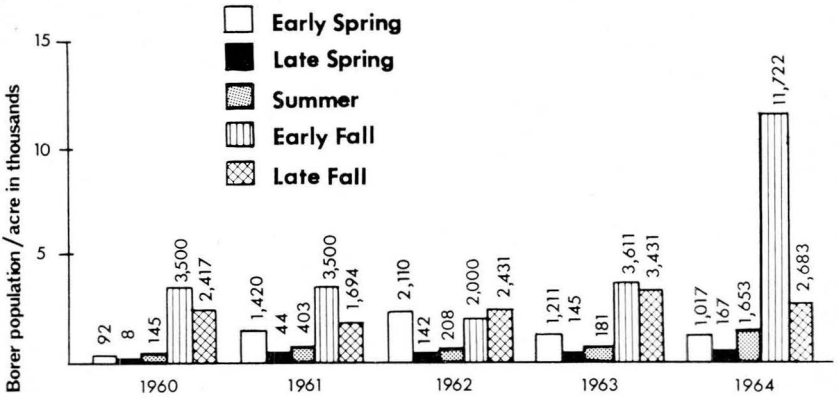

Fig. 6. Average number of borers per acre, New Madrid County, Missouri, 1960–64.

fall during the spring of 1961, the planting period was somewhat extended.

For the 5-year period, 1960-1964, over 35 hybrids were planted by the cooperators. There was no real trend toward using a particular hybrid; however, almost 41% of fields were planted to Pfister hybrids. Hybrids used are listed in Appendix IV F.

Borer Populations

A summary of borer populations in New Madrid County for 1960-1964 is presented in Table 19 and Figure 6. Five censuses were conducted each year for 1960-1964. Heaviest infestation was recorded in 1964.

Quantitative changes in borer populations from time to time each year are presented in Table 20. The results show a sizable reduction in populations from early spring to late spring and a slight reduction

Table 20. Quantitative changes in borer populations in New Madrid County, Missouri.

	1960	1961	1962	1963	1964	Average
Multiple changes						
Early spring to late spring	−11.5	−32.3	−14.9	− 8.4	− 6.1	−14.6
Late spring to summer	18.1	9.2	1.5	1.2	9.9	8.0
Summer to early fall	24.1	8.7	9.6	20.0	7.1	14.0
Early fall to late fall	− 1.4	− 2.1	1.2[a]	− 1.1	− 4.4[b]	− 1.6

[a] Harvest not complete at time of census.
[b] Census delayed until January 1965.

Table 21. Summary of borer populations by planting dates in New Madrid County, Missouri. Number per acre.

Date of planting	1960			1961			1962		
	Summer	Early fall	Late fall	Summer	Early fall	Late fall	Summer	Early fall	Late fall
Before 3/31									
4/1–5	0	1,667	0	0	333	1,000	–	–	–
4/6–10	0	1,667	0	1,000	2,667	333	1,000	0	0
4/11–15	286	2,381	0	0	0	0	250	1,500	2,000
4/16–20	167	1,209	42	2,834	2,334	0	333	222	222
4/21–25	0	3,000	111				333	1,111	667
4/26–30	0	2,333	1,000	556	1,778	889	250	1,750	750
5/1–5				111	5,111	111	0	2,000	867
5/6–10				0	667	0	0	2,000	1,834
5/11–15	0	20,333	20,000	0	1,222	0	0	8,500	18,333
5/16–20				0	5,333	0			
5/21–25				111	8,222	4,000			
After 6/1				0	5,556	8,000			

Date of planting	1963			1964			Average		
	Summer	Early fall	Late fall	Summer	Early fall	Late fall	Summer	Early fall	Late fall
Before 3/31									
4/1–5	83	2,749	833	3,667	2,667	–	938	1,854	611
4/6–10	111	4,000	333	667	8,667	2,333	557	3,400	600
4/11–15	333	3,000	111	3,445	16,000	1,889	863	4,576	800
4/16–20	444	3,333	3,222	1,417	13,000	9,047	1,039	4,020	2,507
4/21–25	0	4,667	18,000	1,400	7,267	7,167	433	4,011	6,486
4/26–30	0	4,333	0	0	3,667	1,667	161	2,772	861
5/1–5	0	5,334	3,778	0	32,333	3,667	28	11,195	2,106
5/6–10	0	4,667	11,000	0	26,333	5,333	0	8,417	4,542
5/11–15							0	10,018	12,778
5/16–20							0	5,333	0
5/21–25							111	8,222	4,000
5/26–31									
After 6/1							0	5,556	8,000

Table 22. Changes in borer populations from spring to summer to fall in New Madrid County, Missouri, and certain weather data for June, July and August, 1960–64. (T, temperature, R, rainfall)

	1960	1961	1962	1963	1964
No. borers/A – spring	8	44	142	145	167
– summer	145	403	208	181	1,653
Multiple change[a] spring to summer	18.1	9.2	1.5	1.2	9.9
No. borers/A – early fall	3,500	3,500	2,000	3,611	11,722
Multiple change[b] summer to early fall	24.1	8.7	9.6	20.0	7.1
June weather					
Departure of mean (T) from normal	–1.7	–3.4	–1.6	+0.1	+0.8
Departure of mean (R) from normal	–0.68	–0.49	–0.30	–0.73	–2.72
No. days 90° or more	12	7	6	14	19
No. days 100° or more	1	0	0	1	0
No. days with .50″ rainfall	3	3	2	3	1
July weather					
Departure of mean (T) from normal	–2.7	–2.5	–2.0	–2.6	–0.7
Departure of mean (R) from normal	–2.18	+1.93	+0.36	+1.65	–1.80
No. days 90° or more	16	12	16	14	23
No. days 100° or more	0	1	0	0	1
No. days with .50″ rainfall	0	4	2	4	1
August weather					
Departure of mean (T) from normal	–0.7	–3.5	–2.4	–2.8	–1.9
Departure of mean (R) from normal	+0.36	–0.72	+2.70	+1.21	+0.19
No. days 90° or more	18	10	13	12	12
No. days 100° or more	0	0	0	0	2
No. days with .50″ rainfall	3	1	2	3	2

[a] Overwinter brood to completion of first brood.
[b] First brood to completion of second brood.

from early fall to late fall. From late spring to summer to early fall a continued increase in populations is noted.

Table 21 is a summary of borer populations in relation to date of planting. The 1960-1964 average shows that in general the early planted corn receives more first brood borers and later planted corn had a higher second brood infestation.

Changes in borer populations are presented in Table 22 along with certain weather data for the county.

Table 23. Summary of corn yield and production in Carroll County, Missouri, for 1956–1963.

Year	Acreage	Bu/A yield	Production bushels
1956	92,000	52.7	4,851,000
1957	75,000	52.4	3,928,000
1958	59,300	58.1	3,447,700
1959	103,500	65.9	6,823,400
1960	109,700	60.7	6,654,000
1961	62,900	79.1	4,975,800
1962	67,900	70.0	4,751,400
1963	78,400	73.2	5,740,400

Carroll County

Area Description

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 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.

A summary of corn production in Carroll County during the NC-20 survey period is presented in Table 23.

Weather Conditions

The average monthly temperatures and the total monthly rainfall for 1960-64 are given in Appendix V A. The deviations of average temperature and rainfall from long-term normal are given in Appendix V B. General weather conditions during the years 1960-64 may be summarized as follows:

1960—Cool temperatures with above normal moisture at planting. Warm and dry later part of season.

1961—Unusually cool most of season with excessive moisture which delayed harvesting some fields until following spring.

1962—Warm during May and cool rest of season. Dry most of season except July.

1963—Most of season dry with near normal temperatures.

1964—Most of season dry. April and May warm, rest of season cool.

Agronomic Practices

The various fertilizer treatments used in Carroll County are summarized in Appendix V C. N.P.K. combinations used as a starter fertilizer were applied on 48% of the farms. Anhydrous and ammon-

Table 24. Planting dates in Carroll County, Missouri.

Planting dates	Percent of fields					
	1960	1961	1962	1963	1964	Average
April 1–10	0	0	0	4.2	0	0.8
April 11–20	0	0	8.3	29.2	8.3	9.2
April 21–30	4.2	4.2	4.2	12.5	8.3	6.7
May 1–10	33.3	12.5	33.3	25.0	58.3	32.5
May 11–20	20.8	33.3	41.7	25.0	25.0	29.2
May 21–31	16.7	37.5	4.2	4.2	0	12.5
June 1–10	20.8	12.5	8.3	0	0	8.3
After June 10	4.2	0	0	0	0	0.8
Total fields observed	24	24	24	24	24	

Table 25. Summary of borer populations at various times each year in Carroll County, Missouri. Number per acre.

	Early spring	Late spring	Summer	Early fall	Late fall
1960 Larvae	42	25	361	4,650	1,388
Tunnels			1,444	9,881	
1961 Larvae	258	225	860	3,463	
Tunnels			2,359	10,612	
1962 Larvae	1,492	308	1,582	18,676	
Tunnels			3,705	37,740	
1963 Larvae	1,346	658	1,207	11,156	4,468
Tunnels			2,816	22,922	
1964 Larvae	2,262		1,707	13,592	1,679
Tunnels			7,062	34,980	
Average					
Larvae	1,080	304	1,143	10,307	2,512
Tunnels			3,477	23,227	

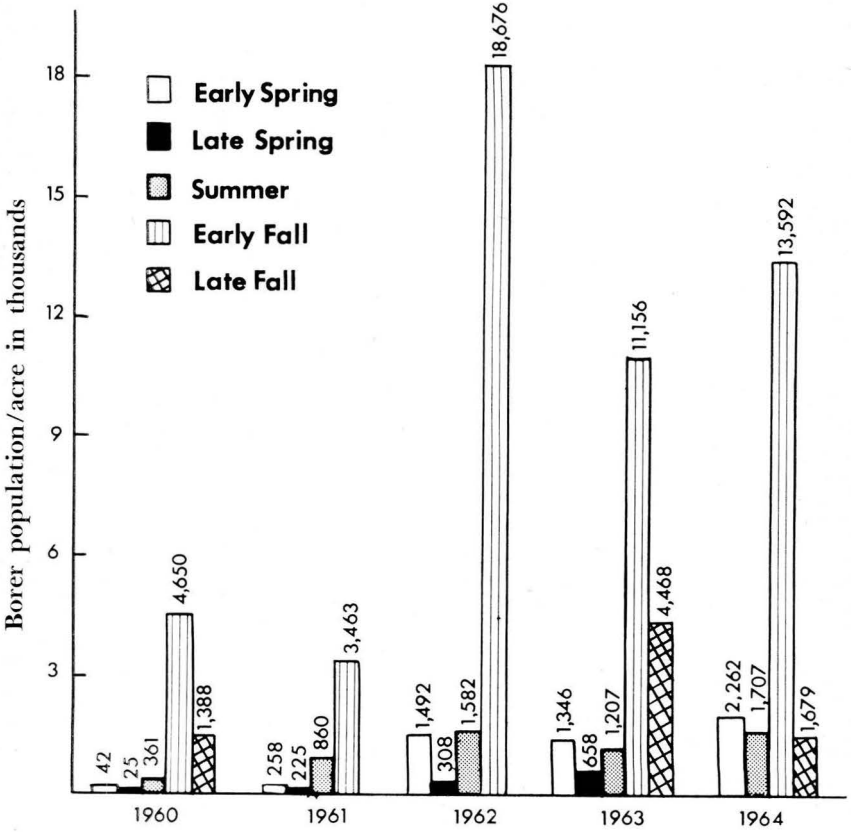

Fig. 7. Average number of borers per acre, Carroll County, Missouri, 1960–64.

Table 26. Quantitative changes in borer populations in Carroll County, Missouri.

	1960	1961	1962	1963	1964	Average
Multiple changes						
Early to late spring	−1.68	−1.15	−4.84	−2.05		− 2.43
Late spring to summer	14.44	3.82	5.14	1.83		6.31
Summer to early fall	12.88	4.03	11.81	9.24	7.96	9.18
Early fall to late fall	−3.35			−2.50	−8.10	− 4.65
Early fall to late spring	−20.67	−11.24	−28.38			−20.10

Table 27. Summary of borer populations by planting date for Carroll County, Missouri. Number per acre.

Date of planting	1960		1961		1962		1963		1964		Average	
	Summer	Early fall	Summer	Early fall	Summer	Early fall	Summer	Early fall	Summer	Early fall	Summer	Early fall
April 5–10							3,996	3,330			3,996	3,330
April 11–15							0	5,328	999	3,996	500	4,662
April 16–20					667	7,826	2,264	5,661	0	6,327	977	6,605
April 21–25	667	0	0	1,665			2,498	7,493	0	3,330	791	3,122
April 26–30					0	4,995	3,663	3,996	1,998	666	1,887	3,219
May 1–5	444	2,334	667	1,665	1,865	8,791	916	15,734	1,199	13,387	1,018	8,382
May 6–10	733	5,729	1,166	666	7,659	23,865	0	30,303	2,775	17,358	2,467	15,584
May 11–15	1,167	1,334	999	889	0	9,241	250	12,904	1,399	15,784	763	8,030
May 16–20	222	8,105	2,498	9,158	722	33,189	167	6,161	0		722	14,153
May 21–25	0	3,111	611	6,438	0	5,328	0	18,981			153	8,465
May 26–31	0	3,333	0	777	0	35,298					0	13,136
June 1–5	0	4,665	0	5,328							0	4,997
June 6–10	0	167	0								0	167
June 11–15	0	26,973									0	26,973

Table 28. Changes in borer populations from spring to summer to fall in Carroll County, Missouri, and certain weather data for June, July and August, 1960–64.

	1960	1961	1962	1963	1964
No. borers/A – late spring	25	225	308	658	
– summer	361	860	1,582	1,207	1,707
Multiple change – late spring to summer	14.40	3.82	5.14	1.83	
No. borers/A – early fall	4,650	3,463	18,676	11,156	13,592
Multiple change – summer to early fall	12.88	4.03	11.81	9.24	7.96
June weather					
No. days 90° or more	4	5	5	13	6
No. days 100° or more	0	0	0	0	0
No. days .50″ rainfall	5	3	2	3	3
July weather					
No. days 90° or more	8	10	10	19	17
No. days 100° or more	0	0	0	1	1
No. days .50″ rainfall	3	5	4	3	0
August weather					
No. days 90° or more	17	8	17	15	14
No. days 100° or more	0	0	2	0	2
No. days .50″ rainfall	2	3	0	3	3

ium nitrate were applied on 40 and 30% of the fields, respectively. A 5-year average of 5% of the fields received no fertilizer treatments.

Corn followed corn on almost 66% of the cooperator farms on a 5-year average (Appendix V D). Approximately 11% followed wheat and 8% followed clover. The rest of the fields followed soybeans, oats, alfalfa or sod rotations.

The plant populations ranged from 8,000 to over 20,000 plants per acre. The 5-year averages indicate a trend toward thicker planting with the five averages fixed at 13,317 plants per acre. A summary of the stand counts is given in Appendix V E.

Planting dates for Carroll County are given in Table 24. With the exception of 1963, no corn was planted before April 11. The 5-year averages show a trend toward earlier planting. More than 70% of the corn was planted by May 10 in both 1963 and 1964. A majority of the corn was planted between May 1 and May 20.

More than 50 hybrids were planted on the cooperator fields during the period 1960 to 1964. DeKalb, Pioneer, Pfister and MFA hybrids were the most popular but a trend toward a specific hybrid was not noted. The hybrids used are included in Appendix V F.

Borer Populations

An attempt was made to sample each field five times during the year but occasionally bad weather prevented this. A summary of the

borer populations at various times during the year is presented in Table 25 and Figure 7. Borer populations were rather high during 1962, 1963 and 1964, being somewhat over the 5-year average of 10,307 borers per acre. The 1960 and 1961 populations were under the 5-year average.

Quantitative changes in borer populations from time to time each year are presented in Table 26.

Table 27 is a summary of borer populations in relation to the date of planting. First brood damage was more pronounced on early planted corn and the second brood was heavier on later planted corn. The tendency for earlier planting dates is clearly shown in Table 27.

The borer populations at various times are summarized in Table 28 along with certain weather data.

CUMING AND HALL COUNTIES, NEBRASKA

Information included in this report has been gathered over the period from the spring of 1960 to fall of 1964. 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 20 and June 8, summer populations between July 18 and Aug. 8 and fall populations between Oct. 4 and Oct. 22. Populations in all cases have been estimated from three areas 1/1000 acre in size from each field.

Cuming County

Area Description

Cuming County is 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 waterways 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 tillable land and occur at several distinct levels, some as high as 60 feet above the adjoining flood plains.

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% of the soil and Wabash silt loam 8.8%, 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.

Weather Conditions

The average monthly temperatures, total monthly rainfall for the 1960-64 growing season and borer degree-day accumulations at West Point, Nebr. are shown in Appendix VI A. Deviations from long-term means are given in Appendix VI B. In general the weather conditions for Cuming County, Nebr., may be summarized as follows:

1960—A cool-wet season. May, June, July and August all were cooler and wetter than normal.

1961—A cool-dry season. May, June, July and August all were cooler than normal. Precipitation was slightly above normal for May but somewhat below for June, July and August.

1962—Season cool; rainfall normal. May was exceptionally warm and slightly wetter than normal, but June, July and August were cooler than normal with precipitation slightly deficient for the three months.

1963—A cool-wet growing season. May was cool and dry, June warm and very wet, July cool and dry and August cooler and wetter than normal.

1964—A cool-wet season. May averaged warmer and wetter than normal. June was cooler and wetter than average followed by a dry July of normal temperatures and an exceptionally cool August with above average rainfall.

Table 29. Planting dates in Cuming County, Nebraska.

Planting dates	Percent of fields					
	1960	1961	1962	1963	1964	Average
May 1–10	8.3	4.2	12.5	29.1	8.3	12.5
May 11–20	50.0	58.3	54.2	54.2	50.0	53.3
May 21–31	37.5	33.3	29.1	16.7	33.4	30.0
June 1–10	4.2	–	–	–	–	0.9
Unknown	–	4.2	4.2	–	8.3	3.3
Average date of planting	May 20	May 18	May 17	May 15	May 18	
Total fields observed	24	24	24	24	24	

Table 30. Population range and average number of borers per acre in Cuming and Hall Counties, Nebraska, 1960–64.

