ECOLOGICAL STUDIES OF EUROPEAN CORN BORER POPULATIONS IN BOONE COUNTY, IOWA

by

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TABLE OF CONTENTS

INTRODUCTION

The European corn borer (*Pyrausta nubilalis* (Hbn.)) the world's worst pest of corn was introduced into the United States sometime during the period of from 1909 to 1914. The means by which this pest gained entrance into this country is not known, but it is speculated that it was introduced in broom corn imported from Central or Southern Europe.

Since the identification of this insect in 1917 (Vinal 1917) in the vicinity of Boston, Massachusetts, the corn borer has spread northward, westward, and southward to become established in 36 of the 48 states and in more than one-half of this nation's counties.

The westward spread of the corn borer has been recorded in the literature, with Ohio reporting infestations in 1921, Illinois in 1926, and Iowa in 1942. Iowa began the fight to combat the corn borer in 1926 with parasite releases (Blickenstaff *et al.* 1953).

The purpose of this investigation has been to record the seasonal and annual populations of the European corn borer as they occur under field conditions in Boone County, Iowa. It was further desired to evaluate the various environmental conditions that influence the corn borer populations in this study area.

Boone County was selected for this investigation on the basis of its proximity to the facilities available at both the European Corn Borer Research Laboratory at Ankeny, Iowa and Iowa State College, located at Ames, Iowa. Agencies that have cooperated in the operation of this investigation are the Iowa Agricultural Experiment Station, and Cereal and

Forage Insects Section, Entomology Research Division of the United States Department of Agriculture, and the Iowa State Extension Service.

REVIEW OF LITERATURE

Historical

The European corn borer (Pyrausta nubilalis (Hbn.)) a world-wide pest of corn was first discovered in the United States in the summer of 1917. Vinal (1917) found this insect infesting sweet corn in the vicinity of Boston, Massachusetts, and reported that the corn borer had been causing severe losses in plantings of sweet corn in this vicinity for three or four years. Although the date of the entry of this pest is not known, Vinal speculated that entrance was gained during the 1910 season, in importations of either broom corn or raw hemp from Central Europe. Caffrey (1919) foresaw in this pest a potential threat to the corn industry of the United States and expressed the need for measures to contain and control the corn borer before it could spread to the major corn producing areas of this nation. Both Caffrey and Vinal state that in spite of the seriousness of the damage done by this insect to corn and its relatives in Europe, little mention of control measures in use was found in European literature.

Thompson and Parker (1928) reported on work initiated by the United States Department of Agriculture to study the abundance, distribution, biology, parasites, control measures, and importance of this insect to both foreign and domestic corn crops. These investigations began in 1919 and continued until 1928. It was determined that the corn borer had in certain seasons destroyed from one-fourth to one-half of the corn and hemp crops in Central Europe. It was noted that it was the most important single pest of corn, hops, millet, hemp, and wild grasses on the continent. Thompson and Parker (1928) summarized meteorological factors and their effect on the corn borer in Europe as well as those control measures that had been in practice.

With the recognition of this pest in the United States, an extensive research program was initiated which resulted in many publications. Wade (1925) compiled a bibliography of publications available until June 1 of that year. A progress report presented by Caffrey and Worthley (1927) covered investigations made from 1918 through 1924 by the United States Department of Agriculture. Clark (1934) discussed the distribution and biology of the corn borer as related to its control in the Orient during the years from 1928 through 1932.

Davis (1935) summarized the events and procedures as related to control that have been maintained in the United States since the introduction of the corn borer and suggested areas for future investigation. Of first importance according to Davis, were investigations on biology.

Abundance and Distribution

An historical account of the distribution of the corn borer from its introduction into the United States until 1927 is presented by Caffrey and Worthley (1927). Included in their account is a summary of the control and quarantine measures adopted in an attempt to limit the spread of the infestation. Several workers including Worthley and Caffrey (1927b), Baker and Vance (1938), and Beck (1949a) record the annual spread of the corn borer from the time when it was first recorded until 1948, in reports issued by the Bureau of Entomology and Plant Quarantine.

Beck (1949a), (1949b) defines the area of corn borer infestation, including all counties in the United States that have reported infestation as well as estimates of the total damage as bushels of corn and actual dollar value through 1948. A situation report issued by the Agricultural Research Service of the United States Department of Agriculture (1955) revises distribution reports until the fall of 1954 as well as damage in dollar value for the 1954 season.

Temperature and Moisture

Temperature wa s reported by Barber (1924) in a study conducted in the New England area, not to be a single criterion whereby winter mortality could be explained, although Barber (1924) found temperature to directly influence the percent of survival. Stirrett (1930) postulated that the environmental temperature in relation to the amount of available moisture was the determining factor for corn borer winter mortality. In an attempt to correlate environmental conditions with the dormancy of the corn borer Babcock (1927a) found that abundant contact moisture influenced the preparation of the corn borer larvae for dormancy if the temperature was maintained at a constant level. Tauber and Bruce (1945) found the longevity of the corn borer larvae to be directly proportional to the relative humidity and inversely proportional to the temperature. The lowest maximum temperature that will kill mature larvae of the corn borer was found by Barber (1929) to be 66° C. This temperature would kill larvae of the corn borer in corn plant residue, but only with an exposure of at least several hours. The highest minimum temperature that will kill exposed larvae of the corn borer was reported to be minus 32° F. (Stirrett 1930).

When humidity was considered alone Caffrey and Worthley (1927) found that a low relative moisture content of the air tends to increase the threshold of development of larvae and at the same time depress the maximum rate of development. Vance (1949) states that moisture is an absolute necessity for larval pupation and that pupal mortality increases with a decrease in relative humidity.

Heavy rains were found by Caesar (1925) to wash off newly hatched larvae of the corn borer, and that larvae that were removed in this manner did not return to the corn plants. The presence of water in the whorl of the corn plants was reported by Painter and Fitch (1925) as sufficient to drown immature larvae that were feeding in that area.

Barber (1925a) reported on studies to determine the longevity and egg production of moths. He found that temperatures below 60° F. gave marked reductions in egg production, however, when temperatures were raised to above 70° F. moth longevity was reduced 50 percent. In additional work Barber (1926) reported maximum egg deposition at temperatures of from 66° to 68° F. He further states that wet weather tends to reduce the number of eggs deposited while hot dry weather will reduce the percentage of egg hatch. A constant supply of available moisture with cool temperatures was thought by Caesar (1926) to permit maximum moth life. Bottger and Kent (1931) reported female moths to live approximately one day longer than do the male moths. The female moths live an average of 13 days and male moths an average of 12 days. They further reported that light rain has little effect on the flight of the moths, but as the intensity of the rain increases the moths will tend to seek shelter. The activity of the moths was found by Stirrett (1938) to be the greatest when the temperatures were in the range of from 60° to 76° F. Huber (1941) found the temperature range at which the moths were the most active as 65° to 70° F. Vance (1949) states that corn borer populations increase during years with abundant moisture and with the absence of extremes in temperature.

The influence of climatic conditions on egg production has been investigated by Barber (1925a) who reported that the low temperatures do reduce the number of eggs that are produced by the individual moths and also (Barber 1926) egg production will fall off during periods of cool, wet, rainy weather. He states further that extremes of dry weather will cause the eggs to fail to hatch, and tend to remove the egg masses from the leaves of the corn plant by the alternate expansion and contraction of the corn leaves. Stirrett (1938) does not agree with the above opinions and states that the relationship between the relative humidity and temperature and the number of eggs laid is not true and further that these factors do not influence the hatchability of the corn borer eggs. Moisture in the absence of excessive heat is reported by Vance (1949) to favor the development of corn borer eggs.

The Corn Plant in Relation to the Corn Borer Populations

The corn borer as influenced by the particular growth stage of the corn plant was noted by Caffrey and Worthley (1927) when they observed that in areas that were infested with a two-generation strain of the corn borer, the earliest planted corn tended to receive the heaviest first generation oviposition, while the latest planted corn received the heaviest oviposition of the second generation. Huber et al. (1928) with a single generation observed that regardless of the planting date of the crop the silking date of a particular planting is correlated with the number of egg masses deposited on that planting. The apparent selective attraction that various plantings of corn exhibit is due to rapid proliferation of new tissue by the corn plant, according to Huber et al. They further state that egg deposition varies directly with the growth of the corn plants and the moths do not necessarily select the plants that are the most suited for corn borer larval establishment.

Kelsheimer and Polivka (1931) found that larval survival was correlated with planting date as well as silking date. Caffrey and Huber (1928) recommended that sweet corn planting be delayed to avoid heavy oviposition and Marston and Dibble (1930) agree in stating that late planting of sweet corn tends to reduce its attractiveness for oviposition. The loss in yield and market value of the crop prevent Marston and Dibble from making the late planting recommendation. They suggest early planting with early harvest in an attempt to salvage the crop before the corn borer takes its toll. Fitch (1931) further investigated the influence of planting date of sweet corn and concluded that late planted corn attracts fewer ovipositing moths and also that the density of the stand has a proportional influence on the rate of oviposition. Weekman (1956) failed to find a significant difference in corn borer populations using stand density as a basis for comparison. There were, however, significant differences in first generation corn borer populations using planting date as a comparison. In this same study second generation populations were not significantly influenced by planting date.

The height of the corn plant or a related factor that is correlated with corn plant height is the predominant factor that influences the rate of oviposition as reported by Patch (1929). Goleman (1954) stated that the height of the corn plants is positively correlated with the number of eggs deposited on given corn plantings. Early planted corn acting as a trap crop for the corn borer where that trap corn is planted in close proximity to plantings to be protected was reported by Fitch (1936).

Air Movement

The influence of air movement has been investigated by several workers. Among them Caffrey and Worthley (1927) found that light winds act as a orientation medium with the moths of both sexes flying into the wind. As the wind velocity increases and the moths attain greater altitude the moths are carried with the wind. Strong winds as reported by Huber et al. (1928) tend to cause the moths to seek shelter and hence reduce their activity. Stirrett (1938), however, found no correlation between the wind action up to 17 miles per hour and the flight of the corn borer moths.

Huber *et al*. (1928) stated that larval dispersion is affected by winds which cause the corn leaves to move. This action of the leaves stimulates the newly hatched larvae to spin down from the leaves, and they are in turn carried by the wind to nearby plants in the same field.

Nature of the Corn Borer Population

The characteristic corn borer population as noted by Babcock (1927b) in the New England area was bivoltine in nature. This multivoltine population remained constant in that area throughout the early years of the infestation. In southern Ontario where the corn borer spread soon after its introduction into the Western Hemisphere Stirrett (1934) noted only a single generation, the moths of which oviposited only in the early summer of each year. A change in the corn borer population from one of univoltine character to bivoltine character was noted by Bottger and Kent (1931) and Vance (1939) in Michigan, northern Ohio, and the northern Indiana region. Later Vance (1942) reported the corn borer populations of the North Central States to be univoltine in nature, although there seemed to be a tendency for a second generation to develop. The conclusion was reached by Bottger and Kent (1931) and later by Vance (1939) that any corn borer population was constituted of two strains of corn borers, one strain with a tendency for univoltine character and a second for bivoltine character. Further investigation along this line by Arbuthnot (1949) led to the conclusion that there were two distinct strains of corn borers in existence in any population. The incidence of either of these strains was then controlled by the climatic factors which would favor either of the strains in their development during a climatic period. In this work, Iowa is defined as an area in which the corn borer population is almost equally divided between either of the two strains.

Predators and Parasites

Studies on the parasite fauna in European areas in which the corn borer is prevalent led Thompson and Parker (1928) to conclude that the borer control exhibited in Europe was not due to any single parasite species or to a series of parasites which would attack the corn borer in the sequence of its life cycle. These authors considered a combination of all environmental factors as the controlling influence and, therefore, did not appear to be too optimistic for corn borer control in the United States by introduction of foreign parasites. Babcock and Vance (1929) reported on comprehensive observations of the parasite fauna in Central Europe. Similar studies were conducted in the Orient by Clark (1934). He concluded that crop practices throughout the Orient were instrumental in controlling the borer. Clark, however, collected and shipped all parasites that he observed to the United States for rearing and further evaluation.

Jones (1929) reported on the establishment of these parasites in the United States and Baker et al. (1949) summarized parasite importation and establishment between the years 1919 and 1940. They state that 26 million corn borer larvae and associated forms have been imported in an attempt to rear and colonize parasites from both Europe and the Orient. From this total of borers some six and one-half million parasites were released. Those species which are known to be established are: Horogenes punctorius (Roman), Macrocentrus gifuensis Ashm., Symplesis viridula Thoms., Chelonus annulipes Wesm., Phaeogenes nigridens Wesm., and Lydella grisescens R.D.

Extensive parasite releases have been carried out in Iowa and are recorded in the Iowa Yearbook of Agriculture, Drake et al. (1944), Drake (1945),(1946), and Harris (1947),(1948) and (1949). Blickenstaff et al. (1953) state that Macrocentrus gifuensis and Lydella grisescens were available for release in Iowa in colonies of 2,000 and 500 adults, respectively. From these records it is known that the only parasite actually released in Boone County was Macrocentrus gifuensis although various native species have been recovered in the county. Goleman (1954) reported that Lydella grisescens was the most numerous of the parasites observed in Boone County from 1950 through 1953.

Predators were reported by Baker et al. (1949) to be damaging 17.8 percent of all eggs deposited near Toledo, Ohio in 1938. Goleman (1954) found that 5 percent of all eggs deposited in Boone County in the years 1950 through 1953 were damaged by predators, the most common being larvae of coccinellids. Baker et al. reported that the coccinellid Ceratomegilla fuscilabris (Muls.) was responsible for 50 percent of the egg damage in their study in Ohio. Macoy (1951 found that Glischrochilus quadrisignatus quadrisignatus (Say), attacked injured larvae of the corn borer and that it could effect some population reduction by this means.

Froeschner (1950) in a field study of the effectiveness of various predators in reducing corn borer egg numbers found *Orius insidiosus* (Say), *Podisus maculiventris* (Say), *Lebia acriventris* (Say), and larvae of *Chrysopa plorobunda* Fitch acting as predators. Froeschner points out that more effective of these predators are *Chrysopa plorobunda* and *Orius insidiosus*.

Birds in the act of feeding upon overwintering larvae of the corn borer were noted by Caffrey (1919), and although these animals did effect a population reduction in areas where they were active they could not be depended upon for effective population reduction. In New England Caffrey and Worthley (1927) reported local reductions in corn borer larvae as the result of bird action to be near 95 percent, but this removal did not affect the over-all population in a large area. Barber (1925b) reports starlings, downy woodpeckers, grackles, and blackbirds in general removed up to 84 percent of the corn borer larvae in localized areas in New England.

The downy woodpecker *Dryobates pubescens medianus* (Swainson) and the red-wing blackbird *Agelaius phoeniceus phoeniceus* are reported by Baker *et al*. (1949) to be the most important of nine species of birds which removed 30 percent of the corn borer larvae in 20 fields studied. Weekman (1956) found 31 percent reduction in larval numbers in plants that were exposed to downy woodpecker action, a figure which was twice as high as that observed by Bigger and Petty (1953).

Zimmack (1956) reported the protozoan *Perezia pyraustae* (Paillot) reduced egg production in corn borer moths reared under laboratory conditions. The fungus *Beauveria bassiana* (Bals.) was reported by Clark (1934) as the only disease agent known to kill corn borer larvae under field conditions.

METHODS AND PROCEDURE

Description of the Study Area

Boone County is located in Central Iowa, almost in the center of the state, convenient to both Iowa State College and the corn borer laboratory at Ankeny. This study is a continuation and evaluation of a project originated in 1950 and continued with uniform methods through seven seasons.

Boone County lies entirely in the Wisconsin drift soil area and hence its soils are primarily of glacial origin. The soils in Boone County have been classified in 17 different groups by the Iowa Agricultural Experiment Station. Of the total area, 93.3 percent is covered by drift soils, 1.9 percent by terrace soils, and 4.8 percent is swamp and bottom land soils. Clarion type soils occupy 61.0 percent, Webster soils 27.4 percent, and Hayden or Ames soils 4.9 percent of the total area.

The type of agriculture practiced in the county is mainly cash grain farming. There is some general farming, and livestock is present on most of the farms. Based on acreages taken from the Iowa Year Book of Agriculture for 1949, the farm crops grown in the area in the order of their importance are as follows: corn, oats, pasture, soybeans, and hay. Corn is the most important crop, occupying 39.8 percent of the total land in farms, and having the greatest monetary value.

The topography of the greater part of Boone County is level to gently rolling. Flat poorly drained areas, with small low knolls rising occasionally within them, are a common occurrence in some parts of the county.

The Des Moines River flows through the center of the county from north to south, and the topography on either side varies from gently rolling to rough and broken. The steeper areas extend from one to three miles back into the surrounding country on either side of the river following the channels of the tributary streams.

The general slope of the county is toward the south and drainage flows in that direction. The Des Moines River with its tributaries affords most of the drainage of the county. The tributary streams occupy broad shallow areas and often have poorly defined channels. As these streams approach the Des Moines River Valley their channels become deeper and narrower and the topography rougher. Along the river itself the valley floor is 130 to 250 feet below the level of the prairie upland.

The drainage in Boone County is rather poor except in the areas adjacent to the Des Moines River, Squaw Creek, and Beaver Creek. In many cases tiling is necessary to make the soils satisfactorily productive.

Location of the Study Fields in Boone County

The Boone County study area includes the entire area of Boone County of 576 square miles. Within this area 32 fields were selected in a restricted random fashion, two fields from each of 16 equal areas within the county. Each of the 16 areas contains 36 square-mile sections. Two of these sections were selected at random from each area. The observation fields were then located randomly in one of four quarter sections in each of the sections previously determined. The only restriction placed on this method was that the chosen field must be accessible from an all-weather road. In Boone County only a very few quarter sections are not adjacent to all-weather roads. Those sections that are not accessible are in the Des Moines River Valley.

The fields were marked in all years by aluminum tags that were suspended from the fences along the most accessible side of the field. Figure 1 shows the arrangement of the fields for the three years 1954 through 1956. With some exceptions, due to crop rotation, the same fields were used in the successive years of the study.

Field Histories

The farm operators of the selected fields were contacted and pertinent information concerning general field practices was obtained. Data were obtained on the following: planting date, corn variety, previous year's crop, type and amount of fertilizer used, size of the field, and method of planting.

This information as well as a small detail map of the field showing field characteristics was included in a booklet kept for each field. This enabled the observer to have at his command a complete history of the sample unit within each field under study. Figures 2, 3, 4, and 5 represent the forms that were used in the collection of raw data in the Boone County study. (Figures 2 and 3 represent the front and reverse of the field history form for each field.) Oviposition and predator records as well as plant height were kept on one form represented in figures 4 and 5. A similar form was included in the booklet for each plant being observed.

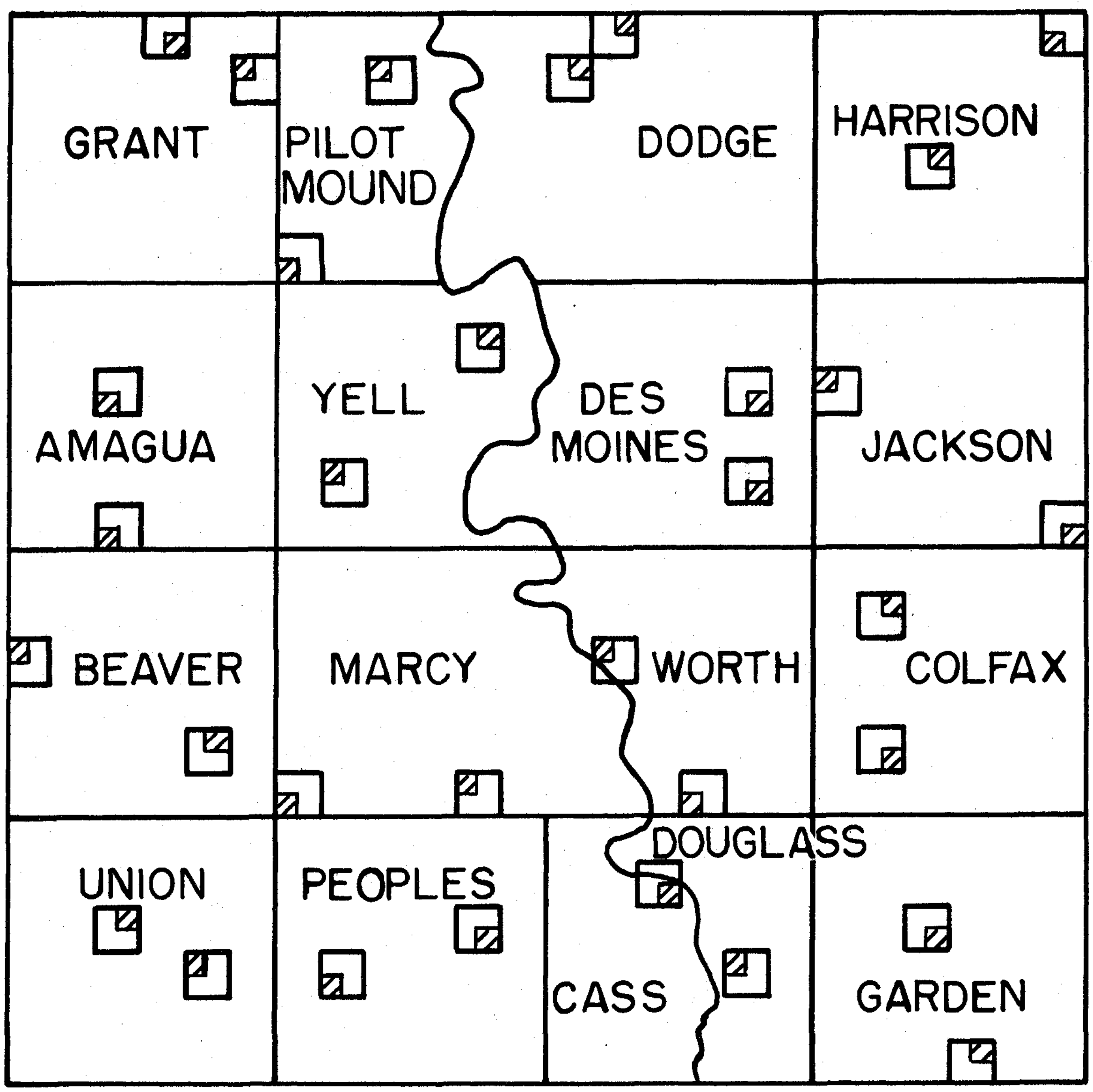


Figure 1. Location and arrangement of the observation fields 1954 through 1956.

BOONE COUNTY STUDY AREA __(year)__

FIELD HISTORIES

Farmer's name ____________________ Address ____________________

Corn variety ____________________ Date planted ____________________

Planting method ____________________ Rate ____________________

Fertilizer used ____________________ When applied ________ Rate ______lbs.

Previous crop ____________________ Field size ____________________acres

Field Map

Field No. __________

Section No. __________

Township __________

Field Height

Date	Average extended height

Figure 2. Field history data form.
(Facing page.)

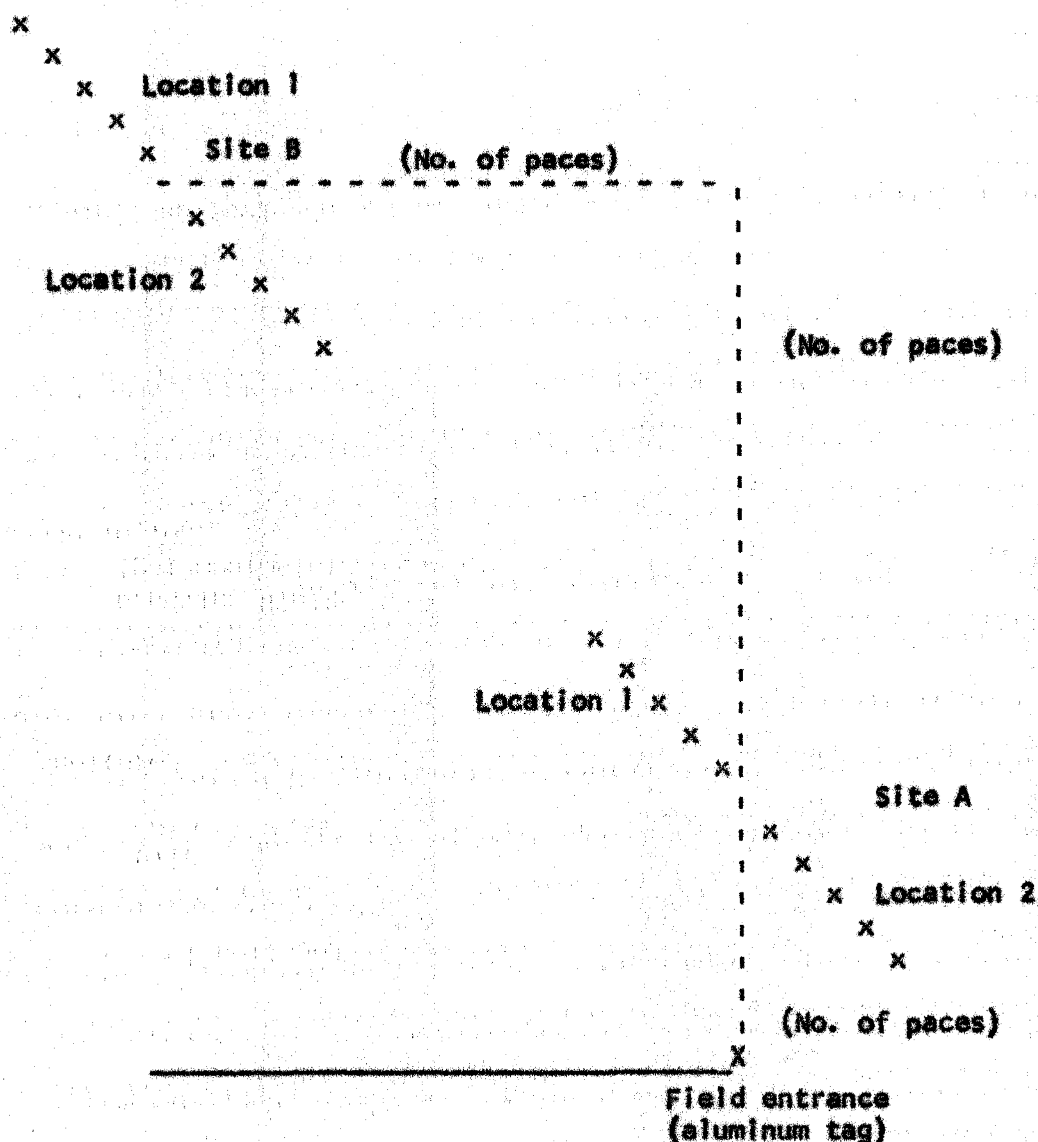


Figure 3. Location of observation plants in the observation fields. (Reverse side of figure 2.)

