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The Biology and Control of the European Corn Borer in Missouri

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COLUMBIA, MISSOURI

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The Biology and Control of the European Corn Borer in Missouri[1]

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INTRODUCTION

The European corn borer, *Ostrinia nubilalis* (Hbn), is an introduced insect pest which apparently was brought into this country about 1909 in broom corn shipments from Europe. It caused the first serious losses, in the 1920's, on field and sweet corn in Northeastern United States and Eastern Canada. The area of infestation progressively increased, until the midwest corn belt was infested by the early 1940's. Denning's (1942) report is the first published record of the corn borer in Missouri. Since then every county in Missouri has become infcested. The purpose of this bulletin is to summarize some of the observations and research accomplishments pertaining to the corn borer problem in Missouri. This should increase understanding of the corn borer's biology and result in more efficient control. It should also serve as a stepping stone to further investigations.

Resume of Life Cycle and Damage Caused.

The general seasonal life history of the corn borer in the North Central States is shown in Figure 1. The chart was taken from a regional publication entitled "The European Corn Borer and its Control in North Central States", Iowa State College Pamphlet 176 (Rev. 1957). The reader may wish to consult the pamphlet for a more general discussion. As shown in the diagram, only the mature larvae go through the winter. With warmer spring temperatures and available moisture the larvae transform into the pupal stage. In two to three

[1]A number of entomologists have contributed to this bulletin by the work they have done on the corn borer in Missouri, i.e., Dr. Leonard Haseman was in charge of most of the early surveys. The entomologists of the Missouri State Department of Agriculture were also active in the early surveys. Professors H. E. Brown and P. C. Stone were engaged in various phases of corn borer research until August of 1955 when Dr. A. K. Burditt, Jr. was appointed as a full-time research worker on the European corn borer. Mr. George W. Thomas, Mr. Stirling Kyd, Mr. Ralph E. Munson, Mr. R. D. Jackson, Mr. B. D. Barry, Mr. A. J. Keaster and other members of the department contributed by making annual surveys.

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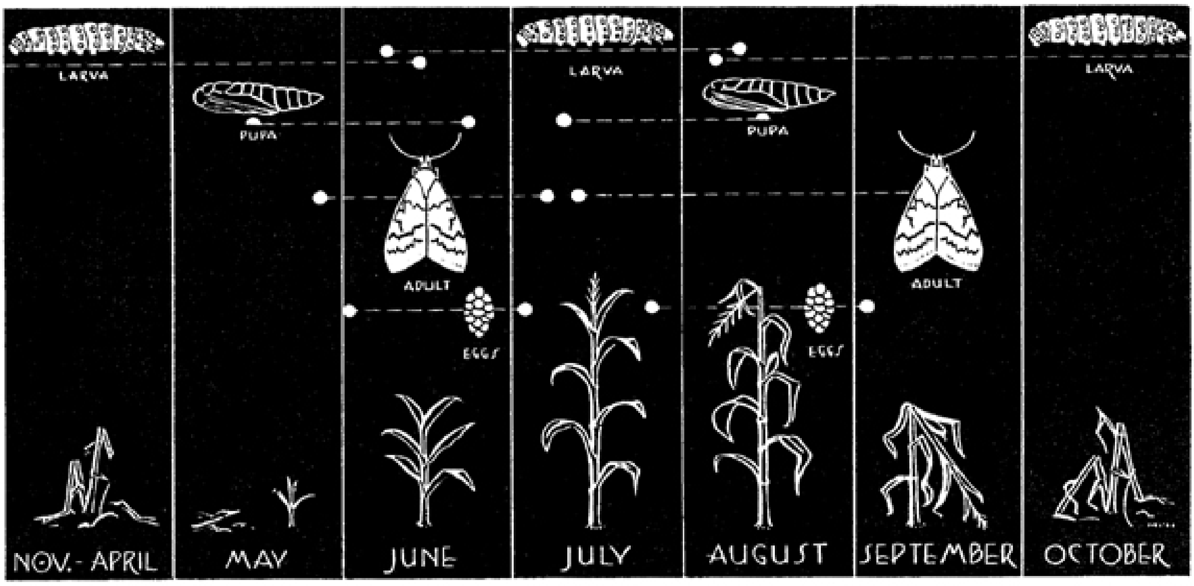

Fig. 1—European corn borer seasonal life history chart—development is earlier southward and later northward.

weeks the moths emerge, mate, and soon begin to lay eggs. The eggs are laid in clusters resembling white fish scales. The eggs hatch in five to seven days depending upon the weather. The newly hatched larvae migrate to the whorl of the corn plant where they feed on the young leaf tissue. As the larvae increase in size, they burrow into the midrib or sheath and then into the stalk. Most full-grown larvae will be found in tunnels in the stalk where they either pupate or enter diapause and pass the winter.

The diagrammatic life cycle of the European corn borer having three broods, or generations, per year is shown in Figure 2. In Southeast Missouri, the European corn borer consistently has three generations and, with above average temperatures, three generations may occur throughout Missouri.

The life history of the corn borer in Missouri was reviewed by Burditt (1956) and, more, recently, by Jackson and Peters (1961). The cage studies at Sikeston, in 1958, effectively summarized these studies by showing the approximate percent of each generation entering diapause (Table 1). The fact that some first brood larvae enter diapause in this warm climate substantiates the persistence of the genetic character for the occurrence of a single brood much as described by Arbuthnot (1944).

Indications from Central and Northern Missouri are that, annually, well over 50% of the first generation larvae pupate. As shown in Figure 1, this may take place over an extended period of almost a month's duration.

The type of damage caused by the corn borer depends upon the stage of growth of the corn plant when the infestation takes place. In the two generation areas, the first generation reduces yields by leaf, midrib, and stalk feeding causing physiological stress and may result in stalk breakage, particularly below the ear. In these areas, second brood damage is manifested as dropped ears and broken tassels with stalk breakage occurring late in the season. In an area hav-

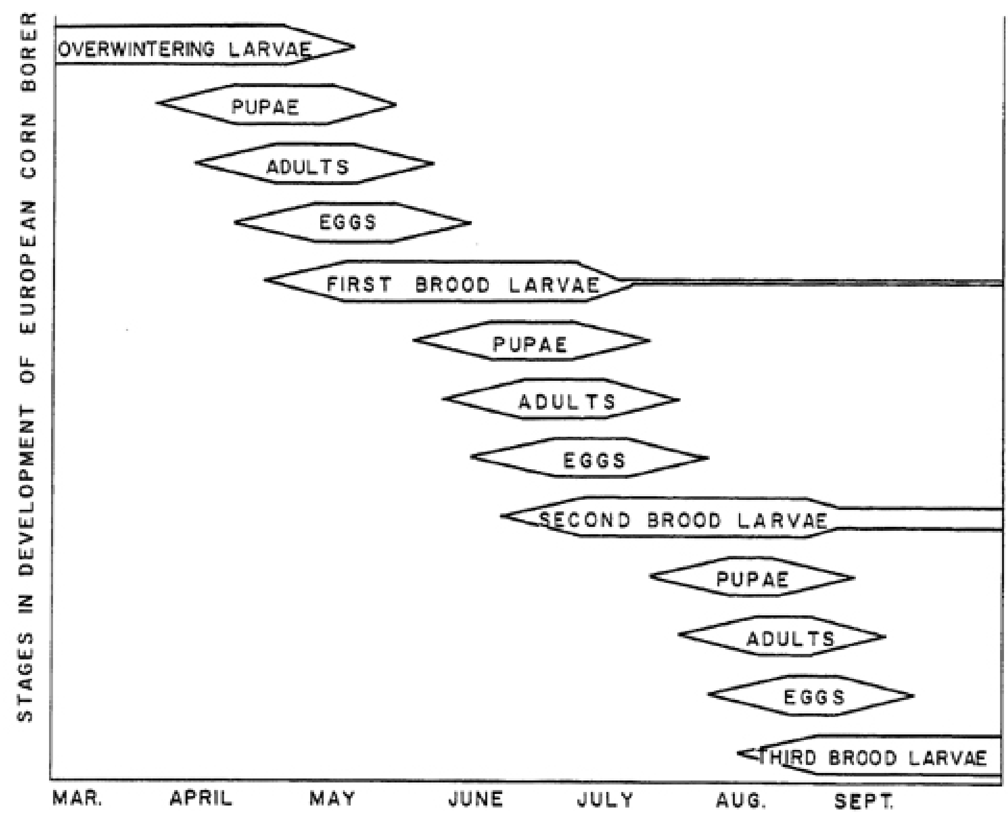

Fig. 2—Diagrammatic life cycle of the European corn borer with three generations per year.

