The Re-introduction and Initial Re-establishment of *Lydella stabulans grisescens* R.-D., a Parasite of the European Corn Borer (*Pyrausta nubilalis* (Hbn.)), in Delaware

by

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science.

February, 1961

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SUMMARY

Between 1947 and 1951 the tachinid fly Lydella stabulans grisescens R.-D., which was released in Delaware between 1941 and 1946, averaged 21.4 percent annual parasitism of the European corn borer, Pyrausta nubilalis (Hbn.). Subsequent to 1951 the parasite appeared to decline in abundance.

The purpose of this work was to instigate a program of biological control against the European corn borer in Delaware in order to reduce its abundance. In the Fall of 1958 and Spring of 1959, overwintering borers were collected to ascertain the status of L. stabulans grisescens. Results indicated the fly to be no longer present in the State.

In the Spring of 1959, a biological control program against the corn borer was undertaken by the University of Delaware, assisted by the United States Department of Agriculture's European Corn Borer Research Laboratory in Ankeny, Iowa. Adult L. stabulans grisescens were sent from Iowa and released in June, 1959. Six release sites were selected throughout the State and a total of 2,933 flies were released.

In the Fall of 1959 and Winter of 1960 corn borer larvae were collected and sent to the Iowa laboratory in order to determine establishment and dissemination of L. stabulans grisescens. For each release area, whenever possible, 16 fields were sampled in addition to the release field.

Starting from the release site samples were taken at intervals of one-half, one, two, and four miles in four directions; North, South, East, and West. In most cases each sample consisted of 50 borers. In all, a total of 88 fields were sampled and 4,249 corn borer larvae were collected and observed for parasitism.

For all fields sampled, parasitism by L. stabulans grisescens averaged 0.6 percent and it was recovered from 18.2 percent of these fields. The range of parasitism was from 2.1 percent to 7.7 percent. Parasite recoveries were made from at least one field in each release area except one, for a total of 16 positive fields. Average parasitism for these 16 fields was 3.45 percent. Maximum dispersal was at least two miles.

The average percentage parasitism (3.45%) in fields where the fly was recovered compares favorably with the percentage parasitism by L. stabulans grisescens in release areas of the State in the 1940's at intervals of from one to two years after release. Since L. stabulans grisescens had completed two generations in Delaware by the time parasitism data was determined in the Spring of 1960, it is highly probable that this fly is re-established in Delaware.

INTRODUCTION

Since its detection in the United States in 1917 the European corn borer, Pyrausta nubilalis (Hbn.) has become progressively more important. For the year 1959 the United States Department of Agriculture Cooperative Economic Insect Report (Vol. 10, No. 18) estimated losses of corn grown for grain due to the corn borer in the United States to be 67,763,000 bushels. This amounted to a monetary loss of $71,979,000.00.

Subsequent to its detection in Delaware in 1934, the borer became an important pest in the State. The population has risen from five borers per 100 corn plants in 1936 to 394 borers per 100 corn plants in 1959, according to Delaware's fall abundance survey records.

In Delaware the corn borer is a major pest of corn, peppers, and potatoes. Estimated loss of corn in the State due to the borer for 1959, according to the United States Department of Agriculture Cooperative Economic Insect Report (Vol. 10, No. 18) was 1,318,000 bushels. This amounted to a monetary loss of $1,608,000.00. Burbutis, et al. (1960) reported an average loss of Delaware's pepper crop in 1958 and 1959 to be between 40 and 50 percent, with cases of infestations of 75 - 100 percent of the fruit in many fields. Figures for reduction of potato yields due to the corn borer are not available.

While insecticides will control the European corn borer, cost prohibits their use on certain crops. Many species of weeds are hosts for the borer, furnishing large unsprayed acreages for the insect as is the case with field corn. Thus, insecticide application cannot be expected to greatly reduce the overall corn borer population.

In the Spring of 1959 a program was launched by the Delaware Agricultural Experiment Station, assisted by the United States Department of Agriculture, in an attempt to establish a biological control program in Delaware against the European corn borer utilizing Lydella stabulans grisescens R.-D.

The purpose of this work was to initiate a program of biological control against the European corn borer in Delaware in order to reduce its abundance. The parasite Lydella stabulans grisescens R.-D. was released with the objective of supplementing the existing density regulating factors of the corn borer in the State, and the initial establishment and dispersal of the parasite was evaluated.

The purpose of evaluating initial establishment and dispersal was to ascertain the progress and degree of parasitism of the borer by L. stabulans grisescens. This information may serve as a basis for future study of the parasite in Delaware.

The importance of establishing L. stabulans grisescens in Delaware is that while 100 percent control of the corn borer cannot be expected, the parasite may build up to the point where the same annual percentage (21.4%) of the corn borer population is parasitized as was formerly the case in Delaware. As discussed by Knipling (1960), a pest population level can be greatly lowered by the addition of a factor to the environmental resistance which supplements the existing factors. His theoretical calculations of boll weevil population dynamics for a three year period indicates that the addition of a biological control factor which causes 50 percent mortality in addition to the existing factors would have a cumulative effect which would reduce the population to only two percent of that of one unexposed to this additional factor at the end of the three years.

While it is not anticipated that L. stabulans grisescens will cause a 50 percent mortality of the borer population, it would seem that parasitism of over 20 percent, when added to the normal mortality factors, would have a cumulative affect on the borer population which undoubtedly would be important.

LITERATURE REVIEW

History of the European Corn Borer in Delaware

The early history of the European corn borer in the United States has been reviewed by Caffrey and Worthley (1927). The insect was first detected here by S. C. Vinal in 1917 in Massachusetts. During 1919, the corn borer was found through areas of the Mohawk Valley and near Lake Erie, New York State, and Erie County, Pennsylvania. By 1924 the pest was established in eastern New England, Southwest Vermont, eastern New York including Brooklyn, Staten Island, and Long Island, along the entire south shore of Lake Erie and in Michigan.

The latest information regarding the distribution of the corn borer in the United States was published in January, 1960 by the United States Department of Agriculture Cooperative Economic Insect Report (Vol. 10., No. 12). The pest is present from Maine to Georgia, west to Oklahoma, Kansas, Nebraska and the Dakotas with areas of infestation in Texas, Colorado, Montana and Wyoming.

Stearns (1940) summarized the history of the corn borer in Delaware through 1940. The borer was first recovered in the State at Stockley, Sussex county, in August, 1934. At that time three larvae were found by United States Department of Agriculture personnel. Surveys in 1939 showed the borer

to be present in New Castle and Kent counties as well as Sussex county. The mean infestation was 8.9 borers per 100 corn plants. The population increased over the years to a high of 394 borers per 100 corn plants in 1959.

The environmental factors affecting the corn borer population in Delaware have been reviewed by Milliron (1958). MacCreary and Rice (1949), and Milliron (1953) summarized the effect of imported parasites on the corn borer population in the State. Of the introduced borer parasites, only L. stabulans grisescens became important, parasitizing annually an average of 21.4 percent of the corn borer population from 1947 to 1951. With the decline of L. stabulans grisescens after 1951, the main factors regulating the borer population density, according to Milliron (1958) were weather and agronomic practices, the action of biotic factors being negligible.

Corn Borer Parasites

Many insect parasites of the European corn borer have been recorded throughout the range of this pest. W. R. Thompson (1943) in his comprehensive Catalog of Parasites and Predators of Insect Pests lists 119 species of corn borer parasites. All are in the orders of Diptera and Hymenoptera.

Of the Hymenoptera there are 2 species of Chalcididae, 30 of Braconidae, 3 of Eulophidae, 53 of Ichneumonidae, 3 of

Pteromalidae, and 3 of Trichogrammidae. The Diptera include 1 species of Phoridae and 24 of Tachinidae.