	Cuming County Number borers per acre		Hall County Number borers per acre	
	Range	Average	Range	Average
Spring	444 – 2,470	1,375	346 – 2,397	1,206
Summer	2,858 – 8,575	5,300	1,637 – 6,753	4,054
Fall	10,947 – 34,784	21,414	16,886 – 47,686	31,252

Agronomic Practices

Farmers in Cuming County generally follow some form of crop rotation. During the past few years the acreage in oats has dropped slightly and soybeans have increased (Appendix VI C). A majority

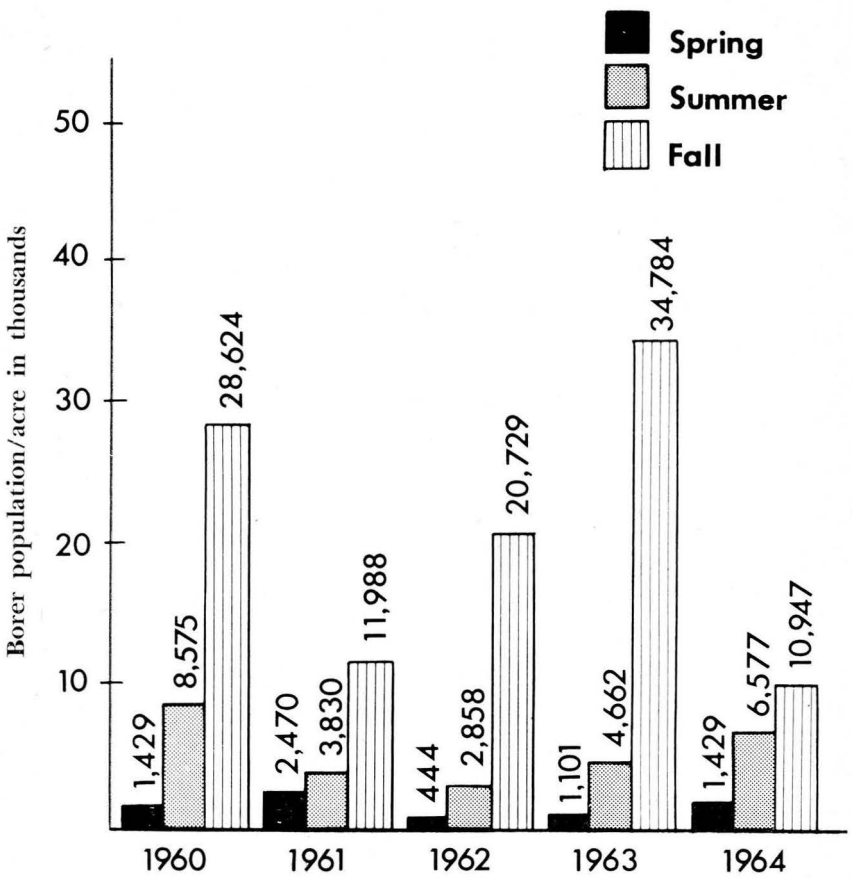

Fig. 8. Average number of borers per acre, Cuming County, Nebraska, 1960–64.

Table 31. 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	Borers per acre
1960 Late spring			–	–	1,429
Late summer	10,922	788	55.2	79	8,575
Fall	10,656	770	91.7	268	28,624
1961 Late spring			–	–	2,470
Late summer	12,321	889	40.4	31	3,830
Fall	12,354	890	86.4	99	11,988
1962 Late spring			–	–	444
Late summer	11,988	865	27.2	23.8	2,858
Fall	11,921	858	93.1	174.1	20,729
1963 Late spring			–	–	1,191
Late summer	12,388	893	44.2	36.5	4,662
Fall	12,321	889	99.9	283.0	34,784
1964 Late spring			–	–	1,429
Late summer	11,822	853	47.1	52.5	6,577
Fall	10,098	798	72.0	96.5	10,947

of the fields checked have corn following corn but this does not necessarily mean continuous corn. Many growers plant corn for 2 or 3 years and then rotate with some other crop. Soybeans, oats, and oats and clover are most popular. Commercial fertilizers were used on an average of 60.8% of the corn fields checked in the county (Appendix VI D). This represents a considerable increase over the previous 5-year period when 15.28% of growers used commercial fertilizer. Drill planting was followed in 80.4% of fields but 15.4% of fields were lister planted (Appendix VI E). The tendency for plant populations to increase was continued during the past five years with an average of 11,930 plants per acre. A list of corn hybrids planted by the various cooperators is presented in Appendix VI F.

Planting dates through the years have remained quite constant with 53.3% of fields planted from May 11 to 20 (Table 29). Dates of planting are controlled almost entirely by weather conditions prevalent each spring; during the "early" spring of 1963 approximately 30% of fields were planted before May 10.

Table 32. Quantitative changes in borer populations in Cuming County, Nebraska.

	1960	1961	1962	1963	1964	Average
Multiple changes						
Fall to spring	–18.3	–11.6	–27.0	–18.8	–24.3	–20.0
Spring to summer	6.1	1.6	6.4	4.2	4.6	4.6
Summer to fall	3.3	3.1	7.3	7.5	1.7	4.6
Winter mortality (%)	94.5	91.4	96.3	94.7	95.9	94.6

Table 33. Changes in borer populations from spring to summer to fall in Cuming County, Nebraska, and certain weather data for June, July and August, 1960–64. (T—temperature; R—rainfall)

	1960	1961	1962	1963	1964
No. borers/A – spring	1,429	2,470	444	1,101	1,429
– summer	8,575	3,830	2,858	4,662	6,577
Multiple change – spring to summer	6.1	1.6	6.4	4.2	4.6
No. borers/A – fall	28,624	11,988	20,729	34,784	10,947
Multiple change – summer to fall	3.3	3.1	7.3	7.5	1.7
June weather					
Departure of mean (T) from normal	–3.4	–2.9	–2.8	0.7	–3.2
Departure of mean (R) from normal	1.72	–0.67	–0.28	5.98	2.06
No. of days 90° or more	3	6	1	8	4
No. of days 100° or more	0	0	0	0	0
No. of days with .50″ rainfall	5	3	3	9	6
July weather					
Departure of mean (T) from normal	–3.1	–3.5	–4.9	–1.9	–0.1
Departure of mean (R) from normal	0.20	–0.66	–0.17	–0.82	–1.05
No. of days 90° or more	15	10	6	13	15
No. of days 100° or more	1	1	0	0	1
No. of days with .50″ rainfall	1	2	1	2	2
August weather					
Departure of mean (T) from normal	–1.6	–2.4	–4.2	–3.6	–7.4
Departure of mean (R) from normal	1.65	–0.21	0.13	2.16	0.98
No. of days 90° or more	12	8	4	5	3
No. of days 100° or more	0	0	0	0	2
No. of days with .50″ rainfall	4	2	3	5	2

Table 34. Relationship of corn borer populations to date of planting in Cuming County, Nebraska, 1960–64.

Date	Average number borers per acre	
	Summer	Fall
May 1–10	9,747	28,243
May 11–20	5,360	20,651
May 21–31	2,821	20,655
Unknown	6,460	14,652

Table 35. Relationship of corn borer populations to fertilizer applications in Cuming County, Nebraska, 1960–64.

Number years fertilizer applied	Summer		Fall	
	No. fields	No. borers/acre	No. fields	No. borers/acre
None	17	1,626	17	16,611
1	29	4,306	29	17,373
2	28	6,075	29	19,854
3 or more	35	7,849	37	28,899
Unknown	10	3,496	9	18,130

Borer Populations

Spring populations in Cuming County have averaged 1,375 borers per acre for the 1960-64 period. Summer and fall populations averaged 5,300 and 21,414 borers per acre respectively (Table 30). Borer populations for each year are shown in Table 31 and graphically in Figure 8. The number of plants showing borer injury varied from year to year and at the time of the summer censuses ranged from 27.2 to 55.2% (Table 31). At the time of the fall censuses from 72.0 to 99.9% of the plants had been infested. The magnitude of the population changes during each of the five years is shown in Table 32. Populations increased from spring to summer and from summer to fall in each of the five years. For the 5-year period this multiple increase has averaged 4.6 times for the first (summer) generation and the second (fall) generation. Winter mortality of the corn borer has averaged 94.6%. A summary of the borer populations and certain weather data for the months of June, July and August is presented in Table 33.

A definite relationship is shown between planting date and borer populations in Table 34. The summer generation was markedly higher on early plantings and lower on late plantings. The same but less definite relationship is indicated for the fall generation. This is somewhat contrary to earlier observations (1955-59) when the later planted corn carried the larger fall populations. A positive relationship is shown in Table 35 between the use of commercial fertilizers and borer populations; corn growing in more fertile soil supports the larger corn borer populations. Experimental studies by Scott *et al.* (1965) and Cannon and Ortega (1966) indicate that high levels of nitrogen increase establishment of first brood larvae on a susceptible hybrid; larval survival on the resistant hybrid was not affected by the amount of nitrogen.

Hall County

Area Description

Hall County is in the 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 is covered with a layer of loosely piled sand in dunes or low irregular hills shaped by wind action.

The soils are all glacial in origin and are divided into 26 different types; 20.2% of the soils are Hall silt loam, 8.6% Hall very fine sandy loam, 8.5% Valentine sand, 7.0% Cass very fine sandy loam, and 6.9% Grundy silt loam. The remainder of the soils are divided among various sandy and silt loams.

Practically all of the soil types 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 past 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.

Weather Conditions

The average monthly temperatures, total monthly rainfall for the five growing seasons (1960-64) and borer degree-day accumulations at Grand Island, Nebr., are shown in Appendix VII A. Deviations from long-term means are given in Appendix VII B. In general the weather conditions for Hall County, Nebr., may be summarized as follows:

1960—This was a cool-wet year. May, June, July and August all were cooler and somewhat wetter than normal.

1961—A cool-wet year. May, June, July and August all were cooler than normal. Rainfall was above normal for May, June and July and below for August. The total for the season was well above normal.

1962—A cool-wet year. May was warmer than normal but June, July and August were cooler. July was exceptionally cool and wet. Rainfall averaged below normal for May, June and August.

Table 36. Planting dates in Hall County, Nebraska.

Planting dates	Percent of fields					
	1960	1961	1962	1963	1964	Average
Last week April	4.0	–	4.0	4.2	–	2.4
May 1–10	4.0	16.0	22.0	54.1	41.7	27.6
May 11–20	48.0	20.0	50.0	16.7	41.7	35.3
May 21–31	40.0	52.0	16.0	25.0	16.6	29.9
June 1–10	4.0	4.0	–	–	–	1.6
Unknown	–	8.0	8.0	–	–	3.2
Average date of planting	May 20	May 21	May 13	May 10	May 12	
Total fields observed	25	25	25	24	24	

1963—A cool-dry season. Except for a warmer June the growing season was cooler than normal. Rainfall for May, June and July was below average and for August somewhat over.

1964—A variable year. May and July were warmer than normal, June about normal but August was exceptionally cool. May was unusually warm and dry but the rainfall recorded for June, July and August was above average.

Agronomic Practices

In Hall County nearly all of the commercially grown corn is raised under irrigation and this has led to the practice of continuous corn season after season. (Appendix VII C). Corn followed corn in 89.5% of fields checked during the period concerned.

This continuous cropping of corn has been followed by a wider and increasing use of commercial fertilizers than would be expected under normal Corn Belt conditions. Commercial fertilizers were used on 99.2% of fields checked in Hall County (Appendix VII D). During the five years (1960-64) there also has been an increase in the use of trace elements—principally zinc, iron and sulfur.

Table 37. 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	Borers per acre
1960	Late spring			–	–	346
	Late summer	13,852	1,041	33.9	36	4,955
	Fall	13,919	1,045	89.9	231	32,194
1961	Late spring			–	–	1,582
	Late summer	15,651	1,174	34.7	27	4,249
	Fall	14,452	1,086	82.7	112	16,886
1962	Late spring			–	–	773
	Late summer	15,184	1,139	40.0	44.5	6,753
	Fall	14,519	1,090	97.0	328.4	47,686
1963	Late spring			–	–	2,397
	Late summer	14,951	1,077	17.6	10.1	1,637
	Fall	15,251	1,100	97.8	197.6	30,108
1964	Late spring			–	–	930
	Late summer	14,152	1,021	20.5	18.2	2,678
	Fall	13,653	985	99.0	215.4	29,387

Table 38. Quantitative changes in borer populations in Hall County, Nebraska.

	1960	1961	1962	1963	1964	Average
Multiple changes						
Fall to spring	-83.8	-20.3	-21.8	-19.9	-32.4	-35.6
Spring to summer	14.6	2.7	8.7	-1.5	2.9	5.5
Summer to fall	6.4	4.0	7.1	18.4	11.0	9.4
Winter mortality (%)	98.8	95.1	95.4	95.0	96.9	96.2

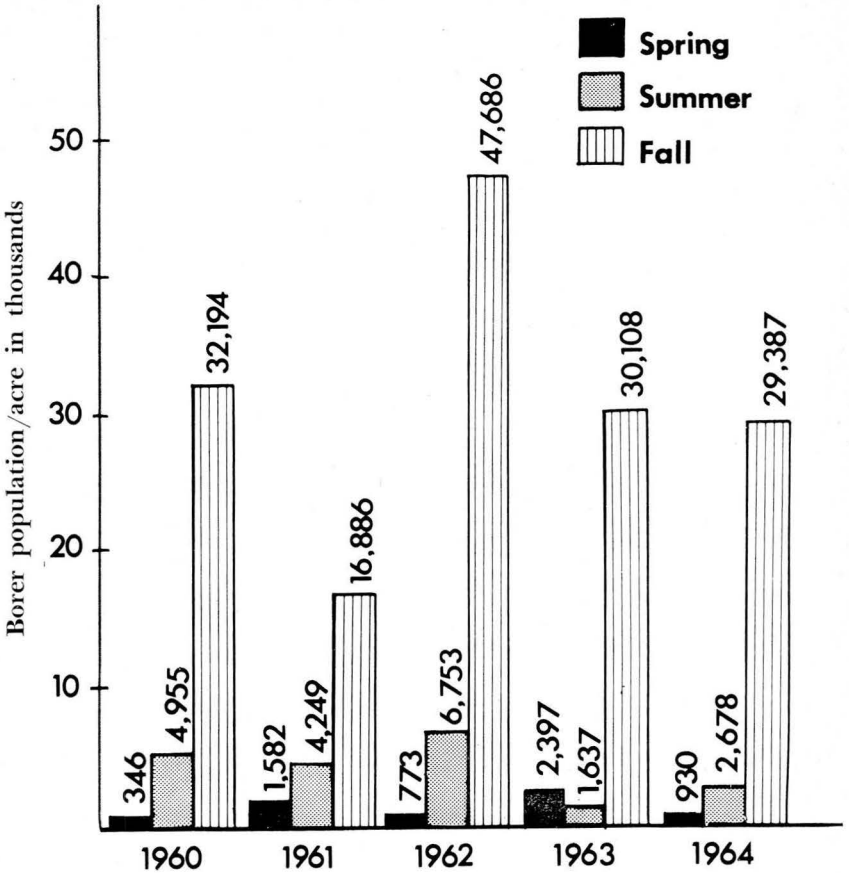

Fig. 9. Average number of borers per acre, Hall County, Nebraska, 1960–64.

Planting methods in Hall County are drill or surface planting (40.5%) and lister planting (55.5%). During the 1960-64 period listing increased slightly. Plant populations have continued to increase and have averaged yearly between 13,903 and 15,345 plants for a 5-year average of 14,677 plants per acre (Appendix VII E).

In Hall County the planting dates have varied somewhat during the 1960-64 period depending on spring weather (Table 36). An average of 35.3% of fields were planted between May 11 and 20 yet nearly as many fields were planted from May 1 to 10 as from 21 to 31. Planting was relatively "late" in 1961 and "early" in 1963.

A list of corn hybrids planted by the various farmer cooperators is presented in Appendix VII F.

Table 39. Changes in borer populations from spring to summer to fall in Hall County, Nebraska, and certain weather data for June, July and August, 1960–64. (T—temperature; R—rainfall)

	1960	1961	1962	1963	1964
No. borers/A – spring	346	1,582	733	2,397	930
– summer	4,955	4,249	6,753	1,637	2,678
Multiple change – spring to summer	14.6	2.7	8.7	–1.5	2.9
No. borers/A – fall	32,194	16,886	47,686	30,108	29,387
Multiple change – summer to fall	6.4	4.0	7.1	18.4	11.0
June weather					
Departure of mean (T) from normal	–3.3	–0.1	–3.1	1.6	–0.2
Departure of mean (R) from normal	0.21	0.35	–1.04	–0.57	0.71
No. of days 90° or more	2	9	2	11	9
No. of days 100° or more	0	3	0	2	0
No. of days with .50″ rainfall	3	3	1	3	4
July weather					
Departure of mean (T) from normal	–4.9	–2.0	–6.8	–1.0	2.2
Departure of mean (R) from normal	0.53	2.13	6.27	–0.33	0.49
No. of days 90° or more	13	16	5	18	22
No. of days 100° or more	1	1	0	3	7
No. of days with .50″ rainfall	3	2	6	1	1
August weather					
Departure of mean (T) from normal	–2.4	–0.8	–3.6	–3.3	–5.8
Departure of mean (R) from normal	0.21	–1.06	–0.70	–0.71	1.09
No. of days 90° or more	14	13	10	12	7
No. of days 100° or more	0	0	0	1	3
No. of days with .50″ rainfall	2	1	1	2	3

Borer Populations

During the 1960 through 1964 seasons, spring populations in Hall County have averaged 1,206 borers per acre. Summer and fall populations averaged 4,054 and 31,252 borers per acre, respectively (Table 30). A summary of borer populations and percent of plants infested for the 5-year period appears in Table 37. The populations are also shown graphically in Figure 9. The number of plants showing borer injury varied from year to year and at the time of the summer censuses ranged from 17.6 to 40.0%. At the time of the fall censuses from 82.7 to 99.0% of the plants had been infested.

Table 40. Relationship of corn borer populations to date of planting in Hall County, Nebraska, 1960–64.

Date	Average number borers per acre	
	Summer	Fall
May 1–10[a]	4,680	27,602
May 11–20	5,169	34,807
May 21–31	2,065	29,599
June 1–10	333	44,511
Unknown	7,160	33,883

[a] One field planted April 22, one April 26, two April 30.