OVIPOSITION RECORD

Field No. _____

Plant No. _____

Egg mass number	No. eggs in mass	(Date of egg mass observation)					
		(Fate of eggs)[1/]					

1/ W - white H - hatched
Y - yellow M - missing
B - blackhead I - infertile

Figure 4. Oviposition record form.
(Letter code to facilitate compilation of observations.)

PLANT HEIGHT AND PREDATOR OBSERVATIONS

		Coccinellids				Chrysopa			
Date	Plant height	Eggs	Larvae	Pupae	Adults	Eggs	Larvae	Pupae	Adults

Figure 5. Plant height and predator record form.
(Reverse side of figure 4.)

Methods of Sampling

Fall and winter populations

Sampling procedures to measure the corn borer population during the spring and summer growth periods and of fall and winter dormant periods were initiated. The method used to measure winter populations was to take three 1/2000 acre samples at random in each of the included fields at each of the predetermined sampling periods. In each of the three 1/2000 acre samples the plant residue was dissected and the number of corn borer forms present recorded.

Spring and summer oviposition

The sampling of oviposition for both generations of the corn borers are the same with the exception that the second generation observations were made on ten plants in two sites within each field, while first generation observations were made using 20 plants in two sites within each field. The two observation sites in each field were located as follows: site A, 45 paces into the field from the field entrance as marked by the aforementioned aluminum tag, and site B, 30 paces further into the field and 50 paces to the left of site A as in figure 6. The individual plants within each site were selected as the plants emerged after planting. (Figure 7). They were selected diagonally in two locations on either side of the center of the two sites with five plants in each of the two locations. Twice weekly observations were made on each of the plants in both sites. All egg masses were marked and numbered on the plant and then recorded as to the number and development of the individual eggs

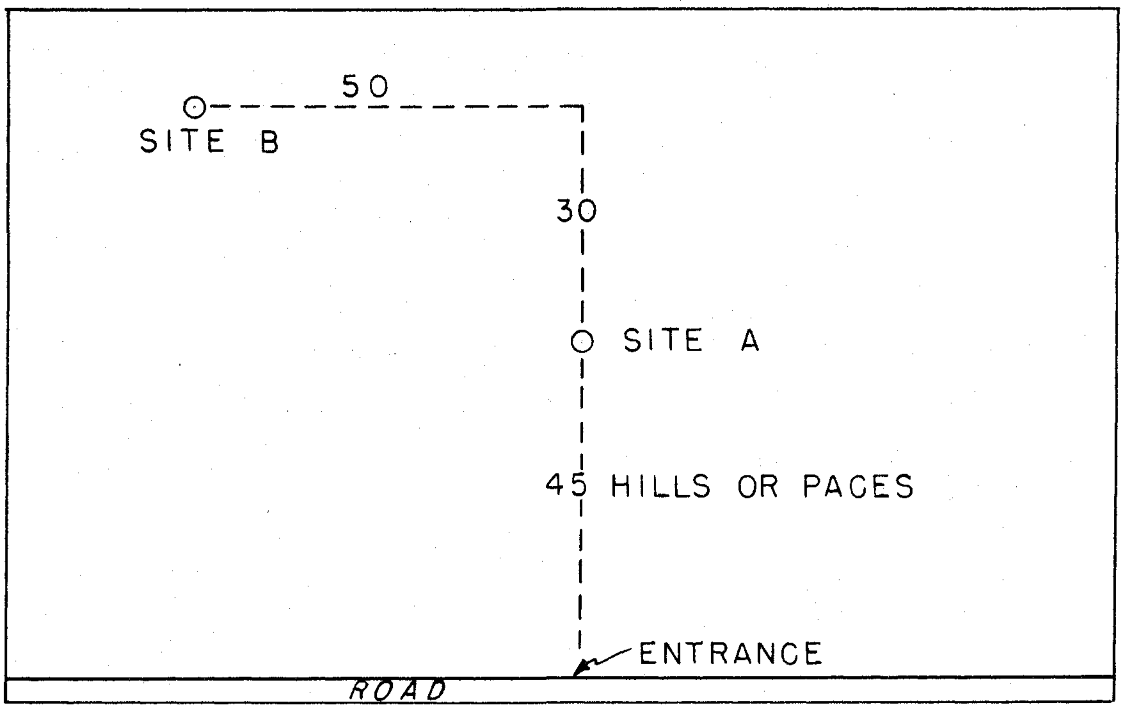


Figure 6. Location of observation sites within each field.

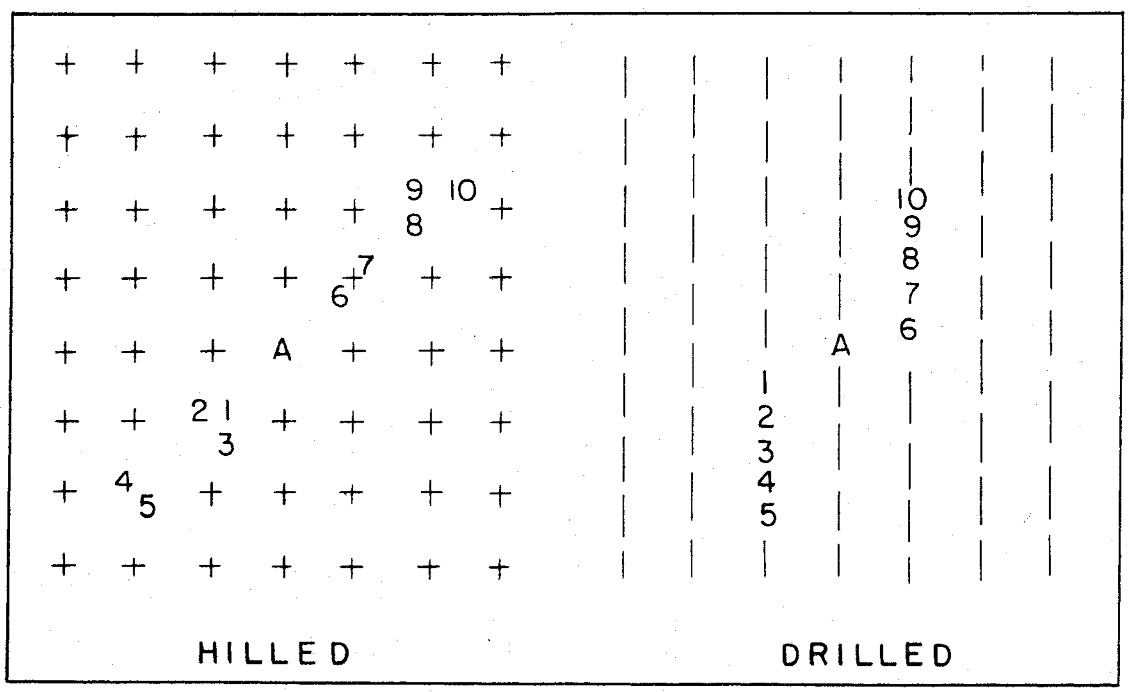


Figure 7. Location of observation plants in either checked or drilled plantings of corn.

within a mass. Second generation observations were similarly made, with the exception that the plants in location 1 at both sites were dissected after first generation oviposition. By this dissection it was possible to determine within reason the fate of the individual eggs deposited during both generations.

Midseason populations

Midseason populations of the corn borer were sampled by two methods. First, all seasons since 1950 the sampling procedure in practice has been to dissect the five plants in location 1 at both sites A and B in each field. The plants dissected were those numbered 1-5 and 10-15 shown in figure 7. These midseason dissections were performed during the second week in July by which time first generation oviposition had terminated and the developing corn borers had matured sufficiently to give readings indicative of first generation survival and the potential size of the second generation moth flight. The sampling procedure which was used in the 1955 and 1956 seasons involved dissections similar to those used for fall and winter population studies. This was done in order that data would be available that would be comparable to that being collected during the dormant stages of the corn borer. In each case the plant material present in three 1/2000 acre samples taken at random in each field was dissected and the corn borer forms present in each recorded.

Pupation and Emergence

Spring

Early season development of the corn borer was observed during the spring months to determine the time of pupation and emergence and the rate at which they occurred. The development of spring pupation and emergence was observed by dissecting corn plant residue in fields selected on the basis of a high population of overwintering corn borers. Two dissections were made each week during the developmental period. The stage of development of 50 borers was recorded for each dissection. In the spring of 1956 the corn borer population that had overwintered was too small to make it possible to observe the required 50 forms in the corn plant residue in any of the study fields in Boone County in the time available. Therefore corn plant residue known to be heavily infested with overwintering forms was placed in two widely separated fields under conditions simulating natural conditions. This material was then dissected at twice-weekly intervals and the corn borer forms and their developmental stages recorded.

Summer

The summer development of the European corn borer was observed each year that the study was in progress. Fields selected for observations of the summer development were those that were known to have a high population of first generation corn borers. In each field at each observation enough corn plants were dissected to give information on the borer development. The number of forms observed at each observation varied with the population of borers present in that particular season. Except in 1955 when the midseason populations were very low and only 25 corn borer forms were observed, 50 forms were dissected from the standing corn in each of the two study fields.

Predator and Parasite Observations

The number and activity of predators was observed during the oviposition periods in all seasons from 1950 through 1956 as a part of the regular oviposition observations. It must be noted that although regular counts of predator populations were made, an actual estimation of the population present within a given field is impossible. No method was developed by which the individual predators could be marked for subsequent observation and identification.

Parasite observations were made on larvae collected during the fall and winter population surveys. Living larvae were collected and taken to the European Corn Borer Research Laboratory at Ankeny, Iowa where Mr. G. T. York and Mr. S. W. Carter made parasite determinations. The parasites that were observed incidentally in the field were recorded at the time of their observation and are considered in computing the percentages of parasitism.

RESULTS AND DISCUSSION

Field Histories

Data from the years 1950 through 1953 that are included in this discussion are taken from Goleman (1954). Since this information is directly comparable to the information collected through the years 1954, 1955, and 1956 it is included and evaluated on an equal basis. The information from the year 1950 is compiled from observations made in 176 fields selected systematically from an area of 1,018.3 square miles, with Boone County as its center. For the years 1951 through 1953, 88 fields were systematically selected within an area of 452.6 square miles entirely within the corporate boundaries of Boone County. Since 1954 the area has been composed of 32 fields selected at random, two from each of 16 equal areas within Boone County, the included area being 576 square miles.

The size of the individual fields recorded for 1950 through 1956 is summarized in table 1.

It is evident from this table that corn field size is relatively constant in Boone County with the farm units roughly 25 to 30 acres in area. Extremes in field size toward either end of the scale are relatively infrequent as can be noted in tables 24, 25, and 26 of the appendix.

Planting dates have been used as a criterion for estimation of corn borer populations in the literature, and were recorded in this work. In general in the Boone County area corn planting is done during the month of May. Within this period, however, there appears to be a concentration of planting activity during the first two weeks of the month. Agronomic recommendations in this region have been and are for the earliest possible planting date, preferably the first week in May. This recommendation is necessarily dependent upon the weather conditions during this rather critical period. A summary of planting dates for all study fields including the range, as well as the mid-planting date is summarized in table 2.

Table 1. Field size, range, and total acres included for 1950 through 1956

Year	Minimum	Average	Maximum	Total
1950	2	26.8	90	-
1951	2	24.8	83	2,179
1952	2	24.9	75	2,198
1953	2	24.2	110	-
1954	2.5	22.5	60	718.5
1955	2.5	29.4	90	942.0
1956	4	25.6	90	817.9

The information shown in table 2 gives an idea of the weather conditions of the various seasons. The years 1950 and 1951 were recorded as being late cold springs with excessive rainfall. The 1954 and 1956 seasons were characterized by early warm springs. The 1955 season opened early and made early planting possible only to become cool for a period of six days. This single period during May of 1955 had considerable effect upon the corn borer populations and will be discussed under the headings of first generation moth flight and first generation oviposition for that year.

Table 2. Summary of observation fields for the period 1950 through 1956

Year	First planting	Mid-planting	Late planting
1950	5/1	5/17	6/4
1951	4/28	5/13	5/29
1952	4/29	5/12	5/24
1953	5/3	5/16	5/28
1954	5/4	5/10	5/17
1955	4/28	5/11	5/20
1956	5/2	5/11	5/19
Average	5/1	5/13	5/25

The effect of fertilization of the soil prior to and at the time of planting has been discussed by various authors, included are Davis (1935) and Weekman (1956). Davis had found little to no effect of fertilizer on corn borer oviposition, whereas Weekman was able to show some differences, but due to the variability of results no significant effects were demonstrated. In this same study Weekman found that if fields were grouped as to planting date with fertilizer, the fields that were planted early and fertilized did receive significantly different amounts of oviposition. In this study the use of fertilizer has been recorded for each field since 1950. Table 3 summarizes the comparative frequency of the use of fertilizer in Boone County classed under the following groups: commercial, manure, and no fertilizer for the 1950 through 1956 seasons. The information in this table amplifies the importance of climatic conditions on agronomic practice and subsequently on the corn borer. The spring weather in the early years of this study was cold and wet and in 1954 a tendency toward drought had developed. The dry period in the fall of 1954 and subsequent lack of moisture in the spring of both 1955 and 1956 has had a marked effect on the use of fertilizer by the individual farmer. Therefore, a gradual increase in the use of fertilizer can be seen from 1950 through 1954, while a decrease in frequency of use is seen during both 1955 and 1956.

Table 3. Percentage of the total fields which fall into each of the three groups: commercial, manure, and no fertilizer for the 1950 through 1956 seasons

Year	Commercial	Manure	No fertilizer	Total fields
1950	11.4	13.6	75.0	176
1951	12.5	17.1	70.4	88
1952	19.3	11.4	69.3	88
1953	22.7	25.0	55.3	88
1954	43.8	9.4	46.8	32
1955	31.3	12.5	56.2	32
1956	25.0	15.6	59.4	32
Average	23.7	14.9	61.8	

The rotation plans used by the growers in Boone County are relatively uniform. In most instances a five-year rotation involving crops of alfalfa, red clover, soybeans, oats, and grass pasture is followed. Little alfalfa has been used in this area, and since 1954 not more than one of the included fields has been from a rotation which had included alfalfa. Since this is the case the clovers will be referred to as legumes, which will include alfalfa, red clover, and sweet clover. The legume crop most frequently used, however, is red clover.

Table 4 summarizes the percent of the previous crop in use in those corn fields included in the Boone County study.

Table 4. Percentage of total fields that were planted to corn, legumes, soybeans, oats, and grass pasture, 1950 through 1956

Year	Corn	Legumes	Soybeans	Oats	Grass pasture	Total
1950	30.1	11.9	18.2	34.1	5.7	176
1951	31.8	22.7	18.2	26.1	1.1	88
1952	39.8	18.2	12.5	26.1	3.4	88
1953	38.6	19.3	21.6	15.9	3.4	88
1954	25.0	59.4	9.4	-	6.3	32
1955	40.6	34.4	12.5	3.1	9.4	32
1956	50.0	28.1	12.5	6.3	3.1	32
Average	36.6	27.7	14.9	15.9	4.6	

In the above table one notes that roughly one-third of the total fields involved in this study are planted to second year corn. The marked increase in the number of fields planted to corn the previous years in 1955 and 1956 can be explained by the knowledge that poor legume stands were obtained during the three years 1954 through 1956 as the result of dry midseason weather. The low percentages of both oats and grass pasture are the results of a general practice in this area of Iowa. That is, oats is used as a nurse crop for legume seedings and in general only a small percent of the land planted to oats is not used for a nurse crop for legumes. The intensive agriculture of this area rules out the existence of permanent pastures except in the case of land not suitable for other crop procedures or in the case of small feed lots that are established for short periods of time only to be returned to general rotation after a few seasons. A complete summary of the field histories for all fields for 1954 through 1956 appears in tables 24, 25, and 26 of the appendix.

Spring Populations

Spring populations were sampled in all years from 1950 through 1956 for two purposes; (1) to determine the winter mortality of the corn borer larvae, and (2) to estimate the potential of the corn borer population for the current year. This spring population survey was made during the month of May with the actual date of observation dependent upon the season. The sampling methods for the period 1950 to 1953 involved the examination of two 1/1000 acre areas in each of 44 observation fields. The fields were not sampled until they had been disced and planted to oats or plowed and prepared for corn or other row crops. The procedure for 1954 through

1956 was to select three 1/2000 acre samples at random in each of the fields included in the study and record the corn borer forms present. Since 1954 fields selected during this period were only those that were planted to oats. This change was made since it was obvious that the early summer corn borer population would be largely made up of those individuals that had overwintered and survived in fields that had been planted to oats. Tables 27, 28, and 29 of the appendix give spring populations by samples for 1954 through 1956. A brief summary of the spring populations that were observed in the two above-stated methods for the years 1950 through 1956 are shown in table 5.

Table 5. Spring populations and winter mortality 1950 through 1956

Year	Borers per acre	Winter mortality	Fields observed
1950	5,200	-	44
1951	1,300	28.8	44
1952	390	34.8	44
1953	1,120	16.8	44
1954	6,240	14.0	32
1955	12,600	14.4	32
1956	840	35.0	32

Although the populations listed above are not directly comparable due to the variation in the methods of sampling, the general trends in the corn borer population are demonstrated. The years 1950 through 1952 show a gradual decrease in the corn borer population. In 1953 the trend toward a population increase developed. The result of the population outbreak during the summer of 1954 is clearly shown in the spring population of 1955. The sudden reduction in numbers shown in the spring population in 1956 can be explained by investigation of the seasonal behavior of the insect during the summer of 1955.

Mortality of overwintering borers has been computed from the number of dead borers found during the spring population observations and is summarized in table 5. This method of computation of mortality is not a true estimate of that portion of borers that die, for many of the borers do not die within the corn stalk where they could be observed in the spring. However, corn borer mortality based on a direct comparison of fall populations before the corn is picked and the spring population survey should show the real corn borer mortality. Table 6 gives the fall populations of borers observed, the spring population observed expressed as borers per acre, and the percent change in the population or winter mortality.

Table 6. Comparison of fall and spring European corn borer populations expressed as borers per acre and the percent mortality

Year	Fall population	Spring population	Winter mortality
1951	13,200	1,300	90.2
1952	9,372	390	95.8
1953	14,400	1,120	92.2
1954	32,520	6,240	80.8
1955	80,520	12,600	84.4
1956	18,960	840	95.6

The six-year average of 89.9 percent winter mortality demonstrates that a large proportion of the corn borer population is removed by environmental factors each year. The remaining 10.1 percent of the population is the number of corn borers which are responsible for the losses inflicted each year. By comparison of the winter mortality percentages for the years 1951 through 1956 given in tables 5 and 6, the inadequacy of the method which uses the number of dead larvae observed during the spring population survey is seen. The method based on the comparison of fall and spring populations takes into consideration all of the factors which can cause reductions in borer numbers. Some of the more important of these are mechanical injury by corn pickers, the feeding of birds on the borers within the corn stalk, the effect of alternately high and low temperatures stimulating the borer to leave the corn residue, and the destruction of borers by spring farming practices.

Spring Pupation and Emergence

Spring development of the corn borer is of prime importance in the prediction of first generation oviposition and subsequent control operations. The threshold of development for the corn borer as stated by Apple (1952) is 50° F. The accumulation then of temperatures expressed as borer degree days is then calculated by subtracting the threshold temperature from the daily mean temperature. The degree day requirements for the appearance for any corn borer stage is attainable and was computed from observations made by Apple. These degree day requirements are: for pupae, 246; moths, 423; eggs, 603; egg hatching, 699; and for summer development pupae, 1,446; moths, 1,716; eggs, 1,787; egg hatching, 1,901. Figure 8 is a graphical illustration of the temperature accumulation data as recorded for the years 1949 through 1956. The temperature accumulations necessary for first appearance of the various stages of corn borer development as indicated by Apple are also marked.

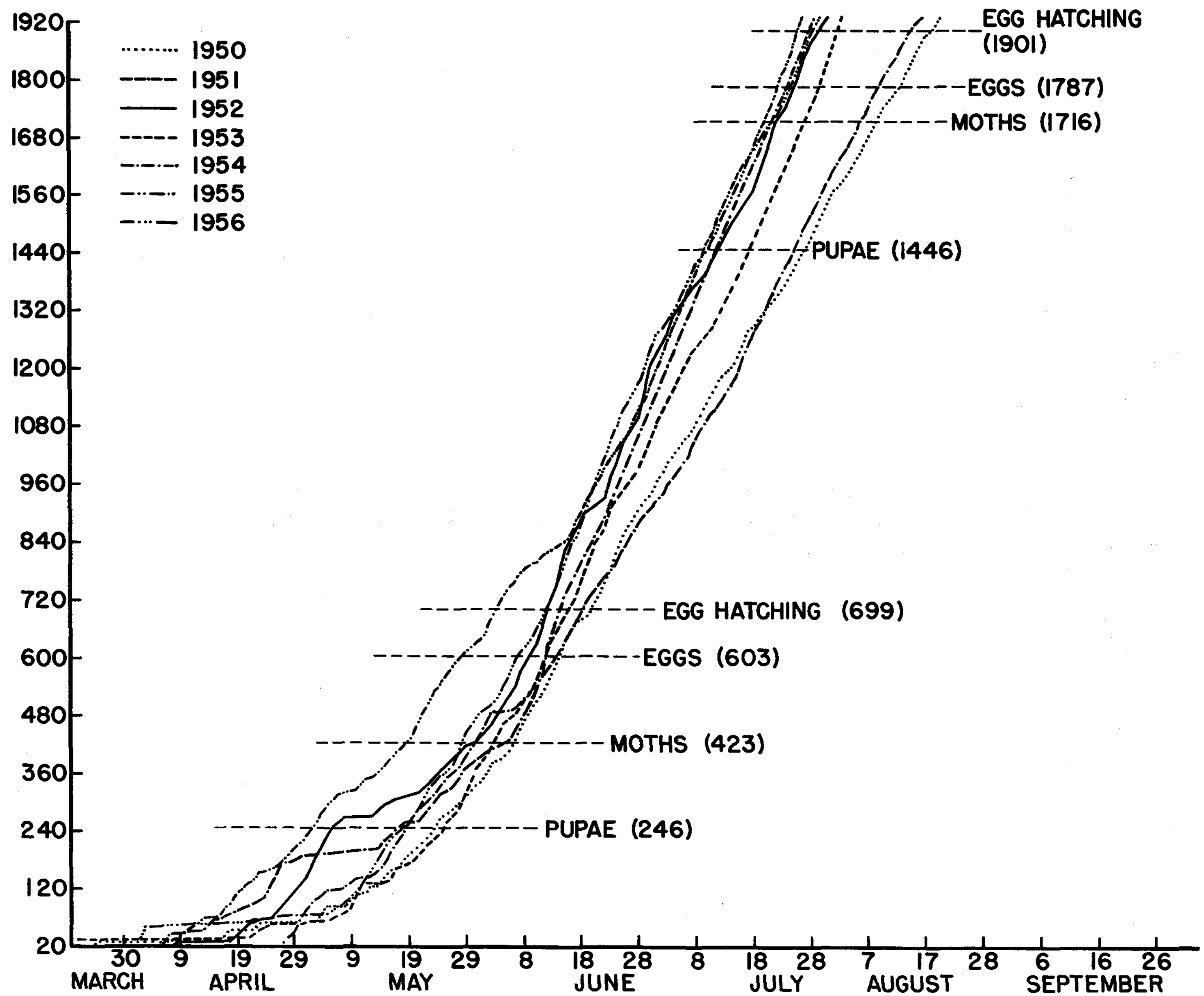
Comparisons made using the predicted date of occurrence of corn borer stages and the actual date of observation are tabulated for the years 1950 through 1956. This information appears in table 7. It is noted in table 7 that although there is some variation in the predicted dates and actual dates of occurrence the variation at the critical periods of egg deposition is not greater than two days. The information shown by figure 8 and table 7 is of use to the entomologist in enabling the individual to coordinate his activities so as to schedule field observations at the time when, for example, first pupation is expected. But further than this the real use of this method of prediction of events is its use as a guide to field observations. With the daily record of temperature accumulation an observer has at his disposal a method whereby he can schedule field observations within the relatively narrow period of a few days and expect with a reasonable amount of confidence to observe the actual first appearance of European corn borer stages.

Spring pupation and emergence for the years 1954 through 1956 was observed in the field by making regular observations in two widely separated fields. The information from these observations is found graphically illustrated in figures 9, 10, and 11. It is of special interest to note in figure 10 for 1955 the marked effect that a period of cool windy weather had upon the emergence of the corn borer moths. This period of cool weather was mentioned previously in the section on spring populations and will be discussed in detail in the section on first generation oviposition.

Table 7. Comparison of predicted and actual dates of appearance of the various stages in the corn borer life cycle as determined by the method arrived at by Apple (1952)

		First generation				Second generation			
Stage		Pupae	Moths	Eggs	Eggs hatch	Pupae	Moths	Eggs	Eggs hatch
Borer degree days		246	423	603	699	1446	1716	1778	1901
Year									
1950	Predicted	5/22	6/6	6/14	6/20	7/28	8/10	8/14	8/21
	Actual	5/18	6/1	6/13	6/20	7/31	8/4	8/14	8/15
1951	Predicted	5/18	5/30	6/13	6/28	7/26	8/7	8/10	8/16
	Actual	5/17	5/28	6/13	6/19	7/26	7/30	8/11	8/15
1952	Predicted	5/5	5/30	6/8	6/12	7/12	7/22	7/25	7/30
	Actual	5/8	6/6	6/10	6/16	7/14	7/24	7/25	7/29
1953	Predicted	5/25	6/3	6/12	6/17	7/18	7/28	7/31	8/3
	Actual	5/19	6/4	6/9	6/16	7/13	7/20	7/27	7/28
1954	Predicted	5/17	6/4	6/13	6/17	7/13	7/23	7/26	7/30
	Actual	5/12	5/31	6/14	6/21	7/16	7/23	7/23	7/29
1955	Predicted	5/17	6/4	6/13	6/17	7/13	7/23	7/26	7/30
	Actual	4/29	5/17	6/3	6/14	7/15	7/11	7/27	8/4
1956	Predicted	5/17	5/28	6/7	6/12	7/10	7/22	7/25	7/29
	Actual	5/15	6/2	6/8	6/11	7/18	7/16	7/22	7/25
Average									
	Predicted	5/17	6/2	6/12	6/16	7/17	7/28	7/31	8/5
	Actual	5/12	5/30	6/10	6/17	7/19	7/23	7/30	8/3

Figure 8. Temperature accumulation curves 1950-1956 computed at Ames, Iowa.