TABLE 1-DIAPAUSING LARVAE AND EMERGING MOTHS UNDER CAGE CONDITIONS AT SIKESTON, MISSOURI IN 1958.

	Larvae Present at Fall Dissection	Moths Emerging During Summer	Percent Emergence	95 Percent Confidence Interval
First Brood	2	52	96.3	86-100%
Second Brood	48	7	12.7	6-27 %
Third Brood	32	0	0	0-12 %
Total	82	59	72.0	62-81%

ing three generations of borers per year, there is usually a greater variation in time of planting and maturity of corn which results in a more complex expression of damage by the different broods. Second brood damage may occur on whorl stage corn and cause damage described as first brood damage above.

Several excellent studies of the effects of corn borer infestations on yield such as those by Kwolek and Brindley (1959) have been made. More information under different conditions, particularly in the southern regions of the "corn belt" is needed. Studies necessary for the development of a more exacting evaluation of corn borer losses are included in this report.

SURVEYS AND HISTORY OF EUROPEAN CORN BORER IN MISSOURI

The initial spread of the borer in the state was extremely rapid, as can be surmised from the following statement made by Dr. Leonard Haseman, only two years after the first recorded infestation, in the 1944 European Corn Borer Research Pool of Information:

> "Surveys made by the State Department of Agriculture to determine the spread of the pest in Missouri showed it to be present in all of the more important corn growing areas of the state. As a result, the State Department of Agriculture revoked the state corn borer quarantine, effective November 1, 1944."

The lack of time necessary to make annual county surveys throughout the state may have limited the accurate chronological recording of new infestations at the county level, but available data indicate other major advances in 1948, 1951, and 1954. Two counties in the heart of the Ozarks were not reported as infested until 1958.

The average infestation in the counties surveyed in each crop reporting district for 1945 through 1959 is recorded by districts in Table 2. The Southwest district was not included because comparatively few acres of corn are grown in that district.

Scotland County in Northeast Missouri was the first county in which a countywide survey indicated an average of more than one borer per plant. This occurred in 1947 when an average of 129 borers were found per 100 plants. The 1957 infestation in Andrew County of 1050 borers per 100 plants is the highest county average reported to date. The statewide average of 346 borers per 100 plants for the 1957 fall survey is also the highest to 1959.

The scattered information on corn borer moth flight in Missouri indicates that the period of adult activity in Southeast Missouri may extend from May 10 to after October 1. In Northwest Missouri, the first moths appear about June 1 and egg mass counts reach a peak between June 20 and 25. Empty pupae cases were found the last week in July in two years of intensive study in Nodaway County. In 1958, moth counts from a black light trap indicated a sustained moth flight throughout August and into September in Carroll County.

COUNTY CENSUS STUDIES

Biological investigations necessarily cover a broad spectrum from precise laboratory studies, to field test plots, to surveys of the pest in its natural habitat. In 1956, Missouri became a contributor to the North Central States Regional Project (NC-20) investigating the factors influencing European corn borer populations. The phase undertaken in Missouri was a county census study of population fluctuations on selected farmers' fields in two counties—Carroll and New Madrid.

TABLE 2-AVERAGE EUROPEAN CORN BORER INFESTATION PER 100 PLANTS IN MISSOURI AS SHOWN BY THE FALL POPULATION SURVEY

Crop reporting District 1/	Year														
	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Northwest	0	0	18	14	179	38	52	20	58	141	224	67	685	161	47
North-Central	0	5	19	15	103	39	35	26	42	214	110	---	580	89	43
Northeast	19	13	35	16	98	45	28	10	41	91	---	46	318	131	56
West	--	0	0	3	---	--	--	16	6	68	111	---	372	137	35
Central	--	---	--	8	18	--	27	44	36	98	32	20	331	69	31
East	11	10	6	18	28	--	42	8	18	32	5	---	40	22	24
Southeast	--	--	1	0	---	--	--	--	131	225	145	226	95	123	42
Southwest	--	--	--	--	---	--	--	--	---	---	---	---	---	32	12

1/ The south-central district was not surveyed and the southwest district was surveyed in 1958 and 1959 only.

Carroll County is located in the north central part of the state on the Missouri River. Corn, soybeans, and small grains, are the most important crops grown in this area. The southern third of the county is fertile, flat, Missouri River bottom land, while the remainder of the county is rolling upland soils of varying fertility. There are usually two complete broods in Carroll County. New Madrid County is located in southeastern Missouri on the fertile Mississippi River Delta. Cotton, corn, and soybeans, are the most important crops in this area. There are at least three generations of European corn borers per year in Southeast Missouri.

The procedures used to measure borer populations consisted of sampling fields within the county three times each year (in spring, summer, and fall). Twelve or more townships, of 36 square miles, were mapped in each county and two or three cooperators were contacted in each township. The farmer response varied so that the numbers of cooperators for the 1956, 1957, and 1958, seasons were 26, 31, and 31, in Carroll County and 10, 12, and 24, in New Madrid County. The sampling on each farm consisted of dissecting the stalks on three millacre sites at each of the three sampling times. In 1959, a late spring census with five samples per farm was conducted. The farmer cooperators were asked to complete spring and fall information sheets. These contained information on date and rate of planting, manurial and fertilizer practices, variety planted, rotation, date of harvest and yield, and expected winter cultural practices. The variability of the reports precludes a statistical evaluation of most of the above factors, but some interesting facts were gained by this information.

In Carroll County, early planting was correlated with relatively high first brood populations in fields of high fertility. In New Madrid County first brood populations have been consistently low and there is no reasonable relationship between relative planting dates and first brood infestations. Second and third brood infestations in both counties are positively correlated with lateness of planting. These observations were made by comparing the distribution of planting dates with the number of borers for the three years in both counties. In Carroll County the planting period was 33 to 42 days in length and in New Madrid County from 43 to 81 days in the three years.

The rate of planting in the two counties ranged between 8,000 and 18,000 plants per acre, but the three year averages from the plant counts at summer and fall dissections in Carroll County were 11,300; 11,100; and 11,400. In New Madrid County, the average plant populations were 13,400; 11,400; and 12,100; for each of the three years, 1956, 1957, and 1958, respectively. Almost all fields were surface drilled.

Commercial fertilizers were used almost exclusively with only an occasional reported use of green manure or barnyard manure. Ammonium nitrate at 100 to 240 pounds per acre and 100 pounds of 12-12-12 appeared to be the most popular materials. There was no noticeable change in fertilizer usage in the three years.

All of the corn grown, in the two counties surveyed, was of hybrid origin. The seed came from 13 different seed corn companies, and, in most instances, each company furnished a number of different hybrids. With so many different hybrids grown, it is impossible to draw any conclusions on the effect of hybrids on borer populations.