The magnitude of population changes from one census period to the next is compared in Tables 38 and 39. With one exception there has been an increase from spring to summer during the 5-year period. Fall populations were always greater than the summer and the 9.4 multiple increase average is relatively high, indicating conditions for second generation establishment and survival have been generally favorable. The average multiple increase from spring to summer was 5.5 or considerably higher than the 0.9 recorded for the 1955-59 period.

Winter mortality or a comparison of a fall population with the following spring population has averaged 96.2% over the five years.

A comparison of planting date and corn borer populations in Hall County (Table 40) illustrates a decrease in the summer population with lateness of planting. However, there appears to be less evidence of a relationship between date of planting and the average fall populations in Hall County. Since commercial fertilizers are used as a general practice on every field, a fertilizer-borer population comparison is not possible for this county.

Comparison of Borer Populations in Cuming and Hall Counties

Cuming and Hall Counties are within 100 miles of one another in what could be considered the western Corn Belt. Cuming County follows the more typical Corn Belt agronomic practices based on the maintenance of soil fertility through the use of crop rotations supplemented with commercial fertilizers. In Hall County, with emphasis

Table 41. Five principal crops harvested, amount of land irrigated, and tons of fertilizer used in Cuming and Hall Counties, Nebraska, in 1963.[a]

Five principal crops:			
Cuming County		Hall County	
Crops	Harvested acres	Crops	Harvested acres
Corn (all purposes)	150,360	Corn (all purposes)	113,180
Hay (all)	41,710	Hay (all)	26,440
Oats	41,180	Winter wheat	24,050
Soybeans	13,120	Sorghum (all)	23,000
Sorghum (all)	2,020	Soybeans	3,380
		Cuming County	**Hall County**
Extent of irrigation:		No. acres	No. acres
Total land irrigated		3,800	128,900
Irrigated corn (for grain)		1,570	93,650
Non-irrigated corn (for grain)		141,420	13,870
Fertilizer used:			
Tons fertilizer sold		7,398	11,295
Total acres fertilized		184,100	122,600

[a] Data from the Nebraska Agricultural Statistics Annual Report for 1963.

on deep well irrigation, continuous cropping with corn has become the rule. Commercial fertilizers are used freely and short crop rotations are seldom seen.

In corn fields checked in Hall County, over the 5-year period (1960-64), 99.2% were commercially fertilized whereas 60.8% of fields in Cuming County were so treated. This represents marked increases in fertilizer use in both counties over the previous 5-year period, for at that time 77.9% of fields were fertilized in Hall County and only 15.3% in Cuming County.

A comparison of the two counties based on principal crops raised, fertilizer used and acres irrigated is shown in Table 41. The 1963 data compared with the 1957 figures (Chiang *et al.*) show that corn and soybean acreages have increased in both counties, oats have decreased (replaced by soybeans in Hall County). The hay and sorghum acreage is also down in both counties but the winter wheat acreage in Hall County remained essentially the same.

Corn borer populations over the 1960-64 period in the two Nebraska counties are shown in Table 30. Although the spring and summer populations averaged higher in Cuming County, fall populations and the total number were greater for Hall County. Total numbers of borers in Cuming County averaged considerably less during 1960-64 compared with the previous 5-year period. However, total borer counts in Hall County were about the same for both periods although spring populations averaged somewhat lower and summer populations were definitely higher during 1960-64.

Spring, summer and fall borer populations for Cuming and Hall counties are shown graphically in Figures 8 and 9 respectively. Of particular interest are low populations shown for both counties for 1961 which was the coolest year recorded during the entire 10 years of the study for Cuming County and also for the first half of the

Table 42. Borer populations infected with *Perezia pyraustae*, parasitized by *Lydella thompsoni* or by *Horogenes punctorius* in Cuming and Hall Counties, Nebraska.

Affective agent	Percent larvae parasitized or infected in fall of year indicated						
	1958	1959	1960	1961	1962	1963	1964
Cuming County							
Lydella	0.5	3.8	6.0	14.8	6.8	4.0	1.0
Horogenes	0.0	?	0.0	0.8	0.7	1.9	10.6
Perezia	?	18.3	28.0	20.8	36.0	100.0	76.9
Hall County							
Lydella	0.0	0.0	0.0	0.8	6.0	7.6	3.4
Horogenes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Perezia	0.0	2.0	4.0	11.9	20.0	36.0	44.0

year in Hall County (see degree-day data, Appendix VI A and VII A). Quite likely the percent first generation larvae diapausing in 1961 was higher than normal. (See section for Boone County, Iowa.)

The most noticeable discrepancies or differences between the population figures in the two counties are those recorded for spring to summer in 1963 and summer to fall of 1964. The 1.5 times decrease in the Hall County summer population followed a June that was warmer and dryer than normal. Although June in Cuming County also was slightly warmer than normal it was a very wet month; receiving almost 6 inches more than the average. The differences in the 1964 fall populations cannot be related entirely to the weather of that year. More likely certain biological factors were responsible for the inability of the Cuming County population to increase during the active season of 1964.

Parasites and disease factors have become increasingly prevalent in Nebraska from 1958 through 1964. A comparison of the incidence and abundance of three biological agents; the parasites, *Lydella thompsoni* and *Horogenes punctorius*, and the protozoan, *Perezia pyraustae*, in the two Nebraska counties is presented in Table 42. The possibility that these factors have significantly affected borer populations, especially in Cuming County, cannot be discounted. Of particular interest is the almost complete "cycle" through which *Lydella thompsoni* has passed in Cuming County. The 14.8% parasitization of borers by this species in 1961 may have contributed to low borer populations in Cuming County that year. Similarly *Horogenes punctorius* increased and in 1964 an estimated 10.6% of the fall population in Cuming County were parasitized.

Perezia infections reached a peak in the fall of 1963 when 100% of sampled Cuming County larvae were infected. Borers collected in the fall of 1964 were 76% infected. This widespread infection certainly has had some effect on the borer populations.

VAN WERT COUNTY, OHIO

Area Description

Van Wert County, 406 square miles in area, is 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. South of this the soil, although still black, is more loamy and is classified as Clyde clay loam, with small areas of yellow Miami clay loam.

Table 43. Planting dates in the fields used in Van Wert County, Ohio.

Planting dates	Percent of fields				
	1960	1961	1962	1963	Average
May 1–10	25.0	4.2	33.3	87.5	37.5
May 11–20	66.7	70.8	58.3	8.3	51.0
May 21–31	8.3	25.0	8.3		10.4
June 3				4.2	1.0
Average date of planting	May 16	May 18	May 13	May 9	
Total fields observed	24	24	24	24	

Weather Conditions

Average monthly temperatures and total monthly rainfall for 1960-63 are given in Appendix VIII A. Data were not collected in Ohio in 1964. Therefore we have 4 years of data instead of 5. 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:

1960—June and July temperatures cool, August normal. June, July and August rainfall somewhat deficient.

1961—June cool, temperatures in July and August below normal. June rainfall somewhat deficient, August rainfall near normal, July wet.

Table 44. Summary of borer populations and injury at various times each year in Van Wert County, Ohio.

	Average number plants per acre	Total number plants checked	Percent plants with injury	Number larvae per 100 plants	Number larvae per acre
1960[a]					
Early spring					1,194
Late spring					308
Summer	15,646	1,153	17.0	24.2	3,833
Fall		1,097	39.4	47.9	7,208
1961					
Early spring					500
Late spring					0
Summer	15,493	1,036	6.3	4.0	611
Fall		1,150	19.6	32.9	5,430
1962					
Early spring					347
Late spring					0
Summer	16,333	1,173	5.1	2.3	361
Fall		1,155	33.8	40.5	6,194
1963					
Early spring					347
Late spring					8
Summer	15,236	1,087	5.1	1.8	291
Fall		1,084	18.0	24.8	3,428

[a] 24 fields observed each season

Table 45. Quantitative changes in borer populations in Van Wert County, Ohio.

	1960	1961	1962	1963	Average
Multiple changes: borers/A					
Summer to fall	1.9	8.9	17.2	11.8	10.0
Fall to early spring	−6.1	−14.4	−15.6	−17.9	−13.5
Early spring to late spring	−3.9	−500.0	−347.0	−43.4	−223.5
Late spring to summer	12.4	611.0	361.0	36.4	255.2
Early spring to summer	3.2	1.2	1.0	−1.2	1.1
Winter mortality %[a]	83.6	93.1	93.6	94.3	91.1
Spring farm operations mortality %[b]	74.2	100.0	100.0	97.7	93.0

[a] Decrease from fall to early spring, confounded with fall or early spring farm operations.
[b] Decrease from early spring to late spring.

1962—June temperatures near normal, July cool, August below normal. June and August rainfall near normal, July somewhat deficient.

1963—June and July temperatures near normal, August below normal. June and August rainfall deficient, July above normal.

Agronomic Practices

Farming procedures in Van Wert County may be characterized as follows (Table 43, and Appendix VIII C, D, E and F): (1) Regular 2-5 year rotations were followed. However, the practice of following corn with corn for at least two consecutive years increased during the 4-year (1960-63) period. More farmers followed corn after corn in 1962 and 1963 compared to the 1958 and 1959 seasons (Chiang *et al.* 1961)). (2) Heavy applications of fertilizers were made annually with little or no barnyard manure. All farmers used N.P.K. combinations; 64.6% (averaged over the 4-year period) of the farmers used heavy applications of nitrogen fertilizer. The use of nitrogen fertilizer increased over the amount used in the 1958-59 seasons (Chiang *et al.* 1961). (3) Plant populations remained rather constant for the 4-year period (15,236-16,333) but increased considerably over the 1956-59 period (Chiang *et al.* 1961). (4) No insecticides were used on field corn. (5) Most of the corn was planted during the first 3 weeks of May in drilled rows (Table 43) and (6) a total of 54 hybrids were used by farmers in the 4-year period.

Borer Populations

The early spring census was taken from April 9-20 during the 4-year period. Approximately half of fields were fall plowed, stalks shredded, or spring disked. Therefore, winter mortality as shown in Table 45 is confounded with fall or early spring operations. Winter mortality during the 4-year period ranged from 83.6 to 94.3% and

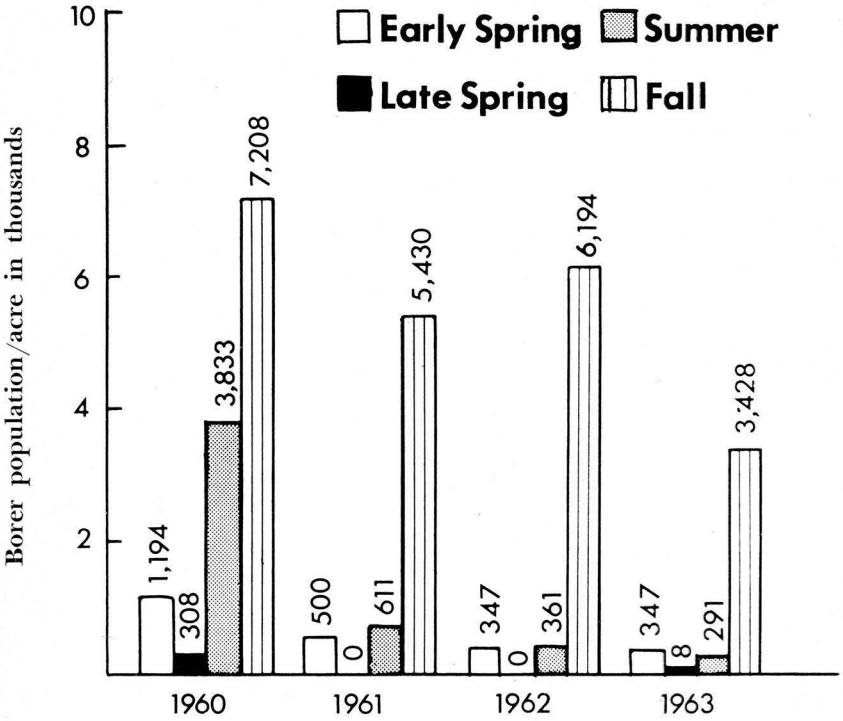

Fig. 10. Average number of borers per acre, Van Wert County, Ohio, 1960–63.

averaged 91.1%. Winter mortality for the 1958-59 season averaged 72.6% (Chiang *et al.* 1961).

The late spring census was taken from June 1-14 during the 4-year period. At this time 78.8% of fields were planted to soybeans, 16.7% to corn and 4.5% to oats; this practice was similar for the 4 years. Farm operations destroyed from 74.2 to 100% of borers which survived winter (Table 45).

Early spring, late spring, summer and fall censuses showed borer populations to be very low in Van Wert County during the 4-year period (Table 44, Figure 10). Early spring populations ranged from 347 to 1,194 borers per acre, late spring populations from 0 to 308 borers per acre, summer populations from 291 to 3,833 per acre and fall populations from 3,428 to 7,208 per acre. The largest increase in population from summer to fall occurred in 1962 (361 to 6,194 borers per acre). Quantitative changes in borer populations between different census dates are shown in Table 45.

Fall populations have always been greater than those found in

Table 46. Population range and average number of borers per acre in Van Wert County, Ohio.

	Number borers per acre							
	1960[a]		1961		1962		1963	
	Range	Average	Range	Average	Range	Average	Range	Average
Early spring	0 – 5,333	1,194	0 – 5,999	500	0 – 1,999	347	0 – 2,000	347
Late spring	0 – 1,200	308	0	0	0	0	0 – 200	8
Summer	333 – 11,333	3,833	0 – 2,666	611	0 – 1,666	361	0 – 1,666	291
Fall	0 – 28,000	7,208	333 – 24,666	5,430	0 – 24,000	6,194	0 – 9,660	3,428

[a] 24 fields observed each season.

Table 47. Changes in borer populations from spring to summer to fall in Van Wert County, Ohio and certain weather data for June, July and August, 1960–63. (T—temperature; R—rainfall)

	1960	1961	1962	1963
No. borers/A – late spring	308	0	0	8
– summer	3,833	611	361	291
Multiple change – spring to summer	12.4	611.0	361.0	36.4
No. borers/A – fall	7,208	5,430	6,194	3,428
Multiple change – summer to fall	1.9	8.9	17.2	11.8
June weather				
Departure of mean (T) from normal	–3.5	–3.5	–0.5	0.5
Departure of mean (R) from normal	–1.12	–1.12	–0.35	–2.58
No. days 90° or more	2	5	1	11
No. of days 100° or more	0	0	0	0
No. of days with .50″ rainfall	1	3	3	1
July weather				
Departure of mean (T) from normal	–4.1	–2.3	–3.6	–0.3
Departure of mean (R) from normal	–0.87	2.68	–1.06	0.63
No. days 90° or more	5	3	2	9
No. days 100° or more	0	0	0	0
No. days with .50″ rainfall	0	4	1	2
August weather				
Departure of mean (T) from normal	0.1	–1.6	–1.3	–3.0
Departure of mean (R) from normal	–0.68	0.10	0.18	–0.77
No. of days 90° or more	6	0	5	2
No. of days 100° or more	0	0	1	0
No. of days with .50″ rainfall	1	2	3	1

summer. Usually a percentage of the fall population is part of the summer population because not all first-generation borers pupate.

The population range and the average population density over the entire period of study for the 24 fields under observation are given in Table 46. Borer populations were also at a low level in Van Wert County during the 4-year period of 1956-59 (Chiang *et al.* 1961). Changes in borer populations and certain weather data for months of the growing season are shown in Table 47.

Parasitization of fall collected borers by *Horogenes punctorius* (Roman) and *Lydella thompsoni* Herting in Van Wert County averaged 23% in 1960, 11.3% in 1961, 3.2% in 1962 and 1.6% in 1963.

Populations have been at a low level throughout most of Ohio during the past several years with only a rare field being moderately to heavily infested. Heavily infested fields as measured in the fall are usually associated with late planting because moths emerging from first brood pupation prefer late planted corn for egg laying and a higher level of establishment usually results on corn in stages of anthesis than on corn that has completed anthesis. Neiswander (1962) lists several factors responsible for low populations throughout Ohio: (1) Resistant inbred lines which are used in many hybrids, (2) parasites have killed as many as 35% of borers during some seasons, (3)

cultural practices and (4) change in the life history of the corn borer; for the first 15 years of its existence in Ohio there was always a single generation each year.

Beginning about 1935 the corn borer changed from univoltine to bivoltine behavior and within a few years this phenomenon was observed in widely separated localities throughout the state. After changing to the bivoltine behavior, moths in the spring emerged from 10 days to 2 weeks earlier than the univoltine borers in previous years.

The earlier emergence has reduced the chances of borer survival of the first generation as compared to that of the single generation in previous years because most of the field corn throughout the state is in the early- to mid-whorl stage of development during first generation moth flight; percent survival of larvae hatching from eggs on corn in this stage of development is considerably less than on corn in a more advanced stage of development. During the years of univoltine behavior, corn was 10 days to 2 weeks more advanced in development during the oviposition period.

GENERAL DISCUSSIONS

Fluctuations in Borer Populations

Although counties used in the present study were selected separately by each state, their distribution throughout the region shows a definite pattern. One county is in Ohio where the borer has been established for the longest time in the region. The other counties are 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 second, the borer populations along the periphery extending from the north to the south.

In addition, in one of the fringe areas of borer spread (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 10 years are extracted from tables presented by Chiang *et al.* (1961) and previously in the present manuscript 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. The spring census dealt with the overwintering larvae, the summer census

Table 48. Seasons of "peak" corn borer populations (number borers per acre) in six North Central states from 1955 to 1964.