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EGG HATCHING (1901)
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PUPAE (1446)
EGG HATCHING (699)
EGGS (603)
MOTHS (423)
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MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER

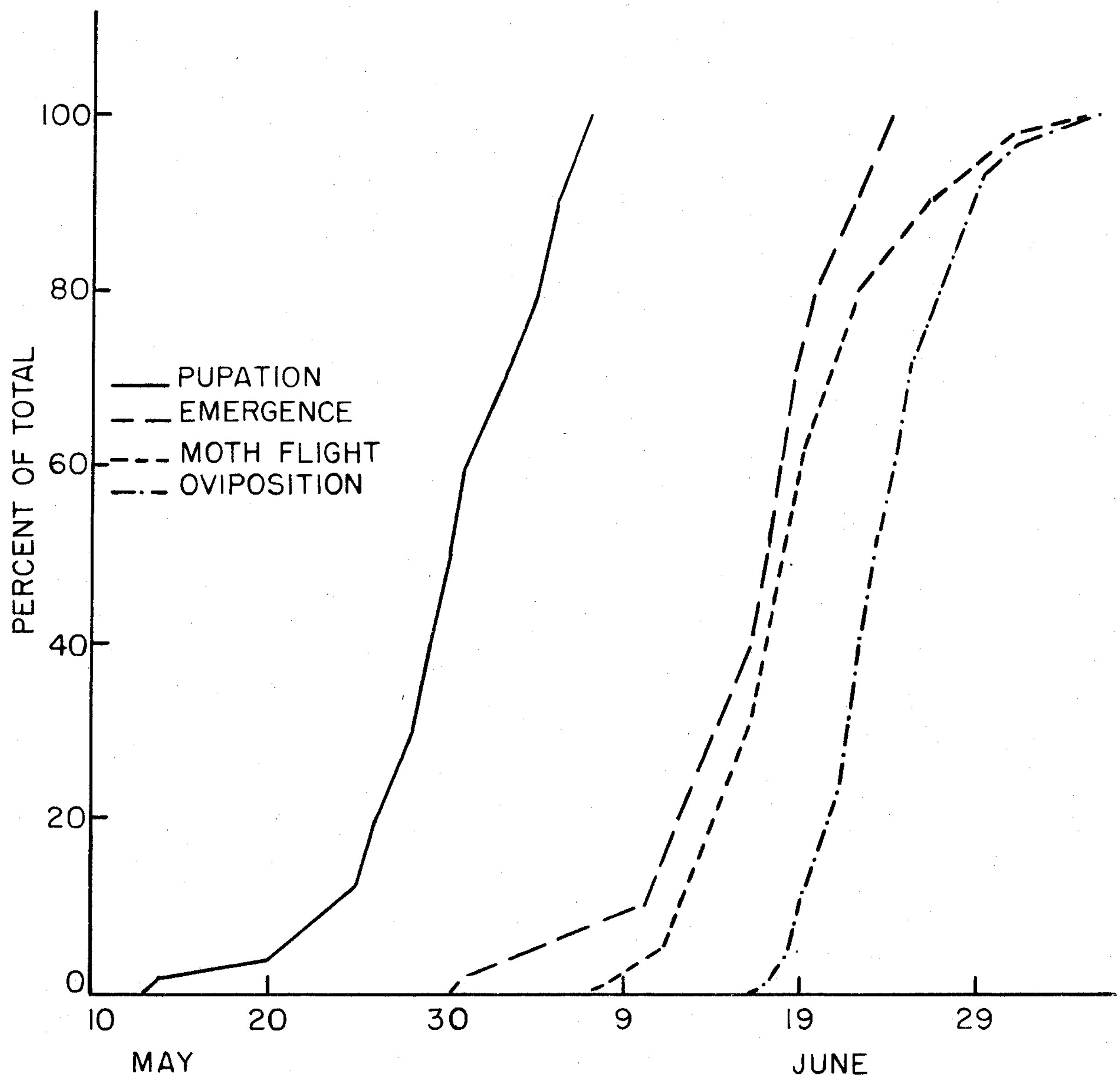
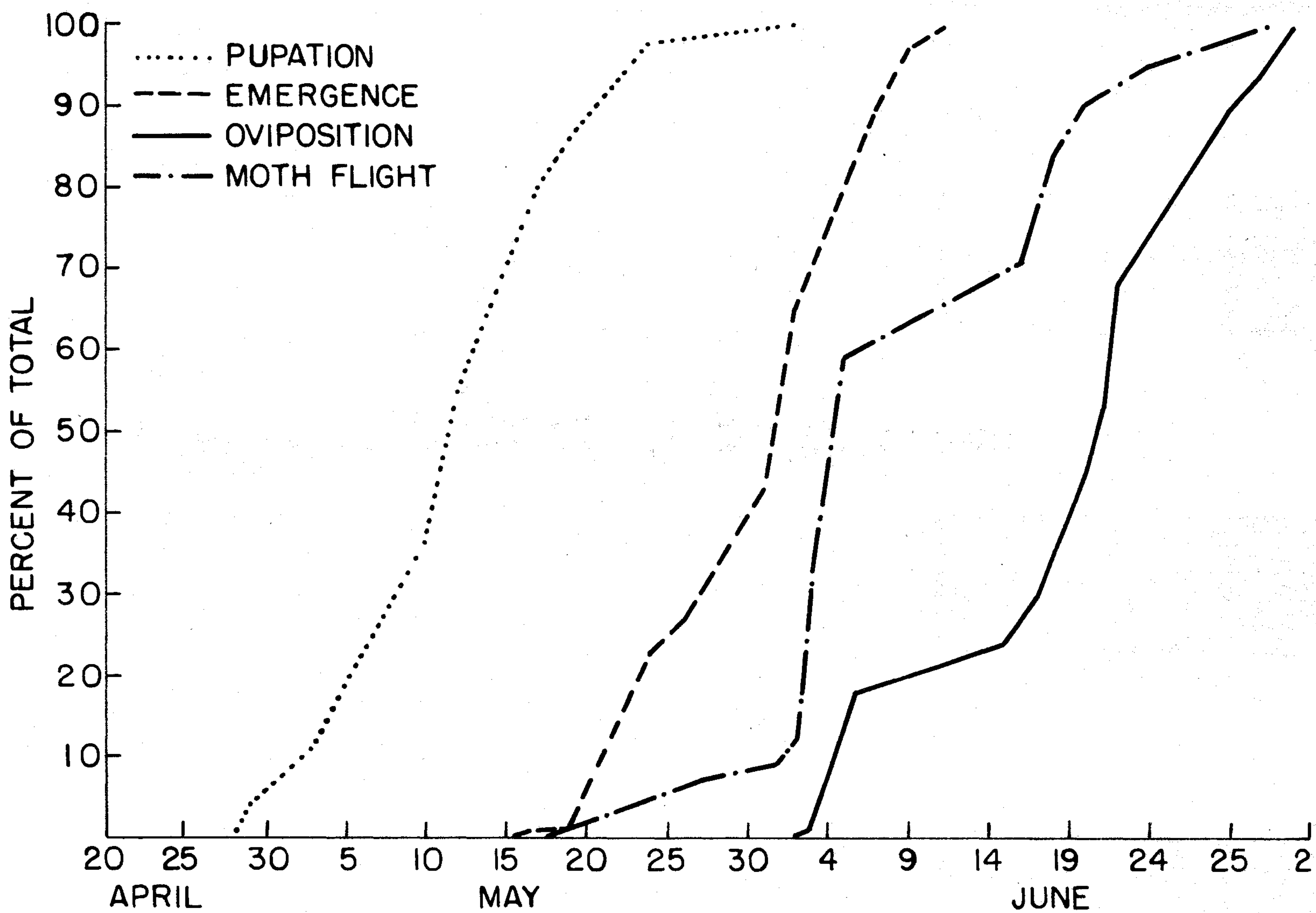


Figure 9. Spring pupation, emergence, moth flight, and oviposition Boone County study area 1954.

Figure 10. Pupation, emergence, moth flight, and oviposition Boone County study area 1955.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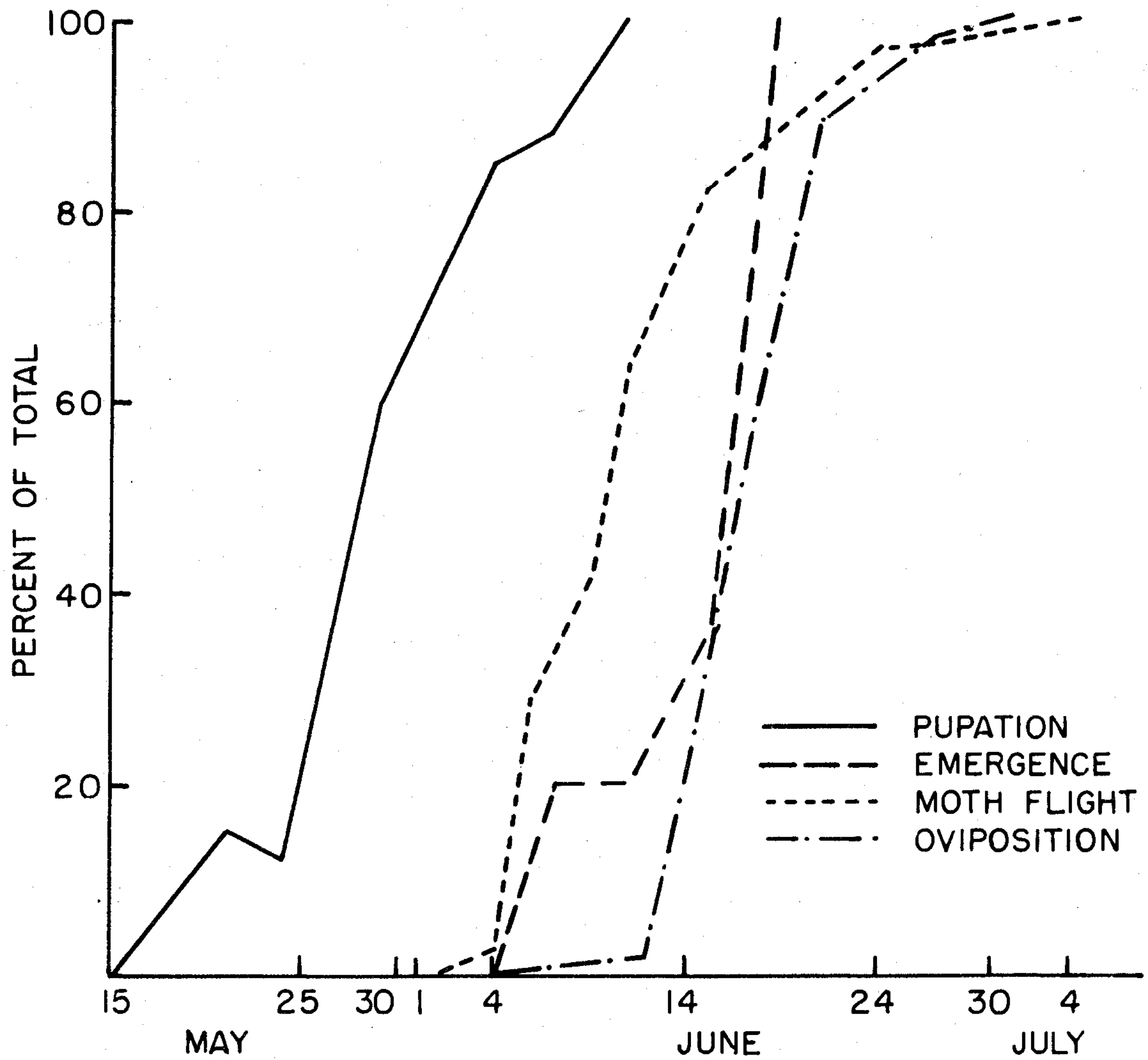


Figure 11. Spring pupation, emergence, moth flight, and oviposition Boone County study area 1956.

First Generation Moth Flight

Corn borer moth flight in the vicinity of Ames, Iowa was followed by the use of light traps. The use of this method of observation is to determine the dates of occurrence of the moth flight and the duration of the subsequent oviposition period. The number of moths trapped, the duration of moth flight, and the number of light traps in operation for the season are summarized in table 8 for the years 1950 through 1956.

Table 8. Moth flight data for all years 1950 through 1956

Year	Total moths	Duration of flight	Date of first moth	Traps
1950	5,507	44	6/8	3
1951	1,710	59	5/28	4
1952	495	37	6/2	3
1953	1,452	34	6/4	6
1954	4,526	30	5/31	6
1955	4,749	51	5/17	4
1956	1,501	34	6/7	4
Average flight length		41.3		

Graphic representation of the moth flight for 1954 through 1956 is shown in figures 9, 10, and 11. Tables 30, 31, and 32 of the appendix show the duration of the moth flight in the various years that this study has been in progress. Those years in which the moth flight lasted for periods longer than 40 days were characterized by rather low second generation populations.

First Generation Oviposition

The spring oviposition is shown in figures 9, 10, and 11 for the three years 1954 through 1956. These figures show the rate and duration of the oviposition periods for these years. As explained in the description of procedures the observations of oviposition were made at twice-weekly intervals in each of the fields under study. Each egg mass as it was located was marked and the eggs within the mass counted and this information was recorded. As a result of this method each egg mass was tabulated and each egg within the mass accounted for while the eggs in a particular egg mass were developing. A summary of the first generation oviposition from 1950 through 1956 is shown in table 9.

Table 9. First generation oviposition, 1950 through 1956, total eggs laid, total masses and range of oviposition on observation plants. (20 plants)

Year	No. of fields	Total eggs	Total Masses	Maximum	Average	Minimum
1950	176	187,200	11,853	176	67.3	1
1951	88	5,529	378	25	4.3	0
1952	88	2,301	150	-	1.7	0
1953	88	10,382	644	29	7.4	0
1954	32	15,807	1,007	80	32.4	3
1955	32	3,731	236	38	7.4	0
1956	32	4,473	294	33	9.1	0

The average oviposition shown in table 9 demonstrates the relative sizes of the corn borer populations in Boone County. The high oviposition of the first generation of 1954 developed the only population of borers which resulted in a second generation outbreak during the period studied. The 1950 population failed entirely to develop a second generation of consequence. An average population of 10.0 egg masses on 20 plants would represent a general population of 50 egg masses per 100 plants or a population of sufficient size to warrant general chemical control program on all fields in the area. From this table it is evident that regardless of the small size of the average population there are always some individual fields in the area which are infested in large enough numbers to warrant a chemical control program.

The length of the oviposition period, the date of maximum oviposition, the height of the corn plants at the start of oviposition, as well as the height at mid-oviposition is summarized in table 10.

Table 10. First generation oviposition compared by plant height at first oviposition, plant height at mid-oviposition, date of mid-oviposition, and duration of oviposition

Year	Height first oviposition	Height mid-oviposition	Date of mid-oviposition	Duration of oviposition period in days
1950	-	-	6/27	36
1951	9.0	25.5	7/1	37
1952	21.2	21.5	6/17	26
1953	11.5	31.6	6/22	32
1954	14.0	29.7	6/22	35
1955	11.1	32.1	6/21	30
1956	19.8	31.6	6/17	23

The actual rate of oviposition is computed in tables 30, 31, and 32 of the appendix. These tables demonstrate the irregular moth flight and the manner in which it is influenced by varying climatic conditions. During the 1955 oviposition period a series of cool windy days occurred soon after the beginning of oviposition. This cool windy period is demonstrated in the moth flight and oviposition rate for that period and it is interesting to note that these adverse conditions were of sufficient intensity to reduce a potential "outbreak" population to one of below average size. The spring population for the year 1955 was 12,600 live corn borers per acre as determined by spring survey methods. Borer development was rapid with the first pupa being found April 29, which was the earliest record of this event in the seven years that the area has been intensively studied. The emergence of moths was correspondingly early as was first oviposition. The early oviposition developed as had been expected with early planted corn fields receiving high infestations during the first week of oviposition period. The second week of the oviposition period was characterized by below normal temperatures and with high northerly winds which in combination tended to throttle the infestation. This period of abnormality was followed by normal conditions during which oviposition continued but at a rate far lower than the predicted. The population of corn borers for the 1955 first generation using the number of eggs per acre produced an estimated population of only 696,000 borers from a spring population of 12,600 borers per acre. The spring population in 1954 of 6,240 borers per acre resulted in an estimated egg population of 3,060,000 eggs per acre. The first generation population in eggs observed in each field as well as the fate of those eggs is summarized for the three years 1954 through 1956 in tables 33, 34, and 35 of the appendix.

Using the present methods of sampling it was possible to determine the fate of all of the eggs deposited on the observation plants in each field. The fate of eggs as determined by this method included the time from when each egg mass was deposited until the time that each egg within the mass hatched or was disposed of in some other manner. Table 11 gives a summary of the relative proportion of eggs which were deposited, that hatched, and/or were disposed of in the following ways: missing, dislodged from the plant and lost, eaten by predators, or infertile and dried up.

Table 11. Fate of eggs by percent for the years 1950 through 1956

Year	Total eggs	Hatched	Missing	Eaten	Infertile and dried	No. of plants
1950	187,200	72.0	22.8	1.1	4.0	3,520
1951	5,529	71.8	17.8	7.7	2.6	1,760
1952	2,301	74.3	16.7	4.9	4.0	1,760
1953	10,433	64.8	25.3	8.3	1.5	1,760
1954	15,807	84.3	13.2	0.5	2.0	640
1955	3,731	78.1	7.8	9.0	5.1	640
1956	4,473	90.2	6.0	1.4	2.5	640
Average percent		76.5	15.7	4.7	3.1	

The percentages for egg hatching appear constant with the exception of two years, 1954 and 1956. Weather conditions through the period of egg deposition are variable and do act as determining factors in the percentage of egg hatch. Both 1954 and 1956 were characterized by periods of hot humid weather. Egg hatch was very rapid occurring in some cases within a period of two days while normal incubation periods are three to four days. This rapid development of the eggs which reduces the chance that they may be dislodged and lost could account for the high hatching percentage. The high percentage of eggs that were removed by predator action is a possible explanation of the decrease in the percentage of hatch in 1955. The number of eggs that were designated as having been infertile and dried up wa s somewhat arbitrary as it was extremely difficult to absolutely determine if a particular egg was infertile or had been damaged in some manner by predators without showing actual evidence of predator feeding. It was also possible that predators could remove some of the egg masses entirely and thereby account for some of the eggs that were listed as missing.

Occurrence of Predators of the First Generation

Froeschner (1950) has defined the most effective predators of the corn borer as *Orius insidiosus* (Say) and *Chrysopa plorabunda* Fitch. Goleman (1954) observed red spiders (Trombidiidae: *Allotrombium* sp.) as well as several species of Coccinellids both larvae and adults feeding on the corn borer eggs. As stated under procedures the predator counts were estimates of abundance of predators on the plants at each observation and not an estimation of the number of predators on a particular plant for the oviposition period. Tables 36, 37, and 38 of the appendix give actual predator counts for the years 1954 through 1956 and define those counts as to the species observed and their stage of development. Table 12 summarizes the total number of predators observed during first generation oviposition, 1950 through 1956, and gives an estimate of the average number of predators that occurred on each plant during the first generation oviposition period.

Table 12. Predator numbers for the years 1950 through 1956 given as total predators observed and predators per plant per season

Year	No. of plants	Total predators	Predators per plant
1950	3,520	1,220	0.3
1951	1,760	555	0.3
1952	1,760	681	0.4
1953	1,760	3,180	1.8
1954	640	557	0.9
1955	640	554	0.9
1956	640	896	1.4

The predator numbers recorded during the first generation oviposition period of each year was low, for this was a period of population consolidation and multiplication. As is always the case, predator populations lag behind that of the host insect except in cases in which a predator is not limited to a single host species. The predators that attack the corn borer are not limited to that insect as a host and are incidental predators of the corn borer being in all probability predators of aphids infesting other crops. These aphids did not develop large populations until mid-summer and the dependent predator population, therefore, does not become numerous until what corresponds to the oviposition period of the second generation. The relationship of these aphids and the predator complex was suggested in the results obtained and discussed under second generation predator observations.

First Generation Survival and Midseason Populations

Midseason populations were determined by dissection of one-half of the total observation plants during the month of July. These populations were used to determine the number of corn borer eggs that survive from the total number of eggs that are deposited on those plants. By this method survival was estimated using the population of eggs deposited as the original population and the number of larvae found in those plants at dissection as the final population. There was, however, room for error, for this method does not determine that portion of the final population that has migrated to the specific plant from a plant on which egg observations were not conducted. Huber et al. (1928) discuss wind action on the leaves as a stimulus to which the young larvae react in such a manner as to spin down from the corn leaves and subsequently be carried to other nearby plants. Huber et al. class this phenomenon as one which is essential in the dispersal of the newly hatched larvae. Assuming this to be true it is possible to imagine moderate numbers of larvae being carried from one plant to another. This migration of larvae would also be characteristic for the second generation as well as the first generation and explains the situation of no recorded egg infestation while dissection demonstrates an infestation at the end of either generation. However, for the purpose of this study one can assume that the migrations are related to the distribution of the original population and that the survival figures reflect, with reasonable accuracy, the mean for the entire population.

The dissections to determine mortality and infestation of the first generation population were made during the period of the first two weeks in July and/or at such a time that first generation oviposition had ended and the maturing borers were fully developed. Table 13 shows the infestation as determined by midseason dissections, the first generation egg population both of hatched eggs and total eggs, and the survival computed on both the total eggs and hatched eggs.

Table 13. Midseason populations plus first generation oviposition populations in borers per 100 plants with survival computed from total and hatched eggs, expressed as a percent

Year	Total eggs	Hatched eggs	Total borers	Survival	
				Total eggs	Hatched eggs
1950	5,318.2	3,828.8	145.6	2.7	3.8
1951	314.1	225.6	21.5	6.8	9.5
1952	130.7	97.2	5.9	4.5	6.1
1953	592.8	385.4	42.9	7.2	11.1
1954	2,469.8	2,081.3	223.4	9.1	10.7
1955	582.9	411.7	44.1	7.6	10.7
1956	698.9	630.3	42.8	6.1	6.8
Average survival				6.2	8.4

The survival values computed in the above table show the large percentage of eggs that do not reach maturity. In 1950 when a tremendously large population of hatched eggs was present establishment was extremely poor and only 3.8 percent of the eggs that hatched developed to mature larvae. In 1954 when a large number of eggs was deposited and borer survival reached a high of 10 percent of the eggs that hatched, a second generation population outbreak did occur. The high survival rates in the other years included in this study did not result in population outbreaks due to the fact that the first generation populations were so low that high survival would not present potential for a population outbreak. These first generation populations which are often overlooked because of the diminutive quantity of borers present when compared to the second generation populations are probably the most damaging populations when considered on a damage per borer basis, and warrant particular observation as their character will determine the magnitude of the more spectacular second generations. Tables 39, 40, and 41 of the appendix summarize the dissection data by fields for the years 1954 through 1956.

Summer Pupation and Emergence

The development of the second generation of the corn borer which takes place in Central Iowa during the month of July has been observed and recorded during all seasons since 1950. Observations of this development were made at twice-weekly intervals usually in two widely separated fields that were known to have a high population of corn borer larvae. The degree to which the second generation develops has a large bearing upon the size of the populations of corn borers and subsequent yield losses. In only two seasons since 1950 has a fairly large proportion of the first generation borers failed to pupate. These years were 1950 and 1951. Arbuthnot (1949) has shown that the corn borer population in Iowa is made up of two particular strains of the corn borer. He states that dependent upon environmental conditions it would be possible to have seasons in which either a single generation or multiple generations would predominate. In both 1950 and 1951 the growing seasons were delayed and in both cases quite adverse for borer development. These years then were favorable to the development of a single generation population. Since 1951, however, the environmental conditions, with the exception of brief periods of adverse conditions, which have affected drastic short-lived reductions in numbers, have been favorable for the development and dominance of the multiple population of the corn borer. Two definite generations were observed and in both years 1955 and 1956 there was a strong suggestion that a small percentage of the second generation larvae continued development and pupated to begin a small third generation. During the fall of 1955 pupae were observed in the fall dissections made in September and moths were caught in light traps until well into the month of October. The number of moths was very small and no new oviposition was observed after the first of September.