Crop rotation systems varied greatly between the two counties, as well as within each county. In Carroll County, corn, soybeans, wheat, and corn, was the most popular rotation. Only five fields in Carroll County were reported as having continuous corn for three years or more. There was no predominant rotation pattern in New Madrid County. The corn and cotton acreage allotments determined crops planted, as did the Federal soil bank plan in Carroll County.

The practice of disking down corn to plant wheat or oats invariably led to much higher spring populations in comparison to fields that were plowed and disked or only plowed.

A greater understanding of how climate affects the biology of the corn borer is necessary before meterological data can be meaningfully correlated with population fluctuations. The temperature variation between the two counties is somewhat intriguing. During 1956-58, the mean temperature in August was higher at Carrollton than at Sikeston; but April, May, June, and September, were usually warmer at Sikeston. In 1957, the July temperature at Sikeston was considerably cooler than at Carrollton; but rainfall at Sikeston was extremely heavy.

The accumulated daily mean temperatures above 50° F, at Carrollton, in July 1957, was 948 degrees, or degree days as used by Apple (1952). This was the highest for any month at either location. During this time the mean daily temperature was 80.6°. July is usually considered the critical month for development of the second brood. Therefore, the fourfold increase in Carroll County, in 1957, from first to second brood, must have been favored by the higher temperature, adequate rainfall, and relatively high humidity.

Chemical controls will certainly influence insect populations. In 1958, all the fields surveyed in Carroll County that had 75% leaf feeding from first brood infestation were treated. The resulting summer population, in 1958 in Carroll County, (Table 3) was only one-third as great as in 1957. Only one field was treated in 1957. Of course, other factors were also operative, but the implication

TABLE 3-BORERS PER ACRE AT DIFFERENT SEASONS IN CARROLL AND NEW MADRID COUNTY, MISSOURI

Date of Survey	Carroll County	New Madrid County
Summer 1956	1020	1030
Fall 1956	1065	5170
Summer 1957	5620	270
Fall 1957	21680	1220
Spring 1958	1699	----
Summer 1958	2000	1311
Fall 1958	4677	1480
E. Spring 1959	1061	----
L. Spring 1959	290	80

should not be overlooked. No chemical control of second or third brood borers has been attempted on any of the fields in this study.

The data summarized in Table 3 gives the number of borers in Carroll and New Madrid Counties at different times of the year for 1956 through 1959. Certainly, these averages are but a small indication of the multiplication potential of the borer. The 20 fold increase from the fall of 1956 to 1957, in Carroll County, is the most outstanding. The eight or nine month winter latent period is apparently the only time when borer numbers decrease in Missouri. During this time, the mechanical injury caused by various field operations coupled with extreme winter weather conditions reduced the borer population 75 to 90%. The warm climate and long growing season apparently result in consistent increases from midsummer to fall except in years of extreme drought.

CORN BORER BIOLOGY IN RELATION TO ITS MAJOR HOST

The strain of corn borers infesting the "corn belt" area of the United States apparently prefers the corn plant as its host. Jenkins and Thomas (1956) have reported their observations of the European corn borer on cotton in Missouri, but infestations of this host are usually associated with heavy populations in corn. Experimental plantings of castor beans adjacent to corn at the Southeast Missouri Research Center were observed to be damaged by corn borers in 1957. The growing of peppers with little or no corn borer damage in Southeast Missouri would also substantiate the assumption of corn being the preferred host. Varied means have been used to evaluate the different components of this insect-host plant relationship. Some of the investigations in Missouri have progressed sufficiently to contribute to the better understanding of this relationship and are recorded below.

Experiments with Dwarf Corn.

Investigations on the effect of brachytic dwarf corn on corn borer infestations were conducted in 1957 and 1958. Some of the results were reported by Peters (1959). The purpose of these studies was to determine the effect that plant height had on borer infestation and survival. Inbreds carrying the brachytic mutant gene (br_2) were used in comparison with hybrids or normal inbreds. The essential difference was in the genetically determined internode lengths.

Before the turn of the century Jablonowski (1898) observed that early corn varieties received heavier European corn borer infestations than did later varieties. This earliness was assumed to be associated with plant height at first brood oviposition. Patch (1942) observed that moths preferred tall plots of corn in about the same manner as tall fields of corn and also stated: "The mean number of egg masses are found to bear a linear relationship to the height of the corn." Second brood egg deposition is more generally associated with stage of growth rather than height, according to Turner and Beard (1950). The studies of Goleman (1954) substantiate the above observations.

In 1957, twenty single crosses among dwarf, semi-dwarf, and normal inbreds, were dissected in the fall. Five plants of each cross were dissected in each of four replications. The results are recorded in Table 4, in order of increasing ear height. There is no apparent correlation with ear or plant height and borer infestation in most of the crosses studied.

TABLE 4-PERFORMANCE OF SOME SINGLE CROSS DWARF, SEMI-DWARF AND NORMAL INBREDS NEAR HUNTSDALE, MISSOURI IN 1957.

Pedigree	Acre Yield Bu.	% Stalk Lodged	Ear High Feet	Plant Height	Larvae Per 100 Plants	Empty Tunnels /100 Plants
$br_2$375xbr_2SW	65.7	0.0	1.2	4.4	75	155
Mo11276xbr_2SW	79.5	6.4	2.0	5.4	110	300
Mo1109xbr_2SW	73.1	1.9	2.1	5.6	120	210
Mo53682xbr_2SW	83.7	6.0	2.2	6.0	100	240
Mo5xOh45	84.6	3.1	2.3	6.0	85	140
Mo5xMo11090	100.7	1.4	2.3	6.2	115	115
Mo5xbr_2SW	94.7	1.7	2.3	6.4	100	140
Mo11276xMo11090	88.7	6.1	2.5	6.0	235	295
Mo11090x$br_2$375	93.9	2.2	2.7	6.0	95	100
Mo11276x$br_2$375	98.1	7.1	2.8	6.0	135	265
Mo5xMo11276	106.2	1.9	2.8	6.4	150	335
ShortOh41xbr_2SW	95.9	29.5	2.8	6.6	65	85
Mo11276xMo33682	95.9	10.0	2.9	6.0	190	320
ShortMo3xbr_2SW	101.3	8.2	3.7	8.2	115	220
Mo11090xShortMo2	109.1	9.2	4.0	8.2	120	155
US13	122.2	3.6	4.0	8.3	150	265
Mo5xShortMo3	120.9	5.8	4.0	8.4	75	185
K148xMo3	116.3	2.7	4.2	9.0	65	225
ShortMo3x$br_2$375	93.6	9.7	4.3	8.2	165	260
R129xShortMo3	94.1	20.8	4.5	9.2	80	225

In 1958, plantings were made at Columbia and Sikeston, Missouri, of three normal corn hybrids and their supposed dwarf counterparts. These were Pa. 602, U.S. 13, and Mo. 880. Mo. 995, the dwarf counterpart of Mo. 880, grew equally as tall as Mo. 880. Both plantings were made on April 30, but with different randomization plans. One first brood egg mass count was made on the Columbia planting as well as a leaf feeding count. Second brood egg mass counts were made on the Sikeston planting. In the fall, one plant was dissected from each hill of the 2 x 5 hill plots and the total number of borers, pupa cases, and empty tunnels, recorded. Another stalk in the same hill was split. In splitting, only one longitudinal incision is made the length of the stalk, whereas in dissecting, finer, transverse, cuts are made to determine more nearly the total number of tunnels or larvae in the stalk. The results are summarized in Table 5. Analysis of the data indicated significant differences only between testing sites. The variability from plot to plot was nearly as great as between varieties. At Sikeston there appeared to be a trend towards more total tunnels in the dwarfs than in the normal hybrids, but this trend was reversed for the Columbia data.