Of these 119 recorded parasites, 24 species were brought to the United States from Europe and Asia between 1920 and 1937 according to Baker, et al. (1949). Six of these have become established in the United States. They are: Eulophus viridulis Thoms. (Hymenoptera, Eulophidae), an ectophagous larval parasite, Phaeogenes nigridens Wesm. (Hymenoptera, Ichneumonidae), a pupal parasite, Chelonus annulipes Wesm. (Hymenoptera, Braconidae), an egg parasite, Horogenes punctorius Rom. (Hymenoptera, Ichneumonidae), an endogenous larval parasite, Macrocentrus gifuensis Ashm. (Hymenoptera, Braconidae), a polyembryonic endogenous larval parasite, and Lydella stabulans grisescens R.-D. (Diptera, Tachinidae), an oviviparous endogenous larval parasite.

With respect to corn borer parasites indigenous to the United States, Baker, et al. (1949) recorded 29 species. However, only small numbers of borers have been parasitized by them and they are unimportant.

Taxonomy of Lydella stabulans grisescens R.-D.

According to Baker, et al. (1949) the currently accepted name for the parasite is Lydella stabulans grisescens R.-D. Lydella stabulans grisescens R.-D. is a calypterate muscoid fly of the family Tachinidae, order Diptera.

The taxonomic history of L. stabulans grisescens was published by Bezzi and Stein in 1907 in the Katalog der Palaarktischen Diptern, Vol. III, according to Thompson and Thompson (1923) who published a description of the parasite from specimens of larvae and adults collected in Europe.

In his paper in 1922, Thompson discussed two other tachinids found in Europe which were practically inseparable from L. stabulans grisescens in the adult stage, but which were morphologically distinct in the immature stages. He attributed the existence of these morphologically homogenous adults as the reason for no reliable references in the literature on the distribution and bionomics of L. stabulans grisescens.

Baker, et al. (1949) list four synonyms for L. stabulans; Masicera senilis Rond., Masicera senilis Meig., Lydella grisescens R.-D., and Ceromasia lepida (Meig.).

Lydella nigrita, which is indigenous to the United States, has frequently been confused with L. stabulans grisescens. The diagnostic character for separating the adult males of these two tachinids has been reviewed by Baker, et al. (1949).

Biology of Lydella stabulans grisescens

The biology of L. stabulans grisescens has been studied in Europe by Thompson (1923) and Thompson and Parker (1928). Clark (1934) reported on the seasonal history and distribution of the parasite in Asia. Baker, et al. (1949) conducted biological studies of the parasite in the United States.

Adult longevity under laboratory conditions (80°F. 70% relative humidity) was determined by Baker, et al. (1949). Average life span was 17 days, that of the male ranging from one to seven days shorter than that of the female.

Under laboratory conditions males emerged from the puparia about two days before the females. Mating occurred two to three days after male emergence. Optimum temperature for mating was found to be 80°F.

Thompson and Parker (1928) found that females of L. stabulans grisescens produced only a few hundred larvae. The maximum number of eggs found in dissected females by Baker, et al. (1949) was 1,000, the average being approximately 660 eggs per female. Egg production was found to increase with the size of the fly and the duration of coition. The eggs were retained until incubated, and hatched during oviposition. The first larvae were deposited five days after mating.

The adult females deposit larvae on cornstalks adjacent to corn borer tunnel openings and on leaves where the borers are present. Borer frass was found to attract adults to these larviposition sites. Subsequent to deposition on the plant, Thompson and Parker found that the maggots did not wait for hosts to pass by, but actively searched for caterpillars, entering borer tunnels. In the laboratory, Baker found that the maggots could search as long as 36 hours for the host, providing they had contact moisture. The maggots were found to invade the caterpillar through a spiracle, between body segments, and through the anus.

Thompson and Thompson (1923) found that the first instar maggot, after entering the host, cut a hole in the wall of a tracheal trunk of the borer and inserted the anal stigmata for breathing. The tracheal epithelium forms a partially sclerotized sheath, dark brown in color at the base around the maggot. The first and second instar maggots feed on the host body fluids. The third instar maggot detaches from the trachea and cuts a hole in the integument, through which the anal stigmata protrudes for breathing. This instar feeds on fatty tissues and internal organs. Pupation generally occurs outside the host in the borer tunnel. At 80°F and 70% relative humidity, Baker found the duration of the first, second and third instars to be 3.1, 2.1 and 2.7 days respectively. The pupal period averaged 7.8 days.

Thompson and Parker (1928) believed the larvae to be unable to penetrate the integument of fourth and fifth instar borers. However, Baker, et al. (1949) has shown that all instars except the first can be successfully parasitized by L. stabulans grisescens. Twenty-four percent of the second and third instar borers and 54 percent of the fourth and fifth instar borers tested were successfully parasitized. The fourth instar borers had the highest percentage of parasitism and appeared to be the most suitable host stage. Size of the puparium of the fly was correlated with size of the host.

Seasonal History of Lydella stabulans grisescens

In regard to the seasonal history of L. stabulans grisescens, Thompson and Parker (1928) believed the parasite to have one generation per year in areas of Europe where univoltine corn borers were present and two generations per year in the case of bivoltine borers. The parasite overwintered as second instar maggots in mature corn borer larvae.

Clark (1934), in his study of the corn borer in Asia was unable to determine the number of generations produced in some areas of Japan by L. stabulans grisescens due to extensive overlapping of parasite generations. In southern Kyushu, while the corn borer annually produces three and a partial fourth generation, L. stabulans grisescens was believed to produce four generations per year.

Baker, et al. (1949), in the United States, found the parasite to produce two generations annually, the second generation overwintering in the second instar, resuming development in early April and emerging as adult flies in late May. In the course of these studies, it was found that some of the first generation L. stabulans grisescens went into diapause during the summer. These did not resume development again until the following April.

History of Lydella stabulans grisescens in the United States

Before discussing the history of L. stabulans grisescens in the United States, its distribution in Europe and Asia, the sources of United States imports, should be considered.

Thompson and Parker (1928) found the parasite to be present in France, Spain, Italy, Yugoslovia, and Hungary. Babcock and Vance (1929) found the parasite in low abundance in Czechoslovakia, Rumania, and in Baden, Germany.

In the Mediterranean coastal zone of France, Thompson and Parker found L. stabulans grisescens to be the dominant corn borer parasite. Average annual parasitism in a five-year study was 12.67 percent with the maximum parasitism for any single year of 23.7 percent. In Galicia (N.W. Spain) a one-year study showed a parasitism of 12.4 percent by L. stabulans grisescens. In the southern Po Valley of Italy

L. stabulans grisescens was the principal borer parasite, with 7.5 percent parasitism in a one-year investigation. In the Naples area of Italy L. stabulans grisescens was found to be the dominant borer parasite, averaging 15.9 percent parasitism annually in a three-year study. Maximum parasitism for any single year was 23.7 percent.

Clark (1934) stated that L. stabulans grisescens was one of the most widely distributed corn borer parasites in the Orient. Cartwright (1933) found it in Hokkaido, Honshu, Shikoku, and Kyushu in Japan. He also found the parasite in Korea, Manchuria, and China. On Hokkaido, it was the dominant borer parasite. On Honshu it was also found to be the chief borer parasite, comprising approximately 94 percent of the parasites recovered from borer collections. In Kyushu it was second in abundance only to Macrocentrus gifuensis. In one area of Korea, 93 percent of the recovered borer parasites were L. stabulans grisescens. The parasite was not found on Formosa.

There are conflicting dates in the literature regarding the year in which L. stabulans grisescens was first introduced into the United States from Europe. Milliron (1953) stated that the parasite was imported from Europe in 1929. However, Baker, et al. (1949) indicated that it was introduced and released in Massachusetts in 1920, being one of the first corn borer parasites imported.

