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# ECOLOGICAL EFFECTS ON F<sub>1</sub> PROGENIES FROM RECIPROCAL MATINGS OF THREE BIOTYPES OF THE EUROPEAN CORN BORER,

OSTRINIA NUBILALIS (HÜBNER)

by

William Broze Showers

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of DOCTOR OF PHILOSOPHY

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### INTRODUCTION

The European corn borer, Ostrinia nubilalis (Hübner), was reported by Babcock (1927) to be univoltine in New York, while under similar environmental conditions, in Massachusetts, it was bivoltine. Holdaway, Cutkomp, and Buzicky (1949) reported the univoltine strain had reached Minnesota by 1943 and the bivoltine strain was reported by Harris and Brindley (1942) to be in Iowa by 1941. In a comprehensive review, Brindley and Dicke (1963) stated that by the early 1960's bivoltinism was dominant through the central Corn Belt.

The F<sub>1</sub> generations of European corn borer whose parental stocks were collected in Minnesota, Iowa, and Missouri were studied in the field under caged conditions for two years at three divergent locations by Sparks et al. (1966b). Ten biological or behaviorial parameters were observed for each population. They concluded that at least two biotypes exist in the Midwest, a northern and a southern, represented by Minnesota and Missouri, respectively. Sparks, Brindley, and Penny (1966a) conducted reciprocal matings of three Midwest populations of European corn borer. Progenies of matings in which at least one parent was of Minnesota origin exhibited a definite influence in incidence of diapause on populations from Iowa and Missouri under laboratory and caged field conditions. Sparks et al. (1966a, b) concluded that diapause in the European corn borer is governed by a

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multi-genetic makeup which responds to photoperiod and temperature. Sparks et al. (1966b) hypothesized that a northern population may produce genes favoring a singlegeneration which are maintained through selection by the environment. The single-generation factor in a southern population would be diluted each year because the individuals that diapause during the first generation are exposed to various hazards during the long, warm season. Chiang, Keaster, and Reed (1968) used experimental procedures similar to Sparks et al. (1966b) and developed additional conclusions that the southern biotype (Missouri) is more sensitive to photoperiod and temperature changes than the northern biotypes (Minnesota).

A survey of the literature determined that many of the conclusions on the effect of photoperiod and temperature on the enhancement or reduction of the incidence of diapause or pupation of the European corn borer have come from research conducted in the laboratory in which photoperiod and temperature do not simulate what the insect would be subjected to in the field. The excellent work that has been conducted in the field (Beck and Apple 1961; Sparks et al. 1966a, b; Chiang et al. 1968) involved borer populations within the same broad geographical area and not from distant points within the species distribution.

What would be the effect on the biology and behavior of

 $F_1$  populations of reciprocal matings of northern fringe, east coast, and southern fringe populations under the influence of simulated photoperiod and temperatures of a June 21 day typical for the latitudes at which the parent populations were collected? If biological and behavioral differences were distinguished in the laboratory, could they be duplicated in the field? The present research was conducted in an attempt to answer these two questions.

### REVIEW OF LITERATURE

The European corn borer, <u>Ostrinia nubilalis</u> (Hübner), was identified as an introduced pest in the United States by Vinal (1917). During the ensuing years extensive studies were conducted on this insect. The significant research on the European corn borer has been reviewed by Brindley and Dicke (1963). The literature discussed in this paper will be limited primarily to ecological studies of the European corn borer with emphasis on geographic strains and a factor which produces such strains, diapause.

#### Voltinism and Strains of Insects

The annual cycle of animals has to be adjusted to their seasonal environment in order to assure survival of the species. Many species are warned of the approach of adverse seasonal conditions through environmental factors which act as token stimuli. The main stimuli according to Ankersmit (1964) come from photoperiod, temperature, food source, and other animals. Stimuli operate on a developmental stage characteristic for the species. This may be, in the case of insects, the egg, larva, pupa, or adult. The responsive stage is not necessarily the same as the sensitive stage (Ankersmit, 1964). The response produced may be migration, seasonal polymorphism, or diapause. Lees (1955) states that diapause prevents the species from being active when

the environmental conditions are unfavorable and also synchronizes post-diapause emergence. Danilevsky (1961) stated that the adjustment of the annual cycle of an insect to its environment involves the synchronization of this cycle with the geographic region in which the insect occurs. Therefore, the degree of adjustment would determine the frequency of generations or voltinism of an insect species in a particular geographical area. Voltinism may be divided into two general categories which are defined by Webster's New International Dictionary (1959) as monovoltine or univoltine in which one brood is produced in a season and polyvoltine or multivoltine, in which several broods are produced in a season. However, in some cases the time interval needed for the completion of one cycle becomes more than one season. The Lasiocampid, Dendrolimus pini L. is bivoltine near the Adriatic coast, univoltine in central and western Europe and according to Ermalajew and Wassiljev (Danilevsky, 1961), semivoltine for one generation every two years in northern Russia.