TABLE 5-SUMMARY OF 1958 DWARF CORN EXPERIMENT DATA

		Mo. 880	Mo. 995	U.S. 13	U.S. 13 Dwarf	Pa. 602	Pa. 602 Dwarf
Borers and Pupa Cases per 40 Plants	Columbia	1	1	3	0	4	5
	Sikeston	22	15	27	17	14	14
Total Tunnels per 40 Dissested Plants	Columbia	32	30	50	27	45	41
	Sikeston	56	59	65	72	49	61
Total Tunnels in 40 Split Stalks	Columbia	22	21	24	8	24	17
	Sikeston	38	33	44	40	43	44
Calculated Yield Bushels per Acre	Columbia	96	85	80	65	91	64
	Sikeston	96	98	92	72	77	63

The above data indicate that growth stage is more important than height in determining the level of infestation of the European corn borer on corn, and that brachytic hybrids are infested to about the same extent as the normal hybrids in the same stage of growth.

CORN BORER RESISTANT HYBRIDS

Burditt (1957) reported that the resistance of northern corn hybrids to the European corn borer was not evident when these hybrids were planted in Southeastern Missouri. The most evident reason for this failure is the multiple brood situation in Southeast Missouri, in comparison to the predominantly single brood population under which the inbreds were selected. For corn to be called resistant to the European corn borer in Missouri, it will have to contain resistance factors to leaf feeding, and sheath or stalk resistance to the second brood population which is often as important as the first brood.

An interesting investigation was conducted in cooperation with the Field Crops Department which serves to illustrate the complexity of corn borer susceptibility or resistance. In this study six inbreds varying in resistance to stalk breakage were evaluated for borer resistance. All combinations of F_1 progeny and first backcross progeny were studied. The data for leaf damage rank per plant, empty tunnels, and larvae, are summarized in Table 6. If it were able to impart its apparent resistance to the F_1 crosses, L317 would have ranked first. It would almost seem as though L3-17, particularly when crossed to a long season inbred, was highly susceptible to the corn borer beyond the leaf feeding stage. The larvae count on L317 x Mo. 22 was highest for any F_1 combination. Any conclusion based on only one of these criterion would be dangerous. Even using all three, the results may vary from year to year even as these did in comparison with Burditt's results in 1956.

In 1958, a cooperative program of selection for resistance from two stiff stalk synthetics and synthetic composed of resistant inbreds of southern and corn belt origin was initiated. Stiff Stalk Synthetic A was planted at the Thompson Farm in Northern Missouri. Eighty plants from a population of about 3,000 plants were selected in the fall with no tunnels. These 80 plants were the sur-

TABLE 6-THREE MEASUREMENTS OF THE REACTION OF SIX INBREDS, THEIR F_1 PROGENY AND BACKCROSSES TO THE EUROPEAN CORN BORER AT HUNTSDALE, MO., 1957.

Type of Cross	Mo. 940	T 8	L317	Ky. 27	Mo. 22	WF 9
			Leaf Damage Observations			
Inbreds	2.26	2.06	2.00	2.61	2.13	2.43
Recurrent B, C,	2.30	2.02	2.10	2.82	2.10	2.36
F_1	2.00	1.97	1.94	2.22	2.04	2.17
Non Recurrent B, C,	2.10	2.28	2.44	2.14	2.38	2.36
E			Empty Tunnels per 100 Plants			
Inbreds	248	277	257	185	170	356
Recurrent B, C,	412	328	300	248	244	388
F_1	190	186	250	198	202	210
Non Recurrent B, C,	332	372	336	256	316	300
			Larvae and Parasites per 100 Plants			
Inbreds	11	32	24	12	40	37
Recurrent B, C,	4	32	32	4	60	44
F_1	50	54	94	58	84	40
Non Recurrent B, C,	24	24	40	24	28	36

vivors of 300 plants marked in August as having little or no visible first brood infestation. Stiff Stalk Synthetic B was apparently more resistant to leaf feeding than Synthetic A in observations made at Huntsdale in 1958. The production of a synthetic of resistant southern and corn belt inbreds was initiated in 1957 and the double-double allowed to interpollinate in 1959. Earlier field crosses appeared to carry resistance.

Date of Planting

Early planting has long been associated with increased borer infestation. Recent publications by Burditt (1956), Zuber, *et al.* (1959), and Jackson and Peters (1961), discuss this phenomenon as it appears in Missouri. Consult these reports for a detailed discussion. These papers indicate that fall borer populations increase as planting time is delayed. It is usually desirable to plant corn early and escape heavy second and third brood infestations, even though early planting may necessitate chemical control of the first brood.

Burditt (1957) was able to demonstrate that, with repeated insecticide applications, late corn would yield almost as much as early corn. If a change in production demands the desirability of double cropping, this practice should be investigated further for economical feasibility.

BIOLOGICAL CONTROL INVESTIGATIONS

The first Missouri releases of exotic parasites of the European corn borer were made in Marion and St. Louis Counties in 1947. Two wasps, *Macrocentrus gifuensis* Ashm., and *Horogenes punctorius* (Roman), and a fly species, *Lydella grisescens* R., were released at several sites in the two counties. (In 1950, releases were made in Monroe County.) From 1947 through 1950, a total of 26 parasite colonies were released at 15 sites in three counties.

Recovery of parasites was attempted in the years following initial releases. In 1947, one *L. grisescens* was recovered in St. Louis County. A native parasite, *Pyraustomyia penitalis* (Coq), was recovered in Marion County in 1947. In 1948, 6 out of 87 mature larvae sent to the Toledo, Ohio, Corn Borer Laboratory for parasite recovery were infested with *L. grisescens.* By 1949, 23% of the larvae in the Meramec area of St. Louis County were infested with *Lydella.*

In the fall of 1953, heavily parasitized European corn borer larvae were found in the southeastern section of Missouri east of Sikeston. This was interesting because it was at least 150 miles from any known release point in Illinois and 75-100 miles from any release in Kentucky. Collections of larvae were made for parasite recovery and as expected *Lydella grisescens* proved to be the parasite involved. One collection contained 35% parasitized larvae.

To date no *H. punctorius* or *M. gifuensis* have been recovered. Burditt (1957) reports the observation of pupae of *Sympiesis viridula* (Thoms) at the University South Farm near Columbia, on July 27, 1956. This is apparently the only record of this introduced parasite in Missouri. Burditt also reported that 5.2 percent of the larvae collected in the fall of 1955 were infested with *Perezia pyraustae,* a protozoan parasite. In 1956, preliminary observations indicated a 6.7 percent *Perezia* infestation of fall collected borers. A single specimen of *Chaetopsis fulvifrons* (Macq.) was collected in 1957 from Montgomery County larvae. In 1958, one native parasite, *Pyraustomyia penitalis,* was collected in Carroll County. The above species apparently have not become sufficiently established to cause any suppression of borer populations.

Lydella grisescens is apparently the most effective corn borer parasite in Missouri. In 1955, Burditt (1956) collected 769 mature corn borer larvae of which 5.7 percent were found to be parasitized by *Lydella.* Of this number, 572 borers were from New Madrid County in Southeast Missouri. All but one of the parasites came from New Madrid County. None of the 84 larvae from Platte County were infested. Only one of 113 from Worth County in Northwestern Missouri was infested.