Figures 12, 13, and 14 show the development of the single generation and pupation and emergence of the multiple generation population of the corn borer. Figures 15, 16, and 17 show the pupation and emergence curves as well as second generation moth flight and oviposition rates for 1954

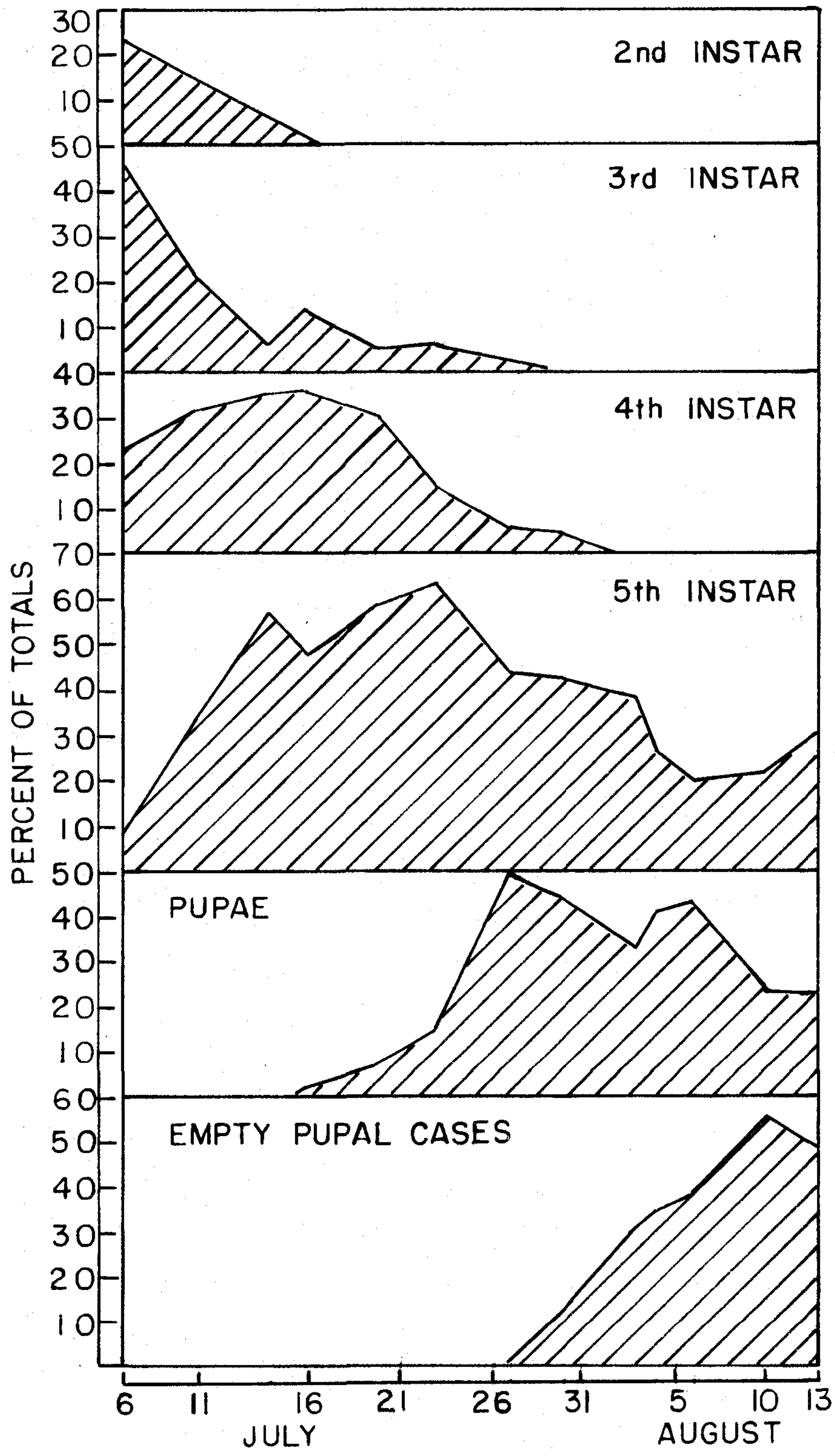


Figure 12. Development of the European corn borer Boone County study area 1954.

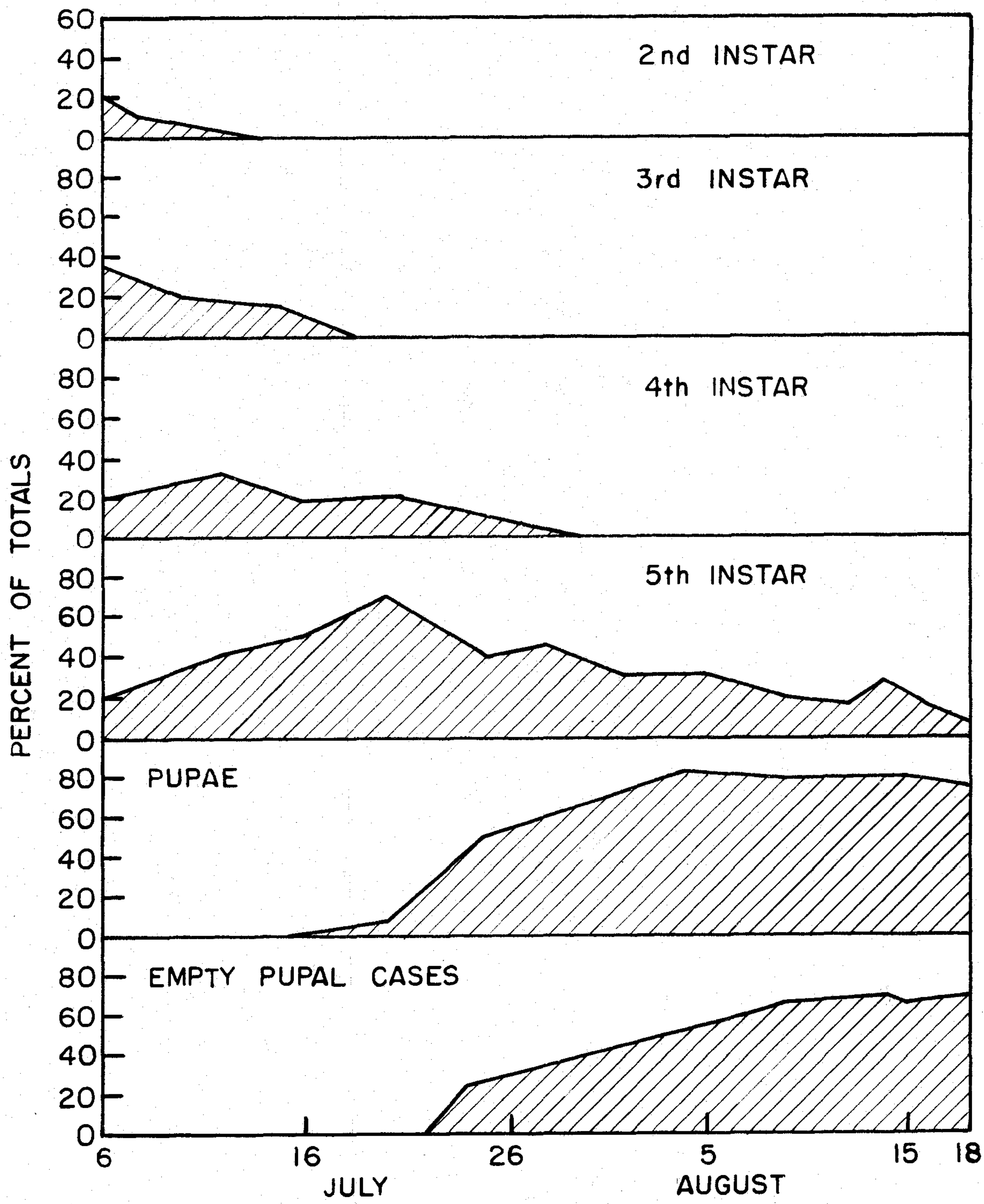


Figure 13. Development of the European Corn Borer Boone County study area 1955.

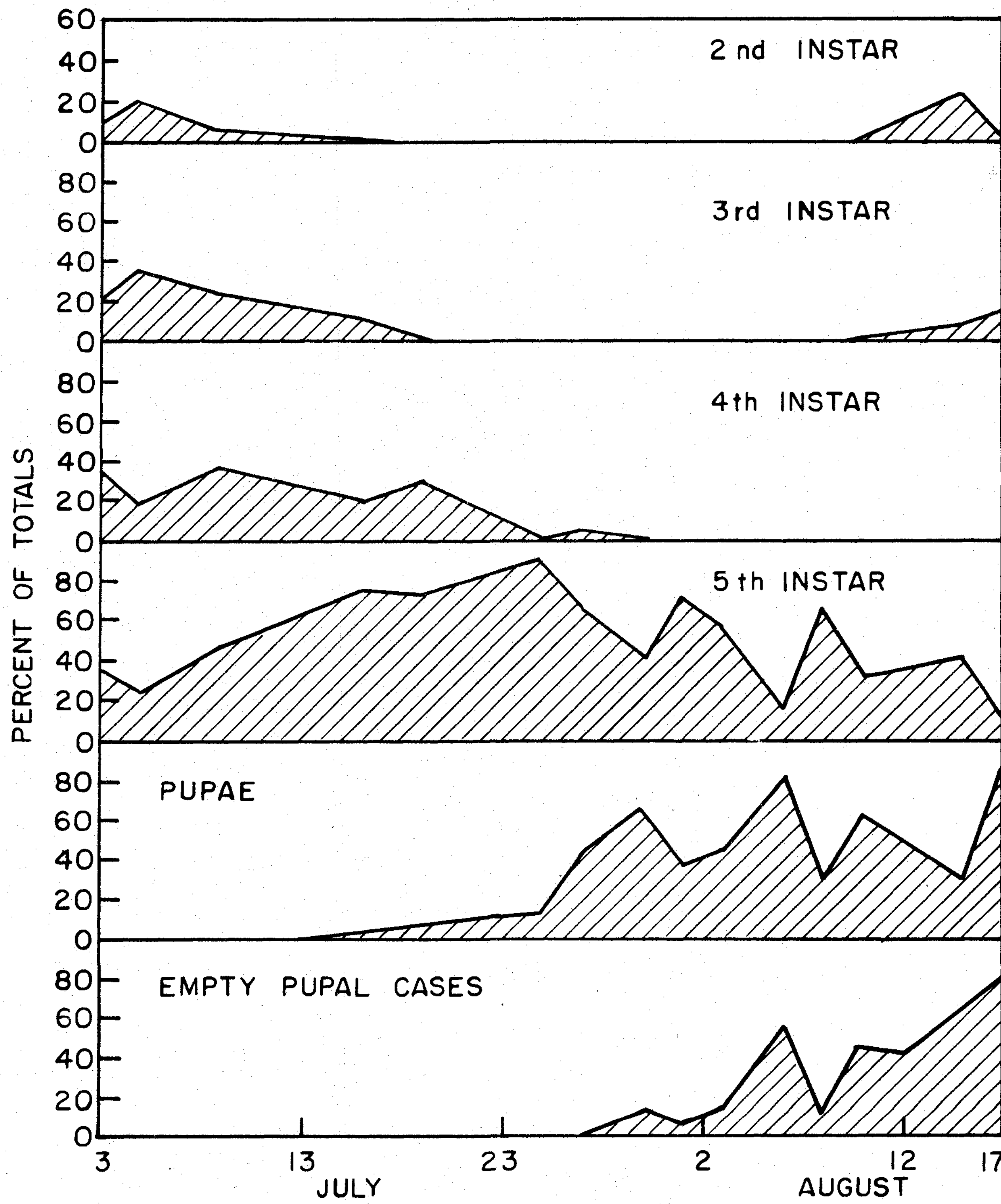


Figure 14. Development of the European corn borer Boone County study area 1956.

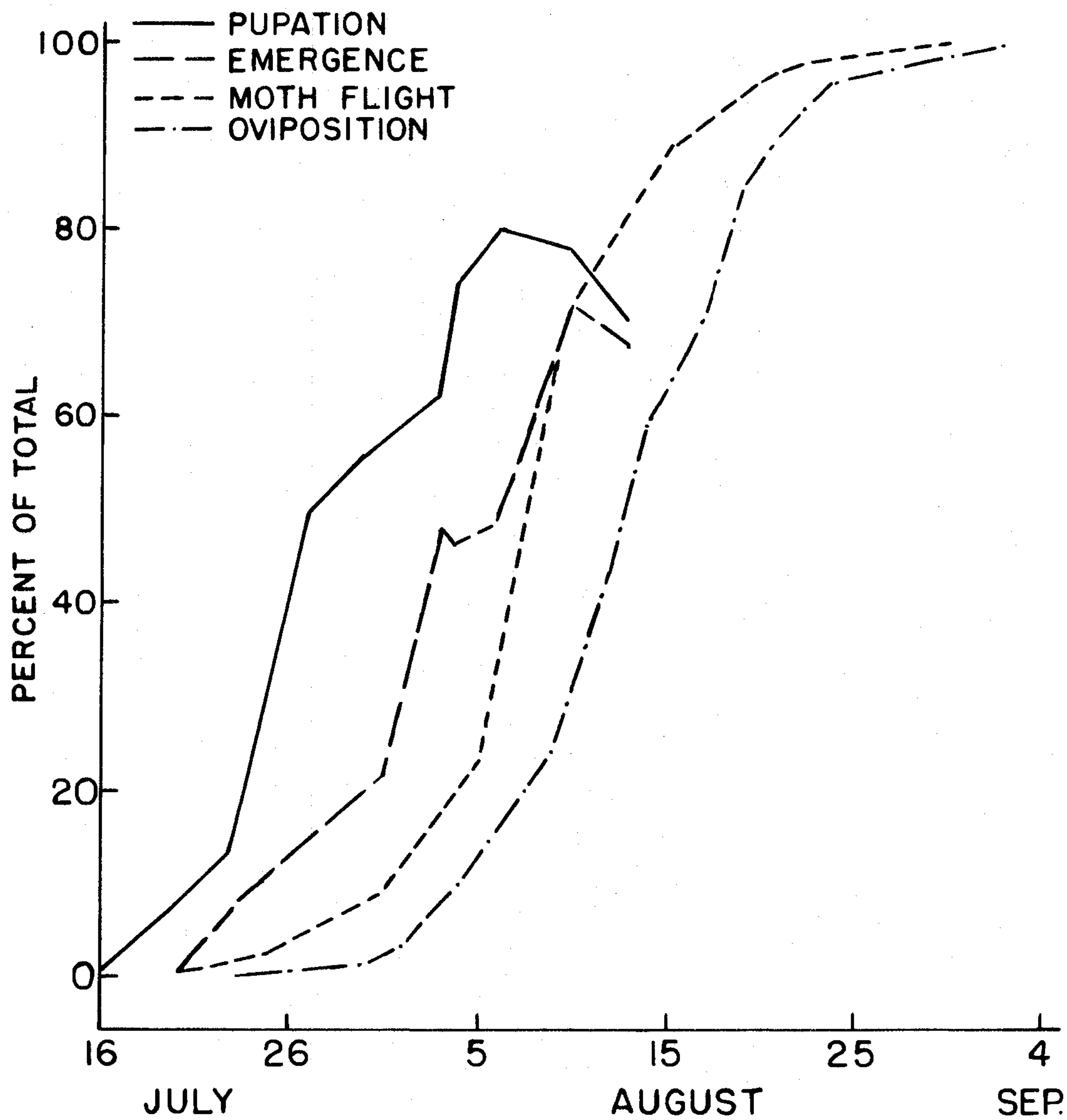
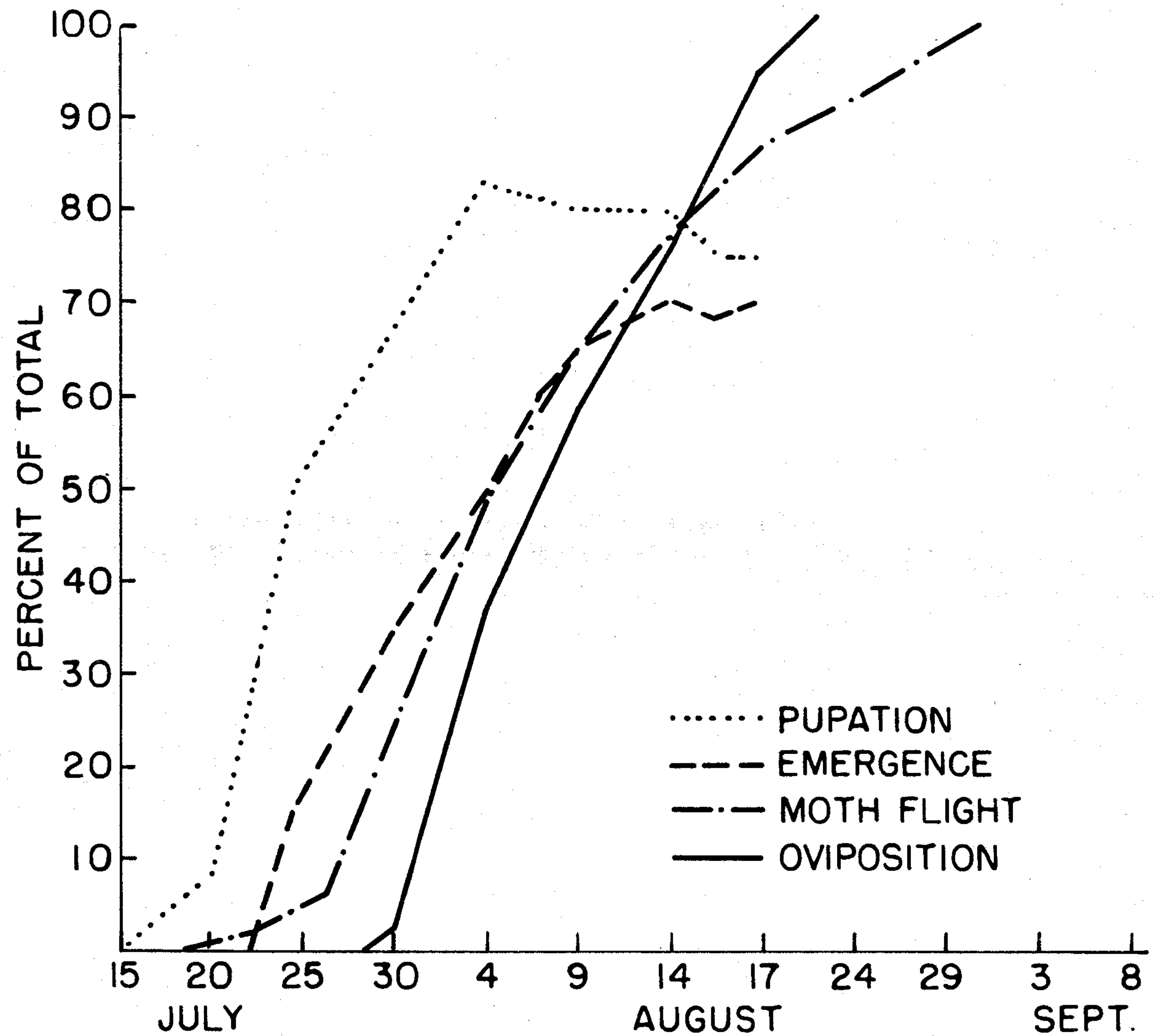


Figure 15. Summer pupation, emergence, moth flight and oviposition Boone County study area 1954.

Figure 16. Summer pupation, emergence, moth flight, and oviposition Boone County study area 1955.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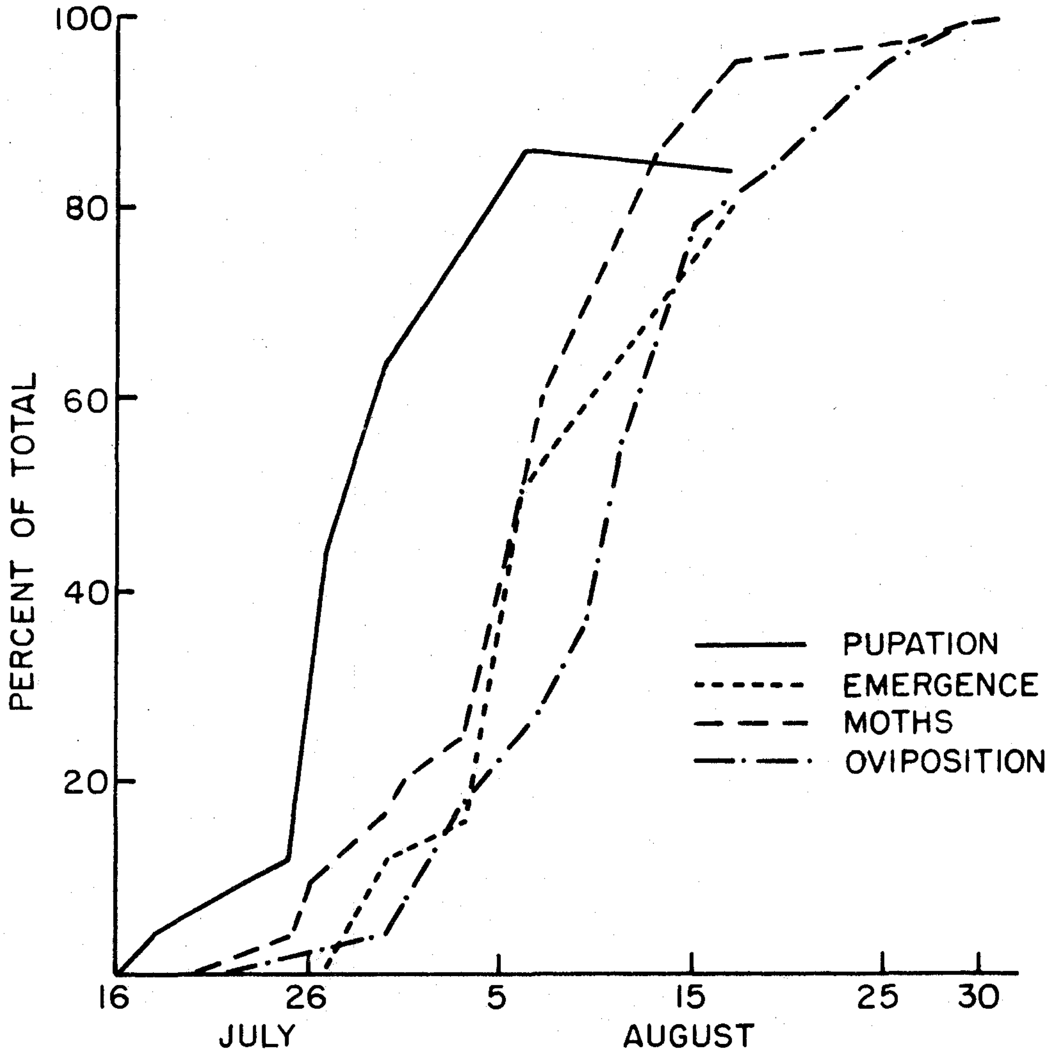


Figure 17. Summer pupation, emergence, moth flight, and oviposition Boone County study area 1956.

through 1956. Table 14 summarizes first generation populations in borers per 100 plants and the percentage of those populations that pupated to produce the second generation populations for the years 1950 through 1956. This table demonstrates quite clearly the potential fluctuations in second generation populations and clarifies why it is impossible to make a single population estimate, and from that information forecast the fate of the population either for one year or for a series of seasons. The midseason population of 1950 from the information given above alone would not be expected to produce a second generation population that would cause serious damage, while the larval population at midseason in 1954 with the high rate of pupation could be anticipated to produce a second generation population that would cause extensive damage. Subsequent evaluations confirmed this appraisal.

Table 14. First generation populations and percent pupation 1950 through 1956

Year	Borers per 100 plants midseason	Percent pupation
1950	145.6	9.0
1951	21.5	36.0
1952	5.9	88.0
1953	42.8	78.9
1954	223.4	80.0
1955	41.1	83.0
1956	42.8	84.0

Tables 42 and 43 of the appendix show the summer development dissection data according to the date each observation was made in 1954 and 1956.

Corn Growth and Weather

The extended height of the corn plant has been measured and recorded as a portion of biological information gathered in the Boone County study. Extended height of the corn plant in this study is the distance from the soil surface in the field to the tip of the longest leaf. This measurement is rather easy to obtain and eliminates the innate error of measuring natural height of the corn plant. The tassel bud height was measured for the 1951 through 1954 seasons and was eliminated on the basis of the difficulty in obtaining an average measurement for any field without destroying a large number of corn plants at each observation. Correlations between the extended height of the corn plant and egg deposition will be discussed later under statistical considerations at which time it will be evident that use of two measurements, that of temperature accumulation observations and simple measurements of extended height of corn plants, will give sufficient information to forecast the periods of greatest first generation egg deposition.

The measurement of extended leaf height can be used as an indicator of the favorability of the climatic conditions for corn growth and if a generalization holds true, an indicator of the development of the first generation population. This generalization is that the more rapid the growth of the corn plant, hence, the more rapid the differentiation of plant tissue, the more favorable are conditions for the oviposition, and the more favorable are conditions for larval establishment and survival. Huber et al. (1928) found that the rapid differentiation of corn plant tissue influences the rate of oviposition as well as the rate of larval establishment. Table 15 shows a comparison of the daily rate of corn growth for all seasons 1950 through 1956 compared with first generation survival.

Table 15. Daily rate of growth for corn in inches
1950 through 1956

Year	Average maximum growth	Average mean growth	Average minimum growth	Percent survival first generation
1950	1.9	1.3	0.8	2.7
1951	2.2	1.2	0.5	6.8
1952	2.5	1.7	1.0	4.5
1953	2.6	1.5	0.8	7.2
1954	2.1	1.8	1.4	9.1
1955	1.8	1.4	1.0	7.6
1956	2.2	1.6	1.3	6.1

In the above table it is evident that in the 1954 season the increase in rate of growth of the corn was followed by an increase in the survival of the corn borers. This relationship is not true for the other seasons. During the 1956 season the corn was severely damaged by drought. The drought conditions were evident during the first generation period in a few widely separated cases and no comparison can be drawn.

The drought, however, as illustrated in figures 18, 19, and 20 was particularly evident only during the late season of 1956 and therefore had no measurable effect on corn growth during the first generation oviposition period. The drought effects seen in table 46 of the appendix appeared at about the last week in June, 1956 when a sharp decrease in the growth rate became apparent. This sharp line of drought effect appeared during a period of not less than five days, but at the very end of first generation oviposition. This period of very hot dry weather did not affect the hatchability of the corn borer eggs nor the survival of the established larvae. If the critical lack of moisture had developed earlier in the season there might possibly have been an effect on corn growth and borer establishment. Subsequent observations during the second generation of 1956 did not bear out the idea that corn growth influences corn borer survival. The drought effects in 1956 will be further discussed under second generation oviposition.

The cool wet springs of 1950 and 1951 demonstrate a marked effect on corn growth in both of those years. The corn borer establishment in both cases was very poor and the resulting second generation populations quite low. The dry weather in the late seasons of all years except in 1954 when heavy rains fell throughout the last week in August had no affect on the growth of the corn plants but a marked affect on the corn borer populations. The heavy rains which fell in August of 1954 acted directly to bring about an abrupt end to the oviposition period of the second generation as shown in table 47 of the appendix.