That the parasite was released in the United States prior to 1929 is substantiated by Baker, et al.(1949) in published records of parasite releases in the United States from 1920 to 1940. Releases were recorded in Monroe County, Michigan in 1927 and in Monroe and St. Claire Counties in Michigan in 1928 as well as Cattaraugas, Cayuga, Chautauqua and Erie Counties in New York in 1928. Records of Importations of borer parasites from Europe from 1920 to 1927, indicate that 10,940 specimens of L. stabulans grisescens were obtained.

Baker, et al. (1949) stated that 1,058,516 specimens of L. stabulans grisescens have been imported into the United States up to 1937 when this program was discontinued. European imports were supplemented with shipments from Asia beginning in 1929. The total number of L. stabulans grisescens imported from Europe was 751,636. From Asia, a total of 306,880 specimens were imported between 1929 - 1936.

Due to the possibility of biotypes, parasites from Europe and Asia were never released in the same area in the United States. The first recovery of L. stabulans grisescens in the United States was in 1930. Beginning in that year the foreign importations were supplemented by domestic collections of Lydella stabulans grisescens, 14,041 being collected between 1930 - 1937. After 1937 all L. stabulans grisescens released

in the United States were collected from areas in the country where the parasite had become established.

Baker and Bradley (1938) reviewed the status of corn borer parasites in the United States from 1920 - 1936. They found L. stabulans grisescens to be established in areas of Massachusetts, Connecticut, New Jersey, Maryland, and Virginia, with average parasitism of 4.4 percent, 0.45 percent, 0.3 percent, 2.7 percent, and 0.55 percent respectively. At most release points in Massachusetts, where the first releases in the United States were made, the parasite was recovered from almost every corn borer collection.

Baker, et al. (1949) reviewed the distribution and abundance of L. stabulans grisescens in the United States through 1940. Aubuthnot (1950) summarized the corn borer parasite situation in the United States through 1947. He stated that L. stabulans grisescens was widely distributed in the Eastern States, even in localities where it was not released. Although abundant in Massachusetts, Rhode Island, Connecticut, the Hudson Valley of New York, and Western New York, the degree of borer parasitism was low. In the Middle Atlantic States it was present in New Jersey, Delaware, Pennsylvania, Maryland, Virginia, and North Carolina, with an average parasitism of 13 percent. It was present in Monroe, Michigan, Erie and Lucas Counties in Ohio with parasitism averages ranging from 10 to 30 percent. The parasite had

been released in nine North Central States since 1944 and was recovered from all of them.

Baker, in a paper presented at the Tenth International Congress of Entomology in 1956, summarized corn borer parasite data in the United States for the period of 1952-1954. Parasitism by L. stabulans grisescens was low in Connecticut. In Illinois, Iowa, Maryland, Michigan, Missouri, Nebraska, New Jersey, Ohio, Pennsylvania, and Wisconsin, it was found to be the dominant corn borer parasite. The maximum concentrations in the United States were in Illinois and Ohio. It was considered to be the most effective borer parasite in the midwest, while Macrocentrus gifuensis was believed to be most important in the East.

History of Lydella stabulans grisescens in Delaware

Releases of L. stabulans grisescens in Delaware were made between 1941 - 1946 by the United States Department of Agriculture in cooperation with the Delaware Agricultural Experiment Station.

The flies released were collected in areas where Lydella stabulans grisescens was established in the United States. MacCreary and Rice (1949) reported on these releases and initial parasite recoveries. They indicated that besides L. stabulans grisescens, the following parasites were released in Delaware in the same period; E. viridulis, H. punctorius, C. annulipes, and M. gifuensis. The five

species released totaled 97,156 specimens of which L. stabulans grisescens comprised 3,179 specimens (3.3%). In addition, Sympiesis viridula Thoms. was released in 1946. L. stabulans grisescens, C. annulipes, and M. gifuensis became established in the State, but only L. stabulans grisescens became an important parasite of the corn borer.

MacCreary and Rice (1949) first recovered L. stabulans grisescens in 1943 from Stockley and Kirkwood, where the fly had been liberated in 1941 and 1943 respectively. Additional releases were made in 1944 at Hockessin, Townsend, Dover, and Fredrica. At Fredrica another release was made in 1945. The parasite was recovered yearly through 1946 from all release sites. It was also recovered from areas where no release had been made; Milton, Laurel, and Farmington. They recovered the fly from 29 of 30 borer collections from all over the state in 1947, thus showing the parasite to be disseminated statewide with an average parasitism of 11.6 percent.

Milliron (1953) reported on the status of the parasite in Delaware from 1947 to 1951. The annual statewide borer sampling was continued through these years. Average annual statewide parasitism for these years was 21.4 percent.

At this point it is interesting to consider borer population fluctuations from 1947 to 1951 in relation to the

percent parasitism of the borer by L. stabulans grisescens. An indicated in Figure 1, at the time of the release of L. stabulans grisescens in Delaware the borer population was increasing. The releases between 1941 - 1946 were followed by a decline in the borer population (between 1947 - 1951), during which time L. stabulans grisescens became abundant on a statewide basis. After 1951 a decrease of the parasite population was accompanied by an increase in the borer population.

Sweetman (1958) has reviewed the literature regarding the evaluation and results of biological control of insects. From his summary on corn borer parasites it is apparent that there are several factors, both biotic and abiotic, involved. It is this complex of factors which complicates the exact evaluation of the influence of parasitism on the borer population.

However, it would appear, from the pattern of borer population fluctuation shown in Figure 1, that from 1947 to 1951 L. stabulans grisescens was an important supplement to other population regulating factors of the corn borer.

Subsequent to 1951, L. stabulans grisescens declined in abundance in Delaware. Milliron (1958) stated that:

> "in recent years this parasite has diminished to the point where it cannot be considered of much importance in checking its host."

There are other cases where the parasite has declined. Peterson (1948) reported its decline on Guam. Baker, et al. (1949) stated that there was a sharp decline in a large area northwest of Boston in 1938 where the fly had previously been very abundant.

A review of the literature suggests several possible causes for the decline of L. stabulans grisescens in Delaware. Thompson and Parker (1928) found puparia of the fly in the fall, winter, and early spring in Europe. Baker, et al. (1949) reported that puparia were found in the Lake States in the United States in the fall. The flies emerged from the fall, winter and early spring puparia in Europe long before young corn borer larvae were available. In the Lake States the insects were killed in the puparia by the advent of cold weather. Such a lack of syrchronization with the host may have occurred in Delaware.

It would appear that in cases of early emergence of the parasite, the presence of an available alternate host would be of benefit. L. stabulans grisescens was believed host specific for the corn borer until York, et al. (1955) recorded it from Papaipema nebris (Guen.), the stalk borer, in Iowa. The findings showed that the parasite emerged before corn borer larvae were available in the spring. Overwintering eggs of P. nebris hatched early in the spring, thus stalk borer larvae were available for the parasite before young corn borer larvae

were present. It was found that L. stabulans grisescens completed one generation in P. nebris. The parasite completed development just as young corn borer larvae became available. P. nebris is present and widespread in Delaware according to Milliron (1958). The stalk borer larvae are present in the spring before the first generation corn borer larvae are available. It is quite possible that a decline in the population of P. nebris, if it were a host of L. stabulans grisescens in Delaware, would have adversely affected the parasite.

Hyperparasitism would not seem to have been responsible for the decline of the parasite in Delaware. MacCreary and Rice (1949), Laird (1949), and Milliron (1953) found hyperparasitism to be negligible. The chalcid Eupteromalus nidulans (Thom.) was occasionally recovered. Thompson and Parker (1928) reported hyperparasitism of L. stabulans grisescens in Europe to be inconsequential. Hyperparasitism of L. stabulans grisescens was reported from Ohio by Baker, et al. (1949). Cartwright (1953) reported extensive hyperparasitism in Asia.