In 1956, larvae collections were sent in for parasite detection from a date of planting experiment conducted in New Madrid County. Thirteen percent of the 589 total larvae were found to contain *Lydella.* Time of larva collection affected the percent of parasitism. Collections on October 8 and 9 had 6.3% parasitization while those on November 12 had 23% parasitization. This indicates that the flies are active for a longer period of time in the fall than the borers and may reduce overwintering borer numbers considerably before the fly larvae hibernate within the host. The flies hibernate as first or second instar larvae. The trend for higher percent *Lydella* parasitism as fall dissections were delayed has been relatively consistent. One exception was observed in 1958 when the Date of Planting dissections at Columbia were made in December. Of the larvae sent in from the second date of planting, 62.5% were found to be parasitized as compared to those collected on the third date when 35.3% were parasitized. In contrast, the ratio of puparia to larvae at dissection was .11 for the second date and .27 for the third date. The final result of combining the two sets of figures emphasizes the dynamics of the parasite populations and indicates that all immature forms and empty puparia must be included in the accurate evaluation of the effectiveness of this parasite.

A comparison of the percent of *Lydella* parasitism in 1957 and 1958 is given in Table 7 for the counties surveyed in both years. On the map in Figure 3, the percent of *Lydella* recovered from overwintering larvae is given for each of the crop-reporting districts surveyed. Populations of *Lydella* apparently are still increasing over the state, except in Southeast Missouri where the percentage dropped from 55%, in 1957, to 20%, in 1958. This percent parasitism was correlated with the borer population in the area as shown in Table 8. These data were of particular significance for at the same time borer populations were increasing in the less heavily *Lydella* parasitized areas. The opposite was true in 1958.

TABLE 7-EUROPEAN CORN BORER PARASITE RECOVERIES IN MISSOURI IN 1957 AND 1958.

District	No. Borers	1957 Lydella Number	1957 Lydella Percent	No. Borers	1958 Lydella Number	1958 Lydella Percent
Northwest	458	10	2.2	116	31	26.7
North-Central	308	39	12.7	153	32	20.9
Northeast	198	32	16.0	51	7	13.7
West-Central	208	16	7.7	68	4	5.9
Central	223	19	8.5	75	27	36.0
East-Central	27	9	33.3	11	1	9.1
Southwest				38	0	0
Southeast	142	76	53.5	284	57	20.1

Some of the *Lydella grisescens* puparia, found during 1957 fall dissections, were broken open and a few contained small hymenopterous larvae, tentatively identified as *Eupteromalus* sp. of the family Pteromalidae. Although no counts of the degree of infestation by this hyperparasite were made, there appeared to be an increase in 1958 over the number observed in 1957.

Some beetle larvae have also been associated with dead corn borer larvae. Larvae of a clerid, *Phyllobaemus* sp. probably *leconteri* Wolc (Det. by G. B. Vogt), were often observed in corn borer tunnels in 1957. Other beetle larvae, *Chauliognathus* sp. of the family Cantharidae were observed on several occasions in corn borer tunnels in 1958.

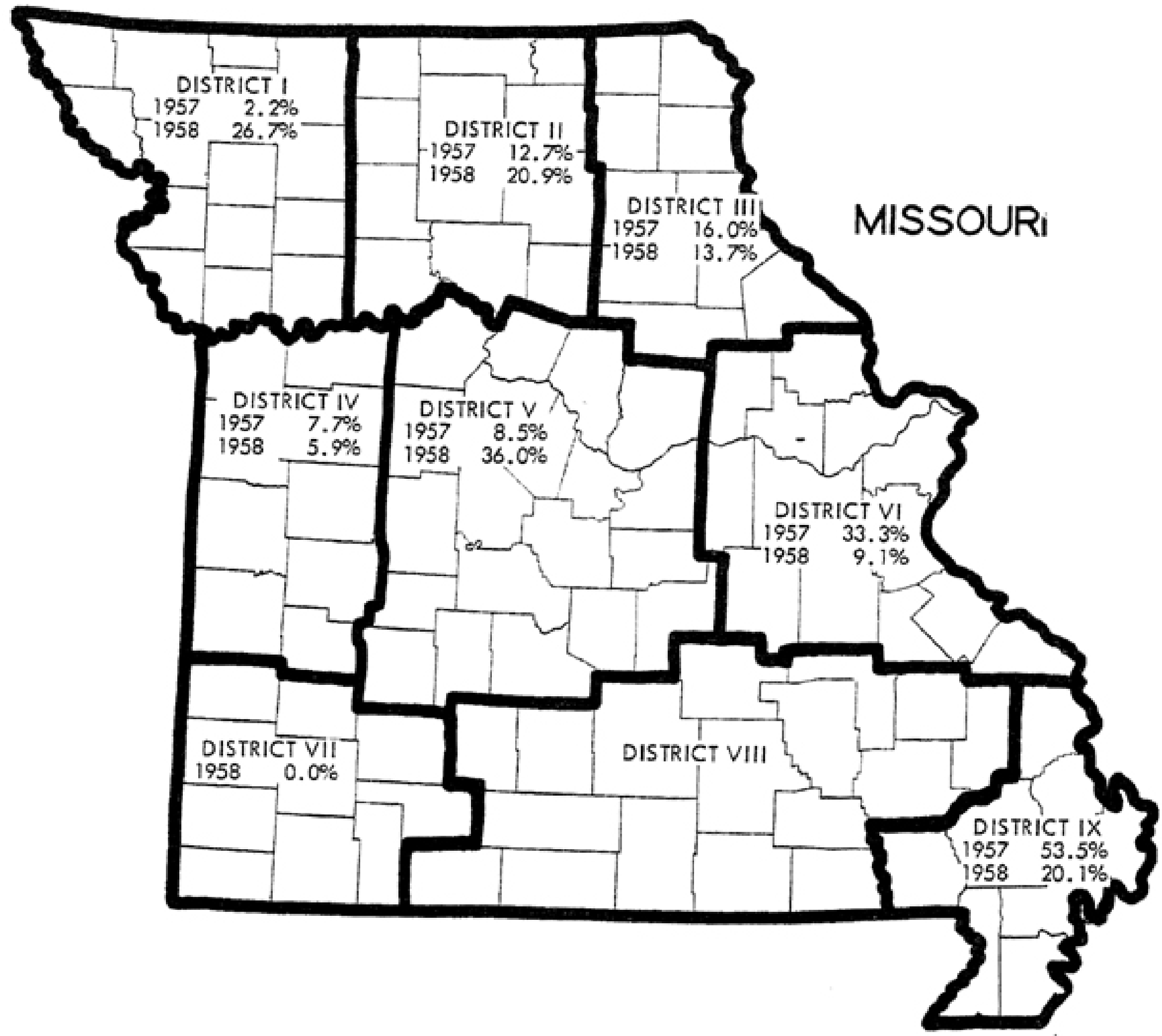

Fig. 3—Percent Lydella parasitization by crop reporting districts in 1957 and 1958.

TABLE 8-FLUCTUATIONS IN FALL CORN BORER POPULATIONS AND PERCENTAGE OF LYDELLA PARASITIZATION IN SOUTHEAST MISSOURI FROM 1955 TO 1958.

	1955	1956	1957	1958
Borers per 100 Plants	145	226	95	123
Percent Parasitized	5.7	13.2	54.5	20.1

CHEMICAL CONTROL

Investigations of chemicals for European corn borer control in Missouri have centered about evaluating candidate insecticides for effectiveness and yield increase under farm conditions. Studies of desirable formulations and means of application have also been made. All the studies reported below were conducted in farmers' fields.

First Brood Control.