Growth rates for corn plants from 1954 through 1956 are shown in

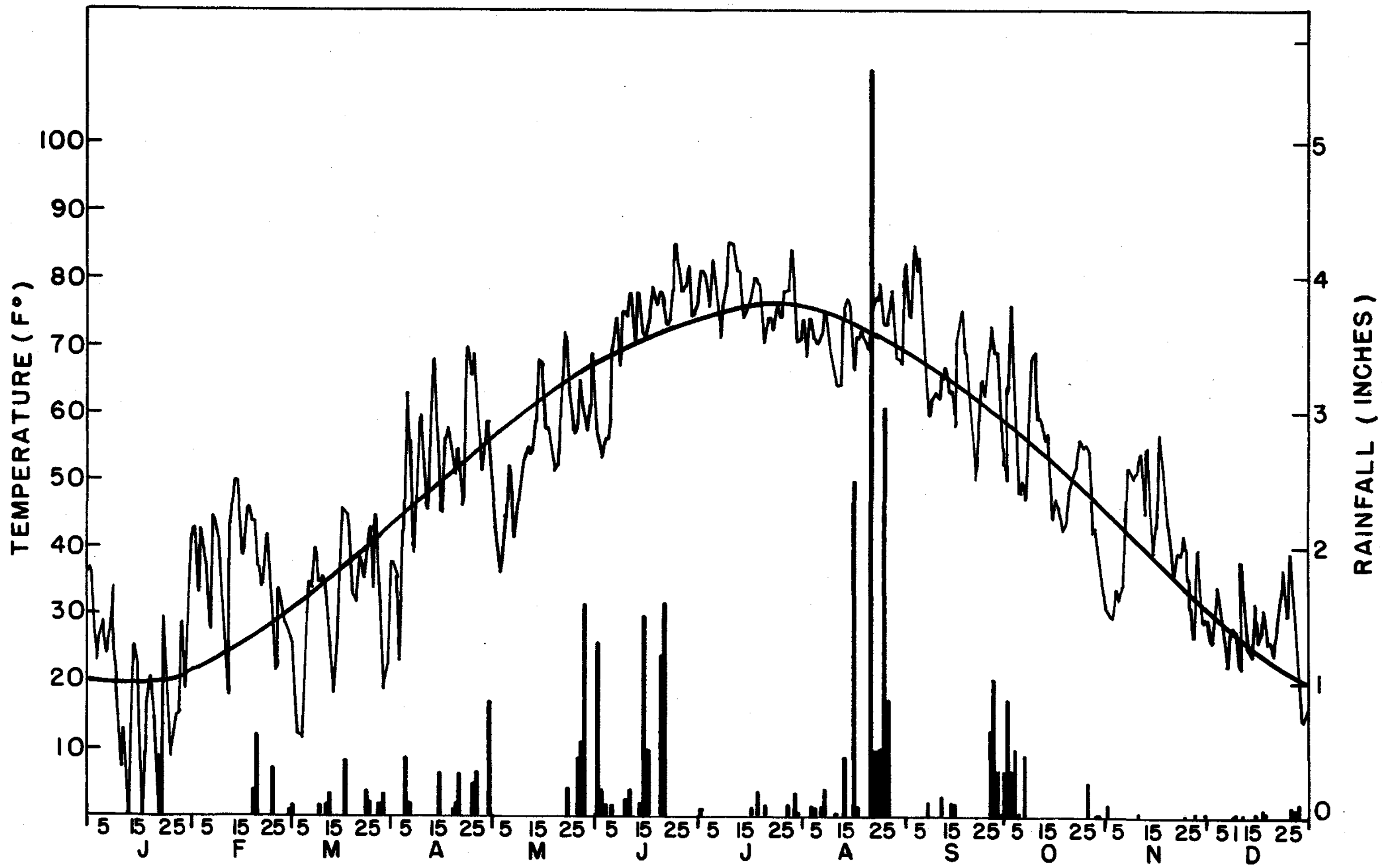


Figure 18. Daily mean temperatures and daily rainfall 1954.

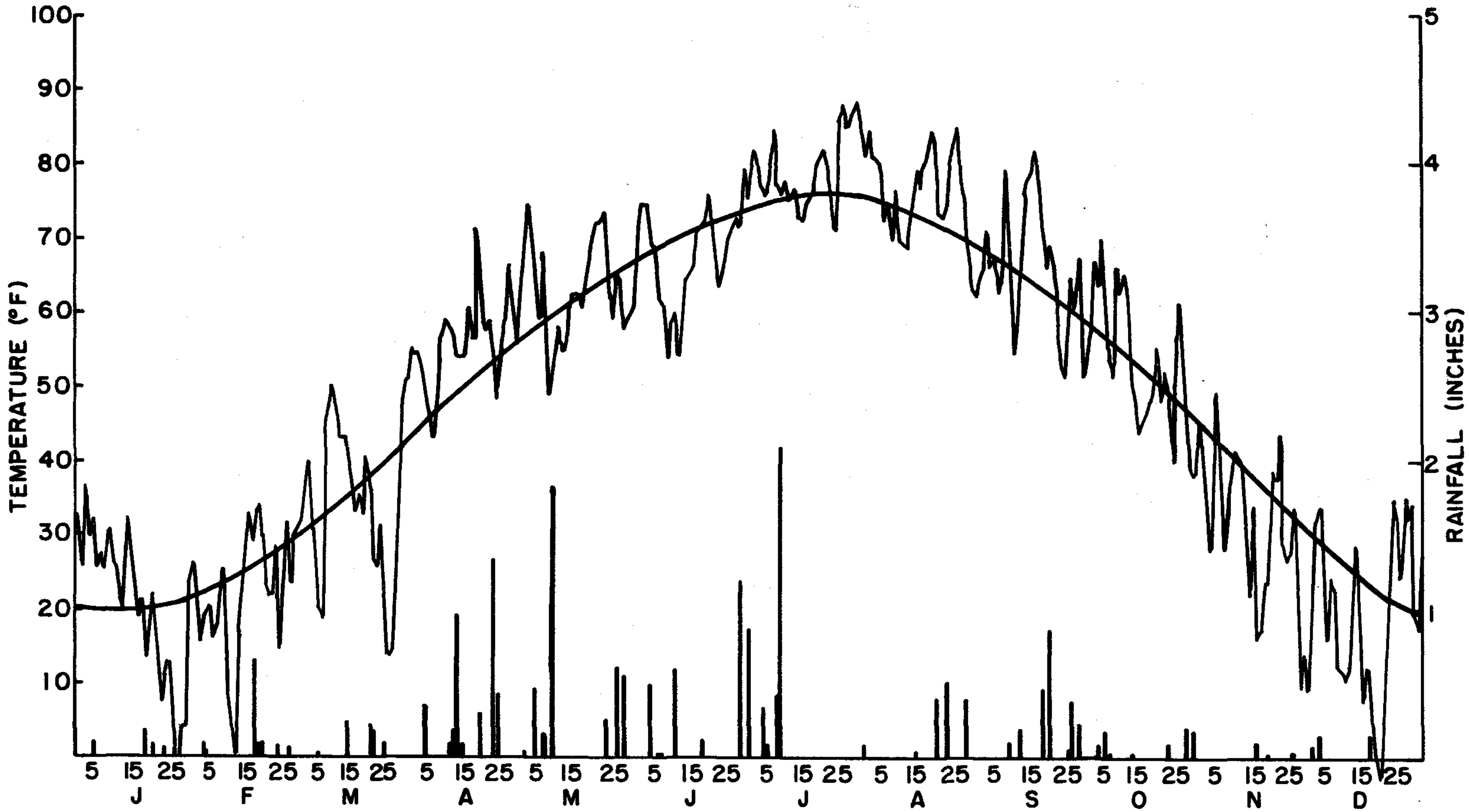


Figure 19. Daily mean temperatures and daily rainfall 1955.

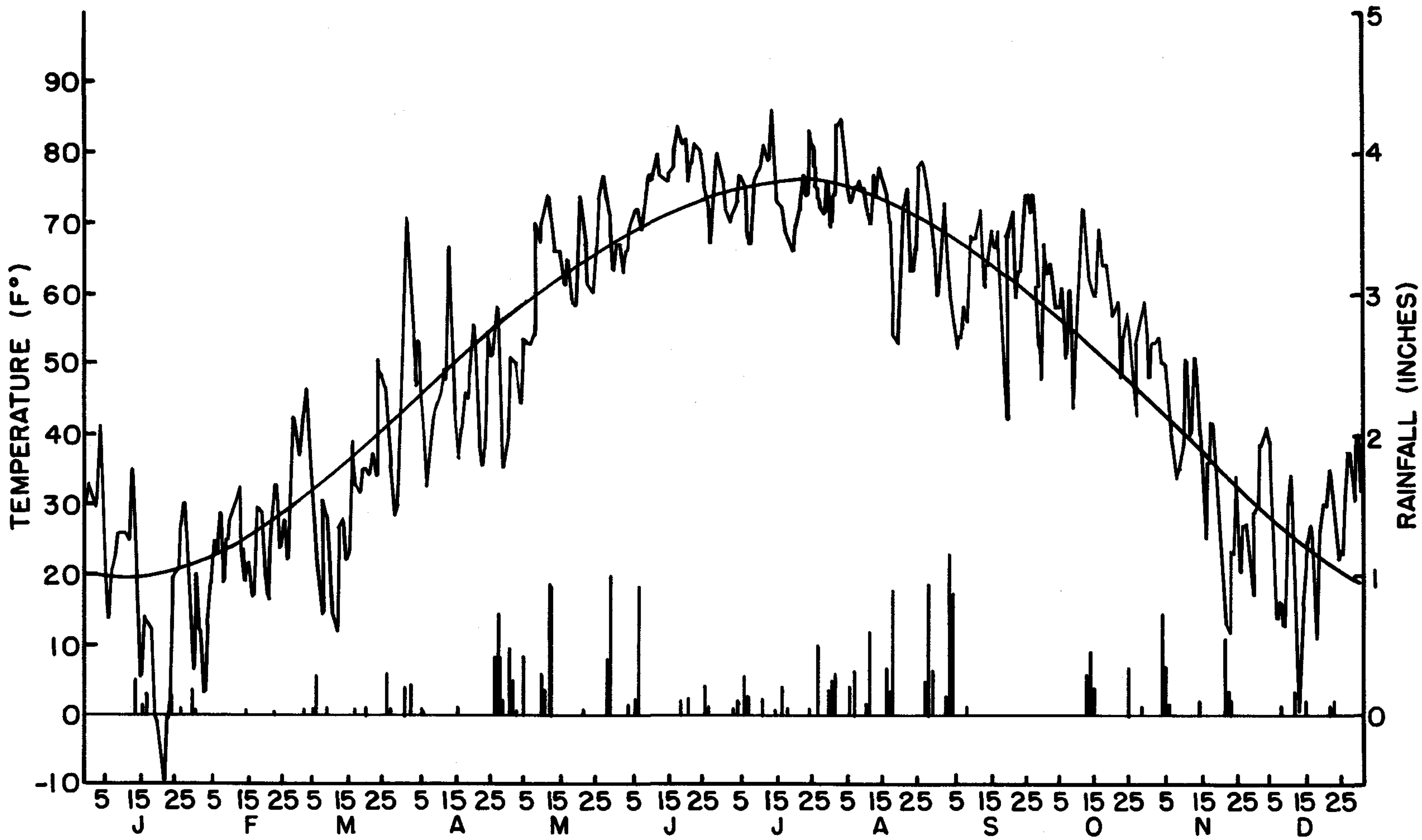


Figure 20. Daily mean temperatures and daily rainfall 1956.

tables 44, 45, and 46 of the appendix. The average height of the corn plants has been computed and was plotted as was the range of plant height for each three-day period through the growing season in figures 21, 22, and 23.

Summer Moth Flight

Moth flight observations for the summer generation of each year were conducted in the same manner as the spring moth flight. The number of light traps that were operating during the night of each date was not constant and no direct comparison of the moth flight numbers will be made. The total number of moths that were trapped is of interest only as it compares with the number of moths observed during the first generation of the same year. In these observations the dates of the first moth flight and the duration of the moth flight was important for it determined the period of oviposition. Summer light trap catches and the duration of moth flight for the years 1950 through 1956 are summarized in table 16.

The light traps were operated in the fall until the moths were no longer flying and during 1955 and 1956 that period continued until the first killing frost. There is a strong indication from moth flight collections that in the two years 1955 and 1956 a small flight of third generation moths emerged. A third generation under Iowa conditions would result in a reduction in the number of overwintering larvae, for those larvae which develop into moths would deposit eggs that could not mature as larvae that would overwinter.

It is apparent from table 16 that the relative length of the moth

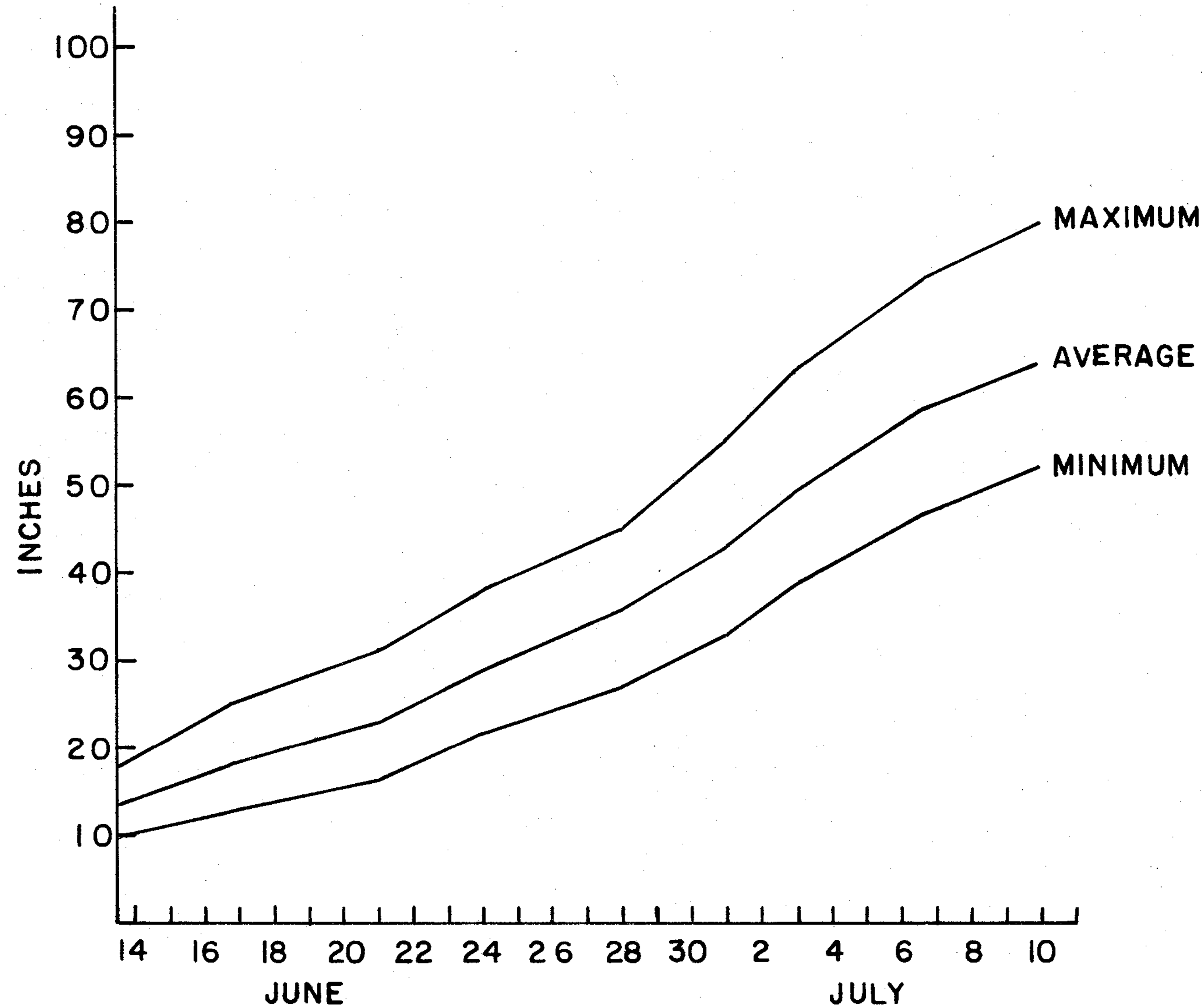


Figure 21. Daily rate of growth. Boone County 1954.

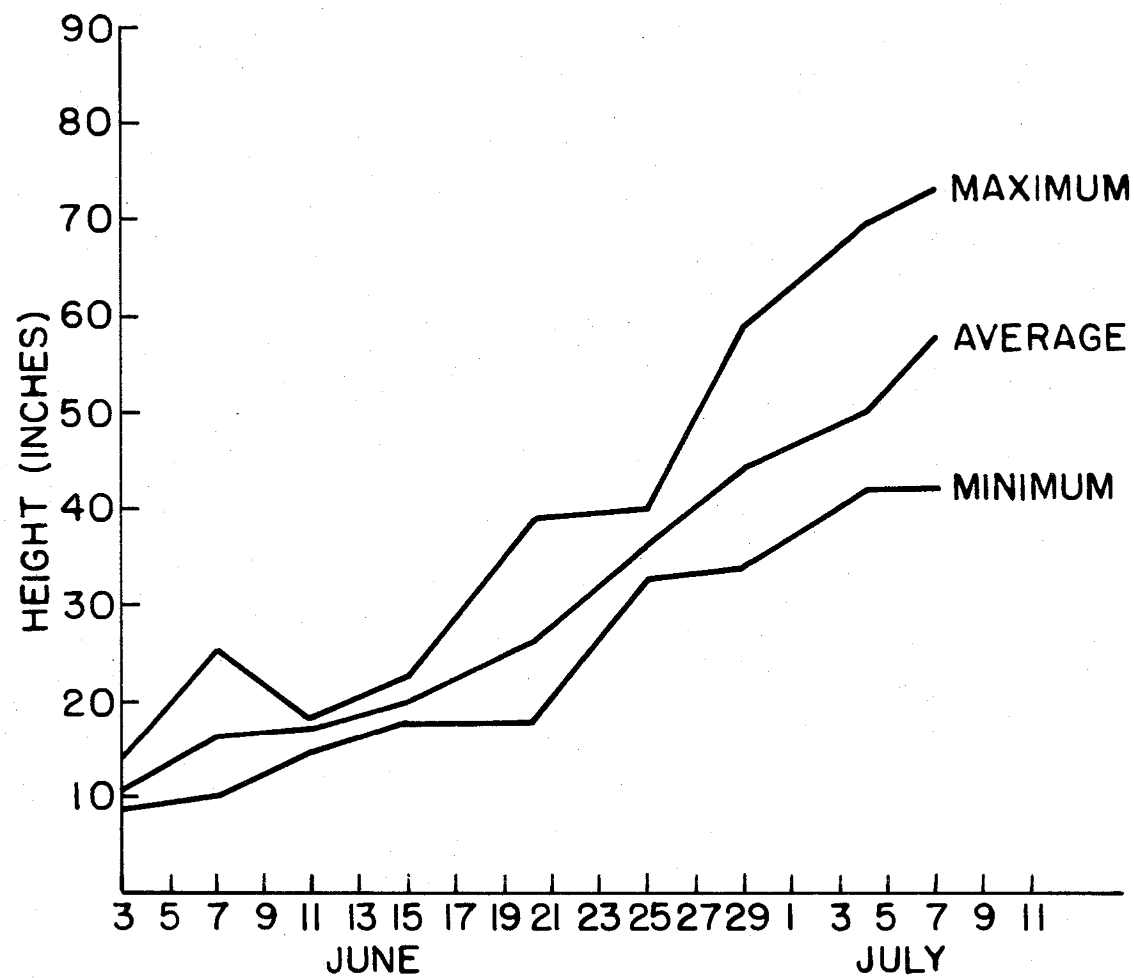
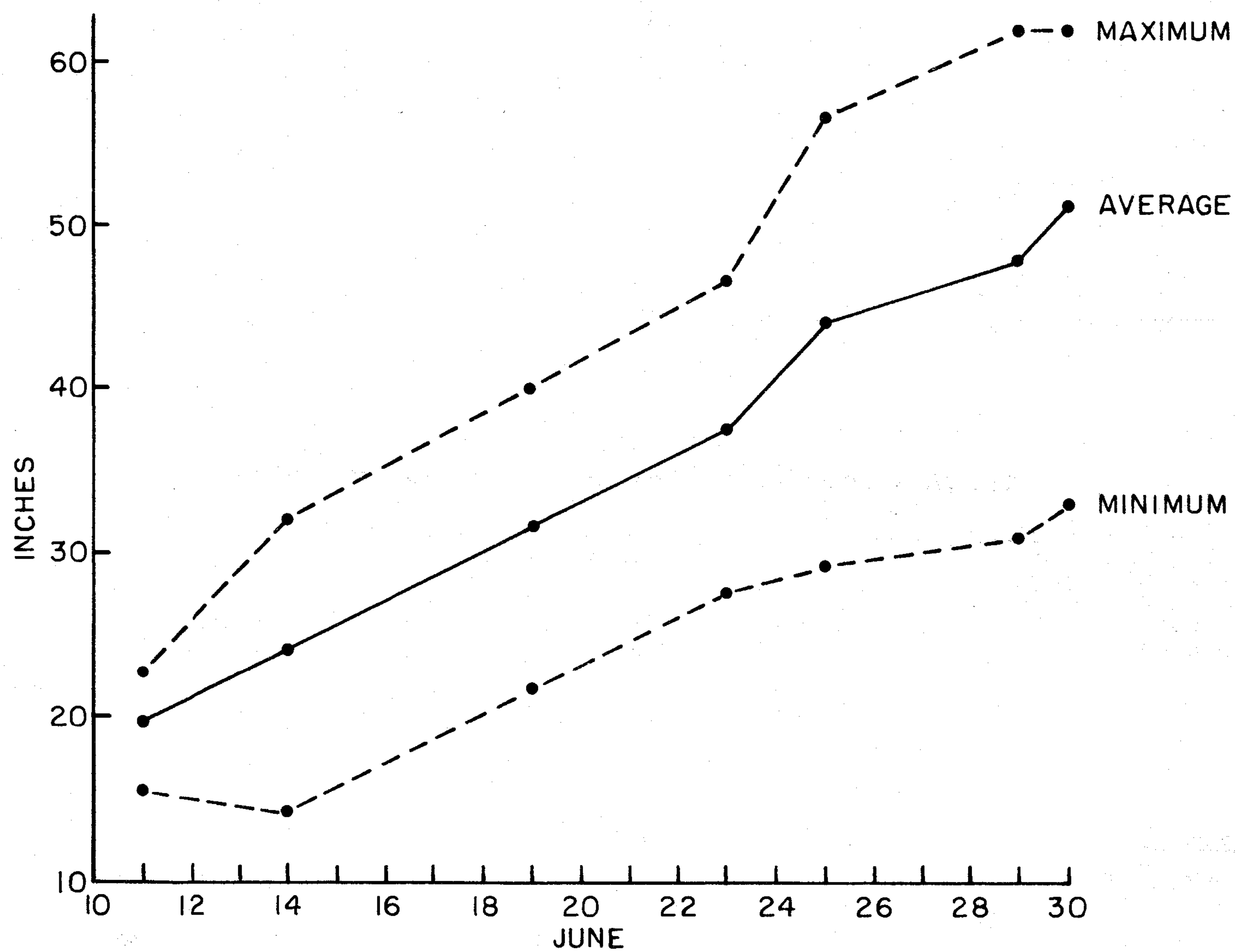


Figure 22. Daily rate of growth. Boone County 1955.

Figure 23. Daily rate of growth. Boone County 1956.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flight has been constant for the second generation. It extends over a period of some 60 days. However, the effective second generation moth flight has not been greater than 40 days. The greater proportion of the flight is completed in approximately 20 days of this 40-day period as is shown in tables 47, 48, and 49 of the appendix. It is interesting to note in comparing first generation moth flight duration with the duration of the effective second generation moth flight that when a second generation develops in the magnitude of 80 percent of first generation survival,

Table 16. Moth flight second generation 1950 through 1956

Year	Total moths	Duration of flight in days	Date of first moth	No. of traps
1950	896	72	7/30	3
1951	1,464	63	7/29	4
1952	1,080	62	7/18	3
1953	12,176	59	7/10	6
1954	47,048	81	7/20	6
1955	4,050	92	7/1	4
1956	3,927	44[a]	7/16	4
Mean		68	7/18	

[a] Flight records kept only to September 1.

roughly three times the number of moths are caught during the second generation moth flight as during the first generation moth flight. For example, in the spring of 1953 there was a population of 1,120 live borers per acre which resulted in a first generation moth flight of 1,452 moths trapped. The mid-summer population of roughly 4,800 live borers per acre gave rise to a moth flight of 12,176 trapped moths. Figures 15, 16, and 17 graphically illustrate moth flight for the second generation populations of 1954 through 1956.

Second Generation Oviposition

The summer oviposition for 1954 through 1956 is represented in figures 15, 16, and 17. These data summarized on a field basis, are shown in tables 50, 51, and 52 of the appendix. In figures 15, 16, and 17 the rate of oviposition is computed as the percent of the total oviposition that occurred daily. The individual eggs within each mass were observed and recorded as in the first generation observations. A summary of total oviposition on ten plants in each of the observation fields for the years 1950 through 1956 is given in table 17. This table clearly demonstrates the high population of the 1954 summer season. The average figure of 64 egg masses on ten plants over an area as large as Boone County brings the over-all population into numbers that are difficult to imagine. The average egg mass size has been computed for both first and second generation oviposition periods since 1950 and is found in table 18. The egg mass size was relatively constant within each generation over the seven seasons and the variation from one year to the next within the same generation was not greater than two eggs per mass. It is of value to note that the summer flight of moths deposited egg masses of slightly larger size than did their progenitors during first generation oviposition.

Table 17. Second generation oviposition on ten plants, Boone County study area

Year	Number of fields	Total eggs observed	Total masses observed	Maximum (Per 10 plants)	Average (Per 10 plants)	Minimum (Per 10 plants)
1950	176	6,286	343	22	2.0	0
1951	88	4,579	256	20	2.9	0
1952	88	5,255	282	17	3.2	0
1953	88	23,172	1,221	46	13.9	1
1954	32	39,949	2,057	101	64.0	2
1955	32	4,259	208	16	7.0	0
1956	32	3,185	173	18	5.4	0

Table 18. Average number of eggs per mass for both first and second generations 1950 through 1956

Year	Eggs per mass: First generation	Eggs per mass: Second generation
1950	15.8	18.3
1951	14.6	17.9
1952	15.3	18.6
1953	16.1	19.0
1954	15.7	19.4
1955	16.2	20.5
1956	15.2	18.4
Average egg mass size	15.6	18.9

The fate of the eggs deposited during second generation oviposition was recorded in this study. The tabulation of egg fate for all years 1950 through 1956 by percentage of the total eggs deposited appears in table 19.