Superparasitism is another factor to be considered. Laboratory investigation has shown that when more than two maggots of L. stabulans grisescens are present in a corn borer larva, the maggots do not survive. However, Thompson and Parker (1928) found that borers attacked by this parasite

seldom contained more than one maggot.

Adverse weather conditions may have affacted the population of L. stabulans grisescens in Delaware. Baker (1958) reported that a decline of this parasite in Illinois from 1952 to 1953 was believed to have been caused by hot, dry weather that may have shortened the lifespan of the adult fly and adversely effected the maggots.

Whatever the cause was, surveys indicated that by 1958 L. stabulans grisescens was probably no longer present in Delaware, and that the degree of parasitism of the corn borer had declined to an extremely low point.

METHODS

Preliminary Studies

In the Fall of 1958 and Spring of 1959 preliminary studies were conducted to ascertain the current degree of parasitism of the corn borer in Delaware. Sixty borer larvae were collected in the Fall from 30 areas, as shown in Figure 2. The larvae were isolated in glass vials which were placed in racks and held in the laboratory for parasite emergence data in the spring. In the spring 184 larvae were collected in the three counties of the State. These larvae were placed in salve tins of 1.9 inches in diameter and 1.1 inches in height. A corrugated cardboard strip 1 inch wide

and 12 inches long was rolled in each tin as a place for the larvae to spin. The tins were labeled with the collection locations and were shipped to the United States Department of Agriculture European Corn Borer Research Laboratory in Ankeny, Iowa, for parasite emergence data.

Release Sites

Prior to the release of adults of L. stabulans grisescens in June, 1959, optimum release sites were selected throughout the State. Six such sites were selected, as is indicated in Figure 3. One was in New Castle County, two in Kent County and three were in Sussex County. The release sites were selected on the basis of high corn borer populations in locations that appeared to be ecologically favorable for the release of adults of L. stabulans grisescens.

The degree of infestation of corn plants by borers in the fields chosen was determined by observing borer damage in 25 plants in the center of each field. Second and third instar borer larvae predominated. Infestation of the plants in the fields selected ranged from 35 - 90 percent with an average of 55.4 percent. The figures are given in Table I. under Host Abundance.

All release areas were spaced at distances which minimized the possibility of any immediate overlapping of parasite populations.

All release areas were adjacent to streams or marshy areas, where shade trees were common, in order to have shade and moisture available for the flies.

Shipping and Releasing

Adult parasites were supplied by the United States Department of Agriculture European Corn Borer Research Laboratory in Ankeny, Iowa. The flies were shipped special delivery air mail from Iowa to Delaware in June, 1959. They were packed in cardboard pint containers with excelsior. The containers were screened at one end to provide ventilation and the sides were wrapped with moist paper towels to cool the flies and furnish moisture during transit. The containers, each with 500 flies, were packed in cardboard boxes. All shipments arrived within 24 hours.

Upon arrival the boxes were opened, and the pint containers were removed and wrapped with moist cloth to maintain moisture and coolness during transportation to the field. They were taken directly to the release fields and the flies were liberated.

Before a container was opened at a release field, a section of cheesecloth (approximately two feet square) was moistened and draped over cornstalks or shrubs to furnish an immediate source of moisture for the flies when they

emerged from the pint containers. When the containers were opened, the flies promptly emerged, either dispersing immediately or going to the moistened cloths. Several flies were observed mating when the containers were opened. After the flies were released from the containers, the excelsior was removed and mortality data was recorded, Table I. Mortality was negligible, ranging from 1.2 percent - 3.8 percent for each container.

Temperature and time of release are recorded for each field in Table I. Shipments arriving in the morning were in the field by the early afternoon, while those arriving in early afternoon were in the field by late afternoon or early evening.

A total of 2,933 adults of L. stabulans grisescens were released in the six fields, averaging approximately 489 flies per release field. Table I shows the number released at each location.

Sampling Technique

In the Fall of 1959 and Winter of 1960 corn borer larvae were collected and sent to the United States Department of Agriculture in Ankeny, Iowa. They were held there for parasite emergence data in the spring in order to determine initial establishment and dispersal of L. stabulans grisescens.

For sampling after initial parasite releases a modification of the strip method, mentioned by Baker, et al. (1949) was utilized. As shown in Figure 4, the release fields were surrounded on the map with concentric circles with radii of one-half, one, two and four miles. Compass lines were drawn through the circles in the directions of North, South, East, and West from the release field. Whenever the lines intersected the circles, a field was sought from which samples could be taken. These together with the release field gave a total of 17 possible fields for each sampling area. Since there were six areas, 102 fields should have been examined. However, in some instances there was no plant material remaining in the field to be sampled, or else there were no corn fields near an intersection of a circle and compass line on the map. The result was that 88 fields were sampled, but from these 4,249 borer larvae were collected. The number of borers collected in each field is shown in Table II.

Each sample was designated with the sampling area number, compass direction, and distance from the release field. For example, II N1 would indicate one mile north of the release field in Area Two.

To facilitate collecting borers for the samples, a metal cylinder 2 inches in diameter and 3 inches high with a funnel-like top stoppered with a rubber plug was used. The

bottom of the cylinder was crimped in such a manner that it would hold a removable salve tin of 1.9 inches in diameter and 1.1 inches in height. A corrugated cardboard strip 1 inch wide and 12 inches long was rolled in the tin.

Plant material was selected at random throughout the fields being sampled on the basis of borer damage and visible borer tunnel openings. This consisted of standing corn, broken stalks, stubble, and debris. The material was slit open with a knife and the borer larvae were removed and dropped into the cylinder. After deposition in the cylinder, the larvae crawled into corrugations of the cardboard in the salve tins.

In planning the sampling, it was decided that 50 borers in the fifth instar would constitute a sample, whenever this number could be collected within a two-hour time limit. After a sample was completed, the salve tin was removed from the cylinder, covered with a top, and labeled with the collection location. The samples were shipped to the United States Department of Agriculture in Iowa in mailing tubes, four tins per tube.

RESULTS

Data

In the Fall of 1958 there were two borers collected from each of the 30 different localities which comprised

the areas sampled in the Fall corn borer abundance survey. From these no L. stabulans grisescens emerged. Four borer larvae died, and two pupae failed to transform to adults. Fifty-four adult moths emerged from the collections. Macrocentrus gifuensis issued from the two dead larvae. The results of the preliminary study in the Fall of 1959 are shown in Table III. No L. stabulans grisescens were recovered from the Spring collections, M. gifuensis was recovered from four larvae.

Parasite recovery data from borers collected in the Fall and Winter of 1959 - 1960 are shown in Table IV. M. gifuensis was recovered from three fields with percent parasitism of 15.9, 5.1 and 2.3. Two of these fields were in Area II, (Middletown) and one was in Area IV (Masten Corner). Agathis agilis (Cress.), a native parasite, was recovered from one field in Area V (Harbeson). L. stabulans grisescens was found parasitizing borers in five of the six sampling sites, but in only two of the original release sites. The directions and distances of dispersal are shown in Figures 5 and 6.

Discussion

Preliminary studies in the Fall of 1958 and Spring of 1959 indicated that the only parasite of the corn borer in corn at the time samples were collected was M. gifuensis and

that this species was present in small numbers. Combined parasitism for the Fall and Spring collections was only 2.17 percent. These studies also strongly indicated that L. stabulans grisescens was no longer present in the State.

While this conclusion may appear to be based on a small sampling of the corn borer population, personal opinion of entomologists at the Delaware Agricultural Experiment Station indicated that L. stabulans grisescens had not been present for several years.