On the Charles Robertson farm near Boonville, two fields of different planting dates were sprayed with 1½ pounds actual DDT in 10.5 gallons of water per acre. The fields showed from 80 to 90% of the plants with some leaf damage. The field planted on May 1 to Pioneer 332, was treated on June 19, 1957. This treatment resulted in an 84% reduction in borer populations when the final counts were made July 19. In the field planted on May 11 to Pioneer 300, the treatment was applied June 20 when the extended plant height was 30 inches. The borer population was reduced by only 10%. However, the population in this field was below economic levels, i.e., the expected gain from control was not greater than the cost of application. Aerial applications of Aldrin and DDT emulsions were made on the Burr Oak Ranch near Tarkio, the first week in July 1957. The counts made have been summarized in Table 9. Yield data indicated no apparent gain from any of the treatments. This might be due to the extreme variability of the soil and heavy second brood borer population. While Aldrin gave poor control according to the summer counts, the fall population in the Aldrin plots was significantly lower than the populations in either the check or DDT treated plots.

TABLE 9-FIRST BROOD EUROPEAN CORN BORER INDEXES (TOTAL NUMBER OF LARVAE, PUPAE, PUPAL CASES AND EMPTY TUNNELS PER 100 PLANTS) FOR AERIAL SPRAYED PLOTS ON BURR OAK RANCH, TARKIO, MISSOURI

Insecticide	Bottom Land Field		Upland Field	Average Percent Reduction
	South Replicate	North Replicate		
Check	170	360	165	--
Aldrin	220	180	145	22
DDT	40	65	10	83

In 1958, comparisons of effectiveness of several different insecticide treatments were made on the Barney Polson farm in Atchison County. All of the fields were treated either with aerial sprays or aerially applied granules. A portion of the field that could not be treated by airplane was used as the untreated check. There were 310 larvae per 100 plants in the untreated portion of the field. In the area treated with .25 pounds actual Endrin Spray per acre, there were only 33 borers per 100 plants or approximately a 90 percent reduction. In the portion treated with DDT granules (one pound actual toxicant per acre) there were only 23 borers per 100 plants, or well over 90 percent control. Observations in the DDT spray strip, at 1½ pounds actual per acre, indicated that the results were somewhat erratic and certainly not as good as those obtained with the granules.

In cooperation with the Extension Entomologists, tests were conducted on the Fergason farm in Carroll County to determine the timing of first brood insecticidal applications for corn borer control. This first brood treatment was applied to two adjacent fields of approximately two weeks difference in planting date. The treatments were intended to be applied at 25% leaf feeding, 50% leaf feeding, 75% leaf feeding, and at lay-by when the corn was approximately 45 to 55 inches in extended height. An additional series of plots was treated at 25% leaf feeding and two weeks later; the latter treatment being applied approximately at the same time as the lay-by treatment. Due to the extremely wet weather the 50 and 75% leaf feeding treatments in the old corn were put on the same day and not all replications of the young corn could be treated at the desired time. These data are summarized more thoroughly in the Master's thesis of Mr. Ralph E. Munson (1961). The general indications are that treating at 75% leaf feeding, or at lay-by, or treating twice, once at approximately 25% leaf feeding and again two weeks later, gave the best control of the borers and showed the best yield increases.

Nine different insecticides in granular formulations were compared on the Frank Trindle farm at Carrollton, Missouri, for first brood corn borer control in 1958 (Table 10). Endrin, Heptachlor, and Toxaphene all gave better control than DDT, the most widely used insecticide for corn borer control. Dieldrin and Aldrin were also quite effective, but their use will depend upon obtaining an acceptable label. Higher rates of Sevin, Kepone, or Dylox, might be effective.

TABLE 10-SUMMARY OF INSECTICIDE COMPARISONS FOR FIRST BROOD CORN BORER CONTROL ON FRANK TRINDLE FARM, CARROLLTON, MISSOURI - JUNE 1958.

Insecticide	Pounds per Acre	Percent Borer Reduction	Percent Tunnel Reduction	Increase in Yield in Bushels
5% Aldrin	7.8	75	69	14.5
5% DDT	21.5	67	56	16.6
2% Dieldrin	15.2	66	65	19.5
5% Dylox	22.5	30	24	-2.8
2% Endrin	12.0	88	83	34.1
5% Kepone	20.4	52	37	14.7
Heptachlor[1]	---	87	77	22.0
5% Sevin	20.5	13	23	15.9
Toxaphene	15.0	71	61	34.4
Check	---	141 borer/100	298 tunnels per 100 plants	98.4 bu. per acre

[1]Average of several rates and formulations tested.

It was possible to test several different formulations of Heptachlor granules on the Trindle farm. These results are given in Table 11. Time of application again seems to be a factor in the percentage of control obtained, particularly in yield increase. Apparently as control is delayed the yield reduction increases even though borer control may still be achieved. The field was approximately ¾ mile long and apparently there was a large variation in the borer populations from north to south.

Other applications on the Trindle farm indicated that the applications of DDT granules with the John Blue Duster were no more effective than the gravity flow Noble machine used in the experimental work. Aerial applications

TABLE 11-SUMMARY OF TREATMENT RESULTS USING 2 1/2% HEPTACHLOR GRANULES FOR FIRST BROOD BORER CONTROL IN CARROLL COUNTY, MISSOURI IN 1958.

Pounds Actual Toxicant	Date Treated	Half of Field Used	Tunnels per 100 plants: Treatment	Tunnels per 100 plants: Comparative Check	Tunnels per 100 plants: Percent Control	Borers per 100 plants: Treatment	Borers per 100 plants: Comparative Check	Borers per 100 plants: Percent Control	Yield in bu./A: Treated Plots	Yield in bu./A: Comparative Check	Yield in bu./A: Increase
1.00	June 11	North	63	368	83	38	180	79	134.4	101.6	32.8
1.00	June 17	North	85	290	71	15	85	82	147.5	131.3	16.2
1.00	June 18	South	20	140	86	10	80	88	118.8	87.5	31.3
0.75	June 27	North	110	360	69	35	175	80	112.5	115.0	-2.5
0.75	June 18	South	40	140	71	10	80	88	114.4	87.5	26.9
0.75	June 27	South	65	173	63	5	80	94	118.3	107.9	10.4
0.50	June 18	South	70	140	50	50	80	38	113.8	87.5	26.3
0.50	June 27	South	45	173	74	10	80	88	112.8	107.9	4.9
1.00	June 27	South	70	173	60	20	80	75	120.1	107.9	12.2
1.00[1]	June 11	North	84	360	77	22	170	87	134.5	96.4	40.1
1.00[2]	June 11	North	53	365	86	13	200	94	136.0	108.5	27.5
Range					50-86			38-94			-2.5 to 40.1

1 5% formulation on Attaclay.
2 10% formulation on Vermiculite.

just before a heavy rain are only about half as effective as applications after the rain. Plots treated with 45 pounds of 5% granules prior to the calibration of the airplane's granular applicator attachment gave no better control than 20 pounds of 5% granular DDT. Ten pounds of 10% Toxaphene applied by air was as effective as 15 or 20 pounds of the same material, but, since the data were somewhat erratic, the 15 pound rate based on other tests must be recommended until further studies can be made.

Second Brood Control.

The timing of second brood corn borer control in relationship to plant maturity was also evaluated in cooperation with the Extension Service. Fifteen pounds of 10% Toxaphene were used to treat all fields at the days indicated in Tables 12 and 13. The borer reduction by timing of insecticide applications to corn at five maturity levels are given in Table 12. The best reductions with the single treatment were achieved in corn that was treated prior to pollen shed. Double applications were best when the first treatment was applied prior to pollen shed and the second treatment 10 days later.

TABLE 12-REDUCTION OF SECOND BROOD CORN BORER LARVAE BY APPLICATIONS OF TOXAPHENE GRANULES IN CARROLL COUNTY, MISSOURI IN 1958.