State and County	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Fall populations										
Minnesota—										
Waseca Co.	9,300		7,200			5,097			3,400	
Iowa—										
Boone Co.		20,254	21,875				11,040		17,240	
Nebraska—										
Cuming Co.	(35,354)[a]		57,262	60,675		28,624			34,784	
Hall Co.			50,376			32,194		47,686		
Kansas—										
Jefferson Co.	(5,483)		22,557							
Missouri—										
Carroll Co.			23,557			4,650		18,676		13,592
New Madrid Co.		(5,478)				3,500	3,500			
Ohio—										
Van Wert Co.		(4,000)			7,306			6,194		
Spring populations										
Minnesota—										
Waseca Co.		600		500			(75)	No data	No data	216
Iowa—										
Boone Co.	(14,354)			7,937				3,187		3,250
Nebraska—										
Cuming Co.		(2,359)			4,676		2,470			(1,429)
Hall Co.		(2,864)					1,582		2,397	
Kansas—										
Jefferson Co.		(1,276)		512						
Missouri—										
Carroll Co.				(1,729)					(658)	No data
New Madrid Co.				(567)						
Ohio—										
Van Wert Co.				(1,027)		308			(8)	No data

Table 48 *(Continued)*

State and County	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
					Summer populations					
Minnesota—										
Waseca Co.		4,400					1,468			
Iowa—										
Boone Co.				3,387			2,485			5,416
Nebraska—										
Cuming Co.	(16,859)			8,287		8,575				6,577
Hall Co.	(1,425)			6,540		4,995		6,753		2,678
Kansas—										
Jefferson Co.				3,387						
Missouri—										
Carrol Co.			5,143					1,582		1,707
New Madrid Co.		(947)		1,013			403			
Ohio—										
Van Wert Co.		(2,306)		2,375		3,833				

[a] Figures in parentheses are considered "peaks" since comparable previous or subsequent data are not available.

with the mature first generation larvae and the fall census with the larvae entering hibernation. It is to be expected that the population will show increases at each successive census during any given year. This relationship was generally true throughout the region. However, exceptions occurred when the population was lower in summer than in late spring (Boone, 1955, 1958 and 1962; Cuming, 1956 and 1959; Hall, 1956 and 1963, and Jefferson, 1956), or lower in fall than in summer (Waseca, 1956, 1961 and 1962; 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. The four lower summer populations in Nebraska occurred in the only four times that June was warmer and dryer than normal. June of 1956 in Jefferson County, Kan. was also warmer and dryer than normal. July was always very cool in the years fall populations were lower than summer populations in Waseca County, Minn. July also was very cool in 1958 in Minnesota when fall and summer populations recorded were identical.

2. Population peaks within a locality. One of the purposes of this study was to determine if the fluctuations of borer populations are cyclic, *i.e.*, have 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 populations, these authors suggested that it is doubtful that population peaks will occur at any regular intervals more often than by chance.

In the present study, records have been kept too few years to permit the drawing of any definite and valid conclusions. It is interesting to note, however, that "major" fall population peaks have occurred at intervals of five years in five of the eight counties (Waseca, 1955 and 1960; Cuming, 1958 and 1963; Hall, 1957 and 1962; Carroll, 1957 and 1962, and New Madrid, 1956 and 1961).

3. Population peaks within the region. Another main objective was to determine if fluctuations in different parts of the region were synchronized. Chiang *et al.* (1961) showed that peaks for the three major yearly censuses in any given locality do not generally occur the same year. Results of the recent five-year extension of this study further confirm that fact. However, an examination of the "peaks" and "lows" for the 10-year study does seem to indicate a *tendency* for the populations in certain parts of the region to be synchronized (Tables 48, 49 and 50). If one considers the "peaks" for the "more bunched" six counties—Waseca, Boone, Cuming, Hall, Jefferson and Carroll—it will be noted that peak borer populations occurred in 50%

Table 49. Seasons of "low" corn borer populations (number borers per acre) in six North Central states from 1955 to 1964.

State and County	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Fall populations										
Minnesota—										
Waseca Co.		3,200		1,100				800		
Iowa—										
Boone Co.	(10,937)[a]				1,562			10,521		
Nebraska—										
Cuming Co.		5,328			26,168		11,988			
Hall Co.	(23,150)			24,614			16,886			
Kansas—										
Jefferson Co.		5,230					1,611			
Missouri—										
Carroll Co.	(2,523)				632		3,463		11,156	
New Madrid Co.					1,022			2,000		
Ohio—										
Van Wert Co.				1,791			5,430		(3,428)	No data
Spring populations										
Minnesota—										
Waseca Co.	(200)		100			67				
Iowa—										
Boone Co.		895				162			2,050	
Nebraska—										
Cuming Co.			846			1,429		444		
Hall Co.						346		773		(930)
Kansas—										
Jefferson Co.			1					17		
Missouri—										
Carroll Co.						25				
New Madrid Co.						8				
Ohio—										
Van Wert Co.					125		0	0		No data

Table 49 *(Continued)*

State and County	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
					Summer populations					
Minnesota—										
Waseca Co.	900				900					
Iowa—										
Boone Co.	(4,979)					645		1,397		
Nebraska—										
Cuming Co.		416			3,080			2,858		
Hall Co.		1,252			1,785		4,249		1,637	
Kansas—										
Jefferson Co.		(846)						28		
Missouri—										
Carrol Co.		(1,123)				361			1,207	
New Madrid Co.			659			145			181	
Ohio—										
Van Wert Co.					319				(291)	No data

[a] Figures in parentheses are considered "lows" since comparable previous or subsequent data are not available.

Table 50. Number of counties[a] showing "peak" populations at indicated seasons and the average multiple change for all populations during indicated seasons.

	No. counties with peaks	Average multiple change in populations	
1955 – Spring	1		
Summer	2	1.0	(spring to summer)
Fall	3	7.7	(summer to fall)
1956 – Spring	4		
Summer	1	2.0	
Fall	1	8.2	
1957 – Spring	0		
Summer	1	5.7	
Fall	6	10.8	
1958 – Spring	4		
Summer	1	5.7	
Fall	1	3.3	
1959 – Spring	1		
Summer	0	2.8	
Fall	0	6.5	
1960 – Spring	0		
Summer	2	9.1	
Fall	4	6.4	
1961 – Spring	3		
Summer	2	4.9	
Fall	1	2.6	
1962 – Spring	1		
Summer	2	3.6	
Fall	2	6.1	
1963 – Spring	2		
Summer	0	1.2	
Fall	3	8.8	
1964 – Spring	3		
Summer	4	2.4	
Fall	2	5.2	

[a] Six counties involved; New Madrid and Van Wert Counties omitted (see text for reason).

or more of this more limited region during the following periods:

Fall 1955 and Spring 1956.

Fall 1957, Spring 1958 and Summer 1958.

Fall 1960 and Spring 1961.

Fall 1963, Spring 1964 and Summer 1964.

It is interesting to note all peak periods and peak sequences began with the fall population (Table 50). This would indicate the growing seasons of 1955, 1957, 1960 and 1963 were favorable for corn borer development.

Average borer populations over the entire study area were lower during the 1960-64 period than they were during the 1955-59 period. Only summer populations in Hall County and fall populations in Carroll, New Madrid and Van Wert counties were higher during the

Table 51. Average corn borer populations for all counties studied.

Locality	Average number borers per acre for 1955-59		
	Late Spring	Summer	Fall
Minnesota (W)	300	1,960	4,560
Iowa (B)	4,911	4,695	13,504
Nebraska (C)	2,581	6,244	36,957
(H)	2,138	2,719	31,475
Kansas (J)	520	1,957	10,836
Missouri (C)	952	2,167	7,871
(NM)	356	730	2,474
Ohio (VW)	125	1,667	4,174
	Average number borers per acre for 1960–64		
Minnesota (W)	142	1,034	1,090
Iowa (B)	2,112	2,581	10,446
Nebraska (C)	1,375	5,300	21,414
(H)	1,206	4,054[a]	31,252[b]
Kansas (J)	59	366	4,390
Missouri (C)	304	1,143	10,307[a]
(NM)	101	518	4,867[a]
Ohio (VW)	79	1,274	5,565[a]

a = Higher than for 1955-59.
b = About the same as 1955-59.

second five-year period (Table 51). Average quantitative changes in borer populations are shown in Table 52. The Waseca County average of 10.2 for late spring to summer increases and the 3.0 for summer to fall populations might be expected for a northern area where first generation larvae diapause more readily than elsewhere in the region. Also, the relatively high average of 12.8 for summer to fall increases in Hall County may reflect the influence of irrigation on the borer ecology and/or the low incidence of natural parasites and diseases in an area more recently invaded by the borer.

Geographical Distribution of Borer Populations

General trends of population changes over the entire region during the 1960-64 period are shown in Figure 11. As was done by Chiang

Table 52. Average multiple changes in borer populations in six North Central states for two census periods (1950–59 and 1960–64).

County	From late spring to summer			From summer to fall		
	1955-59	1960-64	10-year average	1955-59	1960-64	10-year average
Waseca	8.0	12.4(3 yrs)	10.2	4.1	2.0	3.0
Boone	1.5	1.4	1.4	2.7	5.7	4.2
Cuming	−0.2(4 yrs)	4.6	2.2	10.6	4.6	7.6
Hall	0.9(4 yrs)	5.5	3.2	16.1	9.4	12.8
Jefferson	3.3(3 yrs)	0.3	1.8	6.3(4 yrs)	4.0	5.2
Carroll	1.8(2 yrs)	6.3(4 yrs)	4.0	2.7(4 yrs)	9.2	6.0
New Madrid	1.9(2 yrs)	8.0	5.4	3.4(4 yrs)	14.0	8.7
Van Wert	2.6(1 yr)	255.2(4 yrs)	?	10.8(3 yrs)	10.0(4 yrs)	10.4

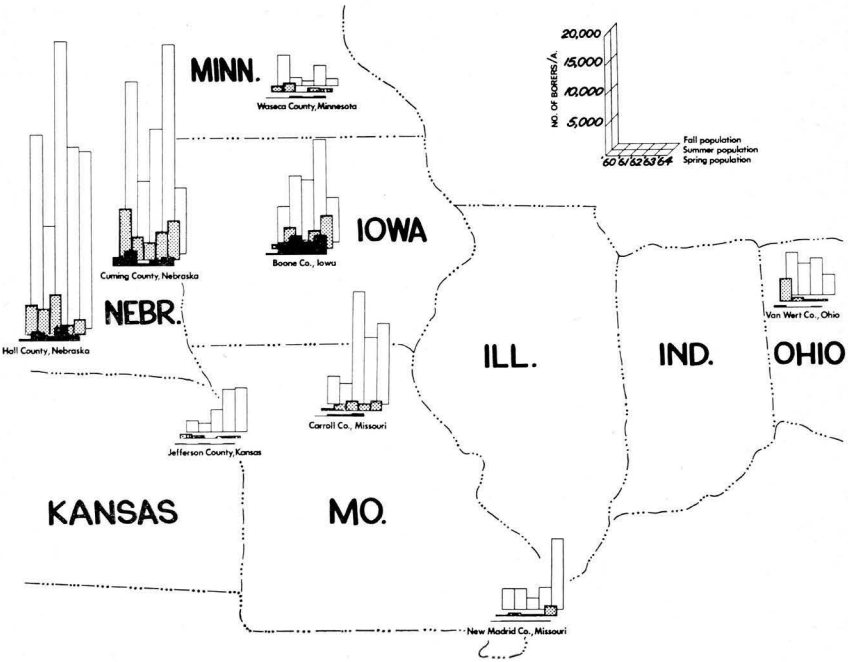

Fig. 11. Average number of borers per acre in eight counties in the North Central United States, 1960–64.

et al. (1961), a comparison of populations 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 at either end. These high *spring* populations might have been due partly to the fact previous season corn fields are more widely seeded to oats without the maximum destruction of the old corn stalks.

Summer populations were progressively higher toward the west to Cuming, falling off slightly in Hall.

Fall populations were progressively higher toward the west, being highest in Hall County where corn is grown under irrigation and where parasites and diseases are less prevalent.

The multiple increase for both *summer* and *fall* populations was highest in the east, lowest in Boone, becoming higher again through Cuming to Hall.

Table 53. Total acreage harvested and the percent acreage harvested by sheller, showing the steady and marked increase in the use of sheller from 1956 to 1964.

State	1956		1960		1964	
	Total acreage harvested	Percent shell harvested	Total acreage harvested	Percent shell harvested	Total acreage harvested	Percent shell harvested
	1,000 acres	percent	1,000 acres	percent	1,000 acres	percent
Iowa	9,413	1	12,166	10	9,804	19
Minnesota	5,035	4	5,846	13	4,612	22
Missouri	3,749	3	4,041	24	3,073	46
Kansas	901	5	1,725	27	1,035	54
Nebraska	4,037	1	6,538	18	4,116	37
Ohio	3,415	3	3,383	8	2,961	24
Total or average	26,550	2.2	33,698	14.4	25,601	27.6

In summary seasonal populations fluctuated the least in the center of the east-west line. The greater seasonal fluctuations were at a lower average population level in the east and at a much higher level in the west.

In general the facts presented above agree with those presented by Chiang *et al.* (1961) with the exception that *summer* populations in the Nebraska counties have averaged higher than at Boone during recent years.

2. Southwestward distribution. Along the line of three counties from Van Wert, Ohio, through Carroll, Mo. to Jefferson, Kan., *spring* populations averaged slightly higher at Carroll. *Summer* populations averaged slightly higher at Van Wert than at Carroll principally because of one unusually high 1960 population. *Summer* populations at Jefferson were quite low. The *fall* population was lowest at Jefferson and highest at Carroll. The average multiple increase from *summer* to *fall* was highest in the east and lowest in the west.

The low average populations and low multiple increases recorded for Jefferson County during the second five-year period is almost the opposite of the relationship noted for this line of distribution during the first five-year census period.

3. Along the north-south line from Waseca through Boone, Carroll to New Madrid, *spring* and *summer* populations were highest in the central part (Boone and Carroll) and decreasing toward the very south (New Madrid). *Fall* populations showed an increase from the lowest at Waseca to highest in Boone and Carroll (essentially the same) and decreasing again toward the south in New Madrid.

These population relationships were similar during the two census study periods over this north-south line. Average *fall* populations were down significantly in the north and up in Missouri during the

1960-64 period. Multiple increases for the *spring* to *summer* borer counts were highest in Waseca, lowest in Boone and becoming greater again toward the south. *Summer* to *fall* population increases were lower in the north (Waseca) becoming higher toward the south (New Madrid).

Possible Control of Borer Populations

According to a study made in Minnesota by Chiang (1964), 26% of moths present in the field in *spring* may be from ears in storage cribs. Harvesting corn by sheller, since it eliminates storage of corn ears, should reduce the source of overwintering borers, and thus the moth populations in the following *spring*.

While records on the methods of harvest were not kept in the censused fields, statistics for the six states involved are available for 1956 and 1960 (Csorba and Kirkbride, 1964) and for 1964 (Strickler and Walther, 1966). The total acreage harvested and the percent acreage shell harvested are given in Table 53. There has been a marked increase in the use of shellers during the period of the present study, from 2.2% in 1956 to 27.6% in 1964. This change in farming practice may have been responsible for some reduction in borer population in the region.

SUMMARY

This corn borer census study has now been conducted in eight counties in six states in the north central United States from 1955 to 1964 inclusive. Standardized procedures were followed in gathering the data. In some instances observations peculiar to individual states were also obtained. Nevertheless the study had several definite objectives. The main objectives and the results obtained under each are summarized in the following paragraphs.

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.* In this report data are presented for the second five-year period (1960-64) from Minnesota, Iowa, Nebraska, Kansas, Missouri and Ohio. Thus borer fluctuations have been recorded for a period of 10 years over much of this region. This is a relatively short period of observation but certain patterns pertaining to the general borer distribution within the region, levels of abundance and seasonal activity have been recorded. It is evident the reasons for these patterns are quite complex and for the most part must await elucidation by further field and laboratory studies.

2. *To evaluate the effect of climatic factors on borer populations.* Weather conditions greatly influenced borer populations, both favor-

ably and unfavorably. Isolated effects of rainfall and temperature on borer populations have been noted but the interactions of these factors probably are very important and if understood would explain the inconsistent temperature-rainfall-borer relationships reported from different localities and different years. In each of the four instances when and only when the summer population was lower than the spring population in Nebraska, June was warmer and dryer than normal. However, in Iowa a reduction in population from spring to summer in 1955 was attributed to cool windy weather in June. June was dry, however. Second generation (fall) populations in Cuming County, Nebr. were significantly and positively associated with total rainfall during June, July and August. Four low fall populations in Waseca County, Minn. all were associated with cooler than normal Julys. Other weather-borer relationships are given in various state reports; the Iowa report cites earlier work and some inconsistencies between published and recent observations.

3. *To analyze the effect of soil and crop management on the borer populations.* Most states reported a relationship between date of planting corn and borer populations. For the years 1960-64 planting dates and first brood populations in Iowa were correlated in only two of the five years (1961 and 1963). The Ohio report makes note of the fact heavily infested fields in the fall are associated with late planting. In Missouri (Carroll County) there is a tendency toward the earlier planting of corn and first brood damage has been greatest on early corn; second brood populations are heavier on late corn.

In Nebraska the first brood was markedly heavier on early planted corn than on corn planted late. However, there was less evidence of a definite relationship between date of planting and average second brood populations during the recent 5-year period than was recorded for the previous 5-year study period.

During the five years (1960-64) more farmers have planted corn after corn. In Minnesota this continuous corn has been at the expense of fewer corn-oats sequences. This gradual decrease in corn-oats over the 10-year period may have contributed to the decrease in borer populations in that state. A similar situation may prevail in Iowa and Nebraska (Cuming County) where the acreage planted to oats is down and to soybeans up. Continuous corn planting is greatest in Hall County where 90% of the corn follows corn. The trend toward corn after corn also is evident in reports from Kansas, Missouri and Ohio.

The planting of oats in the previous year's corn field leads to higher spring populations than where more intensive cultivation practices destroy or bury old corn stalks. However, the effects of

spring operations were emphasized in the Boone County report which indicated mortality caused primarily by the mechanics of oat seeding does reduce the spring population by an average of 29%. Minimum tillage practices which are becoming more widely followed in Nebraska are conducive to higher spring borer populations. In Iowa fall borer populations were reduced an average of 57% by mechanical picking operations each year during the 1960-64 period. The increased use of picker-shellers may also reduce borer populations in some areas by eliminating the storage of corn-ears containing overwintering larvae.

All states report increased use of commercial fertilizers during recent years. Fertilizer use and borer populations were noted in Cuming County where there was a direct relationship in the number of borers per acre and number of years fertilizers were applied.

Irrigation was practiced in Nebraska. During the recent cooler and wetter five-year census period the influence of irrigation on borer populations was not so noticeable as during the dryer 1955-59 period. However, the highest 10-year average multiple borer increase from summer to fall (12.8 times) indicates irrigation provides favorable conditions for borer development.

4. *To determine the presence, or the lack, of synchronization of the changes of borer populations.* Average borer populations over the entire study area were lower during the 1960-64 period than during the 1955-59 period. Only the populations for the first brood in Hall County and the second brood in Carroll, New Madrid and Van Wert Counties averaged higher during the second five-year period.