Table 19. Fate of eggs second generation by percent of total eggs observed 1950 through 1956

Year	Total eggs observed	Hatched	Missing	Eaten	Infertile and dried	Number of plants
1950	6,286	54.5	18.5	9.7	27.5	1,760
1951	4,579	71.3	13.2	13.6	1.9	880
1952	5,255	71.9	9.1	8.8	9.8	880
1953	23,172	63.1	5.3	23.2	8.3	880
1954	39,949	72.2	7.9	13.6	5.5	320
1955	4,239	78.1	7.8	12.1	6.8	320
1956	3,185	93.6	3.8	0.7	1.9	320
Average percent of total						
Second generation		71.1	9.4	11.7	9.8	
First generation		76.5	15.7	4.7	3.1	

A comparison of the average percent of survival for both the first and second generations is included in the above table. The main differences in egg survival between the two generations were found between first and second generation predator effects and the number of eggs reported as missing. The predator effect as has previously been suggested appeared to be the result of higher predator populations during the middle to late summer.

The greater percentage of eggs listed as missing for the first generation was perhaps the result of the morphology of the corn plant and a tendency for the leaves of the small flexible plants to be whipped more violently by wind action. Leaf curling in response to drying during the day and later uncurling when moisture is more plentiful was suggested by Stirrett (1938) as a means by which egg masses are loosened and lost from the leaves of the corn plants. This effect is more pronounced during the first generation oviposition period than during the second.

Drought has been mentioned throughout this discussion in relation to the 1956 season. The amount of rainfall which occurred in each field included in the study was not observed directly. It was possible, however, to delineate those areas within the county that were more severely affected during the summer of 1956 on the basis of the condition of the corn at the end of the season. The areas damaged as a result of the drought are outlined in figure 24. Those areas that were severely damaged are shown by the cross-hatch lines. The small squares within the county represent the sections in which observation fields were located. Those areas marked as affected by the drought were damaged to the extent that practically all corn within the area was lost. Most of these dry fields within the shaded areas were included in the Federal soil bank plan of 1956. They were then grazed by livestock or disced down during the month of August to comply with the regulations of the program. In all cases, however, the small sampling areas in the observation fields

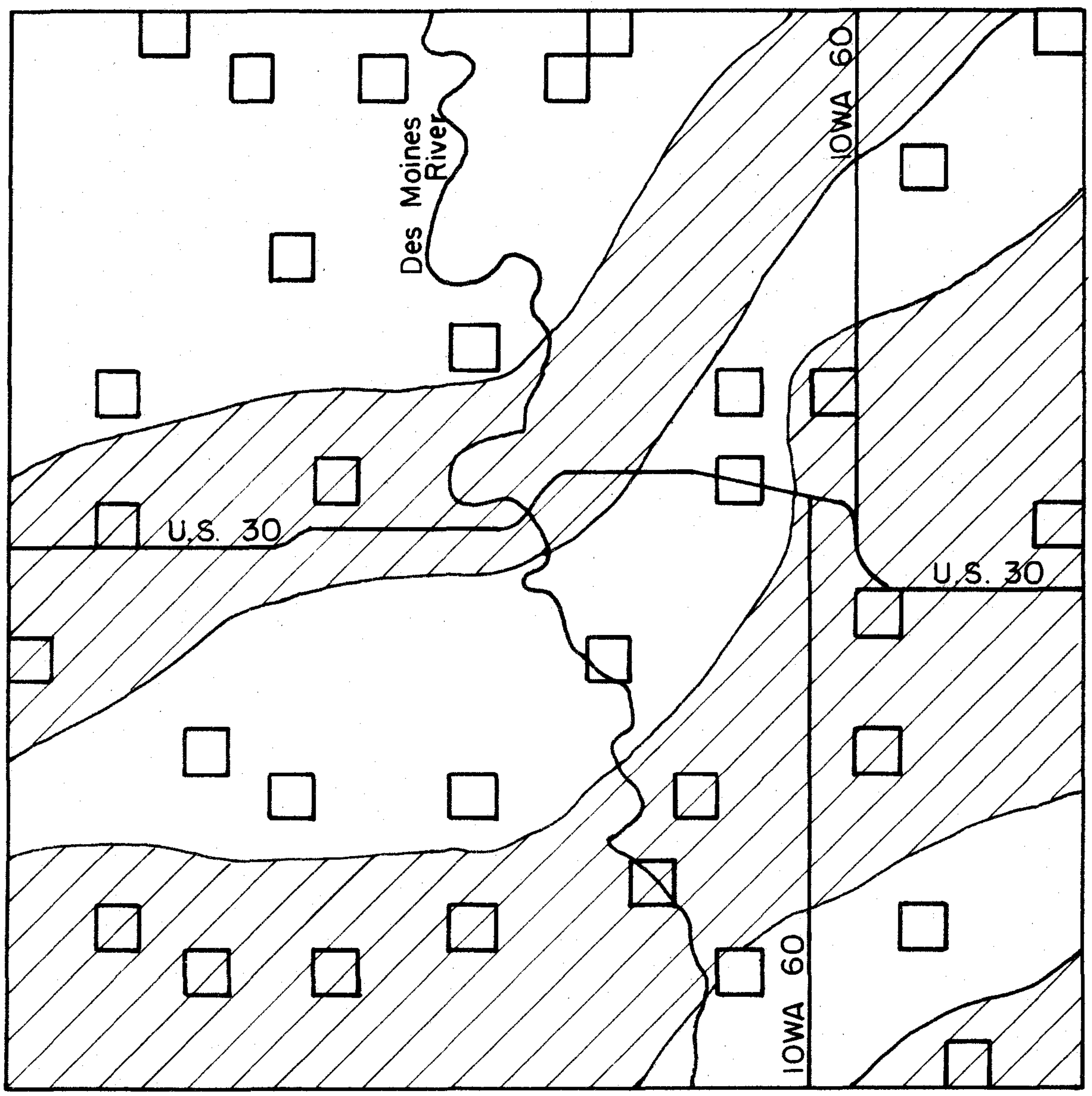

Figure 24. Areas affected by drought Boone County study area 1956.

that were treated in either of the two ways were saved. A comparison was made of the two types of field conditions (1) some moisture available and (2) the corn completely destroyed as a result of drought. Fields included in the drought area received on the average 57.1 egg masses per 100 plants and fields not included in these areas received 51.7 egg masses per 100 plants. From this information one would have to conclude that the drought of 1956 had little to no effect on the corn borer oviposition in Boone County.

Occurrence of Predators Second Generation

The predators observed during second generation oviposition were of the same species as those observed during first generation. The predators observed are listed in tables 53, 54 and 55 of the appendix. In the discussion of the results of first generation observations of predators mention was made of large increase in populations of predators during the second generation. This increase in predator population was observed during the summer months in each of the study areas as can be seen in table 20.

It is of interest to note that even when the predator population exceeded the corn borer egg population per plant in 1950 and 1956, the percent of the eggs damaged by predators remained below 10.0 percent and 0.7 percent, respectively. It would appear evident from this information that the predators observed were not primarily predators of the corn borer eggs, but were general insect predators and that the predation on the corn borer eggs was probably accidental. During the summer of 1956 aphid populations reached large proportions in Boone County and with the increase in aphid populations predator populations increased. The largest increase was in the number of lacewings and coccinellids which are known aphid predators. At no time during the last three years of this study have predators limited corn borer populations except in two widely separated cases in single fields. In the first instance during spring oviposition and in the second during the summer oviposition period. In both of these cases predation was by the red spider *Allotrombium* sp.

Table 20. A comparison of observed predator populations during the first and second generations for the years 1950 through 1956

Year	Total predators all species	Predators per plant first generation	Predators per plant second generation
1950	33,130	0.3	18.8
1951	9,608	0.3	10.9
1952	3,068	0.4	3.5
1953	4,918	1.8	5.6
1954	1,953	0.9	6.1
1955	2,007	0.9	6.3
1956	7,107	1.4	22.2

Second Generation Survival and Fall Populations

The fall corn borer populations were determined by dissection of the remaining plants in each of the observation fields. This information is summarized on a per field basis for 1954 through 1956 in tables 56, 57, and 58 of the appendix. The borers that were observed represent both the second generation larvae that have survived as well as that number of first generation larvae that did not pupate to produce a second generation. To correct for this value the number of borers computed by percentage from the mid-summer population that did not pupate was subtracted from the number of larvae observed in fall dissections. Table 21 summarized second generation survival since 1950. The egg populations and the borer populations are presented as borers per 100 plants.

Table 21. Corn borer survival second generation 1950 through 1956

Year	Total eggs	Hatched eggs	Larvae	Percent survival based on Total eggs	Percent survival based on Hatched eggs
1950	357.2	194.1	100.9	28.2	51.9
1951	520.3	370.8	71.7	13.8	19.3
1952	597.2	429.8	119.3	20.0	27.8
1953	2,633.2	1,661.5	266.3	10.1	16.0
1954	124,818.0	90,150.0	565.4	4.5	6.3
1955	1,315.3	1,034.6	150.8	11.5	14.6
1956	995.3	931.9	187.5	18.3	20.1
Average survival				15.2	22.3

A comparison of the data in tables 13 and 21 shows that the survival for the first and second generations varies widely. The first generation population is characterized by a low survival rate whereas the second generation survival rate was, on the average, twice as high. It is possible that the greater survival of second generation population was due to the rate of establishment of the corn borers during that period. The rate of establishment could increase with the stability of weather conditions and the maturity of the corn plants that are present during the period of second generation oviposition. Figures 15, 16, and 17 show the fluctuations of the daily mean temperatures illustrating the fact that summer daily mean temperatures fluctuate less during July and early August.

Corn borer populations in Boone County expressed as forms per 100 plants for the seven years 1950 through 1956 are given in table 22.

Table 22. European corn borer populations 1950 through 1956

Year	Spring[a]	First generation eggs per 100 plants	Midseason borers per 100 plants	Second generation eggs per 100 plants	Fall borers per 100 plants
1950	5,200	5,318.2	145.6	357.2	100.9
1951	1,300	314.1	21.5	520.3	71.7
1952	390	130.7	5.9	597.2	119.3
1953	1,120	592.8	42.8	2,633.2	266.3
1954	6,240	2,469.8	223.4	124,818.0	565.4
1955	12,600	582.9	44.1	1,315.3	150.8
1956	840	698.9	42.8	995.3	187.5

[a] This population computed as borers per acre.

The gradual build-up in populations until the outbreak of 1954 and the return in 1955 to a small residual population which is presently the case in the study area is clearly shown in table 22. By examination of the collected data for years prior to and including 1954 it is impossible to designate a single factor or group of factors responsible for the 1954 outbreak. A combination of factors highly favorable for corn borer oviposition were operating, for with the very high rates of oviposition the rates of apparent establishment and survival were lower than in any other year that has been studied. The high rate of oviposition during the first generation with a high rate of first generation establishment and survival would contribute to the population outbreak potential. The large number of ovipositing moths which deposited record numbers of eggs made a population outbreak possible even with relatively low egg survival. The fact that no comparable records are available, surrounding periods of corn borer population outbreaks other than for the 1954 season it is impossible to compare build-up conditions and, therefore, impossible to substantiate by comparison the reasons for the 1954 corn borer outbreak.

Parasites

The corn borer larvae collected during the fall and winter dissections of 1954 and 1955 were taken to the European Corn Borer Research Laboratory at Ankeny, Iowa where they were "reared" by G. T. York and S. W. Carter. The parasites that emerged from the mature larvae were recorded and identified. The degree of parasitism as well as the species of parasites involved is as follows: 1954, 2,342 larvae examined, 373 parasites identified as Lydella grisescens R.D. for a percentage of parasitism of 15.9; 1955, 1,882 larvae examined, 318 parasites identified as *L. grisescens* R.D. for parasitism of 16.9 percent of the borers observed. It is apparent from the above information that the only species of parasite that is firmly established in Boone County is *L. grisescens* R.D. Field observations in 1954 and 1955 show parasitism of 3.4 percent and 1.4 percent, respectively, for two years. Those parasites observed in the field were all *L. grisescens* R.D.

STATISTICAL CONSIDERATIONS

The data collected in this study have been analyzed statistically to determine some of the biological factors that influence ovipositing populations of the European corn borer.

The relationship of height of the corn plants to spring oviposition rates is expressed under r and r^2 in table 23. These values are based on the correlation of total egg masses, total eggs, hatched egg masses and hatched eggs to plant height at mid-oviposition. It is evident that total eggs are correlated to a higher degree with plant height than any of the other three measured values. This correlation of total egg masses with plant height would indicate that approximately 20 percent of the variation in the number of egg masses deposited on all plants is due to a factor of the corn plant height. Since the number of egg masses is positively correlated with plant height it would follow that the number of total eggs, hatched egg masses, and hatched eggs are similarly correlated. These correlations mean that under normal field conditions in a county-wide area in which there is variation in plant height between fields, those fields which are the tallest will receive the heavier rates of oviposition.

The rate of plant growth is also positively correlated with the rate of spring oviposition of the corn borer. The correlation coefficients computed on total eggs and rate of plant growth for the three years included in this study appear in table 23. Approximately 10 percent of the variation in oviposition rate is due to the rate of corn growth. It is shown that in 1954 this correlation was not significant. This fact was probably due to the magnitude of spring oviposition during that season. It is known that as the density of the population increases the variation between plants increases and the sampling technique used tends to break down. However, it seems reasonable to assume that when there is some variation in the rate of corn plant growth between fields, those fields having the more rapidly growing corn will receive the heaviest oviposition.

Table 23. Correlations evaluated in the Boone County study 1954 through 1956

Correlations	1954		1955		1956	
All plants	r	$r^2 \times 100$	r	$r^2 \times 100$	r	$r^2 \times 100$
Total egg masses and height at mid-oviposition	.4564**	20.83	.4513**	20.37	.3934**	15.48
Total eggs and height at mid-oviposition	.4127**	17.03	.4188**	17.54	.3689**	13.61
Hatched egg masses and height at mid-oviposition	.4301**	18.50	.3986**	15.89	.3673**	13.84
Hatched eggs and height at mid-oviposition	.4001**	16.01	.3694**	13.65	.3489**	12.17
Infested locations						
Total eggs and the daily rate of growth	.1519	2.31	.3361**	11.30	.4835**	23.38
Total eggs and the planting date	-.1804	3.26	-.3967**	15.74	-.4050**	16.40

** Denotes significance at the 1 percent level.

Recommendations for control have been made in the literature based on the concept that the earliest plantings of sweet corn receive the heaviest rates of oviposition. A correlation evaluation of this concept with field corn is shown in table 23. From this table it is evident that the oviposition rate is negatively correlated with planting date. Approximately 15 percent of the variation in the spring oviposition rate is the result of planting date. In table 23 the 1954 results are not significantly correlated. This is again the result of a breakdown in the sampling technique under extreme condition. From the information presented for 1955 and 1956 the significantly negative correlation shows that with variation in planting date in adjacent fields the earliest planted field in an area tends to receive the heaviest oviposition. On this basis it would be expected that the oviposition rate would decrease in proportion to the date of planting. For example, three fields are planted adjacent to each other, 1 is planted May 1, 2 is planted May 15, and 3 is planted May 30. Field 1 would be expected to receive more corn borer egg masses than either 2 or 3, and field 2 would receive greater oviposition than field 3.

Analyses of variance have been computed using three corn borer populations, they are: first generation eggs, borers found at midseason dissections, and borers found at fall dissections. The analyses of variance for the three populations for the years 1954 through 1956 are given in tables 59, 60, and 61 of the appendix. The components of variance as computed in 1955 and 1956 show the greatest percentage of variation to be between the individual observation plants. The actual figures arrived at have changed slightly from year to year, but the relative percentages of variation from one source to another has remained constant. The analysis of variance for 1954 is included, but the components of variance are not computed. The estimates obtained by normal procedure were negative and the information gained would not warrant the additional computation necessary to arrive at these values.

SUMMARY

The biology of European corn borer populations has been studied in Boone County, Iowa for three seasons, 1954, 1955, and 1956. The observations have been made in 32 fields selected in a restricted random fashion, two fields from each of 16 equal areas within the county. Within each field 20 plants were selected in two sites and marked for successive twice-weekly observations of the following: corn borer oviposition, the fate of all eggs deposited, the extended height of the corn plants, and the predators present on each plant.

Observations on the seasonal development and fate of the corn borer populations were made in the form of dissections performed at selected periods during the growing season of each year.

Larvae of the corn borer that were observed during the fall dissection periods were collected and "reared" to determine the percentage of parasite establishment within Boone County.

Spring populations observed in three 1/2000 acre samples in 32 fields planted to corn the previous year showed an average of 6,240, 12,000, and 840 live borers per acre for the 1954, 1955, and 1956 seasons, respectively.

Winter mortality as determined by comparison of the fall and spring populations of live corn borer larvae gave estimates of 80.8 percent in 1953-1954, 84.4 percent in 1954-1955, and 95.6 percent in 1955-1956 seasons.

Spring development was recorded for the three seasons with first pupation occurring May 14 in 1954, April 29 in 1955, and May 21 in 1956.

First emergence was observed May 31 in 1954, May 17 in 1955 and June 7 in 1956. First oviposition was recorded June 14 in 1954, June 3, 1955 and June 8, 1956.

Average egg populations during the spring oviposition period reached 162 egg masses per 100 plants in 1954, 37 egg masses per 100 plants in 1955, and 46 egg masses per 100 plants in 1956.

Midseason populations of the corn borer as estimated on the average by dissection of ten of the observation plants in each field were 223 larvae per 100 plants in 1954, 44 larvae per 100 plants in 1955, and 43 larvae per 100 plants in 1956.

Summer pupation reached the rate of 80 percent of midseason populations in 1954, 83 percent in 1955, and 84 percent in 1956.

Average summer oviposition populations for the three seasons were 642 egg masses per 100 plants in 1954, 65 egg masses per 100 plants in 1955, and 42 egg masses per 100 plants in 1956.

Fall populations averaged 565 living larvae per 100 plants in 1954, 151 larvae per 100 plants in 1955, and 188 larvae per 100 plants in 1956.

The survival of eggs deposited during spring and summer oviposition was computed for each season. In 1954, 9.1 percent of the spring oviposition survived, and 4.5 percent of the summer oviposition survived. In 1955, 7.6 percent of the spring oviposition and 11.5 percent of the summer oviposition survived. Results in 1956 showed that 6.1 percent of the spring oviposition and 18.3 percent of the summer oviposition survived.

The rate of plant growth as computed from observations of plant height made at twice-weekly intervals was 1.8 inches per day in 1954, 1.4 inches per day in 1955, and 1.6 inches per day in 1956.

Predator populations averaged 0.9 predator per plant during spring oviposition and 6.1 predators per plant during summer oviposition in 1954. In 1955 predator populations averaged 0.9 predator per plant and 6.3 predators per plant during spring and summer oviposition, respectively. The 1956 predator populations per plant were 1.4 predators at spring oviposition and 22.2 predators for summer oviposition.

The percentage of parasitism based on parasitized larvae collected at fall dissection were 15.9 percent in 1954, and 16.2 percent in 1955.

As the result of observations conducted through the 1954, 1955, and 1956 seasons and an evaluation of data from the 1950 through 1953 seasons the following generalizations seem valid:

1. Cool wet springs such as experienced in 1950 and 1951 limit the corn borer population to a single oviposition period. That period will occur during June and early July.

2. Hot dry periods which occur after the completion of spring oviposition as in 1956 will not adversely affect corn borer survival and subsequent corn borer populations.

3. Accurate estimates of the occurrence of the various stages in the corn borer life cycle can be obtained by use of temperature accumulation based on a developmental threshold of 50° F.

4. Spring corn borer oviposition is positively correlated with the extended height of the corn plants at mid-oviposition as well as the rate of corn plant growth.

5. Sampling techniques in which 20 plants were selected in two sites in each field gave adequate estimates of corn borer populations in those fields.

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A P P E N D I X

Table 24. Field history summary Boone County study area 1954

Field No.	Township	Sec. No.	No. acres	Planting date	Hybrid(s)	Planting distance	1953 crop	Fertilizer
1	Jackson	36	22	5/6	DeKalb 627, Pioneer 350-B, Vinton V38	40 x 19	clover	468 - 125#/acre
2	Des Moines	26	30	5/4	DeKalb	40 x 40	clover	- 100#/acre
3	Des Moines	14	15	5/7	Pioneer 350-B	40 x 40	clover	5-20-20 100#
4	Jackson	18	30	5/9	Cargill	40 x 40	corn	4-16-16 100#
5	Harrison	21	8	5/7	Pfister 343	40 x 40	clover	none
6	Harrison	1	5	5/6	Webster 403	40 x 19	corn	none
7	Dodge	5	40	5/14	Pioneer	40 x 19	corn	manure
8	Dodge	7	7	5/12	Pioneer	drill	clover	none
9	Pilot Mound	9	47	5/10	DeKalb 627	40 x 40	clover	none
10	Grant	12	40	5/7	Funks	40 x 40	clover	manure
11	Grant	3	13	5/11	Funks 45	40 x 40	clover	5-20-20 100#
12	Pilot Mound	31	60	5/10	Tama 78	40 x 19	clover	0-0-60
13	Yell	11	16	5/10	Pioneer 352-335	40 x 40	beans	none
14	Yell	29	20	5/10	DeKalb 627, 625, 635	40 x 19	sod	0-10-20 100#
15	Amaqua	16	19	5/12	Carlson 440	40 x 28	clover	none
16	Amaqua	33	18	5/13	Moews 520	40 x 40	corn	5-20-20 100#
17	Beaver	18	30	5/12	Pioneer 352	40 x 40	corn	5-20-10 100#
18	Beaver	26	23	5/10	-	40 x 18	corn	10-10-10 200#
19	Marcy	31	10	5/6	DeKalb 327	40 x 19	clover	3-12-12 150#
20	Union	16	15	5/6	DeKalb 627	40 x 14	sod	none
21	Union	23	40	5/10	Farmers Hybrid	40 x 40	beans	5-20-10,5-20-20 100#
22	Peoples	20	2.5	5/10	Ia.4297	40 x 20	clover	5-20-20 100#
23	Peoples	14	12	5/14	Pioneer 350-B	40 x 20	clover	none
24	Marcy	35	30	5/15	-	40 x 40	corn	none
25	Douglas	9	24	5/6	Pioneer 325	40 x 20	beans	none
26	Douglas	23	32	5/15	Cargill 300AA	40 x 40	alfalfa	none
27	Garden	34	35	5/17	Blacks 840	40 x 40	clover	none
28	Garden	16	11	5/6	Blacks 24	40 x 40	clover	manure
29	Colfax	29	40	5/11	ISC 4298, 4376	40 x 40	clover	12-24-12 70#
30	Worth	34	6	5/16	Cargill 258	40 x 30	corn	anhydrous ammonia
31	Worth	17	10	5/10	-	40 x 14	clover	none
32	Colfax	8	8	5/14	-	40 x 40	clover	none

Table 25. Field history summary Boone County study area 1955

Field No.	Township	Sec. No.	No. acres	Planting date	Hybrid(s)	Planting distance	1954 crop	Fertilizer
1	Jackson	36	5	5/14	Pioneer 354	40 x 28	corn	4-16-8 125#
2	Des Moines	26	30	5/10	DeKalb	40 x 40	corn	100#
3	Des Moines	14	80	5/5	Pioneer	38 x 38	beans	10-20-20 70#
4	Jackson	18	30	5/13	Cargill 333	40 x 40	clover	12-12-12 150#
5	Harrison	21	20	5/9	Pfiester 343	40 x 40	clover	none
6	Harrison	1	45	5/11	Blacks, DeKalb	40 x 40	oats	none
7	Dodge	5	17	5/10	Pioneer	40 x 40	corn	lime + (manure)
8	Dodge	7	12	5/12	Pioneer 347	40 x 40	pasture	manure
9	Pilot Mound	9	52	5/6	DeKalb 627	40 x 40	beans	5-20-20 100#
10	Grant	12	40	5/3	DeKalb 800A, 666	40 x 40	clover	none
11	Grant	3	5	5/13	DeKalb 635	40 x 23	corn	none
12	Pilot Mound	31	60	5/11	Pioneer 335, Tom-78	drill	corn	none
13	Yell	11	13	5/16	Pioneer 354	40 x 40	beans	none
14	Yell	29	20	5/10	Pioneer 354	drill	corn	5-0-20 spotted
15	Amaqua	16	24	5/7	DeKalb	40 x 40	corn	manure
16	Amaqua	33	20	5/9	Moews 14	40 x 40	sod	5-20-20 115#
17	Beaver	18	90	5/8	Farmers	40 x 40	corn	(0-20-9 200# (5-20-10 100#
18	Beaver	26	31	5/13	Pioneer 325 - 318	40 x 40	clover	10-20-5 100#
19	Marcy	31	58	5/3	Pioneer 325	40 x 29	corn	5-20-20 150#
20	Union	16	20	5/6	DeKalb 627	40 x 33	pasture	none
21	Union	23	15	5/12	-	40 x 40	corn	none
22	Peoples	20	2.5	5/11	Ia 504	40 x 20	corn	none
23	Peoples	14	12.5	5/20	Funks	40 x 40	clover	none
24	Marcy	35	13.5	4/28	Pioneer 301B, 354	40 x 40	clover	none
25	Douglas	9	24	5/19	DeKalb 627, Cargill 250A	40 x 22	beans	none
26	Douglas	23	32	5/11	Cargill 300AA	40 x 40	corn	none
27	Garden	34	21.5	5/13	Blacks, Funks	40 x 40	clover	manure
28	Garden	16	10	5/12	Pioneer 350-B	40 x 40	clover	none
29	Colfax	29	64	5/11	Pioneer	40 x 30	clover	none
30	Worth	34	43	5/16	Ia 4376	40 x 40	clover	none
31	Worth	17	24	5/18	Cargill 250-A	40 x 14	corn	none
32	Colfax	8	8	5/16		40 x 40	clover	none