Cooperator	Stage of Corn First Week in Aug.	Borers per 100 Plants in Check	Treatment Dates Aug. 9	Aug. 19	Aug. 29	Aug. 9 & Aug. 19	Aug. 19 & Aug. 29
Kincaid[1]	90% dry silk	141	50%	19%	---	41%	---
Hansel	20% dry silk	208	49%	43%	---	65%	---
Kaiser	90% green silk (Pollen Shedding	135	67%	---	---	---	---
Merten	Just tasseling	127	74%	47%	64%	84%	33%
Kinder	Late whorl	38	---	---	74%	---	---

[1]Treated Aug. 8 and Aug. 22.

The yield data summarized in Table 13 indicated no apparent increase in yield due to insecticidal applications put on following the drying of the corn silks. The application on the Hansel farm, applied during the silking period, did show significant increases in yield. There were no significant differences between the yields of the various times of treatment on the Hansel farm. Five percent DDT was also also used in the tests on the Kaiser farm and the increase in yield was only two bushels per acre, compared to eleven in the Toxaphene-treated plots. Corn borer control was the same for both insecticides. The increases in yield on the Merten farm were best for the August 9 treatments or before pollen shedding. On the Kinder farm, part of the yield loss was due, no doubt, to the fall army worm infestation on this extremely later corn. Several other insecticide comparisons for second brood control were made in Carroll County, in 1958, with both ground and air equipment, but, because of low borer populations and field variability, these studies serve only as the basis for further work before competent results can be published.

TABLE 13-YIELDS OF SECOND BROOD TIMING OF TOXAPHENE GRANULAR APPLICATION STUDIES AT CARROLL COUNTY, MISSOURI IN 1958.

		Bushels per acre by Treatment Dates					
Cooperator	Stage of Corn First Week in Aug.	Untreated	Aug. 9	Aug. 19	Aug. 29	Aug. 9 & Aug. 19	Aug. 19 & Aug. 29
Kincaid[1]	90% dry silk	130	121	128	--	129	--
Hansel	20% dry silk	65	84	79	--	78	--
Kaiser	90% green silk (Pollen Shedding)	112	123	---	--	---	--
Merten[1]	Just tasseling	58	71	60	56	71	59
Kinder[1]	Late whorl	49	---	---	59	---	--

[1]Yields not corrected for moisture content. Kincaid's corn was treated Aug. 8 and Aug. 22.

Third Brood Control is Southeast Missouri.

In 1955, a study was initiated in New Madrid County, when, on September 1, an average of 11 egg masses per plant was found in a field of corn planted on June 20 with the variety Pfister 270. Parts of this field were sprayed by airplane on September 2, 1955, with 1½ and 3 pounds of DDT per acre. At that time, about 60 percent of the eggs had hatched. The borer population was determined on September 15 and again on October 29, 1955. The yield was determined on October 29. These data are summarized in Table 14. A large number of the borers present on September 15 were 4th and 5th instar larvae, indicating a heavy infestation of second brood larvae that were not affected by the insecticide treatment.

TABLE 14-THIRD BROOD CORN BORER CONTROL RESULTS IN SOUTHEAST MISSOURI IN 1955.

		Treatment	
	Check	1 1/2 lbs. DDT	3 lbs. DDT
No. larvae per plant - Sept. 15	23.0	12.2	12.2
No. larvae per plant - Oct. 29	5.1	4.3	1.8
No. tunnels per plant - Oct. 29	10.2	7.7	3.4
Yield - bushels per acre	35.2	47.8	50.2

In 1956, insecticides were evaluated for third brood borer control on the farm of Mr. James Roth in the southwestern part of New Madrid County. The field was in an irrigated mid-June planting of U.S. 13 corn. There were many full-grown second brood larvae present in the field at the time of insecticide application.

Three types of experiments were conducted. The first experiment was to determine the effect of applying sprays and granular insecticides simultaneously. Results of this study are given in Table 15. These data show that the best con-

TABLE 15-INFLUENCE OF METHOD OF APPLICATION OF INSECTICIDES ON CONTROL OF THIRD BROOD EUROPEAN CORN BORER LARVAE IN SOUTHEASTERN MISSOURI - FALL 1956

	Number per 100 Plants	
Treatment	Corn Borer Larvae	Total Borer Index[1]
DDT granular + spray	489.5	752.6
DDT granular	609.4	1005.7
DDT spray	679.3	942.4
DDT granular + water	712.6	1045.6
Untreated	722.6	1135.5

[1]Includes larvae in tunnels, pupae, pupa cases, empty tunnels and corn borer parasites.

trol of corn borer larvae was obtained by a combined application of DDT spray and DDT granules. A combined application of water and DDT granules resulted in the poorest control.

The relative effectiveness of several insecticides in granular formulation was compared in a second experiment. Results of this study are summarized in Table 16. These data show that only small differences were found between the materials tested. All of the other materials tested gave better control of the corn borer than was obtained with granular DDT.

TABLE 16-EFFECTIVENESS OF GRANULAR INSECTICIDES FOR CONTROL OF THIRD BROOD EUROPEAN CORN BORER LARVAE IN SOUTHEASTERN MISSOURI - FALL 1956

	Number per 100 Plants	
Treatment	Corn Borer Larvae	Total Borer Index[1]
Dieldrin granular	306.4	572.8
Aldrin granular	326.3	636.0
DDT spray	329.7	652.7
Endrin granular	366.3	649.4
DDT granular	466.2	809.2
Untreated	576.1	889.1

[1]Includes larvae in tunnels, pupae, pupa cases, empty tunnels and corn borer parasites.

The final test of this group was to determine the most effective time of application of insecticides for control of third brood corn borer larvae. Results of this experiment are given in Table 17. These data show that the best control from a single application of granular material was obtained by applying the DDT on August 24 and the best control from a single application of spray was obtained by applying the DDT on August 27. Two applications of DDT in either the granular form or as a spray resulted in better control than was obtained with single applications.

In 1957, five different treatments were applied on the farm of Charles Gardner near Sikeston, Missouri, on August 8 and August 23, 1957. Results are

TABLE 17-TIMING OF APPLICATIONS OF DDT FOR CONTROL OF THIRD BROOD EUROPEAN CORN BORER LARVAE IN SOUTHEASTERN MISSOURI - FALL 1956

Date of Treatment	Number per 100 Plants			
	Corn Borer Larvae		Total Borer Index[1]	
	Spray	Granular	Spray	Granular
		Single Applications		
Aug. 24	702.6	419.6	1019.0	725.9
Aug. 27	672.7	499.5	935.7	815.9
Aug. 31	749.3	456.2	1052.3	745.9
Sept. 7	1012.3	612.7	1621.7	1049.0
		Two Applications		
Aug. 24, Aug. 31	602.7	329.7	889.1	542.8
Aug. 24, Sept. 7	556.1	432.9	819.2	679.3
Untreated	1005.7	689.3	1418.6	1039.0

[1] Includes larvae in tunnels, pupae, pupa cases, empty tunnels and corn borer parasites.

given in Table 18. Each treatment was repeated three times, with each plot consisting of 12 rows a quarter mile long. For the borer counts, ten plants were dissected in each plot. All of the treatment resulted in significant reductions of the borer when compared with the check, but the difference between 5% DDT granules and the Toxaphene emulsion was the only significant difference between the treatments. Heptachlor granules, the use of which was originally planned for this study, were, unfortunately, not included. This was the only experiment in which Heptachlor emulsion was used. Yield records were not taken on this field because of the leaf diseases that developed some time after the insecticide application.

TABLE 18-CORN BORER CONTROL ON THE CHARLES GARDNER FARM NEAR SIKESTON, MISSOURI RESULTING FROM TWO APPLICATIONS ON AUGUST 8 AND 23, 1957.