From the data obtained it is apparent that L. stabulans grisescens is again the dominant insect parasite from Fall and Winter collections of the borer in corn. The average parasitism for the 88 fields sampled was 0.6 percent. However, L. stabulans grisescens was found parasitizing borers in 18.2 percent of the 88 fields sampled for a total of 16 fields. Parasitism in these 16 fields (Table V) ranged from 2.1 percent to 7.7 percent with a mean of 3.45 percent. In six of these fields parasitism was 4 percent or higher. The highest degree of parasitism in any single sampling area was found around Area II (Middletown), where percentages of 5.4, 7.1 and 4.3 were recorded.

As the data indicates, the parasite showed rather strong outward dispersal from the original release sites. Recoveries were made in all four compass directions; North - five, East - four, West - three, South - two, and at the Center - two.

The range of distance dispersed was found to be from zero to two miles, with two recovery fields at center, eight at one mile, five at one-half mile, and one at two miles. As can be seen in Table V more adult parasites were recovered at the one mile point than at any other sampling point. However, if the percentage of recovery fields in relation to the number of fields sampled at each distance is calculated, a different picture is presented. These values are given in Table V.

While numerically there were more recoveries at one mile (Table V), the percent recovery relative to the number of fields sampled indicates that proportionally more recoveries were made at the center and one-half mile distances than at the one mile distance and beyond. The relative percent parasitism decreased from one-half miles to four miles.

A similar trend was observed by MacCreary and Rice (1949) in their investigations in the years immediately following the releases of L. stabulans grisescens in the 1940's. There was a decrease in parasitism as distance increased beyond one mile from the release center.

When the parasites were released in June 1959 it is believed that the bulk of the borers present were second brood larvae. Thus the progeny of the released flies (the first brood of parasites) attacked mainly second brood hosts.

The subsequent brood of parasites would have attacked chiefly third brood larvae. These third brood borers were collected for the samples. However, the proportion of second brood parasites which they contained, cannot be determined because of the possibility that a few were diapausing first brood. Diapause of L. stabulans grisescens is dependent on host diapause and the proportion of second brood borers diapausing in Delaware is not known.

Baker, et al. (1949) indicated that L. stabulans grisescens dispersed at a maximum rate of about two miles per year in the Lake States, a two generation borer area. MacCreary and Rice (1949) found that in Delaware the parasite dispersed up to a maximum of between three to five miles from the release point within two years. This would indicate a maximum dispersal rate of about two and one-half miles per year in the State at the time when the two generation borer strain was prevalent.

Since the flies emerging from the collections were in all probility chiefly the second brood parasites, it would not be expected that any recoveries should have been made beyond approximately two and one-half miles. This proved to be true. Had any recoveries been made at the four mile distance, it would not have been correct to surmise that the parasites released in June, 1959 had dispersed

four miles in two generations. This means that any parasite which would have been recovered at the four mile point probably would not have been directly related to the flies released in June, 1959. Rather they would have been the progeny of flies which had been established in Delaware since the 1940's. That none were found tends to confirm the belief that parasite was not present for some time prior to the June, 1959 releases.

The degree of parasitism of the European corn borer by L. stabulans grisescens found in this study agrees with parasitism data recorded by MacCreary and Rice in the release areas in Delaware in the 1940's. At Kirkwood, where a release was made in 1943, a sample was taken the same year. Parasitism was found to be 2.7 percent for the initial release year. Collections made in 1945 at release areas in Hockessin, Dover, Townsend and Fredrica one year after the initial releases of L. stabulans grisescens showed the percent parasitism to be 4.0, 2.4, 26.5, and 4.0 respectively. With the exception of Townsend, these figures compare favorably with the present study.

The results obtained also correspond well with investigations from other areas on parasitism by this fly in the initial release year and the year following release. For example, Rolston, et al. (1958) recorded parasitism by L. stabulans grisescens during the initial year of release from

several Ohio locations. Of ten counties sampled during the initial release year, only four counties showed positive data for the release year. In seven of these counties larger numbers of the parasite were released than in Delaware. Numbers comparable to Delaware releases were recorded from three counties. For one of these three counties parasitism averaged 0.5 percent during the initial release year. In the other two counties no recoveries of L. stabulans grisescens were made from release year collections.

However, after five years parasitism reached 25.7 percent in one of these counties. In the other two, percent parasitism reached 16.5 and 25.3 within six years.

The recovery of only one specimen of A. agilis, an indigenous borer parasite, should be considered inconsequential. This recovery, when added to the previous recoveries of A. agilis in Delaware in the 1940's, makes a total of only seven specimens of this parasite recovered in the State.

The fact that Cremastus minor Cush. (Ichneumonidae) and Pyraustomyia penitalis (Coq.) (Tachinidae), both native corn borer parasites previously recovered in the state in small numbers, were not recovered further indicates the ineffectiveness of indigenous borer parasites.

In considering M. gifuensis, its parasitism of 15.9 percent in one field cannot be ignored. However, its presence in only three of the 88 fields sampled corroborates previous data regarding its low abundance in borers in corn. The low abundance of M. gifuensis in the samples may have been due to various factors. The borers collected were taken only from corn. D. W. Jones of the United States Department of Agriculture stated that M. gifuensis prefers to attack borers feeding on potatoes. Thompson and Parker (1928) observed that the parasite commonly attacked borers only in Artemisia (common mugwort) in some areas of Europe. Since the corn borer has a wide host range which includes potatoes and weeds in Delaware, it is possible that this braconid is more abundant in the State than the surveys from corn would indicate. Another factor to be considered is the time of the year when the samples were taken. From the work of Cartwright (1933) and Clark (1934) in Asia, it appears that M. gifuensis is most effective in July in the Orient. This could also hold true in the United States. Since borer collections in Delaware were made in fall, winter, and early spring, it is possible that the true degree of parasitism of M. gifuensis was not measured.

On the other hand, it would appear that the times of the year in which the borer collections were made favored the recovery of L. stabulans grisescens. Laird (1949), in

his study of hyperparasitism in Delaware, found that flies of the second generation were more prevalent than flies of the first generation.

Thus, it may be that M. gifuensis is more effective in parasitism of spring and early summer borers while L. stabulans grisescens is the dominant parasite of late summer borers.

CONCLUSIONS

In conclusion, it would appear from the results of this study that L. stabulans grisescens is initially re-established in Delaware and may become a potentially important factor in contributing to the regulation of the corn borer population in future years.

Furthermore the results of this investigation suggest that this parasite warrants additional study to ascertain its dispersal and degree of parasitism in Delaware in future years. When the average annual statewide parasitism by L. stabulans grisescens of 21.4 percent for 1947 - 1951 is recalled, it is clear that it is of more than academic interest to follow its progress in the future.

Had parasitism by L. stabulans grisescens been measured annually subsequent to 1950 it would seem that a definite indication of the parasite's gradual decline would have been found rather than a sudden disappearance. At the start of

its decline, or shortly thereafter, the release of more L. stabulans grisescens might have returned the population to its maximum level, or even higher.

By following the progress of the parasite during its dispersal in the immediate years it can be determined which areas are not suitable for it. Correlations of the ecological characteristics of these unpopulated areas may yield information regarding the requirements of L. stabulans grisescens. Then, should future releases be made, parasites would not be wasted in such locations.

Once a high average annual statewide parasitism is reached, surveys should continue. There may be a definite trend toward cyclic decreases of the parasite periodically, which could lead to its disappearance. Should such a trend be found, additional releases could probably prevent extermination.

In considering the value of the data that would be collected by annual corn borer parasite surveys in Delaware these surveys would seem to be fully justified.

ACKNOWLEDGEMENTS

The author would like to express his appreciation to those who have assisted in this research.

I am indebted to Mr. H. P. Cannon, Bridgeville, Delaware, who made this work possible by supporting the assistantship under which the work was conducted.

Thanks is due Dr. D. F. Bray, Chairman of the Department of Entomology at the University of Delaware and all other members of the Department for helpful advice concerning this research.