Table 26. Field history summary Boone County study area 1956

Field No.	Township	Sec. No.	No. acres	Hybrid(s)	Planting distance	1955 crop	Fertilizer
1	Jackson	36	18	Pioneer	40 x 36	corn	5-20-20 100# anhydrous 50#
2	Des Moines	26	50	DeKalb	40 x 14	clover	none
3	Des Moines	14	8.9	Pfiester	40 x 40	beans	none
4	Jackson	18	15	Pioneer	40 x 30	alfalfa	none
5	Harrison	21	15	Cargill, DeKalb	40 x 40	clover	none
6	Harrison	1	50	Webster	40 x 40	beans	none
7	Dodge	5	38	Pioneer	40 x 40	corn	none
8	Dodge	7	10	Pioneer	40 x 40	corn	none
9	Pilot Mound	9	46.5	Pioneer	40 x 40	oats	none
10	Grant	12	30	Pioneer	40 x 40	clover	none
11	Grant	3	4	Pioneer	40 x 24	corn	manure
12	Pilot Mound	31	30	Tom.	drill	corn	manure
13	Yell	11	10	Pioneer	40 x 40	oats	none
14	Yell	29	20	Pioneer	40 x 16	clover	none
15	Amaqua	16	15	Pfiester	40 x 28	sod	none
16	Amaqua	33	20	Moews	40 x 28	corn	5-20-30 100#, 33 1/3 150#
17	Beaver	18	90	Pioneer	40 x 40	corn	5-20-10 300#
18	Beaver	26	31	DeKalb	40 x 40	corn	5-20-10 100#, 33 1/3 120#
19	Marcy	31	15	DeKalb	40 x 27	beans	3-12-12 150#
20	Union	16	21	DeKalb	40 x 24	corn	5-20-20 100#
21	Union	23	40	Farmers	40 x 40	beans	5-20-20 90#
22	Peoples	20	13	Bergstrom	40 x 40	corn	Textop 100#
23	Peoples	14	13.5	DeKalb	40 x 20	corn	none
24	Marcy	35	40	Pioneer	40 x 40	clover	none
25	Douglas	9	12	Cargill, DeKalb, Pioneer	40 x 22	corn	manure
26	Douglas	23	32	Cargill	40 x 40	corn	none
27	Garden	34	35	Blacks	40 x 40	clover	none
28	Garden	16	14	Pfiester	40 x 34	corn	manure
29	Colfax	29	16	Pfiester	40 x 30	corn	none
30	Worth	34	23	Pioneer, Pfiester	40 x 40	clover	none
31	Worth	17	24	Pioneer	40 x 40	corn	none
32	Colfax	8	18	DeKalb	drill	clover	manure

Table 27. Spring population survey Boone County study area 1954

Field No.	Date	Sample I Live borers	Sample I Dead borers	Sample I Para-sites	Sample II Live borers	Sample II Dead borers	Sample II Para-sites	Sample III Live borers	Sample III Dead borers	Sample III Para-sites
1	5/6	3			7			2		
2	"	1			2	2		2		
3	"	5	1		4			1		
4	"				1			1		
5	"	1			8			1		
6	"	3			4			2		
7	"				3					
8	"		1		7	2		4	1	
9	"	1			9	1	1	20	2	
10	"	6		1	13			2	2	1
11	"	1						1		1
12	"				3	1	1	12	3	1
13	5/7	6			2			2		
14	"	2			1			1		
15	"	1						2		
16	"	17	1	1				3		
17	"	1			2					
18	"	4	1		3	1				
19	"	16	1		2	3		3		
20	"	1			4			6	1	
21	"	4	1		5	1		7		
22	"	1	1		1	1		3		
23	"				3	3		5	1	
24	"	2			3			4		
25	5/8									
26	"	2			6	1		2		
27	"	1	1		2					
28	"	4			6	2	2	5	1	2
29	"	6		1	6	1		5		
30	"	1						1		
31	"							1		
32	"	2	3		1			2	1	
Total		92	11	3	108	19	4	100	12	5

Table 28. Spring population survey Boone County study area 1955

Field	Sample I			Sample II			Sample III		
No.	Larvae	Pupae	Parasites	Larvae	Pupae	Parasites	Larvae	Pupae	Parasites
1	2			5			4		
2	5			5	2	1	13	1	1
3	5		1	3	1		2	1	
4	1			4	1		2	1	
5	7			3			3		
6	13			12			6		
7	6			11			14	1	1
8	4	1		16			7	2	
9		1		9	6		6	2	
10	5	1		3	1	1	4	1	
11	1	1	1	5	3	1	7	1	
12	18	4		9	2		9	4	
13	10			8			4	1	
14	1			4	1		4	1	1
15	1			2			8	2	1
16	6		1	4			6	1	
17	6			19			11		
18	2			5		1	4	7	1
19	10	2	1	12	1	2	13	2	
20							2		
21	9	1		2			5	1	
22	2	1		4	2		3	1	1
23	12			7			10		
24	10			5			12		
25	5			3					
26	5	1		1	2		7	1	
27	8	3		15	3			1	
28	10	2		9			5	1	1
29	8		1	15		1	7	4	1
30	5			10			15	1	1
31	2			1			5		
32	2	1		8	2		6	1	
Total	181	19	5	219	26	7	204	41	9

Table 29. Spring population survey Boone County study area 1956

Field No.	Date	Sample I Live borers	Sample I Dead borers	Sample I Para-sites	Sample II Live borers	Sample II Dead borers	Sample II Para-sites	Sample III Live borers	Sample III Dead borers	Sample III Para-sites
1	4/18				1			1		
2	"									
3	"				1					
4	"									
5	"	1	1		1					
6	"				3	2			1	
7	"	1	1		1			1		
8	"							1	1	
9	4/19	1						3		
10	"	1								
11	"	1			1			1		
12	"		1					2		
13	"	2	1							
14	"				2					
15	"	1								
16	"									
17	"		2							
18	"									
19	"								1	
20	"					1				
21	4/20							1		
22	"									
23	"									
24	"				1			3	1	
25	"							2		
26	"									
27	"	1	1							
28	"									
29	"									
30	"									
31	"									
32	"	2			1			2		
Total		11	7		12	3		17	4	

Table 30. First generation moth flight and oviposition
Boone County study area 1954

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
6/7	16	0.35	0.35			
8	31	0.68	1.03			
9	28	0.61	1.64			
10	59	1.3	2.94			
11	121	2.67	5.61			
12	134	2.96	8.57			
13	290	6.4	14.97			
14	140	3.09	18.06	1	0.09	0.09
15	255	5.63	23.69	0		0.09
16	353	7.79	31.48	2	0.19	0.28
17	735	16.23	47.71	9	0.88	1.16
18	156	3.44	51.15	34	3.35	4.51
19	514	11.35	62.50	58	6.72	11.23
20	162	3.57	66.07	0		11.23
21	156	3.44	69.51	123	12.14	23.37
22	451	9.96	79.47	147	14.51	37.88
23	273	6.03	85.50	120	11.84	49.72
24	45	0.99	86.49	82	8.09	57.81
25	54	1.19	87.68	145	14.31	72.12
26	110	2.43	90.11	51	5.03	77.15
27	95	2.09	92.20	3	0.29	77.44
28	15	0.33	92.53	87	8.58	86.02
29	48	1.06	93.59	71	7.00	93.02
30	57	1.25	94.84	18	1.77	94.79
7/1	114	2.51	97.35	24	2.36	97.15
2	27	0.59	97.94	17	1.67	98.82
3	43	0.95	98.89	7	0.69	99.51
4	21	0.46	99.35	0		99.51
5	17	0.37	99.72	0		99.51
6	12	0.26	99.98	9	0.88	100.39
Total	4,526		100.00	1,007		100.00

Table 31. First generation moth flight and oviposition
Boone County study area 1955

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
5/17	8	0.01	0.01			
18	1	0	0.01			
19	5	0.01	0.01			
20	11	0.36	0.37			
21	97	2.04	2.41			
22	160	3.4	5.81			
23	71	1.5	7.31			
24	8	0.01	7.32			
25	3	0.01	7.33			
26	5	0.01	7.34			
27	0		7.34			
28	83	1.7	9.04			
29	4	0.01	9.05			
30	0		9.05			
31	1	0	9.05			
6/1	4	0.01	9.06			
2	163	3.4	12.46			
3	977	20.6	33.06	1	0.4	0.4
4	598	12.6	45.66	0		0.4
5	647	13.6	59.26	0		0.4
6	231	4.9	64.16	0		0.4
7	0		64.16	43	18.2	18.6
8	1	0	64.16	2	0.8	19.4
9	1	0	64.16	0		19.4
10	14	0.3	64.46			
11	127	2.7	67.16	1	0.4	19.8
12	4	0.01	67.17	0		19.8
13	8	0.01	67.18	0		19.8
14	4	0.01	67.19	0		19.8
15	131	2.8	69.99	11	4.7	24.5
16	81	1.7	71.69	7	2.9	27.4
17	338	7.1	78.79	9	2.9	30.3
18	271	5.7	84.49	1	0.4	30.7
19	165	3.4	87.89	3	1.2	31.9
20	147	3.1	90.99	33	13.9	45.8

Table 31. (Continued)

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
6/21	108	2.3	93.29	19	8.1	53.9
22	58	1.2	94.49	34	14.4	68.3
23	22	0.5	94.99	10	3.0	71.3
24	43	1.0	95.99	6	2.9	74.2
25	39	0.9	96.89	11	4.7	78.9
26	18	0.4	97.29	0		78.9
27	23	0.5	97.79	25	10.6	89.5
28	25	0.5	98.21	0		89.5
29	9	0.01	98.30	2	0.8	90.3
30	8	0.01	98.31	7	2.9	93.2
7/1	2	0	98.31	7	2.9	96.1
2	1	0	98.31	4	1.2	97.3
3	5	0.01	98.32	0		97.3
4	10	0.02	98.34	0		97.3
5	3	0.01	98.35			
6	0		98.35			
Total	4,749		100	236		100

Table 32. First generation moth flight and oviposition
Boone County study area 1956

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
6/2	2	0.13	0.13			
3	0		0.13			
4	43	2.86	2.99			
5	166	11.06	14.05			
6	238	15.86	29.91			
7	53	3.53	33.44			
8	29	1.93	35.37	2	0.68	0.68
9	92	6.13	41.50	0		0.68
10	180	11.99	53.49	0		0.68
11	169	11.26	64.75	3	1.02	1.70
12	125	8.33	73.08	1	0.34	2.04
13	65	4.33	77.41	20	6.82	8.86
14	24	1.59	79.00	42	14.33	23.19
15	52	3.46	82.46	20	6.82	30.01
16	8	0.53	82.99	19	6.48	36.49
17	63	4.20	87.19	0		36.49
18	0		87.19	72	24.57	61.06
19	35	2.33	89.52	26	8.87	69.93
20	17	1.13	90.65	27	9.21	79.14
21	39	2.59	93.24	30	10.24	89.34
22	16	1.07	94.31	6	2.05	91.43
23	13	0.87	95.18	10	3.41	94.84
24	37	2.46	97.64	0		94.84
25	3	0.20	97.84	12	4.09	98.93
26	12	0.79	98.63	0		98.93
27	2	0.13	98.76	1	0.34	99.27
28	0		98.76	0		99.27
29	8	0.53	99.29	1	0.34	99.61
30	2	0.13	99.42	1	0.34	99.95
7/1	1	0.07	99.49	0		99.95
2	6	0.39	99.88			
3	0		99.88			
4	0		99.88			
5	1	0.07	99.95			
Total	1,501		100.00	293		100.00

Table 33. Fate of eggs, first generation, Boone County study area 1954

Field No.	Total	Hatched	Missing	Infertile	Eaten	Dried
1	602	586		16		
2	442	429	13			
3	1069	834	138	11	50	36
4	142	136	6			
5	620	392	228			
6	288	249	39			
7	743	668	70	5		
8	647	449	198			
9	651	572	71	8		
10	683	539	144			
11	580	514	66			
12	230	205	25			
13	476	411	49			16
14						
15	338	281	27			30
16	949	770	165			24
17	388	346	38	4		
18	157	152		5		
19	983	879	39	42	23	
20	743	550	193			
21	540	424	98	18		
22	301	289	9			3
23	230	219	11			
24	29	29				
25	773	670	92	11		
26	212	172	40			
27	601	480	67	54		
28	495	435	53	7		
29	599	476	102	7	14	
30	484	418	54	3		9
31	732	678	44	10		
32	80	80				
Total	15,807	13,332	2,079	201	87	118
Percent of total		84.34	13.15	1.27	0.55	0.75

Table 34. Fate of eggs, first generation, Boone County study area 1955

Field No.	Total	Hatched	Missing	Infertile	Eaten	Dried
1	96	82	14			
2	121	52	14	55		
3	148	113	22	13		
4	195	128	77			
5	194	156	38			
6	158	119	39			
7	148	85	63			
8	46	27				19
9	109	88	21			
10	30	30				
11	134	109	25			
12	39	16	23			
13	17	17				
14	15	15				
15	64	24	40			
16	83	83				
17	246	165	72	9		
18	126	45	59		22	
19	592	440	137	15		
20	388	176	194	18		
21	30	30				
22	98	85	13			
23	0					
24	431	362	63	3		3
25	10	10				
26	22	10	12			
27	0					
28	14	14				
29	29	13	16			
30	164	107	57			
31	34	34				
32	0					
Total	3,731	2,635	939	113	22	22
Percent of total		70.6	25.2	3.0	0.6	0.6

Table 35. Fate of eggs, first generation, Boone County study area 1956

Field No.	Total	Hatched	Missing	Infertile	Eaten	Dried
1	35	35				
2	153	153				
3	183	152	7		24	
4	94	94				
5	51	51				
6	217	214			3	
7	93	74	9		10	
8	419	347	52	20		
9	38	29		9		
10	441	387	50		4	
11	317	314			3	
12	137	137				
13	101	101				
14	154	147	7			
15	55	55				
16	121	121				
17	297	252	45			
18	117	117				
19	104	104				
20	495	418	77			
21	0					
22	43	43				
23	49	49				
24	258	197	20	19	12	10
25	90	32		15		43
26	0					
27	28	28				
28	9	9				
29	144	144				
30	95	95				
31	135	135				
32	0					
Total	4,473	4,034	267	63	56	53
Percent of total		90.2	6.0	1.4	1.3	1.2

Table 36. Occurrence of predators, first generation, Boone County study area, 1954

Field No.	Predators: Red spider[1/]	Orius	Chrysopa: Eggs	Larvae	Pupae	Adult	Lady bird beetles: Eggs	Larvae	Pupae	Adult
1			18							7
2			7							18
3	8		11							1
4			2							4
5										1
6			3							7
7			11				10			8
8			4							8
9			1							10
10			6							12
11			3							1
12			1							3
13			1							5
14										
15			3							3
16			10							9
17			5				28			14
18			5			1				10
19			19				37	1		15
20			5							17
21		1	8							10
22			12							9
23			10							5
24			8							1
25			14	1						7
26		1	7							6
27			2				25			15
28			21							5
29			9							5
30			2							3
31			6							4
32			2							5
Total	8	2	217	1		1	100	1		227

[1/] _Trombididae allothrombium_ sp.

Table 37. Occurrence of predators, first generation, Boone County study area, 1955

Field No.	Predators									
	Red spider[1/]	Orius	Chrysopa				Lady bird beetles			
			Eggs	Larvae	Pupae	Adult	Eggs	Larvae	Pupae	Adult
1			6							10
2		6	3				13			4
3		1	19			1				4
4			2				12			2
5			10							2
6			7							1
7			7	1						8
8			10							3
9			7				29			
10			6							3
11		1	19							1
12			10				8			
13										5
14			2							2
15			11				7			7
16			15							3
17			56				10			4
18		1	17							12
19			13	4						11
20		1	8				13			4
21			2							1
22			11							4
23			3							2
24			16				6	6		16
25			3							3
26			7							7
27			4							2
28			3							
29			5	1						8
30			5							4
31			9							3
32										1
Total		10	296	6		1	98	6		137

1/ *Trombididae allothrombium* sp.

Table 38. Occurrence of predators, first generation, Boone County study area, 1956

Field	Predators									
	Red		Chrysopa				Lady bird beetles			
No.	spider[1/]	Orius	Eggs	Larvae	Pupae	Adult	Eggs	Larvae	Pupae	Adult
1			2							19
2			4							20
3			7				3			28
4			1				8			27
5			12							9
6			11			1				29
7			9			1				18
8			5							69
9			5							19
10			14							81
11			15							17
12			0							3
13			7							24
14			4							28
15			0							7
16			8							15
17			23							50
18			19							18
19			16							12
20			17							38
21			3							3
22			5							2
23			3							12
24			10							38
25			8							6
26			2			1				6
27			4							3
28			5							6
29			6			1				3
30			17							6
31			2							24
32			2							5
Total			236			4	11			645

[1/] Trombididae allothrombium sp.

Table 39. Midseason dissections Boone County study area 1954

Field No.	Instars I	II	III	IV	V	Pupae	Parasites	Total
1			8	22	27			57
2		1	1	10	14			26
3			4	12	19			35
4		1		3	8			12
5			2	9	5			16
6			1	4	5			10
7		1	7	16	17			41
8			8	12	19			39
9				1	4			5
10			4	10	12			26
11			7	12	18			37
12		2		4				6
13		2	4	4	5			15
14			2	7	10	2	1	22
15				1	2			3
16			5	8	11			24
17			1	8	10	2		21
18				2	1			3
19			2	10	24	3		39
20			1	3	13	2		19
21				2	8			10
22				3	7	3	1	14
23				6	15	5		26
24					1	1		2
25				12	27	2		41
26				3	6			9
27			1		5	1		7
28			1	3	15	3	1	23
29			1	26	26			53
30			9	22	29			60
31								0
32			1	4	9			14
Total		7	70	239	372	24	3	715
Percent of total		0.97	9.79	33.43	52.03	3.36	0.42	100.00

Table 40. Midseason dissections Boone County study area 1955

Field No.	Instars I	II	III	IV	V	Pupae	Parasites	Total
1			1	4	1			6
2		1		1	1			3
3		1		5	2			8
4			3	5	4			18
5			3	3	4			10
6			2	4	5			11
7				2	5		1	8
8					4			4
9				3	6			9
10			1	1				2
11			1	1				2
12				1	1			2
13					2			2
14								
15				2	7			9
16			1	1				2
17		1		3	3	1		8
18		1	1	3	3			8
19				4	2			6
20				1	3			4
21								
22				1	2			3
23			1	1				2
24					1			1
25				1				1
26					2			2
27					1			1
28								
29				1	2			3
30				3	6			9
31					2			2
32					1			1
Total		4	14	51	70	1	1	141
Percent of total		2.8	9.9	36.2	49.6	0.7	0.7	98.64

Table 41. Midseason dissections Boone County study area 1956

Field No.	Instars I	II	III	IV	V	Pupae	Parasites	Total
1				2	2			4
2			3	2				5
3			2	4	3			9
4			1	1				2
5								
6		1	4	6	1			12
7			4	2	1			7
8			1					1
9			1	3	2			6
10			3		1			4
11					2			2
12								
13			4	4				8
14			1	1	3			5
15								
16			6	7				13
17				2				2
18				1	1			2
19			1	4	8			13
20			4	2	1			7
21			1					1
22			2	3	1			6
23				3	1			4
24			2		1			3
25								
26		2						2
27			2		2			4
28				3	4			7
29				1				1
30			1		2			3
31				1	2			3
32								
Total		4	43	52	38			137
Percent of total		2.9	31.4	38.0	27.7			100.00

Table 42. Summer pupation and emergence
Boone County study area 1954

Date	Plants dissected	Instars I	II	III	IV	V	Pupae	Emerged	Percent pupation	Percent emergence
7/6	12		24	47	23	8				
10	13		17	23	34	36				
14	14			6	36	61				
16	320		8	51	135	176	2		1	
20	320			17	96	186	23		7	
23	22			6	14	63	14	1	13	7
27	13			1	3	22	25		49	
30	27				4	42	44	12	55	21
8/3	15					20	17	16	62	48
4	10					13	20	17	74	46
6	17					10	21	19	80	48
10	30					22	23	55	78	71
13	14					15	11	24	70	67
Total			49	151	345	674	200	144		

Table 43. Summer pupation and emergence
Boone County study area 1956

Date	Instars					Pupae	Emerged	Percent pupation	Percent emergence
	I	II	III	IV	V				
7/3		2	5	9	9				
5		8	9	5	6				
9		1	6	9	11				
16			3	5	17				
18				8	16	1		4	
25					22	3		12	
27				1	16	11		44	
30					9	13	3	64	12
8/1					18	7	1	32	4
3					14	7	4	44	16
6					4	10	14	86	50
8					17	5	3	32	12
10					8	6	12	69	46
15		6	1		10	1	7	32	28
17			3		2	1	20	84	80
Total		17	27	37	179	65	64		

Table 44. Daily rate of growth Boone County study area 1954

Field No.	June 11	12	14	15	16	17	18	19	21	22	23	24	25
1	13			19			22.5			30.4			36.8
2	11.5			19.5			19			24.6			30.3
3	16			25			27.5			34.7			41.8
4	11			17			18.7			24			29.3
5	12			19			22.3			28			34.6
6	10			14.5			18.4			23.6			27.9
7	11			15			18.2			26.2			32.7
8	12			14			21.8			26.6			35.7
9	12			18.5			24			27			31
10	14			17			22.3			28.7			33.9
11	12.5			18			25.3			32.5			38.9
12	11			15			18.6			23.3			28.2
13		12			15.4			19.9			25.0		
14		14			19.6			25.3			-		
15		11			15.8			21.6			28.3		
16		18			23.7			29.9			37.9		
17		15			21.2			27.0			33.9		
18		11			13.4			16.7			22.7		
19		17.5			23.4			30.4			38.2		
20		19			24.2			31.2			38.5		
21			17.5			21			26.5			34.7	
22			16			21.5			30.1			35.7	
23			15			17.4			25.3			30.6	
24			13			13.1			18.8			23.2	
25			14.5			16.7			24.5			31.2	
26			13			14			22			28.6	
27			15			19.4			27.4			32.3	
28			18			18.6			25.3			30.3	
29			17			20.9			28.2			33.4	
30			16			17.1			25.5			31.35	
31			17.5			19.2			27.1			-	
32			12			14.3			21			26.2	
Average			14			18.2			23.8			29.7	

Table 44. (Continued)

Field No.	June				July							Total plant growth	Rate of growth
	26	28	29	30	1	2	3	6	7	9	10		
1			46.6			52.7		62.5		66.2		53.2	1.8
2			37.9			44.4		54.9		61.3		49.8	1.7
3			49.8			56.1		67.9		72.3		56.3	1.9
4			35			40.2		47.9		52.8		41.8	1.4
5			47.4			48		56.5		60.6		48.6	1.7
6			33.6			39.2		48.2		53.4		43.4	1.5
7			41.3			49.4		57.3		62.9		51.9	1.8
8			43			50.2		59.1		65.9		53.9	1.9
9			38.5			44		52.2		57.5		45.5	1.6
10			41.1			46.5		57.4		62.4		48.4	1.7
11			47.9			53.2		65.2		69.6		57.1	2.0
12			34.5			39.5		49.4		55.4		44.4	1.5
13	30.7			36.9			42.3		49.5		53.7	41.7	1.4
14	-			49.9			-		69.6		75.9	61.9	2.1
15	32.3			38			44.2		50.8		55.7	44.7	1.5
16	43.4			52.2			59.9		68.3		73.3	55.3	1.9
17	36.5			47.9			55.9		64.9		69.2	54.2	1.9
18	28.7			36.2			41.2		52.9		57.6	46.6	1.6
19	42.5			55.3			62.9		72.4		75.2	57.7	2.0
20	45.2			54.5			63.1		74.4		79.9	60.9	2.1
21		43.1			48.2				63.7			46.2	1.9
22		43.5			47.6				66.5			50.5	2.1
23		38.2			44.3				63.5			48.5	2.0
24		30			36.3				51.2			38.2	1.6
25		38.8			44.1				57.1			42.6	1.8
26		36.6			40.4				60.2			47.2	2.0
27		41.8			47.4				64.4			49.4	2.1
28		36.6			43.3				60.4			42.4	1.8
29		40.5			46.2				60.1			43.1	1.8
30		39.1			44.4				57			41.0	1.7
31		39.4			44.2				53.8			36.3	1.5
32		33.2			39.4				54.7			42.7	1.8
Average		36.2			43.5		49.9		59.2		64.1		

Table 45. Daily rate of growth Boone County study area 1955

Field	June											
No.	3	7	10	11	13	14	15	16	17	20	21	22
1	9.95			15.5			17.25					30.60
2	10.20			14.85			18.70					30.55
3	12.84			18.30			21.30					34.95
4	9.90			15.10			17.80					29.40
5	11.10			17.95			21.15					32.55
6	11.00			16.95			19.15					31.50
7		20.00		18.40			22.30					34.00
8				18.40			21.45					33.36
9		17.00			18.75			22.75		27.15		
10		10.00			12.60			14.85		17.30		
11		14.00			16.30			20.40		25.70		
12		11.00			12.45			15.40		18.70		
13		12.00			13.50			15.90		21.40		
14		12.00			12.30			14.70		17.70		
15		15.00			16.80			20.55		26.15		
16		14.00			14.30			18.10		22.45		
17		20.00			26.70			31.75		38.45		
18	(6/1)	20.50			21.40			25.25		32.50		
19	13.00	21.80			24.70			29.70		37.00		
20		19.25			20.60			24.75		31.10		
21			11.00			11.75			15.20		21.00	
22			17.00			14.5			18.95		24.85	
23		10.00	11.00			10.50			13.45		20.10	
24		25.57	24.60			28.25			33.85		39.75	
25		10.00	10.55			11.45			14.15		20.05	
26			12.45			13.70			16.65		22.90	
27			10.00			11.85			14.55		25.10	
28			11.65			13.30			17.20		22.75	
29			16.85			19.45			25.05		32.65	
30			12.45			14.65			19.25		25.85	
31			12.20			13.45			17.95		25.20	
32			12.65			14.95			19.30		26.65	
Average	11.14	16.32	13.4	16.93	17.53	14.82	19.89	21.17	18.79	26.47	25.57	32.11

Table 45. (Continued)