Insecticide	Formulation	Actual per Acre	Borers per 100 plants	Reduction in Percentages
DDT	5% granules	1.0 lb.	23[1]	87
Toxaphene	10% granules	1.5 lbs.	43	76
Heptachlor	emulsion	1.0 lb.	43	76
DDT	emulsion	1.5 lbs.	67	63
Toxaphene	emulsion	2.0 lbs.	73	59
Check	---	--	180	0

[1] Means connected by lines are not significantly different.

Several different insecticides were applied on the Frank Van Horn farm as single treatments for both second and third brood borer control in 1957. Second brood borer survival was too low to indicate differences among the plots treated for this brood. The peak of third brood egg laying was between August 19 and August 26. Ten different treatments were applied on August 23. The treatments were four row plots, one-eighth mile long, repeated three times. The results of the fall dissection on October 10 are shown in Table 19. In an earlier dissection

TABLE 19-THIRD BROOD BORER CONTROL ON FRANK VAN HORN FARM, SIKESTON, MISSOURI ON AUGUST 23, 1957.

Insecticide	Formulation	Actual per Acre	Borers per 100 Plants	Reduction in Percentages
Dieldrin	2% granules	0.4 lbs.	53	85
Endrin	1% granules	0.4 lb.	67	81
Heptachlor	5% granules	1.0 lb.	70	80+
DDT	25% emulsion	1.5 lbs.	73	80-
Toxaphene	10% granules	1.5 lbs.	90	74
DDT	5% granules	1.0 lb.	103	71
Dylox	2.5% granules	1.0 lb.	103	71
Aldrin	2.5% granules	0.5 lb.	103	71
Heptachlor	2.5% granules	1.0 lb.	123	66
Chlordane	5% granules	1.0 lb.	130	64
Check	---	---	357	0

on September 9, control by 2½% and 5% Heptachlor granules differed by only three borers per 100 plants. This might be interpreted to mean a longer residual effectiveness by the higher concentration of granules. It should be emphasized that third brood borer control does not show as high a level of effectiveness as work done on first brood control. This is because of the extended egg laying period of the second and third brood moths in Missouri.

Another area of study conducted on the Van Horn farm involved the chronological timing of applications of Heptachlor, Endrin, and DDT, as well as double application of the same insecticide. One series of plots was treated three times in order to study reduction in borer population by such treatments. The numbers are based on fall dissection of ten plants in each of three replications. From these data presented in Table 20, it is apparent that chronological timing is not the only criterion of insecticide applications for third brood corn borer control.

TABLE 20-PERCENT REDUCTION IN CORN BORERS BY GRANULAR INSECTICIDE TREATMENTS AT DIFFERENT DATES IN 1957 AT SIKESTON, MISSOURI

	July 25	Aug. 8	Aug. 23	Aug. 29	July 25 & Aug. 29	Aug. 8 & Aug. 29	July 25 Aug. 22 Sept. 5
Endrin	35	28	81	46	55	85	83
Heptachlor	28	43	66	39	61	76	81
DDT	13	19	71	---	73	50	74
Borers per 100 Plants (in check)	447	303	357	330	396	246	415

The only third brood test in 1958 was on the J. W. McIllwain farm. This plot was located two miles south of East Prairie, Missouri. At the time of the first application, August 16, the corn was in the "green silk" stage. The second application was made September 2, after all the silks were dry. Each application consisted of 20 pounds of 5% Heptachlor granules per acre. The granules were applied with a high clearance sprayer with a granular insecticide attachment.

The plots had been harvested and sown to rye prior to the time that it was possible to collect the fall data. Data was collected by sampling 20 whole stalks, or nearly whole stalks, left in the two center rows of each plot. The total tunnels for each stalk were counted and recorded. The results are summarized in Table 21.

TABLE 21-CORN BORER TUNNELS PER 100 STALKS AFTER VARIOUS TREATMENT TIMES ON McILLWAIN FARM IN 1958 NEAR EAST PRAIRIE, MISSOURI

Treatment Date	Replication 1	Replication 2	Replication 2	Average
Aug. 16	405	505	345	418
Sept. 2	515	695	550	587
Aug. 16 & Sept. 2	255	460	330	348
Untreated	680	695	635	670

SUMMARY

1. The life cycle of the European corn borer in Missouri is reviewed.
2. Fifteen years of fall population surveys reported by crop districts show cycle increased.
3. Census studies in Carroll and New Madrid Counties indicate that date of planting, climate, soil fertility, and degree of biological and chemical control, are the most important factors influencing populations.
4. Brachytic dwarfed corn is attacked as heavily as the same hybrids with normal internode length and growth stage.
5. A program for breeding corn resistant to all generations of corn borers is outlined.
6. *Lydella grisescens* is the most important parasite in Missouri and can apparently cause significant population reductions.
7. Endrin, Heptachlor, and Toxaphene, granules are as good as, and often more effective than, DDT for corn borer control.
8. Best second brood control occurs when corn in a susceptible state of growth (tasseling at peak of egg laying) is treated after tasseling, but before pollen shed is completed.
9. Third brood control on late corn should be applied some time after August 20, but before the silks are dried.

BIBLIOGRAPHY

Apple, J. W. 1952. Corn borer development and control on canning corn in relation to temperature accumulation. Jour. Econ. Ent. 45:887-879.

Arbuthnot, K. D. 1944. Strains of the European corn borer in the United States. U.S.D.A. Technical Bul. 976.

Burditt, A. K., Jr. 1956. The effect of planting date on corn borer populations in Southeastern Missouri. Proc. North Central Branch, Ent. Soc. Am. 11:66-67.

Burditt, A. K., Jr. 1956. Unpublished Progress Report, Project 270, Missouri Agr. Exp. Sta.

Burditt, A. K., Jr. 1957. Unpublished Progress Report, Project 270, Missouri Agr. Exp. Sta.

Denning, J. Allison. 1942. Missouri State Department of Agriculture Bulletin 40(13):22-24.

Goleman, D. Lyle. 1954. Biological study of the European corn borer in Boone County, Iowa. Doctoral Dissertation, Iowa State College.

Grogan, C. O., M. S. Zuber, Norman Brown, D. C. Peters, and H. E. Brown. 1959. Date of planting studies with corn. University of Missouri Res. Bul. 706, 68 p.

Jackson, R. D. and D. C. Peters. 1961. Biological studies of the European corn borer in Southeast Missouri. (Submitted for publication in the Journal of Economic Entomology.)

Jablonowski, Josef. 1898. A kukoricamoly *(Botys nubilalis).* In Kiserletugyi Kozlemenyek (reports of experiment station), Budapest, 1, pp. 33-47.

Jenkins, Lee and G. W. Thomas. 1956. European corn borer attacking cotton in Missouri. Jour. Econ. Ent. 49:270-271.

Kwolek, W. F. and T. A. Brindley. 1959. The effects of the European corn borer, *Pyrausta nubilalis* (Hbn.), on corn yield. Iowa State Coll. Jour. Sci. 33:293-323.

Munson, R. E. 1961. Unpublished data.

North Central Advisory Committee on Entomology and Economic Zoology. 1957. The European corn borer and its control in the North Central States. Iowa State Coll., Agr. Ext. Serv., Pamphlet 176 (Rev. 1957).

Patch, L. H. 1942. Height of corn as a factor in egg laying by the European corn borer moth in the one-generation area. Jour. Agr. Res. 64:503-515.

Peters, D. C. 1959. The effect of dwarf corn on European corn borer infestations. Proc. North Central Branch, Ent. Soc. Am. 14:5-6.

Turner, N. and R. L. Beard. 1950. Effect of stage of growth of field corn inbreds on oviposition and survival of the European corn borer. Jour. Econ. Ent. 43:17-22.