I am particularly grateful to Dr. Paul P. Burbutis, my thesis advisor, under whose guidance and encouragement this work was initiated and carried out.

The help of Dr. G. T. York, Grain and Forage Insects Research Branch of the United States Department of Agriculture, for furnishing adult Lydella stabulans grisescens, recording parasite emergence data, and contributing advice regarding this work is gratefully acknowledged.

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Table I. Releases of L. stabulans grisescens, June, 1959, Delaware.

Location	Host(1) Abundance	Date	Release Time	Temp.	No. Shipped	No. Dead	Re-leased	Mortality
I (Bridgeville)	60 - 70%	6/16	12:30 P.M.	80°F	500	11	489	2.2
II (Middletown)	80 - 90%	6/12	4:15 P.M.	81°F	500	9	491	1.8
III (Dover)	40 - 50%	6/12	5:15 P.M.	81°F	500	19	481	3.8
IV (Masten) (Corner)	60%	6/12	7:00 P.M.	81°F	500	6	494	1.2
V (Harbeson)	35 - 40%	6/12	8:15 P.M.	75°F	500	16	484	3.2
VI (East) (Laurel)	40%	6/16	2:30 P.M.	80°F	500	6	494	1.2

(1) Percentage of plants infested with European corn borer larvae.

Table II. Number of Borers Collected at each Sampling Site, Fall of 1959 and Winter of 1960, Delaware.

Location	Center	North				South				East				West			
		1/2	1	2	4	1/2	1	2	4	1/2	1	2	4	1/2	1	2	4
I (Bridgeville)	50		50	50	50		50	50	51		40	50	51		50	50	50
II (Middletown)	50	50	50	50	50	50	50	50	50	50	50	50	50		50	50	50
III (Dover)	50		50	50	50		50	50	50	50	50	50	50		50	50	50
IV (Mastens) (Corner)	50		50	50	50		50	50	50	50	50	50	50	50	50	50	49
V(Harbeson)	45		50	50	44		45	50	50	51	50	50	50	40	40	40	50
VI (E. Laurel)	13		50	50	50	50	50	50	50		50	19	21	50	50	50	50

Table III. Parasite Recoveries from Borers Collected in Fall of 1959, Delaware.

Location (County)	No. Borers Collected	No. Borers With Parasites	Percent Parasitism
Kent	33	0	0.0
New Castle	48	4	8.3
Sussex	103	0	0.0

Table IV. Parasite Recoveries from Borers Collected in Fall of 1959 and Winter of 1960, Delaware.

Locality		No. Borers Observed	L. stabulans No.	L. stabulans %	M. gifuenses No.	M. gifuenses %	A. agilis No.	A. agilis %
I	N1	41	1	2.4				
	N2	46	1	2.2				
II	C	39			2	5.1		
	N 1/2	37	2	5.4				
	N 4	44			7	15.9		
	E 1/2	42	3	7.1				
	W 1	44	2	4.3				
III	S 1	42	1	2.4				
	E 1/2	40	2	5.0				
	E 1	48	1	2.1				
IV	C	40	1	2.5				
	N 1	50	2	4.0				
	S 4	43			1	2.3		
	E 1/2	47	1	2.1				
	W 1/2	47	1	2.1				
V	S 4	44					1	2.3
VI	C	13	1	7.7				
	N 1	44	1	2.3				
	S 1	41	1	2.4				
	W 1	46	1	2.2				

Table V. Percentage of L. stabulans grisescens Recovery Fields in Relation to the Number of Fields Sampled in Fall of 1959 and Winter of 1960, Delaware.

Location	No. Fields Sampled	No. Recoveries	Percent Recovery
Center	6	2	33
1/2 Mile	10	5	50
1 Mile	24	8	30
2 Miles	24	1	4
4 Miles	24	0	0

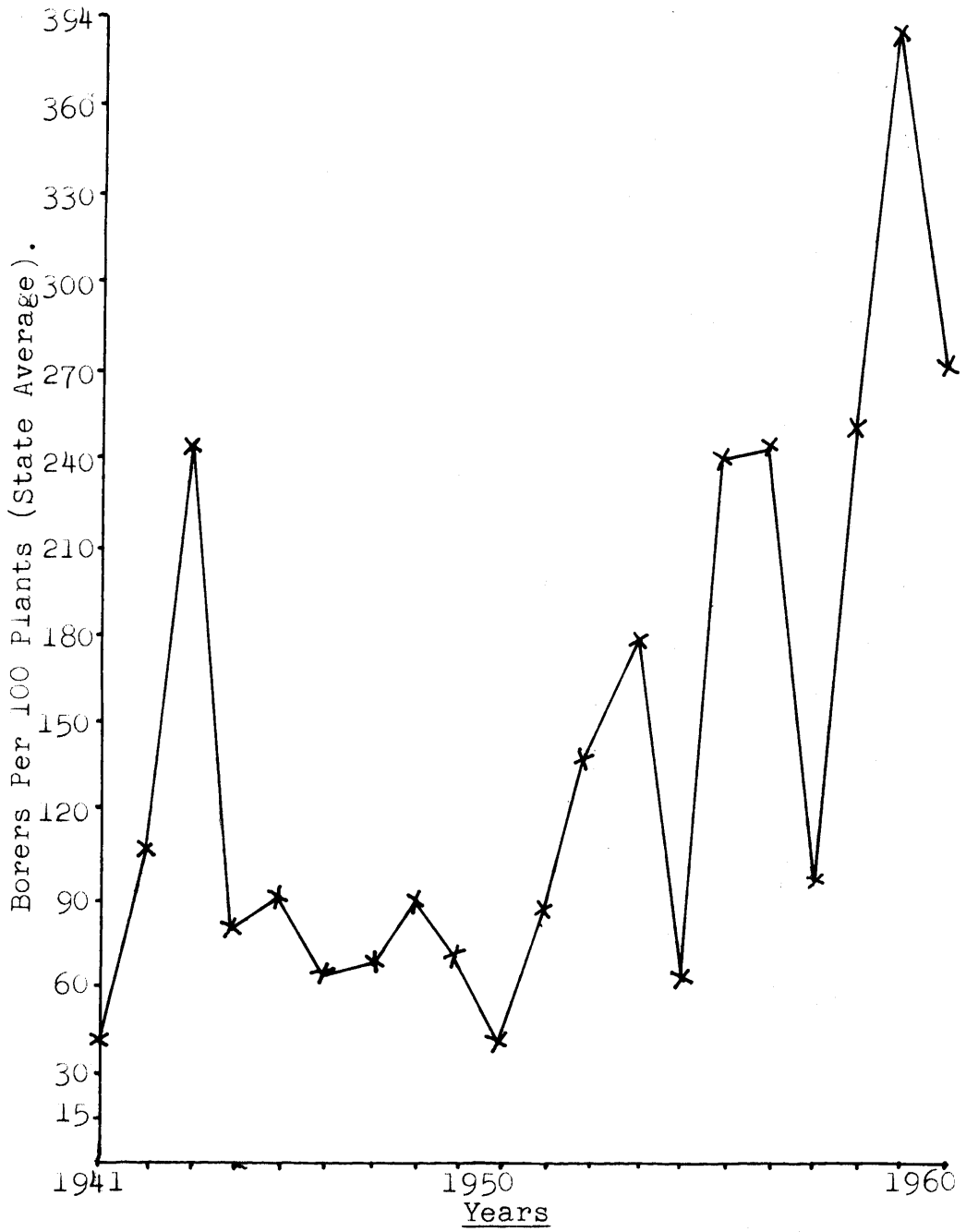

Figure 1. European Corn Borer Fall Abundance Surveys for Years 1941 - 1960 Showing Population Fluctuations