Data show some correlation between borer numbers within counties from one census to the next. Ten three-season-peak sequences were recorded (one in Waseca, two in Boone, three in Cuming, two in Hall, one in Jefferson and one in Van Wert). Six additional three-season-peaks may have occurred (one in Waseca, one in Boone, one in Cuming, two in Carroll and one in New Madrid).

An examination of the "peaks" and "lows" for the ten-year study indicates a tendency for the populations in certain parts of the North Central Region to be synchronized. An examination of data from the six more closely bunched counties—Waseca, Boone, Cuming, Hall, Jefferson and Carroll—reveals that peak borer populations occurred over 50% of this more limited region during the fall of 1955 and spring of 1956; the fall of 1957, spring and summer of 1958; the fall of 1960 and spring of 1961; and the fall of 1963, spring and summer of 1964.

5. *To develop a sampling method which may be adopted for routine borer surveys.* In the previous 5-year study (Chiang *et al.* 1961),

the validity of the sampling method was discussed in some detail. The general conclusion reached was "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." It was further concluded that "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."

6. *To evaluate the effect of biological agents on borer populations.* The Ohio, Iowa and Nebraska reports discuss the effects of parasites and disease on the borer populations. *Horogenes punctorius* (Roman) and *Lydella thompsoni* Herting have parasitized from 1.6 to 23.0% of the Ohio larvae collected in the fall during the 1960 to 1963 period. In Iowa a high *Perezia* infection combined with the abnormally cool August and cool September of 1964 is suspected to have contributed to the greatest fall to post-harvest reduction in borer populations recorded in that state. In Nebraska parasites (*Lydella* and *Horogenes*) and disease (*Perezia*) factors have become increasingly prevalent from 1958 through 1964. The possibility that these factors have significantly affected borer populations, especially in Cuming County, cannot be discounted.

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APPENDIX I

I A. Weather conditions in Boone County, Iowa during the growing season.

Month	1960	1961	1962	1963	1964
	Average temperature for the month (° F.)				
May	60.2	58.6	67.4	58.9	66.5
June	67.3	69.6	69.5	72.8	69.8
July	72.2	73.2	71.8	73.4	76.4
August	72.4	71.6	72.3	68.8	69.8
	Total rainfall for the month (inches)				
May	7.02	1.91	5.22	3.63	3.62
June	2.68	4.25	2.55	1.17	8.12
July	3.47	8.04	3.05	3.14	2.65
August	5.81	4.21	2.30	6.79	4.04
	Borer-degree day accumulations				
April 15	48.5	8.5	13.0	143.5	26.5
May 1	172.5	57.0	140.5	215.5	119.5
May 15	280.0	187.0	361.5	394.5	332.0
June 1	521.0	356.0	678.5	572.5	641.0
June 15	746.5	644.0	906.5	922.0	883.0
July 1	1031.5	951.5	1279.5	1313.5	1273.0
July 15	1310.5	1255.0	1630.0	1635.5	1574.0
Aug. 1	1727.5	1661.0	1946.5	2085.5	2057.0
Aug. 15	2047.5	1968.0	2262.5	2417.0	2321.0
Sept 1	2428.0	2329.0	2636.5	2715.0	2650.0

I B. Weather conditions in Boone County, Iowa; deviation from long-term normal.

Month	1960	1961	1962	1963	1964
	Monthly temperature				
May	−1.0	−2.6	+6.2	−2.3	+5.3
June	—3.9	−1.6	−1.7	+1.6	−1.4
July	−4.4	−3.4	−4.8	−3.2	−0.2
August	−1.3	−2.1	−1.4	−4.9	−3.9
	Monthly rainfall				
May	+2.90	−2.21	+1.10	−0.49	−0.50
June	−2.69	−1.12	−2.82	−4.20	+2.75
July	−0.26	+4.31	−0.68	−0.59	−1.08
August	+1.75	+0.15	−1.76	+2.73	−0.02

I C. Fertilizer treatments in fields used in Boone County, Iowa.

	Percent of fields					
Fertilizer application	1960	1961	1962	1963	1964	Average
N.P.K. combinations	34.4	56.3	68.8	78.1	81.2	63.8
Anhydrous ammonia (side dress)	3.1	9.4	28.1	56.2	68.8	33.1
Starter fertilizer	0	6.3	18.7	15.6	21.9	12.5
Manure	21.9	15.6	6.9	9.4	12.5	13.3
None	40.6	25.0	21.8	6.3	6.3	20.0
Total fields checked	32	32	32	32	32	

I D. Previous year's crop in fields used in Boone County, Iowa.

Previous crop	Percent of fields					
	1960	1961	1962	1963	1964	Average
Corn	46.9	43.8	40.6	25.0	43.8	40.0
Clover	0	3.1	3.1	6.3	3.1	3.1
Soybeans	18.8	12.5	25.0	37.5	34.4	25.6
Oats	21.9	15.6	9.4	12.5	6.3	13.1
Alfalfa	9.4	18.8	15.6	15.6	6.3	13.1
Sod	3.1	6.3	0	0	0	1.9
Soil bank	0	0	6.3	3.1	6.3	3.1

I E. Planting methods and plant population in fields used in Boone County, Iowa.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Type of planting						
Power checked	84.4	84.3	91.6	78.1	75.0	82.5
Wire checked	12.5	9.4	3.1	0	0	5.0
Drilled	3.1	6.3	6.3	21.9	25.0	12.5
Total fields observed	32	32	32	32	32	
Plants per acre						
Less than 10,000	0	0	28.2	9.4	0	7.5
10,000 – 10,999	12.5	6.3	12.5	12.5	9.4	10.5
11,000 – 11,999	12.5	15.6	12.5	9.4	6.3	11.8
12,000 – 12,999	21.9	15.6	15.6	9.4	3.1	13.0
13,000 – 13,999	12.5	15.6	12.5	6.3	12.5	11.8
14,000 – 14,999	21.9	25.0	3.1	25.0	18.8	18.7
15,000 – 15,999	9.4	9.4	12.5	15.6	9.4	11.2
16,000 – 16,999	9.4	6.3	3.1	3.1	12.5	6.8
Over 17,000	0	6.3	0	9.4	28.1	8.7
Average	13,166	13,584	11,354	13,125	15,188	13,283
Total fields observed	32	32	32	32	32	

I F. Corn hybrids used in fields for study in Boone County, Iowa.

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Bergstrom 600	0	3.1	0	0	0	0.6
Blacks 24	3.1	3.1	3.1	0	0	1.9
Cargill 255	3.1	0	0	0	0	0.6
Cargill 285	0	3.1	3.1	3.1	3.1	2.1
Cargill 349	0	3.1	0	0	0	0.6
Cargill 725	0	3.1	0	0	0	0.6
Cargill unknown	0	0	3.1	0	0	0.6
Total	3.1	9.3	6.2	3.1	3.1	4.9
Crows 307	0	3.1	0	0	0	0.6
Crows 607	0	3.1	0	0	0	0.6
Crows 722	0	0	0	3.1	3.1	1.2
Total	0	6.2	0	3.1	3.1	2.5
DeKalb 361	0	0	0	3.1	3.1	1.2
DeKalb 444	0	0	0	3.1	0	0.6
DeKalb 627	0	3.1	0	0	0	0.6
DeKalb 628	0	0	0	3.1	0	0.6
DeKalb 630	0	3.1	0	0	0	0.6
DeKalb 633	0	3.1	0	0	0	0.6
DeKalb 661	0	0	3.1	0	0	0.6
DeKalb unknown	3.1	0	0	0	3.1	1.2
Total	3.1	9.3	3.1	9.3	6.2	6.2
Eveland 460	0	3.1	0	0	0	0.6
Eveland 704	0	0	3.1	3.1	0	1.2
Eveland unknown	0	0	3.1	0	0	0.6
Total	0	3.1	6.2	3.1	0	2.5
Farmers 300	0	0	0	3.1	0	0.6
Farmers 312	3.1	0	0	0	0	0.6
Farmers 322	3.1	0	0	0	0	0.6
Farmers 425	3.1	0	0	0	0	0.6
Farmers 427A	3.1	0	0	0	0	0.6
Farmers unknown	0	6.2	0	0	0	1.2
Total	12.4	6.2	0	3.1	0	4.3
Funks G34	0	0	3.1	3.1	0	1.2
Funks G70	0	0	0	0	3.1	0.6
Funks G72	0	0	3.1	3.1	0	1.2
Funks G73	0	3.1	0	0	0	0.6
Funks G75	3.1	0	0	3.1	3.1	1.9
Funks 76	3.1	0	0	0	0	0.6
Funks 93	3.1	0	0	0	0	0.6
Funks 95A	3.1	3.1	3.1	0	0	1.9
Funks 4582	0	0	0	0	3.1	0.6
Funks 4389	0	0	0	0	3.1	0.6
Total	12.4	6.2	9.3	6.2	12.4	9.3
Iowealth	3.1	0	0	0	0	0.6
Iowa State 100	3.1	0	0	0	0	0.6
Iowa State 112	6.2	3.1	3.1	6.2	3.1	4.3
Total	9.3	3.1	3.1	6.2	3.1	4.9

I F *(Continued)*

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Moews 48A	0	3.1	0	0	0	0.6
Moews 65	0	3.1	0	0	0	0.6
Moews 70	0	0	0	0	3.1	0.6
Moews 505A	0	0	3.1	3.1	3.1	1.9
Moews 520	3.1	3.1	0	0	0	1.2
Moews 523	3.1	3.1	0	3.1	0	1.9
Moews 524	0	0	0	0	3.1	0.6
Moews unknown	3.1	0	6.2	0	0	1.9
Total	9.3	12.4	9.3	6.2	9.3	9.3
Northrup King DX5	3.1	0	0	0	0	0.6
Northrup King KT6	0	0	0	0	3.1	0.6
Total	3.1	0	0	0	3.1	1.2
Pioneer 301B	3.1	6.2	0	0	0	1.9
Pioneer 320	3.1	0	0	3.1	3.1	1.9
Pioneer 328	0	0	0	3.1	0	0.6
Pioneer 329	0	12.4	6.2	3.1	6.2	5.6
Pioneer 347	3.1	0	0	0	0	0.6
Pioneer 350	0	0	3.1	0	0	0.6
Pioneer 352	9.3	3.1	6.2	6.2	3.1	5.9
Pioneer 354	12.4	6.2	3.1	12.4	9.3	8.7
Pioneer 371	3.1	3.1	0	6.2	0	2.5
Pioneer 3280	0	0	0	3.1	3.1	1.2
Pioneer 3414	0	0	0	0	6.2	1.2
Pioneer 3418	0	0	0	0	3.1	0.6
Pioneer 3445	0	0	3.1	0	0	0.6
Pioneer 3510	0	0	0	0	3.1	0.6
Pioneer unknown	6.2	0	18.6	0	3.1	5.6
Total	40.3	31.0	40.3	37.2	40.3	37.8
Pfister 277	3.1	0	0	0	0	0.6
Pfister 303	0	3.1	0	0	0	0.6
Pfister 323	0	3.1	3.1	0	0	1.2
Pfister 347	3.1	0	0	0	0	0.6
Pfister 383	3.1	0	0	0	0	0.6
Pfister 403	3.1	0	0	0	0	0.6
Pfister 418	0	3.1	6.2	9.3	6.2	4.9
Pfister 444	0	3.1	0	0	0	0.6
Pfister 1212	0	0	0	0	3.1	0.6
Pfister unknown	0	0	6.2	0	0	1.2
Total	12.4	12.4	15.5	9.3	9.3	11.8
Tomco 555	0	3.1	0	0	0	0.6
Tomco 628	0	0	0	3.1	3.1	1.2
Tomco unknown	0	3.1	0	3.1	3.1	1.9
Total	0	6.2	0	6.2	6.2	3.7
Turners 49	3.1	0	0	0	0	0.6
Turners 408	0	3.1	0	0	0	0.6
Total	3.1	3.1	0	0	0	1.2
Vinton	0	3.1	0	0	0	0.6

APPENDIX II

II A. Weather conditions in Jefferson County, Kan., during growing season.

Month	1960	1961	1962	1963	1964
	Average temperature for the month (° F.)				
May	63.8	60.7	72.5	65.7	65.4
June	72.8	72.0	72.4	77.1	72.7
July	75.8	77.3	76.2	80.2	81.3
August	78.3	75.0	77.0	78.1	74.6
	Total rainfall for the month (inches)				
May	2.09	5.20	7.36	5.33	3.57
June	4.63	3.01	4.79	2.57	8.09
July	3.20	7.99	4.10	3.04	3.33
August	3.76	2.64	5.27	2.45	6.86

II B. Weather conditions in Jefferson County, Kan., deviation from long-term normal.

Month	1960	1961	1962	1963	1964
	Monthly temperature				
May	−0.6	−3.6	8.2	0.8	0.4
June	−1.7	−2.4	−2.1	2.3	−2.5
July	−3.9	−2.4	−3.2	0.5	1.2
August	.4	−2.9	−1.2	−0.2	−3.6
	Monthly rainfall				
May	−2.62	0.72	2.82	0.81	−0.90
June	−0.34	−1.97	−0.55	−2.47	3.43
July	−0.13	4.66	0.50	−0.65	−2.26
August	−0.86	−1.97	1.07	−1.83	2.52

II C. Fertilizer treatments in fields used in Jefferson County, Kan.

Fertilizer application	Percent of fields					
	1960	1961	1962	1963	1964	Average
N.P.K. combinations[a]	50.0	37.5	62.5	62.5	62.5	55.0
Ammonium nitrate	8.3	16.7	8.3	25.0	20.9	15.8
Starter fertilizer	0	12.5	0	0	0	2.5
Green manure	4.2	8.3	0	0	0	2.5
No treatment	37.5	25.0	29.2	12.5	16.6	24.2
Total fields checked	24	24	24	24	24	

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

8–24– 8	12–12–12	16–20– 0	13–39– 0	10–20– 0
15–15– 0	30–10– 0	16–48– 0	14–28– 0	14–28–14
16–48–16	29–14– 0	16–39– 0	10–10–10	15–15–15
16–20–20	6–18– 6	20–10–10	15– 5– 5	8–25– 0
4–12– 4	14–14– 0	33–20– 0		

II D. Crop history in fields used in Jefferson County, Kan.

Type of rotation	Percent of fields					
	1960	1961	1962	1963	1964	Average
Continuous corn	95.8	83.4	66.7	62.3	79.2	77.5
Two crop rotations						
Corn–wheat	4.2	8.3	0	4.2	0	3.3
Corn–clover	0	0	0	4.2	4.2	1.7
Corn–alfalfa	0	0	0	4.2	0	.8
Corn–soybeans	0	0	0	0	4.2	.8
Corn–brome	0	0	0	4.2	0	.8
Corn–fallow	0	0	0	4.2	0	.8
Total	4.2	8.3	0	21.0	8.3	8.3
Three-crop rotations						
Corn–wheat–wheat	0	0	0	4.2	4.2	1.7
Corn–wheat–fallow	0	0	0	4.2	4.2	1.7
Corn–sorghum–sorghum	0	0	0	0	4.2	.8
Corn–wheat–soybeans	0	0	4.2	0	0	.8
Corn–soybeans–fallow	0	0	4.2	0	0	.8
Corn–sorghum–fallow	0	0	8.3	4.2	0	2.5
Corn–brome–brome	0	0	4.2	0	0	.8
Corn–alfalfa–sorghum	0	0	4.2	0	0	.8
Corn–alfalfa–alfalfa	0	4.2	4.2	0	0	1.7
Corn–clover–clover	0	4.2	4.2	4.2	0	2.5
Total	0	8.3	33.3	16.7	12.5	14.2
Total number fields checked	24	24	24	24	24	

II E. Planting methods and plant populations in fields used in Jefferson County, Kan.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Type of planting						
Listed	50.0	41.6	37.5	37.5	20.9	37.5
Furrow opened	45.8	50.0	45.8	37.5	50.0	45.8
Surface planted	4.2	8.3	16.7	25.0	29.1	16.7
Total fields observed	24	24	24	24	24	
Plants per acre						
Less than 10,000	41.6	16.7	29.0	54.1	25.0	33.3
10,000 – 10,999	33.4	25.0	20.9	8.3	41.7	25.8
11,000 – 11,999	8.3	20.9	20.9	12.5	8.3	14.2
12,000 – 12,999	4.2	29.1	16.7	16.7	12.5	15.8
13,000 – 13,999	8.3	8.3	0	4.2	8.3	5.8
14,000 – 14,999	0	0	4.2	0	4.2	1.7
15,000 – 15,999	4.2	0	0	4.2	0	1.7
16,000 – 16,999	0	0	8.3	0	0	1.7
Average	10,416	11,180	11,236	9,916	10,666	10,683
Total fields observed	24	24	24	24	24	

II F. Corn hybrids used in fields for study in Jefferson County, Kan.