Field No.	June 23	June 24	June 25	June 27	June 30	July 1	July 2	July 5	July 6	July 7	Total plant growth	Rate of growth
1			34.75				41.65		58.30		48.35	1.40
2			37.70				49.15		55.90		43.90	1.29
3							51.80		59.95		43.11	1.26
4			33.15				45.05		53.70		43.80	1.28
5			36.85				51.15		61.00		49.90	1.46
6			35.70				48.45		59.25		48.25	1.41
7			39.40				53.15		61.10		41.10	1.37
8			38.60				53.65		62.65		44.25	1.77
9	32.50			40.70	45.25						28.25	1.17
10	20.80			27.00	30.50					40.15	30.15	0.97
11	30.60			39.05	44.50					61.45	47.45	1.53
12	22.70			28.85	33.30					47.55	36.55	1.21
13	24.65			32.10	35.75					49.00	37.00	1.19
14	21.50			29.40	34.70					48.00	36.00	1.16
15	31.55			40.60	47.05					64.75	49.75	1.65
16	27.85			35.65	41.10					55.30	41.30	1.37
17	45.20			50.85	59.30					73.70	53.70	1.73
18	37.90			43.40	52.45					69.60	49.10	1.58
19	44.15			52.25	58.50					70.40	48.60	1.56
20	37.35			44.35	51.20					67.80	48.55	1.56
21		25.00				35.60		43.10			32.10	1.23
22		29.55				40.55		50.40			33.40	1.15
23		25.05				36.95		46.45			36.45	1.25
24		47.55				62.00		70.55			44.98	1.55
25		23.55				34.45		42.10			32.10	1.10
26		27.90				38.35		48.20			35.75	1.37
27		35.85				36.40		45.36			35.36	1.36
28		27.90				39.70		50.65			39.00	1.50
29		38.40				52.20		62.30			45.45	1.75
30		30.30				42.15		52.50			40.05	1.54
31		29.00				38.20		45.95			33.75	1.29
32		30.25				41.30		49.70			37.05	1.42
Average	31.39	30.85	36.59	38.68	44.47	41.47	49.26	50.06	58.98	58.88		

Table 46. Daily rate of growth Boone County study area 1956

Field No.	June 11	12	13	14	15	16	18	19	20	21
1			16.5			22.0			29.0	
2			19.6			27.6			35.0	
3			20.7			29.8			37.4	
4			23.2			30.5			36.3	
5			17.9			22.9			29.4	
6			24.0			30.8			39.4	
7			22.5			28.1			36.2	
8			29.4			37.4			45.5	
9				21.6			30.7			33.0
10				31.0			40.2			45.5
11				29.9			36.3			41.7
12				15.9			21.8			27.6
13				29.0			37.2			41.3
14				27.8			37.8			41.9
15				20.3			28.5			32.2
16				28.3			34.1			35.6
17				31.5			37.6			39.5
18				27.2			35.1			40.7
19				25.3			33.2			40.2
20	15.7			32.1			39.9			46.7
21					14.2			19.5		
22					25.3			33.0		
23					22.6			30.3		
24	19.2				27.6			35.9		
25					22.4			30.8		
26					19.3			28.7		
27		17.9			22.8			30.0		
28					23.1			31.8		
29		22.5			26.8			36.1		
30		22.2			28.3			38.3		
31					26.2			33.3		
32					15.5			22.1		
Average		19.8			24.1			31.6		37.7

Table 46. (Continued)

Field No.	June						Total plant growth	Rate of growth
	23	25	27	28	29	30		
1	34.5		40.7			44.9	28.4	1.8
2	41.1		46.2			51.3	31.7	1.8
3	44.8		50.2			54.5	33.8	1.9
4	43.3		47.5			50.6	27.4	1.5
5	34.2		39.1			42.7	24.8	1.4
6	43.9		48.9			53.4	29.4	1.6
7	42.7		48.1			52.5	30.0	1.7
8	51.8		57.8			62.1	32.7	1.8
9		36.4		44.8			23.2	1.5
10		48.0		58.9			27.9	1.9
11		36.7		62.1			32.2	2.1
12		29.5		38.3			22.4	1.5
13		51.7		55.9			26.9	1.8
14		49.0		50.4			22.6	1.5
15		33.6		42.4			22.1	1.5
16		43.3		53.8			25.5	1.7
17		49.5		55.1			23.6	1.6
18		47.0		52.3			25.1	1.7
19		49.6		50.4			25.1	1.6
20		53.9		56.0			40.3	2.2
21					31.1		16.9	1.1
22					48.9		23.6	1.6
23					44.6		22.0	1.5
24					54.1		34.9	1.8
25					41.7		19.3	1.3
26					43.4		24.1	1.3
27					44.1		26.2	1.5
28					47.5		24.4	1.6
29					50.0		27.5	1.5
30					54.8		32.6	1.8
31					50.9		24.7	1.6
32					36.2		20.7	1.4
Average		44.2			48.3	51.5		

Table 47. Second generation moth flight and oviposition
Boone County study area 1954

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
7/20	24	0.05	0.05			
21	60	0.12	0.17			
22	70	0.14	0.31			
23	184	0.39	0.70			
24	352	0.74	1.44	2	0.09	0.09
25	494	1.04	2.48	0		0.09
26	484	1.02	3.50	0		0.09
27	216	0.45	3.95	6	0.29	0.38
28	254	0.53	4.48	5	0.24	0.62
29	889	1.88	6.36	7	0.34	0.96
30	244	0.51	6.87	13	0.63	1.59
31	979	2.08	8.95	24	1.16	2.75
8/1	1556	3.30	12.25	0		2.75
2	3100	6.58	18.83	41	1.99	4.74
3	513	1.09	19.92	63	3.06	7.80
4	865	1.83	21.75	50	3.43	10.23
5	761	1.61	23.36	58	2.81	13.04
6	2630	5.59	28.95	55	2.67	15.71
7	7423	15.77	44.72	63	3.06	18.77
8	2153	4.57	49.29	0		18.77
9	7248	15.40	64.69	125	6.07	24.84
10	1147	2.43	67.12	141	6.85	31.69
11	1442	3.06	70.18	94	4.56	36.25
12	1614	3.43	73.61	149	7.24	43.49
13	2006	4.26	77.87	232	11.27	54.76
14	2330	4.55	82.82	68	3.30	58.06
15	2232	4.74	87.56	0		58.06
16	1182	2.51	90.07	230	11.18	69.24
17	153	0.31	90.39	0		69.24
18	250	0.53	90.92	123	5.97	75.21
19	1561	3.31	94.23	155	7.53	82.74
20	1053	2.23	96.46	132	6.41	89.15
21	232	0.49	96.95	28	1.36	90.51
22	62	0.13	97.08	0		90.51
23	251	0.53	97.61	78	3.79	94.30

Table 47. (Continued)

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
8/24	214	0.45	98.06	41	1.99	96.29
25	184	0.39	98.45	18	0.80	97.09
26	69	0.14	98.59	0		97.09
27	16	0.03	98.62	0		97.09
28	258	0.54	99.16	0		97.09
29	224	0.47	99.63	0		97.09
30	69	0.14	99.77	23	1.11	98.20
31				33	1.60	99.80
Total	47,048		100.00	2,057		100.00

Table 48. Second generation moth flight and oviposition
Boone County study area 1955

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
7/1	2	0.05	0.05			
2	1	0.02	0.07			
3	5	0.12	0.19			
4	10	0.25	0.44			
5	3	0.07	0.51			
6	0		0.51			
7	0		0.51			
8	0		0.51			
9	0		0.51			
10	0		0.51			
11	1	0.02	0.53			
12	5	0.12	0.65			
13	1	0.02	0.67			
14	0		0.67			
15	2	0.05	0.72			
16	3	0.07	0.79			
17	1	0.02	0.81			
18	9	0.22	1.03			
19	1	0.02	1.05			
20	13	0.32	1.37			
21	7	0.17	1.54			
22	26	0.64	2.18			
23	10	0.25	2.43			
24	20	0.49	2.92			
25	97	2.39	5.31			
26	65	1.60	6.91			
27	129	3.18	10.09			
28	164	4.05	14.14	2	0.96	0.96
29	235	5.80	19.94	4	1.92	2.88
30	206	5.08	25.02	0		2.88
31	301	7.43	32.45	0		2.88
8/1	96	2.37	34.82	12	5.77	8.65
2	167	4.12	38.94	11	5.29	13.94
3	198	4.89	43.83	17	8.17	22.11
4	215	5.31	49.14	31	14.90	37.01

Table 48. (Continued)

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
8/5	198	4.89	54.03	12	5.77	42.78
6	297	7.33	61.36	2	0.96	43.74
7	123	3.04	64.40	0		43.74
8	37	0.91	65.31	20	9.61	53.35
9	19	0.47	65.78	13	6.25	59.60
10	313	7.73	73.51	12	5.77	65.37
11	25	0.61	74.12	13	6.25	71.62
12	29	0.72	74.84	5	2.40	74.02
13	67	1.65	76.49	7	3.36	77.38
14	31	0.77	77.26	0		77.38
15	64	1.58	78.84	14	6.73	84.11
16	72	1.78	80.62	4	1.92	86.03
17	98	2.42	83.04	9	4.33	90.36
18	123	3.04	86.08	6	2.88	93.24
19	74	1.83	87.91	2	0.96	94.20
20	37	0.91	88.82	3	1.44	95.64
21	26	0.64	89.46	0		95.64
22	40	0.99	90.45	3	1.44	97.08
23	25	0.62	91.07	3	1.44	98.52
24	74	1.83	92.90	0		98.52
25	58	1.43	94.33	3	1.44	99.96
26	47	1.16	95.49			
27	83	2.05	97.54			
28	50	1.23	98.77			
29	38	0.94	99.71			
30	3	0.07	99.78			
31	6	0.15	99.93			
Total	4,050		100.00	208		100.00

Table 49. Second generation moth flight and oviposition
Boone County study area 1956

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
7/16	5	0.12	0.12			
17	4	0.10	0.22			
18	11	0.28	0.50			
19	0		0.50			
20	3	0.07	0.57			
21	0		0.57			
22	0		0.57	1	0.58	0.58
23	63	1.60	2.17	0		0.58
24	72	1.83	4.00	0		0.58
25	42	1.07	5.07	0		0.58
26	171	4.35	9.42	1	0.58	1.16
27	139	3.54	12.96	1	0.58	1.74
28	24	0.61	13.57	0		1.74
29	16	0.40	13.97	0		1.74
30	99	2.52	16.49	3	1.73	3.47
31	138	3.51	20.00	8	4.62	8.09
8/1	108	2.75	22.75	1	0.58	8.67
2	87	2.22	24.97	1	0.58	9.25
3	33	0.84	25.81	15	8.67	17.92
4	535	13.62	39.43	5	2.89	20.81
5	170	4.33	43.76	0		20.81
6	470	11.97	55.67	0		20.81
7	186	4.74	60.41	11	6.35	27.16
8	211	5.37	65.78	0		27.16
9	102	2.59	68.37	14	8.09	35.25
10	189	4.81	73.18	19	10.98	46.23
11	202	5.14	78.32	14	8.09	54.32
12	186	4.74	83.06	0		54.32
13	83	2.11	85.17	6	3.47	57.79
14	88	2.24	87.41	18	10.40	68.19
15	175	4.46	91.87	17	9.82	78.01
16	76	1.93	93.80	4	2.31	80.32
17	53	1.35	95.15	0		80.32
18	40	1.01	96.16	0		80.32
19				7	4.04	84.36

Table 49. (Continued)

Date	No. moths	Percent of total	Cumulative percent	Egg masses	Percent of total	Cumulative percent
8/20				4	2.31	86.67
21				4	2.31	88.98
22	7	0.18	96.34	2	1.15	90.13
23	14	0.36	96.70	3	1.73	91.86
24	11	0.28	96.98	5	2.89	94.75
25	10	0.25	97.23	2	1.15	95.90
26	26	0.66	97.89	1	0.58	96.48
27	56	1.42	99.31	2	1.15	97.63
28	12	0.30	99.61	3	1.73	99.36
29	10	0.25	99.86	1	0.58	99.94
Total	3,927		100.00	173		100.00

Table 50. Fate of eggs, second generation, Boone County study area 1954

Field No.	Total	Hatched	Missing	Infertile	Eaten	Dried
1	1920	682	118	193	634	47
2	1934	1386	122	42	345	39
3	904	479	73	0	302	50
4	1886	1346	117	151	266	6
5	805	548	48	0	209	0
6	1855	1079	51	162	466	97
7	1198	900	55	33	192	18
8	969	735	75	30	129	0
9	1905	1366	269	71	199	0
10	2326	1612	320	73	307	14
11	723	307	131	29	256	0
12	1060	923	53	0	68	16
13	1681	1231	184	16	195	55
14	298	119	53	0	126	0
15	1283	961	118	0	54	150
16	845	683	59	12	53	38
17	1711	1105	167	128	246	65
18	1705	1335	224	59	57	30
19	564	478	26	44	16	0
20	630	570	17	38	5	0
21	1539	1130	116	76	183	34
22	237	221	16	0	0	0
23	742	686	56	0	0	0
24	1057	861	60	54	82	0
25	1400	1175	110	0	115	0
26	1524	1384	33	0	107	0
27	935	841	34	0	42	18
28	1320	1005	138	54	123	0
29	1779	1391	94	21	208	65
30	1996	1577	212	35	141	31
31	52	52	0	0	0	0
32	1159	680	34	125	320	0
Total	39,942	28,848	3,183	1,446	5,446	773
Percent of total		72.2	7.9	3.6	13.6	1.9

Table 51. Fate of eggs, second generation, Boone County study area 1955

Field No.	Total	Hatched	Missing	Infertile	Eaten	Dried
1	10	10				
2	47	47				
3	35	35				
4	56	51			5	
5	206	101	52		53	
6	182	167		15		
7	87	48	10			29
8	419	331	36			52
9	258	169	48		41	
10	374	226	24	11	113	
11	74	74				
12	210	139	36	14	21	
13	312	246	41		25	
14	152	152				
15	232	212				20
16	293	205	59			29
17	89	89				
18	31	14	17			
19	50	50				
20	44	44				
21	79	62		17		
22						
23	32	26	6			
24	33	33				
25	175	87			88	
26	86	86				
27	72	57		15		
28	233	233				
29	83	52			31	
30	77	77				
31	23	23				
32	185	163		13	9	
Total	4,239	3,309	329	85	386	130
Percent of total	100.0	78.1	7.8	2.0	9.1	3.1

Table 52. Fate of eggs, second generation, Boone County study area 1956

Field No.	Total	Hatched	Missing	Infertile	Eaten	Dried
1	316	305		11		
2	86	86				
3	62	44	18			
4						
5	121	121				
6	20	20				
7	120	102		18		
8	80	80				
9	68	68				
10	91	91				
11	55	55				
12	28	28				
13	44	44				
14						
15	51	37		14		
16	110	110				
17	18	8	10			
18	82	65		17		
19	128	128				
20	56	56				
21	159	159				
22	120	120				
23	44	44				
24	118	118				
25	138	124			14	
26	154	154				
27	61	54			7	
28	269	269				
29	135	135				
30	306	226	80			
31	34	34				
32	111	97	14			
Total	3,185	2,982	122	60	21	
Percent of total		93.6	3.8	1.9	0.7	

Table 53. Occurrence of predators, second generation, Boone County study area, 1954

Field	Predators									
	Red		Chrysopa				Lady bird beetles			
No.	spider[1/]	Orius	Eggs	Larvae	Pupae	Adult	Eggs	Larvae	Pupae	Adult
1	12	5	8					6	1	
2		10	24	2			67		1	1
3		2	3	1		1	60	2	4	3
4	2	7	2	1		2	110	8	4	15
5		1	20			1				2
6		2	26	4		2	52		2	4
7		1	2					3	1	1
8		13	32	1		2	37	6	3	7
9	1	1	8	1			14	4	1	7
10	1	5	12	2		2	26	26		4
11	5	4	24					2		1
12		2	29			5	11			2
13	1	3	14	1		2	19	2	2	21
14	5		10				14	1		1
15		1	38	1		1	44			1
16		2	4				23			1
17		2	15	2		1	17			1
18		4	38	2		1	52			1
19		2	17			3	5			
20			9							1
21		2	4	2				2		
22			7				17			8
23		2	2							
24		2	3			1	33			4
25		2	12	1				5	2	7
26		2	39	3		3	100	4	2	4
27	91	6	21			1	71			9
28	1	4	19	1		2	20	9	2	5
29	2	6	18	1		4	33	1		6
30		3	9	1	1	7	67	9	1	11
31			5							2
32	1	6	24	3			44	3	2	2
Total	122	102	498	30	1	41	936	93	28	132

[1/] Trombididae aliothrombium sp.

Table 54. Occurrence of predators, second generation, Boone County study area, 1955

Field No.	Red spider[1/]	Orius	Predators: Chrysopa Eggs	Chrysopa Larvae	Chrysopa Pupae	Chrysopa Adult	Lady bird beetles Eggs	Lady bird beetles Larvae	Lady bird beetles Pupae	Lady bird beetles Adult
1		3	21	2			16	2	1	8
2		8	28	2		2	50			3
3		4	39			2	15	1		2
4		7	37	2		1	36	2		9
5		7	19			1		1		
6			11	1			18			1
7		1	19	1		1		3		11
8		4	69	1		2	20			2
9		5	37				24	3	1	11
10	3	5	4			1				
11		2	27					3		9
12		10	38	1		1	34			6
13		6	14				41	3		16
14		7	26	3		1	13	3	1	38
15		4	23	1		3	42			17
16		2	24	1			38	9		
17		5	33			2				1
18			14	1		1		2		6
19		6	26	7		2		3		3
20		2	30							4
21		3	27			2				24
22			16			1		1	1	6
23		3	31			2	8			6
24			19			1	39	8		9
25		1	13			2	24	4		10
26		1	19	1			15			8
27		5	28				18			5
28		3	44	1		5	15	2		13
29			42	1		1		8	4	5
30		2	20				46	1		3
31			8				21	5		7
32	3	7	46	2		8	112		2	10
Total	6	113	852	22		42	645	64	10	253

[1/] *Trombididae allothrombium* sp.

Table 55. Occurrence of predators, second generation, Boone County study area, 1956

Field No.	Red spider[1]	Orius	Chrysopa Eggs	Chrysopa Larvae	Chrysopa Pupae	Chrysopa Adult	Lady bird beetles Eggs	Lady bird beetles Larvae	Lady bird beetles Pupae	Lady bird beetles Adult
1			17			2	73	4	2	5
2			65	1			116	1	4	9
3			68			2	83	11	2	12
4			25			2				3
5			60	1		2	19	1		2
6			52			2		5		10
7			118	1		6	394	128	45	27
8			62	1		3	23	7	1	9
9			68	3		1	186	16	15	34
10			65			2	110	10		4
11			40	3		1	343	39	6	6
12			99				158	23	1	6
13		1	31	2		4	68	28	19	21
14			107	1		3	156	35	40	11
15			78			2	181	37	12	13
16			28	3		3	31	40	6	27
17			61				164	15	16	29
18			105				153	38	36	26
19		1	57			1	108	11	2	13
20			42				8	13		1
21			52			1	222	8	5	2
22			62			4	60	6	10	3
23			65	1		2	51	8	1	2
24			38							4
25			51				179	174	22	12
26			58				162	10	2	2
27			25				117	4	5	
28			49	1		3	67	23	10	7
29		1	76	7			192	29	38	15
30			28			1	20	5	3	3
31			65	2			137	59	5	7
32			17			1	176	15	1	1
Total		3	1834	27		48	3757	803	309	326

[1] *Trombididae allothrombium* sp.

Table 56. Fall dissection Boone County study area 1954

Field No.	Entrance holes	Instars I	II	III	IV	V	Pupae	Empty pupal cases	Parasites	Total	Percent plants infested
1	67			1	4	35		28		69	100
2	35			2	5	24		3		40	100
3	46				11	19		10		40	100
4	44			1	6	27				37	100
5	81			3	7	59		6		75	100
6	57			4	6	51		1		62	100
7	143		1	12	24	120		36	7	202	100
8	89			5	16	62		12		95	100
9	78		1	2	14	76		3		97	100
10	61			7	13	68		2		90	100
11	63			7	14	41		5		67	100
12	46				3	37		3		44	100
13	52			1	6	41		10	5	63	100
14	37					8		21		29	100
15	37			1	10	47		4		62	100
16	66			2	7	42		11		62	100
17	128			4	15	92		15		128	100
18	62			2	7	65		3	3	80	100
19	80			1	6	31		23	1	62	100
20	50				3	19		19	1	42	100
21	65				5	33		5	1	44	100
22	72			3	8	34		8		53	100
23	80				2	47		9	1	60	100
24	41			4	5	31				40	90
25	67				2	40		18	1	64	100
26	66				5	54		1	1	61	100
27	73			1	4	52		14	1	73	100
28	96				3	74		5	2	84	100
29	76				7	59		5	2	74	100
30	113			4	13	70		27	3	118	100
31	13				1	8				9	60
32	37			1	5	20		2		28	80
Total	2,091		2	68	237	1,486		309	29	2,148	
Percent of total			0.09	3.16	11.03	69.18		14.38	1.35		

Table 57. Fall dissection Boone County study area 1955

Field No.	Entrance holes	Instars I	Instars II	Instars III	Instars IV	Instars V	Pupae	Empty pupal cases	Para-sites	Total	Percent plants infested
1	13				4	3				7	50
2	12				1	5		1		7	40
3	19			1	1	6		1	1	10	80
4	7			1		1				2	50
5	44			1	13	23		2	4	43	100
6	29				3	18				21	70
7	15				2	6				8	70
8	48				4	27				31	80
9	44			1	4	18		1	3	27	90
10	28				3	12			1	16	80
11	22			1	4	8		1		14	90
12	46			1	5	33			1	40	80
13	32				2	25				27	100
14	9				2	1			1	4	70
15	40				2	35				37	80
16	42				7	21				28	100
17	33			1	2	11		2	2	18	100
18	8							4		4	60
19	24				2	10			1	13	90
20	22				1	9		1		11	80
21	20				3	11				14	60
22	4										20
23	7					5		1		6	60
24	20				5	9				14	70
25	12				1	10			1	12	60
26	16					12		2		14	60
27	19				2	12				14	80
28	54				3	38				41	100
29	13				4	6				10	60
30	26			1	3	15			1	20	80
31	2				1					1	20
32	15				4	4		1	1	10	70
Total	745			8	88	394		17	17	524	
Percent of total				1.5	16.8	75.2		3.2	3.2		

Table 58. Fall dissection Boone County study area 1956

Field No.	Entrance holes	Instars I	II	III	IV	V	Pupae	Empty pupal cases	Parasites	Total	Percent plants infested
1	13			2	9	11				22	70
2	17				4	15				19	70
3	14				12	11		1		24	50
4	2									0	10
5	25			2	9	19				30	90
6	23				6	6		8		20	80
7	10				4	6				10	50
8	28				8	11				19	90
9	15				4	12				16	70
10	26			3	4	13		2		22	80
11	11				2	3				5	50
12	8					6				6	50
13	9				1	7				8	40
14	8				1	1		4		6	60
15	26			1	7	15		2	1	26	80
16	36				6	25		3		34	80
17	34			1	10	23				34	90
18	44			1	7	21				29	100
19	29				4	18	1	2		25	90
20	31				6	19		1		26	80
21	44				13	27	1			41	100
22	26			1	4	17				22	70
23	5					4				4	30
24	28				12	14		2		28	90
25	8				1	3				4	30
26	21			2	3	20		2		27	90
27	11				2	9		1		12	50
28	23				9	18				27	80
29	31			1	4	14		3		22	80
30	8				8	5		1		14	60
31	1					1				1	10
32	15				8	16				24	70
Total	630			14	168	390	2	32	1	607	
Percent of total				2.3	27.7	64.3	0.3	5.3	0.1		

Table 59. Analyses of variance
Boone County study area 1954

Source of variation	d.f.	S.S.	M.S.
Total first brood eggs			
Areas	15	36,418.96	2,427.93
Fields/areas	15	75,205.23	5,013.68
Sites/fields/areas	31	28,587.35	922.17
Locations/sites/fields/areas	62	68,400.10	1,103.23
Plants/locations/sites/fields/areas	496	358,055.60	721.89
Total	619	566,667.24	
First generation larvae (midseason)			
Areas	15	323.371875	21.5581
Fields/areas	16	555.450000	34.7156
Sites/fields/areas	32	377.300000	11.7906
Plants/sites/fields/areas	256	840.000000	3.2812
Total	319	2,096.121875	
First and second generation larvae (fall)			
Areas	15	2,046.0875	136.4058
Fields/areas	16	1,599.5000	99.9688
Sites/fields/areas	32	638.8000	19.9625
Plants/sites/fields/areas	256	5,617.6000	21.9438
Total	319	9,901.9875	

Table 60. Analyses of variance
Boone County study area 1955

Source of variation	d.f.	S.S.	M.S.	s^2	Percent of totals^2
Total first brood eggs					
Areas	15	22,445.37	1,496.36	29.53	14.47
Fields/areas	16	5,045.73	315.36	0.25	.12
Sites/fields/areas	32	9,930.85	310.34	3.85	1.89
Locations/sites/fields/areas	64	17,399.50	271.87	25.37	12.44
Plants/locations/sites/fields/areas	512	74,245.60	145.01	145.01	71.08
Total	639	129,067.05		204.01	100.00
First generation larvae (midseason)					
Areas	15	26.1719	1.7448	0.0449	6.35
Fields/areas	16	13.5000	0.8469	0.0269	3.80
Sites/fields/areas	32	18.5000	0.5781	-0.0144	-2.04
Plants/sites/fields/areas	256	166.4000	0.6500	0.6500	91.89
Total	319	244.6219		0.7074	100.00
First and second generation larvae (fall)					
Areas	15	271.3969	18.0931	.4523	8.09
Fields/areas	16	144.7500	9.0469	.3025	5.41
Sites/fields/areas	32	192.7000	6.0219	.2972	5.32
Plants/sites/fields/areas	256	1,161.2000	4.5359	4.5359	81.18
Total	319	1,770.0469		5.5879	100.00

Table 61. Analyses of variance
Boone County study area 1956

Source of variation	d.f.	M.S.	s^2	Percent of total s^2
Total first brood eggs				
Areas	15	880.00	3.15	1.70
Fields/areas	16	753.93	29.35	15.85
Sites/fields/areas	32	166.84	0.43	0.23
Locations/sites/fields/areas	64	162.54	2.57	1.39
Plants/locations/sites/fields/areas	512	149.68	149.68	80.83
Total	639		185.18	100.00
First generation larvae (midseason)				
Areas	15	1.0265	-0.0356	-4.29
Fields/areas	16	1.7281	0.0750	9.05
Sites/fields/areas	32	0.9781	0.0472	5.69
Plants/sites/fields/areas	256	0.7422	0.7422	89.55
Total	319		0.8288	100.00
First and second generation larvae (fall)				
Areas	15	15.3248	0.2401	4.06
Fields/areas	16	10.5219	0.3200	5.41
Sites/fields/areas	32	7.3219	0.4928	8.34
Plants/sites/fields/areas	256	4.8578	4.8578	82.19
Total	319		5.9107	100.00