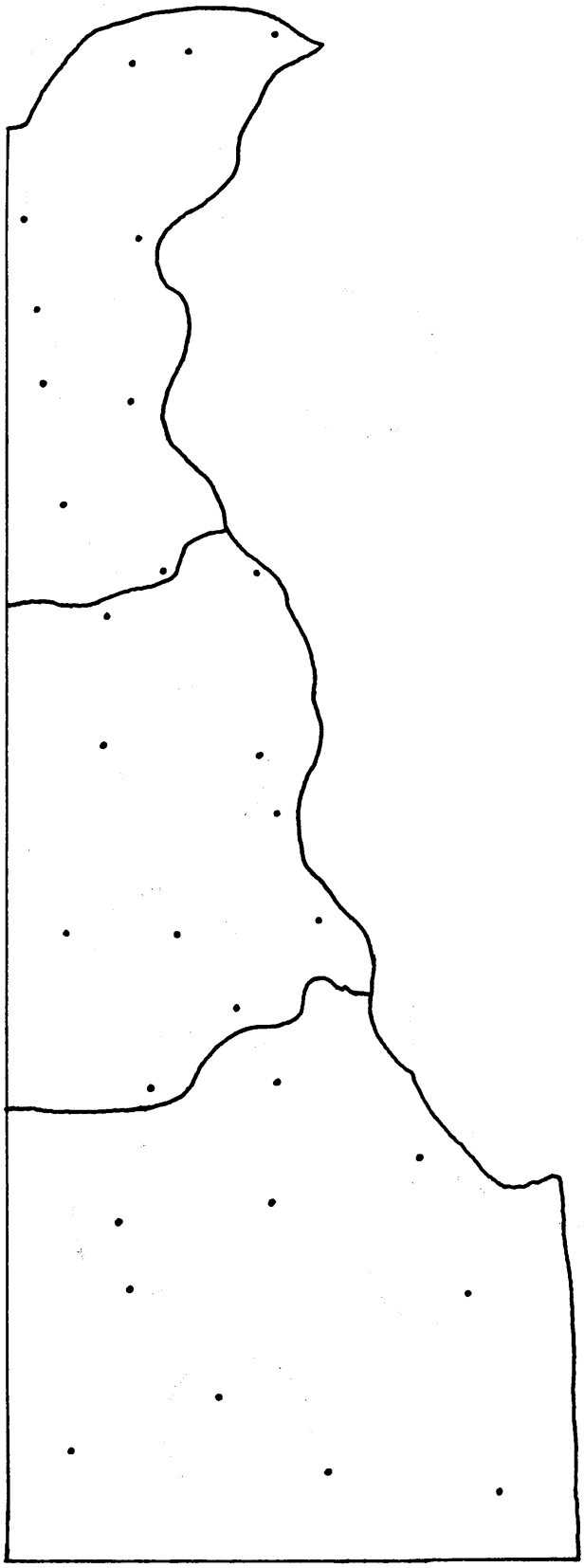

Figure 2. Outline Map of the State of Delaware, Points Indicating Locations of the Fields for the 1958 European Corn Borer Fall Abundance Survey.

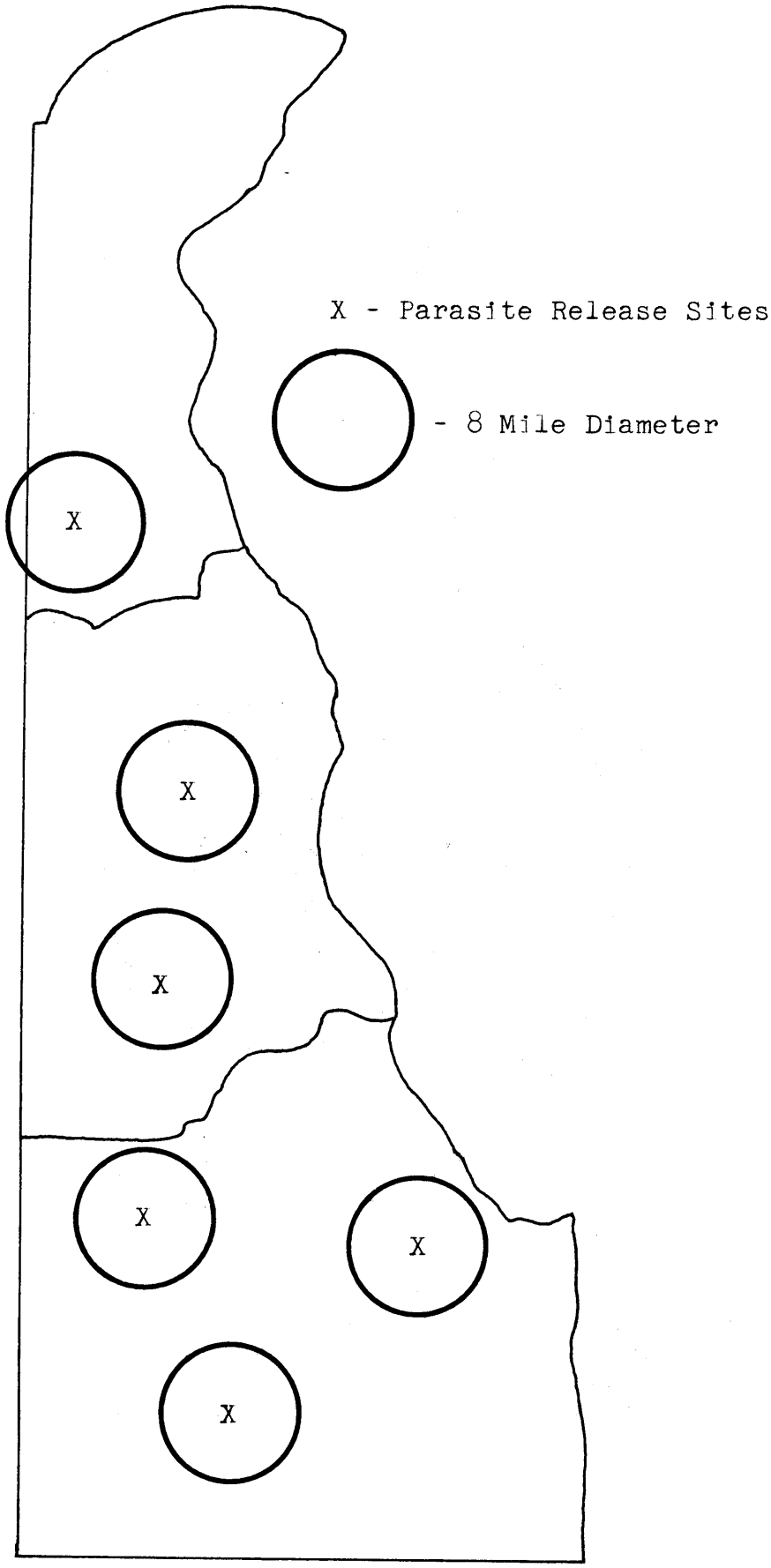

Figure 3. Outline Map of the State of Delaware Showing Parasite Release Sites (X) and Sampling Areas (Circled)