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Commercial						
Pioneer 300	12.5	4.2	4.2	0	0	5.0
Pioneer 302	4.2	0	0	4.2	0	1.7
Pioneer 314	0	4.2	0	0	0	.8
Pioneer 318	0	0	4.2	0	0	.8
Pioneer 320	0	4.2	4.2	0	0	1.7
Pioneer 321	0	0	0	8.3	0	1.7
Pioneer 312A	0	0	12.5	0	8.3	4.2
Pioneer unknown	0	16.7	0	0	4.2	4.2
Total	16.7	29.1	25.0	12.5	12.5	19.2
DeKalb 3X2	12.5	8.3	20.9	4.2	4.2	10.0
DeKalb 3X1	4.2	0	4.2	0	4.2	2.5
DeKalb 3X3	0	0	0	0	4.2	.8
DeKalb 707	0	0	0	0	4.2	.8
DeKalb 805	0	0	0	4.2	0	.8
DeKalb 812A	0	0	0	0	4.2	.8
DeKalb 854	0	0	0	4.2	4.2	1.7
DeKalb 925	0	0	4.2	4.2	0	1.7
DeKalb unknown	4.2	0	0	0	4.2	.8
Total	20.9	8.3	29.1	16.7	25.0	20.0
United–Hagie W50	0	0	0	4.2	0	.8
United–Hagie 60	8.3	0	0	4.2	4.2	3.3
United–Hagie 65A	4.2	0	4.2	0	0	1.7
United–Hagie 66	0	0	4.2	4.2	0	1.7
United–Hagie unknown	0	0	0	0	4.2	.8
Total	12.5	0	8.3	12.5	8.3	8.3
Steckleys Giant 15	4.2	4.2	0	4.2	0	2.5
Steckleys 113	4.2	8.3	8.3	4.2	4.2	5.8
Steckleys 214	0	0	0	8.3	4.2	2.5
Steckleys 315	0	0	0	4.2	8.3	2.5
Total	8.4	12.5	8.3	20.9	16.7	13.3
Funks 95A	8.3	4.2	4.2	0	0	3.3
Funks 96	0	0	0	8.3	4.2	2.5
Funks 114	4.2	0	0	12.5	4.2	4.2
Funks unknown	0	8.3	0	0	0	1.7
Total	8.5	12.5	4.2	20.8	8.4	11.7
KFU 150	0	0	4.2	0	0	.8
KFU 275	0	0	4.2	0	0	.8
KFU 523W	0	4.2	0	0	0	.8
Total	0	4.2	8.3	0	0	2.5
Cornhusker W60	0	0	0	0	4.2	.8
Cargill	4.2	4.2	0	0	0	1.7
Northrup King 649	0	0	0	4.2	4.2	1.7
Unknown	0	0	0	0	4.2	.8
Embryo WW60	0	0	4.2	0	0	.8
Mangleadorf	4.2	0	0	0	0	.8
Pfister 314	0	0	0	0	4.2	.8
Pfister 320	0	0	4.2	0	0	.8
Pfister unknown	4.2	12.5	0	0	0	3.3
Total	4.2	12.5	4.2	0	4.2	4.9
Experiment Station						
Kansas 523	0	4.2	0	0	4.2	1.7
Kansas 904W	4.2	4.2	0	0	4.2	2.5
Kansas 1639	0	0	4.2	0	4.2	1.7

II F *(Continued)*

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Kansas 1859	4.2	0	0	12.5	0	3.3
Kansas unknown	8.3	8.3	0	0	0	3.3
Missouri Hybrid	0	0	4.2	0	0	.8
Total	25.0	29.2	16.8	12.5	20.0	20.1
Total number fields observed	24	24	24	24	24	
Total number of hybrids	17	15	17	17	23	

APPENDIX III

III A. Weather conditions in Waseca County, Minn., during growing season.

Month	1960	1961	1962	1963	1964
Average temperature for the month (° F.)					
May	58.1	55.7	61.5	56.3	61.5
June	65.4	68.1	65.7	70.3	66.6
July	71.3	69.8	67.6	71.8	73.6
August	71.6	70.6	68.6	68.1	64.8
Total rainfall for the month (inches)					
May	3.44	2.28	– .12	–1.23	2.13
June	5.09	.98	3.49	5.41	1.93
July	2.26	6.73	5.11	5.18	2.68
August	2.59	5.65	8.53	2.27	4.53

III B. Weather conditions in Waseca County, Minn., deviation from long-term normal.

Month	1960	1961	1962	1963	1964
Monthly temperature					
May	–0.5	–2.9	2.8	–2.4	2.8
June	–2.8	–0.1	–2.4	2.2	–1.5
July	–2.0	–3.5	–5.3	–1.1	.7
August	0.8	–0.2	–2.3	–2.8	–6.1
Monthly rainfall					
May	3.44	2.28	– .12	–1.23	2.13
June	.52	–3.59	–1.09	.83	–2.65
July	– .99	3.48	1.85	1.92	– .58
August	– .81	2.25	5.06	–1.20	1.06

III C. Crop history in fields used in Waseca County, Minn.

Type of rotation	Percent of fields					
	1960	1961	1962	1963	1964	5 year average
Continuous corn	57.14	33.33	45.83	43.47	37.50	43.45
Two crop rotations						
Corn–grain		8.33		21.74		6.01
Corn–pasture	9.52	4.17	4.17		6.25	4.82
Corn–oats	9.52	12.50	12.50	8.70	12.50	11.14
Corn–soybeans	9.52	12.50	16.67	13.04	25.00	15.35
Corn–(oats + soybeans)		4.17			6.25	2.08
Corn–(grain + soybeans)		4.17			6.25	2.08
Corn–(peas + soybeans)		4.17				0.83
Total	28.56	50.01	33.34	43.48	56.25	42.33
Three crop rotations						
Corn–soybeans–oats	14.29	4.17	12.50			6.19
Corn–grain–soybeans		4.17	4.17	4.35		2.54
Corn–grain–pasture		4.17		4.35		1.70
Corn–pasture–oats			4.17			0.83
Corn–pasture–(oats + pasture)				4.35		0.87
Corn–pasture–(oats + peas)		4.17				0.83
Corn–pasture (oats + soybeans)					6.25	1.25
Total	14.29	16.68	20.84	13.05	6.25	14.22
Total number fields checked	21	24	24	23	16	
Previous crop						
Corn	57.14	29.17	45.83	34.78	37.50	40.88
Sweetcorn		4.17		8.69		2.57
Grain		12.50		26.09		7.72
Pasture	9.52	4.17	8.33	4.35	6.25	6.52
Oats	14.29	16.67	20.83	8.69	12.50	14.60
Soybeans	19.05	12.50	25.00	13.04	25.00	18.92
(Oats + soybeans)		4.17			12.50	3.33
(Grain + soybeans)		4.17			6.25	2.08
(Peas + soybeans)		4.17				0.83
(Oats + pasture)		4.17		4.35		1.70
(Grain + pasture)		4.17				0.83
Total fields observed	21	24	24	23	16	

III D. Fertilizer treatments in fields used in Waseca County, Minn.

Fertilizer application	Percent of fields					
	1960	1961	1962	1963	1964	Average
N.P.K. combinations[a]	37.5	20.8	12.5	37.5	29.2	27.50
N.P.K. combinations[a] + nitrogen	12.5	8.3	33.3	25.0	66.7	29.16
N.P.K. combinations[a] + manure	4.2	37.5	16.7	4.2		12.52
N.P.K. combinations[a] + anhydrous ammonia + manure		4.2				0.84
N.P.K. combinations[a] + nitrogen + manure		8.3	16.7			5.00
Nitrogen		4.2				0.84
Manure	21.0	8.3	12.5	4.2		9.20
No treatment		8.3		4.2	4.2	3.34
Unknown	25.0		8.3	25.0		11.66
Total number of fields checked	24	24	24	24	24	

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

0/20/20	6/24/24	10/10/10
3/5/2	7/28/14	10/27/23
5/20/10	7/26/26	12/20/24
5/20/20	8/24/12	
6/24/12	8/32/16	

III E. Planting methods and plant population in fields used in Waseca County, Minn.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Type of planting						
Checked	13.3	12.5	--	9.1	0	8.7
Hill drop	40.0	29.2	--	81.8	54.2	51.3
Drilled	46.7	58.3	--	9.1	45.8	40.0
Total fields observed	15	24	--	11	24	
Plants per acre, average	13,155	16,170	15,125	18,000	14,580	15,406
Total fields observed	24	24	24	23	24	

III F. Corn hybrids used in fields for study in Waseca County, Minn.

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Blaney		3.48				0.70
Cargill A	8.33	1.37				1.94
DeKalb 25XL					4.16	0.83
DeKalb 46	4.16					0.83
DeKalb 56	4.16		4.16			1.66
DeKalb 59		3.48				0.70
DeKalb 80A				2.08		0.42
DeKalb 206					1.37	0.27
DeKalb 224					1.37	0.27
DeKalb 368A					1.37	0.27
DeKalb 409		8.33	4.16			2.50
DeKalb 427		2.08				0.42
DeKalb unknown	4.16	5.54	4.16	13.87	8.33	7.21
Total	12.48	19.43	12.48	15.95	16.60	15.39
Farmers 108	4.16					0.83
Funks G21		1.37		2.08		0.69
Funks G26		1.37				0.27
Funks unknown	4.16	8.33	8.33			4.16
Total	4.16	11.07	8.33	2.08		5.13
Haapala 130A	4.16	4.16	4.16	4.16		3.33
Iowa bred 4630				4.16	8.33	2.50
Jacques	4.16				4.16	1.66
Kingscrost 352			4.16			0.83
Kingscrost unknown	8.33	4.16	4.16	4.16	8.33	5.83
Total	8.33	4.16	8.32	4.16	8.33	6.66
Minhybrid 409		1.37				0.27
Minhybrid unknown		4.16				0.83
Total		5.53				1.10
Pfister 62			4.16			0.83
Pfister unknown	2.08	2.75		1.37		1.24
Total	2.08	2.75	4.16	1.37		2.07
Pioneer 8		1.37				0.27
Pioneer 37	4.16					0.83
Pioneer 71		1.37				0.27
Pioneer 349	9.70	2.08	8.33	4.16	2.08	5.27
Pioneer 352		2.08			2.08	0.83
Pioneer 354					2.08	0.42
Pioneer 368					4.16	0.83
Pioneer 368A			8.33		8.33	3.33
Pioneer 371	10.42	4.16	8.33	8.33		6.25
Pioneer 375		4.16				0.83
Pioneer 376	4.16	8.33	4.16		2.08	3.75
Pioneer 377A	4.16		4.16	4.16	4.16	3.33
Pioneer 379			4.16			0.83
Pioneer 383	1.37					0.27
Pioneer 385				4.16	4.16	1.66
Pioneer unknown	6.25	9.70	8.33	18.04	20.83	12.63
Total	40.22	33.25	45.80	38.85	49.96	41.61
Pride 57	4.16					0.83
Pride unknown		4.16				0.83
Total	4.16	4.16				1.66
Sugar sweet silage corn		4				0.83
Tomahawk 139	2.08	4.16				1.25
Tomco 433			4.16			0.83

III F *(Continued)*

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Tomco unknown	4.16		4.16	6.25		2.91
Total	6.24	4.16	8.32	6.25		4.99
Trojan unknown	1.37	2.08		6.25		1.94
Unknown			8.33	16.66	12.5	7.50
Total number fields observed	24	24	24	24	24	
Total number of hybrids	21	25	18	15	29	21.6

APPENDIX IV

IV A. Weather conditions in New Madrid County, Mo., during growing season.

Month	1960	1961	1962	1963	1964
	Average temperature for the month (° F.)				
April	60.0	53.4	55.5	62.4	61.8
May	65.0	63.3	75.0	68.5	69.8
June	75.4	73.7	75.5	77.2	77.9
July	77.5	77.7	78.2	77.6	79.5
August	78.3	75.5	76.6	76.2	77.1
September	73.5	73.0	68.2	69.8	70.6
October	61.0	60.3	62.6	65.6	57.2
	Total rainfall for the month (inches)				
April	2.92	3.70	3.05	1.26	4.80
May	4.57	9.60	2.85	4.00	3.02
June	3.48	3.67	3.86	3.43	1.44
July	0.94	5.05	3.48	4.77	1.32
August	3.28	2.20	5.62	4.13	3.11
September	2.25	0.78	7.08	2.01	4.33
October	1.66	1.00	4.46	0.09	T

T = trace

IV B. Weather conditions in New Madrid County, Mo.; deviations from long-term normal.

Month	1960	1961	1962	1963	1964
	Monthly temperature				
April	+1.6	−5.0	−2.9	+4.0	+3.4
May	−2.9	−4.6	+7.1	+0.6	+1.9
June	−1.7	−3.4	−1.6	+0.1	+0.8
July	−2.7	−2.5	−2.0	−2.6	−0.7
August	−0.7	−3.5	−2.4	−2.8	−1.9
September	+1.7	+1.2	−2.0	−2.0	−1.2
October	0	−0.1	+1.6	+4.6	−3.8
	Monthly rainfall				
April	−1.48	−0.70	−1.35	−3.14	+0.40
May	+0.13	+5.16	−1.61	−0.44	−1.42
June	−0.68	−0.49	−0.30	−0.73	−2.72
July	−2.18	+1.93	+0.36	+1.65	−1.80
August	+0.36	−0.72	+2.70	+1.21	+0.19
September	−1.54	−3.01	−1.78	−1.78	+0.54
October	−1.34	−2.00	+1.46	−2.91	−3.00

IV C. Fertilizer treatments in fields used in New Madrid County, Mo.

Fertilizer application	Percent of fields					
	1960	1961	1962	1963	1964	Average
N.P.K. combinations	77.3	78.3	91.7	82.6	86.4	83.3[a]
Ammonium nitrate	13.6	21.7	0	4.3	4.5	8.8
Anhydrous ammonia	77.3	82.6	87.5	91.3	81.8	84.1
Nitrogen	4.5	0	4.2	4.3	9.1	4.4
Starter fertilizer	89.5	70.8	82.6	79.2	77.3	79.9
Manure	0	0	0	0	0	0
No application	0	0	0	0	0	0
Total number of fields checked	22	23	24	23	22	

[a] Includes applications of starter fertilizer.

IV D. Crop history in fields used in New Madrid County, Mo.

Previous crop	Percent of fields					
	1960	1961	1962	1963	1964	Average
Clover	0	4.4	0	0	0	0.9
Corn	47.7	34.7	62.4	50.5	52.4	49.5
Cotton	26.1	17.4	25.0	16.6	9.5	18.9
Pasture	4.4[a]	0	0	0	0	0.9
Small grain	4.4	13.0	0	4.2	0	4.3
Sorghum	0	0	0	0	4.8	1.0
Soybeans	17.4	26.1	4.2	25.0	33.3	21.2
Rye and vetch	0	4.4	4.2	4.2	0	2.6
Fallowed	0	0	4.2	0	0	0.8
Total number fields checked	22	22	24	24	21	

[a] Sudan grass

IV E. Plant populations in fields used in New Madrid County, Mo.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Plants per acre						
8,000 – 8,999	9.1	4.6	0	0	0	2.7
9,000 – 9,999	0	4.6	0	0	0	2.7
10,000 – 10,999	9.1	9.1	4.8	0	4.2	5.4
11,000 – 11,999	13.6	13.6	4.8	0	0	5.3
12,000 – 12,999	4.6	22.6	9.6	26.1	4.2	13.4
13,000 – 13,999	18.1	13.6	14.2	13.0	25.0	16.8
14,000 – 14,999	22.7	9.1	14.2	8.7	4.2	11.8
15,000 – 15,999	4.6	9.1	28.6	8.7	25.0	15.2
16,000 – 16,999	13.6	9.1	19.0	21.8	4.2	13.5
17,000 – 17,999	0	4.6	4.8	13.0	12.5	7.0
over 18,000	4.6	0	0	8.7	20.8	6.8
Average	12,070	12,776	12,870	14,048	15,209	13,395
Total fields observed	22	22	21	23	24	

IV F. Corn hybrids used in fields for study in New Madrid County, Mo.

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Pfister 146	0	0	0	5.6	0	1.1
Pfister 312	10.0	0	0	0	0	2.0
Pfister 347	10.0	8.3	0	0	0	3.7
Pfister 351	10.0	0	0	0	0	2.0
Pfister 385	10.0	0	0	0	0	2.0
Pfister 403	10.0	0	0	0	0	2.0
Pfister 418	0	8.3	12.5	5.6	0	5.3
Pfister 428	10.0	0	0	0	0	2.0
Pfister 434	0	16.7	12.5	16.7	8.7	10.9
Pfister 631W	10.0	0	0	0	0	2.0
Pfister SX29	0	0	0	22.2	17.4	7.9
Total	70.0	33.3	25.0	50.1	26.1	40.9
Pioneer 321	0	0	0	0	4.3	0.9
Pioneer 338A	0	0	0	0	4.3	0.9
Total	0	0	0	0	8.6	1.7
Funks G91	0	0	0	5.6	0	1.1
Funks G96	0	0	6.3	0	0	1.3
Funks 134	10.0	8.3	0	0	0	3.7
Funks 144	0	8.3	6.3	11.1	4.3	6.0
Funks 433	0	0	6.3	0	0	1.3
Total	10.0	16.6	18.9	16.7	12.9	15.0
Schenk S–87	0	8.3	0	0	0	1.7
DeKalb 633	0	0	6.3	0	0	1.3
DeKalb SX805	0	0	0	5.6	0	1.1
Total	0	0	6.3	5.6	0	2.4
MFA 120	0	8.3	0	0	0	1.7
MFA 2120	0	0	0	0	4.3	0.9
MFA 3232	0	0	0	0	4.3	0.9
Total	0	8.3	0	0	8.6	1.7
Zimmerman Z800	0	0	12.5	11.1	4.3	5.6
Zimmerman Z824	0	0	0	5.6	0	1.1
Total	0	0	12.5	16.7	4.3	6.7
Princton 648	0	8.3	0	0	0	1.7
Princton 8A	0	0	0	0	8.7	1.7
Total	0	8.3	0	0	8.7	3.4
Indiana 900A	0	0	12.5	0	0	2.5
Indiana 909	10.0	0	6.3	0	13.0	5.9
Total	10.0	0	18.8	0	13.0	8.4
Embro 44XE	0	0	6.3	0	0	1.3
US 13	10.0	8.3	12.5	5.6	8.7	9.0
US 523W	0	8.3	0	0	0	1.7
total	10.0	10.6	12.5	5.6	8.7	10.7
Mo. 880	0	8.3	0	5.6	4.3	3.6
Griffith 125	0	0	0	0	4.3	0.9
Griffith unknown	0	0	0	0	8.7	1.7
Total	0	0	0	0	13.0	2.6
Total number of fields observed	10	12	16	18	23	
Total number of hybrids	10	11	11	11	14	

APPENDIX V

V A. Weather conditions in Carroll County, Mo., during growing season.

Month	1960	1961	1962	1963	1964
	Average temperature for the month (° F.)				
April	57.2	49.9	52.6	57.7	57.3
May	63.5	60.6	73.0	64.7	68.9
June	72.4	71.2	72.6	76.2	72.3
July	74.8	75.6	75.9	78.6	79.2
August	77.3	73.9	76.6	75.3	74.2
September	70.0	66.0	65.1	69.8	68.3
October	57.5	57.2	59.2	66.0	53.8
	Total rainfall for the month (inches)				
April	4.86	4.17	0.98	1.53	6.18
May	5.33	5.60	3.77	5.92	4.56
June	5.78	3.08	3.02	2.63	6.89
July	6.01	8.60	5.13	4.21	1.27
August	2.18	3.48	0.78	3.73	2.34
September	1.41	15.25	4.95	1.51	4.40
October	4.59	5.39	3.25	3.91	0.34

V B. Weather conditions in Carroll County, Mo., deviations from long-term normal.[a]

Month	1960	1961	1962	1963	1964
	Monthly temperatures				
April	3.2	−3.9	−0.6	3.9	3.0
May	−0.6	−3.2	8.4	0.1	4.7
June	−2.0	−2.7	−1.4	2.3	−1.8
July	−4.3	−3.4	−3.2	−0.8	0.7
August	0.5	−2.2	−0.7	−1.8	−2.2
September	2.1	−1.9	−3.4	1.0	−0.1
October	1.0	0.6	1.9	9.3	−2.7
	Monthly rainfall				
April	0.93	0.53	−1.91	−1.82	2.71
May	1.04	−0.23	0.03	−0.34	−1.26
June	1.32	−2.73	−1.43	−3.57	−0.35
July	0.51	8.03	3.19	0.15	−1.75
August	−1.15	0.20	−1.76	1.63	−0.98
September	−2.80	7.28	0.75	−2.23	2.39
October	1.85	1.64	0.87	0.77	−2.53

[a] Long-term normal temperature and rainfall are not available for the county. The mean of the long-term normal readings of two neighboring stations (Brunswick and Chillicothe) was used in the calculation of the deviations.