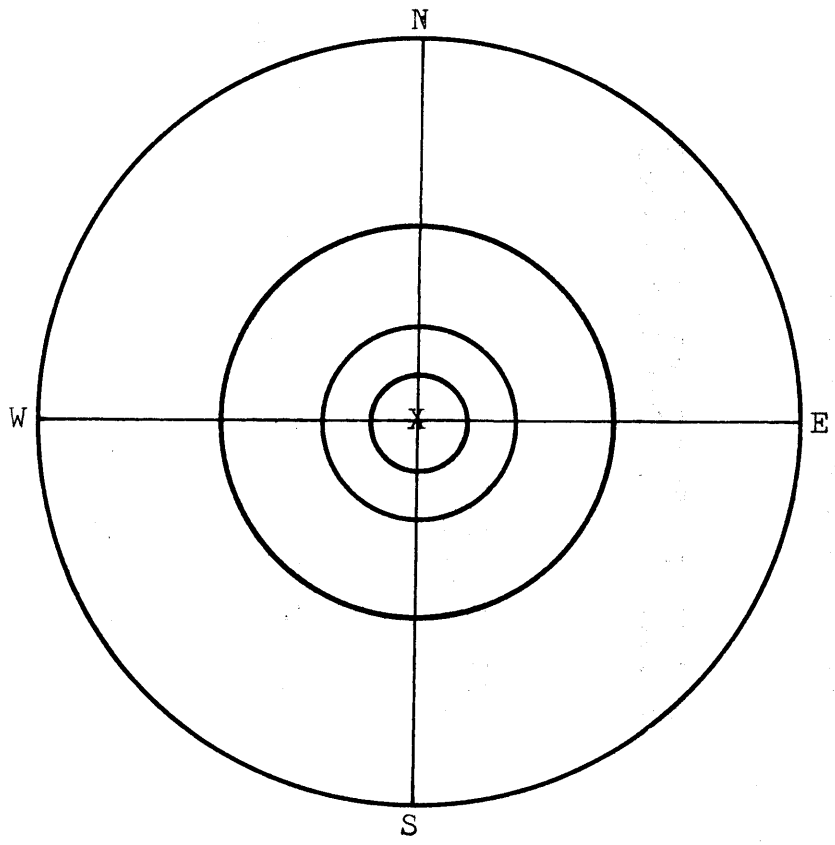

Figure 4. Diagram of Typical Release Site (X) and Sampling Area Showing One-half, One, Two, and Four Mile Radii from Original Release Site. Fields were Sampled Whenever Compass Lines Crossed Circles.

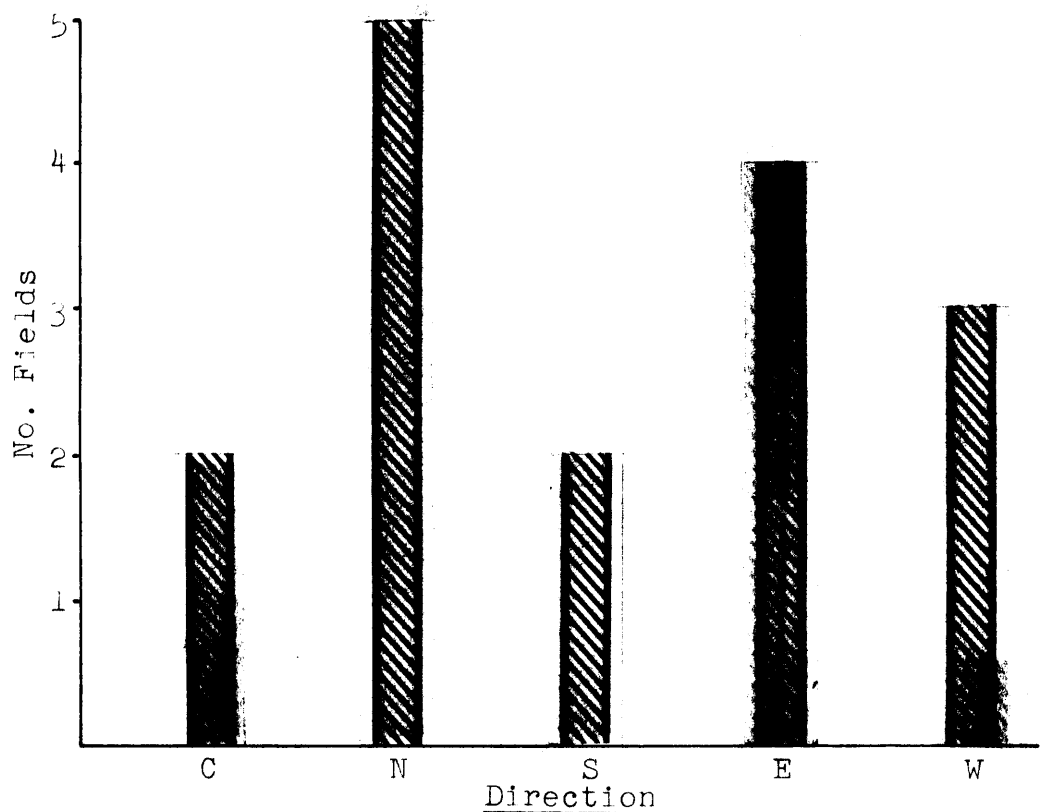

Figure 5. Direction of Dispersal of Parasites and the Number of Recovery Fields in each Compass Direction from Original Release Sites.

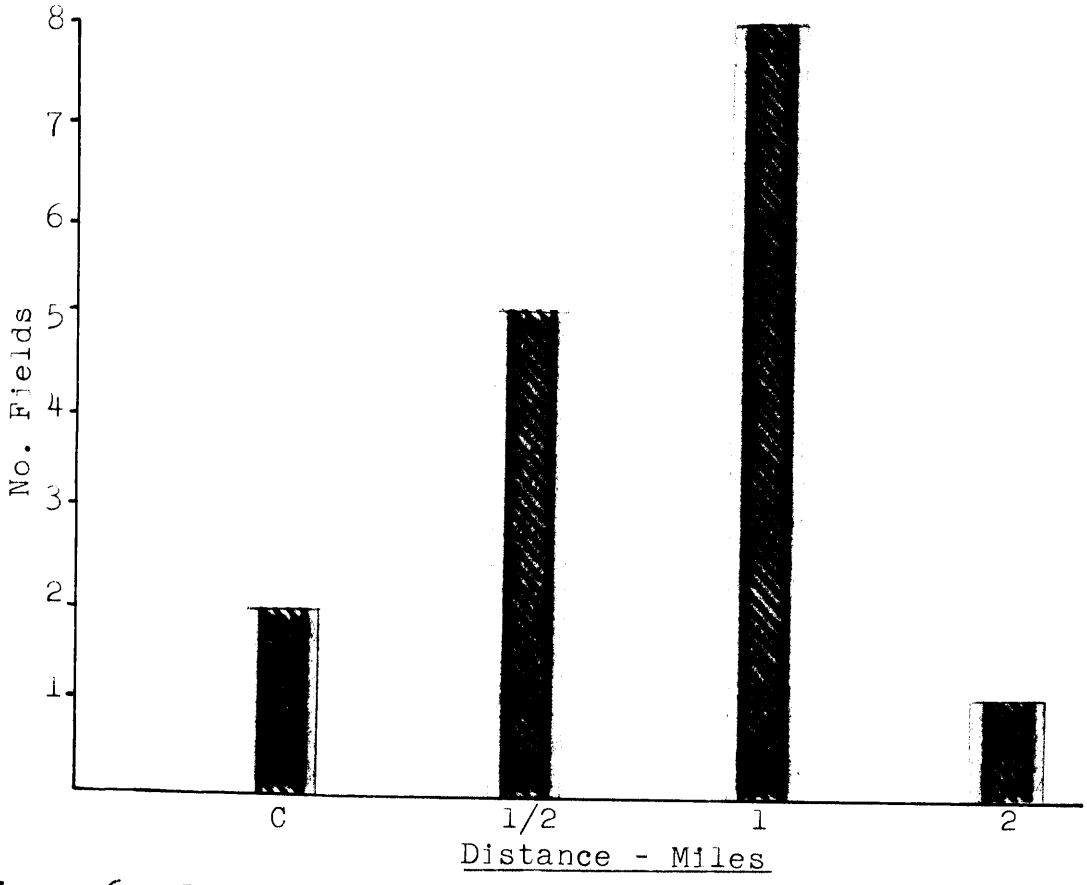

Figure 6. Distance of Dispersal of Parasites and the Number of Recovery Fields at each Distance from Original Release Sites.