V C. Fertilizer treatments in fields used in Carroll County, Mo.

Fertilizer application	Percent of fields					
	1960	1961	1962	1963	1964	Average
N.P.K. combinations	50.0	33.3	50.0	54.2	54.1	48.3
Ammonium nitrate	41.7	37.5	29.2	20.8	20.8	30.0
Anhydrous ammonia	8.3	37.5	41.7	41.7	70.8	40.0
Nitrogen	12.5	12.5	12.5	25.0	4.2	13.3
Green manure	4.2	0	0	0	0	0.8
No applications	16.6	8.3	0	0	0	5.0
Total number of fields checked	24	24	24	24	24	

V D. Crop history in fields used in Carroll County, Mo.

Previous crop	Percent of fields					
	1960	1961	1962	1963	1964	Average
Corn	70.8	54.2	50.0	87.5	66.6	65.8
Wheat	16.6	16.6	12.5	0	8.3	10.8
Soybeans	4.2	4.2	4.2	4.2	16.6	6.7
Oats	4.2	0	4.2	0	0	1.7
Clover	4.2	20.8	16.6	0	0	8.3
Idle	0	4.2	8.3	4.2	4.2	4.2
Alfalfa	0	0	4.2	0	4.2	1.6
Pasture	0	0	0	4.2	0	0.8
Total number fields checked	24	24	24	24	24	

V E. Plant populations in fields used in Carroll County, Mo.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Plants per acre						
8,000 – 8,999	0	0	0	0	4.2	0.8
9,000 – 9,999	20.8	8.3	4.2	0	0	6.7
10,000 – 10,999	16.7	16.7	8.3	8.3	0	10.0
11,000 – 11,999	8.3	25.0	12.5	12.5	8.3	13.3
12,000 – 12,999	25.0	16.7	29.2	0	12.5	16.7
13,000 – 13,999	4.2	12.5	25.0	29.2	8.3	15.8
14,000 – 14,999	16.7	4.2	16.7	16.7	16.7	14.2
15,000 – 15,999	4.2	8.3	4.2	25.0	12.5	10.8
16,000 – 16,999	0	4.2	0	4.2	8.3	3.3
17,000 – 17,999	0	4.2	0	0	8.3	2.5
18,000 – 18,999	4.2	0	0	0	12.5	3.3
19,000 – 19,999	0	0	0	0	4.2	0.8
20,000 or more	0	0	0	4.2	4.2	1.6
Average	12,076	12,430	12,764	14,104	15,209	13,317
Total fields observed	24	24	24	24	24	

V F. Corn hybrids used in fields for study in Carroll County, Mo.

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
DeKalb 3x1	4.2	4.2	0	0	0	1.7
DeKalb 3x2	8.3	12.5	4.2	0	0	5.0
DeKalb 362	0	0	0	0	4.2	0.8
DeKalb 444	0	4.2	0	0	0	0.8
DeKalb 624	0	0	0	0	4.2	0.8
DeKalb 630	8.3	4.2	4.2	0	0	3.3
DeKalb 633	0	0	4.2	8.3	8.3	4.2
DeKalb 640	0	0	0	0	4.2	0.8
DeKalb 661	4.2	4.2	0	0	0	1.7
DeKalb 805	0	0	4.2	4.2	12.5	4.2
DeKalb 824	4.2	4.2	4.2	0	0	2.5
DeKalb 826	0	0	4.2	4.2	0	1.7
DeKalb 862	0	0	0	0	4.2	0.8
DeKalb unknown	4.2	0	0	0	0	0.8
Total	33.4	21.5	25.2	16.7	37.6	26.9

V F *(Continued)*

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Pioneer 1x	0	0	0	4.2	0	0.8
Pioneer 312A	4.2	4.2	0	0	0	1.7
Pioneer 314	0	0	4.2	0	12.5	3.3
Pioneer 318	0	4.2	4.2	0	0	1.7
Pioneer 320	0	4.2	4.2	12.5	12.5	6.7
Pioneer 321	0	0	4.2	4.2	0	1.7
Pioneer 328	0	0	4.2	4.2	8.3	3.3
Pioneer 329	4.2	0	4.2	0	0	1.7
Pioneer 339	4.2	4.2	0	0	0	1.7
Total	12.6	16.8	25.2	25.1	33.3	22.6
Pfister 29	0	0	0	0	4.2	0.8
Pfister 347	12.5	4.2	0	0	0	3.3
Pfister 401	4.2	4.2	0	0	0	1.7
Pfister 403	0	4.2	4.2	0	0	1.7
Pfister 418	4.2	0	12.5	16.7	0	6.7
Pfister 436	0	4.2	0	0	4.2	1.7
Pfister unknown	4.2	0	4.2	0	0	1.7
Total	25.1	16.8	20.9	16.7	8.4	17.6
MFA K6–SC	0	4.2	0	0	0	0.8
MFA 90	0	0	4.2	4.2	0	1.7
MFA 118	4.2	0	0	0	0	0.8
MFA 1418A	0	0	0	0	4.2	0.8
MFA 2120	4.2	4.2	0	0	0	1.7
MFA 2123	0	0	0	0	4.2	0.8
MFA white	0	4.2	4.2	0	0	1.7
Total	8.4	12.6	8.4	4.2	8.4	8.4
Maygold 37	4.2	0	4.2	0	0	1.7
Maygold 58	0	0	0	0	4.2	0.8
Maygold 59A	4.2	4.2	0	0	0	1.7
Maygold 68	0	0	4.2	8.3	4.2	3.3
Total	8.4	4.2	8.4	8.3	8.2	7.5
Cargill 310	0	4.2	4.2	0	0	1.7
Cargill 340	0	0	4.2	4.2	0	1.7
Total	0	4.2	8.4	4.2	0	3.4
Plymouth P37	0	4.2	0	0	0	0.8
Plymouth P97	4.2	0	0	0	0	0.8
Total	4.2	4.2	0	0	0	1.7
Kellog Kelly 28	4.2	0	0	0	0	0.8
Kellog Kelly 77A	0	4.2	0	0	0	0.8
Total	4.2	4.2	0	0	0	1.7
Monier 702	4.2	4.2	4.2	4.2	4.2	4.2
Funk unknown	0	0	0	4.2	0	0.8
Embro unknown	0	0	0	4.2	0	0.8
Earl May unknown	0	0	0	4.2	0	0.8
Mo. Cobcorn	0	0	0	4.2	0	0.8
Total number of fields observed	24	24	24	24	24	
Total number of hybrids	20	22	22	16	16	

APPENDIX VI

VI A. Weather conditions at West Point, Cuming County, Neb., during growing season.

Month	1960	1961	1962	1963	1964
	Average temperature for the month (° F.)				
May	60.6	57.8	67.6	60.7	64.9
June	69.2	69.7	69.8	73.3	69.4
July	75.6	75.2	73.4	76.4	78.2
August	74.5	73.7	71.9	72.5	68.7
	Total rainfall for the month (inches)				
May	4.70	3.47	4.03	2.94	6.66
June	6.27	3.88	4.20	10.46	6.54
July	3.20	2.34	3.10	2.45	2.22
August	4.80	2.94	3.40	5.43	4.25
	Borer degree–day accumulations				
April 15	44.5	2.5	6.0	130.5	29.0
May 1	176.5	69.5	125.5	180.5	111.0
May 15	283.0	177.5	382.5	376.0	272.0
June 1	527.5	345.0	681.5	539.0	585.0
June 15	763.0	623.0	905.0	881.0	817.5
July 1	1090.0	952.5	1287.0	1254.0	1186.0
July 15	1421.0	1289.0	1654.0	1587.5	1550.5
Aug. 1	1892.5	1724.0	2000.5	2066.5	2071.0
Aug. 15	2233.0	2064.5	2317.5	2404.0	2355.5
Sept. 1	2656.0	2454.5	2674.5	2751.5	2634.5

VI B. Weather conditions at West Point, Cuming County, Neb.; deviations from long-term normal.

Month	1960	1961	1962	1963	1964
	Monthly temperatures				
May	–1.5	–4.3	5.4	–1.5	2.7
June	–3.4	–2.9	–2.8	0.7	–3.2
July	–3.1	–3.5	–4.9	–1.9	–0.1
August	–1.6	–2.4	–4.2	–3.6	–7.4
	Monthly rainfall				
May	1.29	0.06	0.41	–0.68	3.04
June	1.72	–0.67	–0.28	5.98	2.06
July	0.20	–0.66	–0.17	–0.82	–1.05
August	1.65	–0.21	0.13	2.16	0.98

VI C. Previous year's crop in fields used in Cuming County, Neb.

Previous crop	Percent of fields					
	1960	1961	1962	1963	1964	Average
Corn	75.0	70.8	66.7	58.3	70.8	68.3
Oats	8.3	4.2	8.3	4.2	8.3	6.7
Oats & clover	4.2	8.3	4.2	8.3	0	5.0
Barley	4.2	4.2	4.2	0	0	2.5
Alfalfa	0	8.3	0	0	4.2	2.5
Soybeans	0	4.2	4.2	16.7	12.5	7.5
Sorghum	4.2	0	4.2	4.2	0	2.5
Wheat	0	0	4.2	0	0	0.8
Pasture	4.2	0	0	4.2	4.2	2.5
Soil bank	0	0	4.2	4.2	0	1.7
Total number fields checked	24	24	24	24	24	

VI D. Use of fertilizer in fields used in Cuming County, Neb.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Commercial fertilizer	37.5	62.5	66.7	83.3	54.2	60.8
Trace elements	0	0	0	0	0	0
Manure	25.0	4.2	8.3	8.3	4.2	10.0
None	37.5	33.3	20.8	4.2	25.0	24.1
Unknown	0	0	4.2	4.2	16.7	5.0
Total number fields checked	24	24	24	24	24	

VI E. Planting methods and plant populations in fields used in Cuming County, Neb.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Type of planting						
Checked	0	0	0	0	0	0
Hill drop	4.2	4.2	0	0	4.2	2.5
Drilled	83.3	75.0	81.2	79.1	83.3	80.4
Listed	12.5	16.7	14.6	20.8	12.5	15.4
Unknown	0	4.2	4.2	0	0	1.7
Total fields observed	24	24	24	24	24	
Plants per acre						
10,000 or less	33.3	8.3	12.5	4.2	20.8	15.8
10,000 – 10,999	33.3	25.0	12.5	25.0	25.0	24.2
11,000 – 11,999	12.5	16.7	37.5	25.0	16.7	21.7
12,000 – 12,999	8.3	20.8	16.7	12.5	12.5	14.2
13,000 – 13,999	8.3	12.5	8.3	16.7	12.5	11.7
14,000 – 14,999	4.2	0	4.2	8.3	8.3	5.0
15,000 – 15,999	0	8.3	4.2	4.2	4.2	4.2
16,000 – 16,999	0	4.2	4.2	0	0	1.7
17,000 – 17,999	0	0	0	4.2	0	.8
18,000 – 18,999	0	0	0	0	0	0
19,000 – 19,999	0	4.2	0	0	0	.8
Average	10,962	12,557	12,045	12,404	11,682	11,930
Total fields observed	24	24	24	24	24	

VI F. Corn hybrids used in fields for study in Cuming County, Neb.

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Cargill 310	2.1	0	0	0	0	0.4
Cargill 384	0	0	0	0	2.1	0.4
Cargill unknown	0	0	0	4.2	2.1	1.3
Total	2.1	0	0	4.2	4.2	2.1
Conrad 111	4.2	0	0	0	0	0.8
Conrad 112	0	0	0	0	4.2	0.8
Conrad 116	0	0	0	4.2	0	0.8
Total	4.2	0	0	4.2	4.2	2.5
DeKalb 3x0	0	0	2.1	0	2.1	0.8
DeKalb 3x1	13.3	13.8	10.4	9.7	8.3	11.1
DeKalb 3x2	5.0	6.2	2.1	3.4	0	3.3
DeKalb 3x3	4.2	2.1	8.3	7.6	0	4.4
DeKalb 3x4	4.2	0	0	0	4.2	1.7
DeKalb 627	0	0	2.1	0	0	0.4
DeKalb 661	0	6.2	12.5	4.2	4.2	5.4
DeKalb unknown	4.2	6.2	0	8.3	6.2	5.0
Total	30.9	34.5	37.5	33.2	25.0	32.2
Farmers 537	0	0	2.1	0	0	0.4
Farmers hybrid	0	0	2.1	0	0	0.4
Farmers Union	0	0	0	0	4.2	0.8
Total	0	0	4.2	0	4.2	1.7
Funks G53	0	0	4.2	0	0	0.8
Funks 72	0	0	4.2	0	0	0.8
Funks 72A	0	4.2	0	0	0	0.8
Funks 75	6.2	0	0	0	0	1.2
Funks 75A	9.2	8.3	4.2	2.1	0	4.8
Funks G75	4.2	0	0	0	4.2	1.7
Funks 76	1.0	0	0	0	0	0.2
Funks G76	0	0	2.1	0	0	0.4
Funks 83	0	0	0	4.2	0	0.8
Funks 95A	0	4.2	0	0	0	0.8
Funks unknown	0	2.1	0	0	0	0.4
Total	20.6	18.8	14.7	6.3	4.2	12.9
Hagemeyer 707	0	0	0	1.0	0	0.2
Hagemeyer 717	2.1	0	0	1.0	0	0.6
Total	2.1	0	0	2.0	0	0.8
Hulting	3.4	3.4	0	0	0	1.4
KF	0	2.1	0	0	0	0.4
Moews	1.3	1.3	0	2.1	0	0.9
Moews 65	0	0	4.2	0	0	0.8
Total	1.3	1.3	4.2	2.1	0	1.8
McCurdys 944	0	0	4.2	0	0	0.8
Nebraska Certified						
NC 401	2.1	0	2.1	0	2.1	1.3
NC 440	0	0	0	4.2	0	0.8
NC 450A	0	0	4.2	0	0	0.8
NC 501	2.1	0	0	0	0	0.4
NC 501D	0	2.1	0	0	4.2	1.3
NC 504	0	2.1	0	0	0	0.4
NC 603	0	0	4.2	4.2	4.2	2.5
NC+ 72	0	0	0	0	2.1	0.4
NC+ 501	0	0	0	2.1	0	0.4
NC+ 705	0	0	0	0	4.2	0.8
NC+ 806	0	0	0	4.2	0	0.8

VI F *(Continued)*

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
NC unknown	0	2.1	0	0	2.1	0.8
Total	4.2	6.3	10.5	14.7	18.9	10.9
Northrup King K6	0	4.2	0	0	0	0.8
Northrup King KX4	4.2	0	0	0	0	0.8
Northrup King NY6	0	0	2.1	0	0	0.4
Northrup King NY623	0	0	2.1	0	0	0.4
Northrup King single cross	0	0	0	4.2	0	0.8
KT 623	0	0	0	0	4.2	0.8
Total	4.2	4.2	4.2	4.2	4.2	4.2
Jonson	4.2	0	0	0	0	0.8
Pfisters 42	0.8	0	0	0	0	0.2
Pfisters unknown	0	2.1	4.2	0	0	1.3
Total	0.8	2.1	4.2	0	0	1.4
Pioneer 314	0	0	1.3	1.0	0	0.5
Pioneer 318A	0	0	0	4.2	4.2	1.7
Pioneer 320	1.0	4.2	1.3	1.0	0	1.5
Pioneer 328	0	0	3.4	0	0	0.7
Pioneer 329	1.3	0	0	0	0	0.3
Pioneer 335	0	4.2	0	0	0	0.8
Pioneer 352	1.3	0	0	0	0	0.3
Pioneer 354	1.3	0	0	0	0	0.3
Pioneer unknown	8.3	0	0	4.2	8.3	4.2
Total	13.2	8.4	6.0	10.4	12.5	10.1
Pride 78	0	0	0	4.2	0	0.8
Pride 78A	0	2.1	0	0	0	0.4
Pride 79A	0	2.1	0	0	0	0.4
Pride 84	0	0	2.1	0	0	0.4
Pride unknown	0	0	0	0	2.1	0.4
Total	0	4.2	2.1	4.2	2.1	2.5
Shumpal single cross	0	0	0	4.2	0	0.8
Steckly GG10	0	0	4.2	0	0	0.8
Steckley unknown	2.1	1.3	0	2.1	2.1	1.5
Total	2.1	1.3	4.2	2.1	2.1	2.4
Tomco 617	4.2	0	0	0	0	0.8
Tomco unknown	1.3	0	0	0	0	0.3
Total	5.5	0	0	0	0	1.1
Tekseed 91	0	0	0	0	4.2	0.8
Tekseed 115	0.8	0	0	0	0	0.2
Tekseed unknown	0	0	0	0	2.1	0.4
Total	0.8	0	0	0	6.3	1.4
115 day corn	0	0	0	4.2	0	0.8
115 day yellow dent hybrid	0	0	0	0	4.2	0.8
Unknown	0	12.5	4.2	4.2	8.3	5.8
Total number fields observed	24	24	24	24	24	

APPENDIX VII

VII A. Weather conditions at Grand Island, Hall County, Neb., during growing season.

Month	1960	1961	1962	1963	1964
	Average temperature for the month (° F.)				
May	59.7	57.7	66.9	60.2	66.6
June	68.3	71.5	69.4	74.1	70.8
July	74.0	76.9	71.9	77.7	79.4
August	73.8	75.4	73.2	73.5	69.5
	Total rainfall for the month (inches)				
May	4.07	7.49	3.43	3.28	0.43
June	3.87	4.01	2.75	3.22	4.50
July	3.16	4.76	8.78	2.18	3.00
August	2.60	1.33	1.65	3.06	3.44
	Borer degree–day accumulations				
April 15	45.0	13.5	15.5	129.0	45.5
May 1	166.5	84.5	151.0	179.0	135.0
May 15	264.0	177.5	427.5	387.5	329.0
June 1	486.5	359.5	675.0	524.5	645.0
June 15	721.5	640.0	898.5	842.5	889.0
July 1	1032.5	1010.0	1273.0	1259.5	1298.0
July 15	1356.0	1368.0	1621.0	1640.5	1683.0
Aug. 1	1787.5	1842.0	1949.5	2117.0	2217.0
Aug. 15	2128.0	2205.5	2287.5	2462.0	2534.5
Sept. 1	2528.0	2627.0	2662.5	2823.5	2811.0

VII B. Weather conditions at Grand Island, Hall County, Neb.; deviations from long-term normal.

Month	1960	1961	1962	1963	1964
	Monthly temperatures				
May	–1.4	–3.4	4.8	–1.9	6.0
June	–3.3	–0.1	–3.1	1.6	–0.2
July	–4.9	–2.0	–6.8	–1.0	2.2
August	–2.4	–0.8	–3.6	–3.3	–5.8
	Monthly rainfall				
May	0.20	3.62	–0.42	–0.57	–3.42
June	0.21	0.35	–1.04	–0.57	0.71
July	0.53	2.13	6.27	–0.33	0.49
August	0.21	–1.06	–0.70	0.71	1.09

VII C. Previous year's crop in fields used in Hall County, Neb.

Previous crop	Percent of fields					
	1960	1961	1962	1963	1964	Average
Corn	92.0	84.0	88.0	83.3	100.0	89.5
Sorghum	4.0	8.0	4.0	4.2	0	4.0
Soybeans	4.0	4.0	8.0	0	0	3.2
Pasture	0	0	0	4.2	0	0.8
Soil bank	0	0	0	8.3	0	1.7
Unknown	0	4.0	0	0	0	0.8
Total number fields checked	25	25	25	24	24	

VII D. Use of fertilizer in fields used in Hall County, Neb.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Commercial fertilizer	96.0	100.0	100.0	100.0	100.0	99.2
Trace elements	4.0	4.0	8.0	17.0	17.0	10.0
Manure	4.0	0	0	0	0	0.8
None	0	0	0	0	0	0
Total number fields checked	25	25	25	24	24	

VII E. Planting methods and plant populations in fields used in Hall County, Neb.

	Percent of fields					
	1960	1961	1962	1963	1964	Average
Type of planting						
Checked	0	0	0	0	0	0
Hill drop	8.0	4.0	0	0	0	2.4
Drilled	48.0	48.0	44.0	33.3	29.2	40.5
Listed	44.0	44.0	52.0	66.7	70.8	55.5
Unknown	0	4.0	4.0	0	0	1.6
Total fields observed	25	25	25	24	24	
Plants per acre						
10,000 or less	12.0	4.0	4.0	4.2	4.2	5.7
10,000 – 10,999	0	0	4.0	0	0	.8
11,000 – 11,999	16.0	0	4.0	4.2	8.3	6.5
12,000 – 12,999	8.0	16.0	8.0	12.5	20.8	13.1
13,000 – 13,999	8.0	20.0	20.0	16.7	20.8	17.1
14,000 – 14,999	20.0	12.0	20.0	16.7	16.7	17.1
15,000 – 15,999	16.0	8.0	4.0	8.3	8.3	8.9
16,000 – 16,999	16.0	20.0	8.0	12.5	12.5	13.8
17,000 – 17,999	0	0	20.0	8.3	8.3	7.3
18,000 – 18,999	4.0	8.0	8.0	12.5	0	6.5
19,000 – 19,999	0	8.0	0	0	0	1.6
20,000 – 20,999	0	4.0	0	4.2	0	1.6
Average	14,026	15,345	14,945	15,165	13,903	14,677
Total fields observed	25	25	25	24	24	

VII F. Corn hybrids used in fields for study in Hall County, Neb.

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Cargill 330	0	0	1.0	0	0	0.2
Cargill 340	0	0	1.0	0	4.2	1.0
Total	0	0	2.0	0	4.2	1.2
DeKalb 3x0	2.0	2.0	0	0	0	0.8
DeKalb 3x1	23.4	21.3	24.0	16.7	20.8	21.2
DeKalb 3x2	5.4	0	6.0	0	4.2	3.1
DeKalb 3x2A	0	0	4.0	0	0	0.8
DeKalb 3x4	4.0	0	0	0	0	0.8
DeKalb 4x1	0	4.0	0	0	0	0.8
DeKalb XL50	0	0	2.0	0	0	0.4
DeKalb XL361	0	0	0	2.1	0	0.4
DeKalb 661	0	0	0	6.2	0	1.2
DeKalb 847	4.0	0	0	0	0	0.8
DeKalb unknown	4.0	4.0	0	4.2	0	2.4
Total	42.8	31.3	36.0	29.2	25.0	32.9
Farmer's Hybrid 4	0	4.0	1.3	0	0	1.1
Farmer's Hybrid 426XL	0	0	0	0	4.2	0.8
Farmer's Hybrid 488	0	0	1.3	0	0	0.3
Farmer's Hybrid 511	0	0	2.0	0	0	0.4
Farmer's Hybrid 537	0	0	3.3	0	0	0.7
Farmers Hybrid unknown	4.0	0	0	4.2	0	1.6
Total	4.0	4.0	7.9	4.2	4.2	4.9
Funks 75A	4.0	4.0	6.0	0	4.2	3.6
Funks 76	2.0	0	0	0	0	0.4
Funks 83	0	0	2.0	0	0	0.4
Funks G83	0	2.0	0	0	0	0.4
Funks 93	0	0	0	4.2	0	0.8
Funks G93	0	0	0	4.2	4.2	1.7
Funks G95	4.0	0	0	0	0	0.8
Funks 144	10.0	0	0	0	0	2.0
Funks G144	0	2.0	0	0	0	0.4
Funks single cross 4401	0	0	0	0	4.2	0.8
Funks unknown	0	1.3	0	4.2	0	1.1
Funks 711AA	0	4.0	0	0	0	0.8
Total	20.0	13.3	8.0	12.6	12.6	13.3
Links 48	0	0	1.0	2.1	0	0.6
Links 52	0	0	1.0	2.1	0	0.6
Total	0	0	2.0	4.2	0	1.2
Maygold 67	0	4.0	4.0	0	0	1.6
Maygold 68A	0	0	0	4.2	0	0.8
Maygold unknown	0	0	0	0	2.1	0.4
Total	0	4.0	4.0	4.2	2.1	2.8
Nebraska Certified						
NC ser p55	0	0	1.0	0	0	0.2
NC 70	0	0	1.0	0	0	0.2
NC 501D	6.0	6.0	1.0	2.1	0	3.0
NC+ 501D	0	0	0	4.2	1.3	1.1
NC 705	0	0	0	0	1.3	0.3
NC+ 705	0	0	0	0	4.2	0.8
NC 806	2.0	2.0	1.0	0	1.3	1.3
NC+ 806	0	0	0	2.1	0	0.4
Total	8.0	8.0	4.0	8.4	8.1	7.3
NK 649	0	0	0	4.2	0	0.8
Pfisters 386	0	0	0	0	4.2	0.8

VII F *(Continued)*

Hybrid	Percent of fields					
	1960	1961	1962	1963	1964	Average
Pioneer 314	0	2.0	0	0	4.2	1.2
Pioneer 318	0	2.0	0	4.2	0	1.2
Pioneer 318A	0	4.0	4.0	0	8.3	3.3
Pioneer 320	0	2.0	2.0	8.3	0	2.5
Pioneer 328	0	0	0	2.1	0	0.4
Pioneer unknown	0	4.0	0	4.2	12.5	4.1
Total	0	14.0	6.0	18.8	25.0	12.8
Prairie Valley AAA	1.4	0	0	0	0	0.3
Prairie Valley unknown	0	0	0	0	2.1	0.4
Total	1.4	0	0	0	2.1	0.7
Steckly 12	8.0	0	0	0	0	1.6
Steckly GG12	0	4.0	0	4.2	0	1.6
Steckly unknown	0	0	0	4.2	4.2	1.7
Total	8.0	4.0	0	8.4	4.2	4.9
Tekseed 73	0	0	4.0	0	0	0.8
Tekseed 81A	4.0	0	2.0	0	0	1.2
Tekseed 93TS	0	0	0	0	4.2	0.8
Tekseed 115A	0	0	2.0	0	0	0.4
Tekseed unknown	0	5.3	2.0	2.1	0	1.9
Total	4.0	5.3	10.0	2.1	4.2	5.1
Tomco 812	0	0	4.0	0	0	0.8
Tomco unknown	4.0	4.0	0	0	4.2	2.4
Total	4.0	4.0	4.0	0	4.2	3.2
Tomahawk 78	0	0	4.0	0	0	0.8
Tomahawk 617	2.0	0	0	0	0	0.4
Tomahawk 812	2.0	0	0	0	0	0.4
Total	4.0	0	4.0	0	0	1.6
Unknown	4.0	12.0	12.0	4.2	0	6.4
Total number fields observed	25	25	25	24	24	

APPENDIX VIII

VIII A. Weather conditions in Van Wert County, Ohio during growing season.

Month	1960	1961	1962	1963
Average temperature for the month (° F.)				
April	53.3	45.4	49.8	51.9
May	58.2	56.7	67.0	58.8
June	67.7	67.7	70.2	71.2
July	70.9	72.7	70.9	74.2
August	72.9	71.2	71.5	69.8
September	68.4	69.3	62.9	64.2
October	54.1	55.6	56.3	62.4
Total rainfall for the month (inches)				
April	2.25	6.45	0.95	3.45
May	4.49	2.03	3.85	2.55
June	3.07	3.07	3.98	1.75
July	2.60	6.15	2.47	4.16
August	1.92	2.70	2.69	1.74
September	0.70	3.37	2.14	1.41
October	1.93	1.66	2.09	0.01

VIII B. Weather conditions in Van Wert County, Ohio; deviations from long-term normal.

Month	1960	1961	1962	1963
Monthly temperatures				
April	3.5	–4.4	–0.1	2.0
May	–2.7	–4.2	6.1	–2.1
June	–3.5	–3.5	–0.5	0.5
July	–4.1	–2.3	–3.6	–0.3
August	0.1	–1.6	–1.3	–3.0
September	2.4	3.3	–3.1	–1.8
October	–0.8	0.7	1.5	7.6
Monthly rainfall				
April	–1.20	3.00	–2.64	–0.14
May	0.44	–2.02	–0.21	–1.51
June	–1.12	–1.12	–0.35	–2.58
July	–0.87	2.68	–1.06	0.63
August	–0.68	0.10	0.18	–0.77
September	–2.37	0.30	–0.81	–1.54
October	–1.01	–1.28	–0.74	–2.82

VIII C. Fertilizer treatments in fields used in Van Wert County, Ohio.

Application	Percent of fields				
	1960	1961	1962	1963	Average
N.P.K. combinations[a]	100.0	100.0	100.0	100.0	100.0
Ammonium nitrate[b]	41.7	70.8	79.2	66.7	64.6
Manure	–	–	–	4.2	1.0
	Pounds per acre				
N.P.K.	267.1	242.3	239.8	262.8	
Nitrogen (actual)[c]	82.1	79.0	76.2	83.2	
Total number fields observed	24	24	24	24	

[a] N.P.K. combinations included the following:

0–20–0	7–28–14	12–12–12	18–46–0
3–12–12	8–16–16	13–13–13	
4–16–16	8–24–12	14–14–14	
5–20–20	8–32–16	15–10–0	
6–18–6	10–10–10	16–40–6	
6–24–12	10–40–8	16–8–8	

[b] Always in combination with other fertilizer applications.
[c] Rate calculated for fields treated.

VIII D. Crop history in fields used in Van Wert County, Ohio.

Type of rotation	Percent of fields				
	1960	1961	1962	1963	Average
Continuous corn					
Two years	4.2	8.3	75.0	45.8	33.3
Three years	4.2	0	0	12.5	4.2
Four years	0	0	0	4.2	1.0
Two-crop rotation					
Corn–soybeans	12.5	4.2	4.2	4.2	6.2
Corn–small grain	0	0	0	4.2	1.0
Corn–legume	0	4.2	0	0	1.0
Three-crop rotation					
Corn–soybeans–small grain	20.8	33.3	0	4.2	14.6
Corn–soybeans–legume	0	8.3	0	4.2	3.1
Corn–small grain–legume	0	4.2	4.2	0	2.1
Corn–small grain–soybeans	0	0	0	8.3	2.1
Four-crop rotation					
Corn–soybeans–small grain–grass	0	0	0	4.2	1.0
Corn–soybeans–small grain–soybeans	0	0	4.2	0	1.0
Corn–soybeans–small grain–legume	41.7	29.2	0	8.3	19.8
Corn–soybeans–small grain–small grain	0	4.2	0	0	1.0
Corn–soybeans–legume–small grain	4.2	0	0	0	1.0
Corn–small grain–soybeans–small grain	4.2	0	0	0	1.0
Corn–small grain–soybeans–soybeans	0	0	4.2	0	1.0
Corn–small grain–small grain–legume	0	0	4.2	0	1.0
Corn–small grain–legume–soybeans	4.2	4.2	0	0	2.1
Corn–legume–legume–beets	4.2	0	0	0	1.0
Corn–legume–small grain–soybeans	0	0	4.2	0	1.0
Number of fields observed	24	24	24	24	

VIII E. Planting methods and plant populations in fields used in Van Wert County, Ohio.

	Percent of fields				
	1960	1961	1962	1963	Average
Type of planting:					
Drilled	100	100	100	100	100
Plants per acre:					
10,000 or less	0	4.2	0	4.2	2.1
11,000	4.2	0	0	0	1.0
12,000	12.5	8.3	0	12.5	8.3
13,000	4.2	8.3	12.5	12.5	9.4
14,000	20.8	12.5	16.7	12.5	15.6
15,000	0	20.8	16.7	16.7	13.5
16,000	12.5	8.3	8.3	0	7.3
17,000	25.0	4.2	12.5	20.8	15.6
18,000	8.3	16.7	16.7	8.3	12.5
19,000	4.2	12.5	8.3	8.3	8.3
20,000	4.2	4.2	0	–	2.8
21,000 or more	4.2	–	8.3	4.2	5.6
Average	15,646	15,493	16,333	15,236	
Total fields observed	24	24	24	24	

VIII F. Corn hybrids used in fields for study in Van Wert County, Ohio.

Hybrid	Percent of fields				
	1960	1961	1962	1963	Average
Experiment Station and U. S. Hybrids					
Indiana 608	4.2	4.2	4.2	0	3.1
Indiana 620	29.2	16.7	4.2	0	12.5
Indiana 621	8.3	0	0	0	2.1
Indiana 458	0	4.2	0	0	1.0
Ohio C54	12.5	8.3	4.2	4.2	7.3
AES 805	4.2	0	8.3	0	3.1
Total	58.3	33.3	20.8	4.2	29.2
DeKalb 441	0	4.2	0	4.2	2.1
DeKalb 444	4.2	0	0	0	1.0
Total	4.2	4.2	0	4.2	3.1
Pioneer 323	0	0	4.2	0	1.0
Pioneer 342	0	4.2	0	0	1.0
Pioneer 354	4.2	0	0	0	1.0
Pioneer 371	0	4.2	4.2	16.7	5.2
Pioneer 373	0	0	0	4.2	1.0
Total	4.2	8.3	8.3	20.8	10.4
Pfister SX9	0	0	0	4.2	1.0
Pfister 28S	0	0	0	4.2	1.0
Pfister 346	4.2	0	0	0	1.0
Pfister 444	0	4.2	0	0	1.0
Pfister 555	4.2	4.2	0	0	2.1
Total	8.3	8.3	0	8.3	6.2
Funks G72	0	0	0	4.2	1.0
Funks G76	4.2	0	0	0	1.0
Funks G983	0	0	4.2	0	1.0
Funks G94	0	0	0	4.2	1.0
Funks G96	0	0	4.2	4.2	2.1
Funks 214	0	0	4.2	0	1.0
Total	4.2	0	12.5	12.5	7.3
Parker Single Cross	0	4.2	4.2	0	2.1
Parker 49	0	0	0	4.2	1.0
Parker 425	4.2	0	0	0	1.0
Parker 620	0	0	12.5	8.3	5.2
Total	4.2	4.2	16.7	12.5	9.4
Marsh 643	0	0	0	4.2	1.0
Marsh 673	0	0	8.3	12.5	5.2
Marsh 863	0	0	0	4.2	1.0
Marsh 864	0	0	4.2	0	1.0
Total	0	0	12.5	20.8	8.3
Tieman 62	0	4.2	0	0	1.0
Tieman 68	0	0	0	4.2	1.0
Tieman 78	4.2	0	4.2	0	2.1
Total	4.2	4.2	4.2	4.2	4.2
Moews 500A	0	4.2	0	0	1.0
Moews 535	4.2	0	0	0	1.0
Total	4.2	4.2	0	0	2.1
Lowe 505	0	4.2	0	0	1.0
Lowe 511	0	0	4.2	4.2	2.1
Total	0	4.2	4.2	4.2	3.1
Cargill (unknown)	0	0	4.2	0	1.0
Cargill 285	0	0	0	4.2	1.0
Total	0	0	4.2	4.2	2.1

VIII F *(Continued)*

Hybrid	Percent of fields				
	1960	1961	1962	1963	Average
Bayles single cross	0	4.2	4.2	0	2.1
Good's G62A	4.2	8.3	0	0	3.1
Northrup King (unknown)	0	4.2	0	0	1.0
Northrup King KT6	4.2	0	0	0	1.0
Total	4.2	4.2	0	0	2.1
Mitchell C570	0	0	0	8.3	2.1
Crowe 658	0	4.2	0	0	1.0
Hultings (unknown)	0	4.2	0	0	1.0
Waybright 659	0	4.2	0	0	1.0
Hancock 49	0	0	4.2	0	1.0
Golden Golieth (unknown)	0	0	4.2	0	1.0
Crib Filler 66	0	0	4.2	0	1.0
Greenleaf (unknown)	0	0	4.2	0	1.0
Unknown	0	4.2	0	0	1.0
Total number fields observed	24	24	24	24	
Total number of hybrids	15	20	21	18	