Seasonal cycles of day length are different at different latitudes. In areas of high latitude, day length changes are relatively extreme, late spring and summer day lengths are very long. Temperatures during the growing season are relatively low, and the growing season comparatively short. In contrast, areas of lower latitudes have relatively

shorter days during the relatively longer and warmer growing These seasonal differences between areas of different season. latitudes indicate that insect populations of high latitudes must adapt to different conditions than those which confront insect populations of low latitudes. Therefore, it is quite logical that northern populations of a widely distributed insect species might differ from southern populations in several characteristics because of necessary adaptation to day length and temperature. Beck (1968) lists six orders with 20 families which includes 31 species of insects and the order Acarina with one family with three species of mites in which geographical population differences within species have been demonstrated. The European corn borer, Ostrinia nubilalis (Hübner) is one species which shows these demonstrable differences.

Beck (1968) notes that most of the work done on geographical populations has been done on old, well established populations that were in reasonably stable equilibria with their environments. He believes that the European corn borer is an exception as it represents a 20th century introduction into North America, therefore, most borer populations are still in the process of becoming adapted to local seasonal conditions.

Sparks et al. (1966a) reviewed the results of experiments dating back to the 1920's which examined the presence

of geographic races of the European corn borer in North America. Only the more pertinent studies will be discussed here.

The European corn borer in New York was reported by Babcock (1927) to be univoltine, while under similar climatic conditions, in Massachusetts it was bivoltine. These two populations continued to display this characteristic difference while reared under caged conditions in both New York and Massachusetts by Caffrey and Worthley (1927). O'Kane and Lowry (1927) reported that the borer in New Hampshire showed mixed voltinism. However, in the eastern portion of the Midwest, the borer was univoltine (Caffrey and Worthley, 1927). By the mid-1920's and early 1930's the univoltine strain had spread to Indiana (Ficht, 1936) and Wisconsin (Chambers, 1941). Holdaway et al. (1949) reported the univoltine strain had reached Minnesota by 1943. The bivoltine strain was reported by Caffrey and Worthley (1927) to be in Illinois in 1926, in Iowa by 1941 (Harris and Brindley, 1942), and in Missouri by 1942 (Vance, 1942).

The borer in the Great Lakes Region was thought by the early workers (Felt, 1919) to be univoltine; however, a partial second generation was reported in Ontario by Spencer and Crawford (1923), along the southern shore of Lake Erie and western New York by Caffrey and Worthley (1927), and in southeastern Michigan by Bottger and Kent (1931). Multi-

voltinism was reported by Vance (1947) to have increased throughout the Midwest by the mid-1940's and Brindley and Dicke (1963) stated that by the early 1960's bivoltinism was predominant through the central Corn Belt. The first reported incidence of 3-generations a year occurred in Virginia (Jones, Walker, and Anderson, 1939) and more recently in Alabama (Eden, 1956), and Missouri (Peters, Burditt, and Fairchild, 1961). DuRant (1969) reported four generations of European corn borer a year in South Carolina. Results of reciprocal experiments under caged conditions at Medford, Massachusetts and Silver Creek, New York, conducted by Caffrey and Worthley (1927) indicated geographic races of the European corn borer might exist. Barber (1928) attempted reciprocal crosses of the single generation (New York) and 2-generation (Massachusetts) strains. He found that under similar conditions the pupation and emergence of the New York strain was delayed so that it was difficult to secure matings between the two populations. However, when matings occurred the resulting progeny were fertile. This indicated the populations were strains of a single species and not two separate species.

Arbuthnot (1944) utilized laboratory-reared larvae whose parental stock was collected in Connecticut (homogenecus multiple-generation strain) and Ohio (heterogeneous complex of multi- and univoltine strains) in an attempt to

isolate the genetic characteristics which would produce population strains of the corn borer. He concluded that the single generation disposition was a recessive character to the multiple generation attribute. Later, Arbuthnot (1949) attempted to predict the geographical location in the United States in which one, two, three, or more generations per year of the European corn borer would occur. He based the predictions on the effect of historical weather data on the borer in Europe and Asia. He discussed relationship with observed numbers of generations in the United States with the temperatures and precipitation of each zone.

Apple (1952) developed a system of heat accumulation, called borer degree days, in which he showed that the maximum and minimum temperature for each day above 50° F contributed to borer development. Chiang and Hodson (1959) used the temperature accumulation method of Apple (1952) and demonstrated a second generation in southern Minnesota was dependent, to some extent, on early summer temperatures. They also suggested that photoperiod might be involved.

Mutchmor (1959) found that voltinism in an Ontario borer population could be predicted based on the earliness of spring moth flight, which correlated with spring temperatures, and the development of larvae prior to day lengths of 14.5 hours which induced diapause. He concluded the change from a 1- to a 2-generation habit in Ontario resulted from

climatic changes rather than from a reversal of dominance of voltine strain. Beck and Apple (1961) investigated the effects of temperature and photoperiod on European corn borer populations from several geographical locations within the species distribution in the United States and Canada. The results of their laboratory experiments indicate significant differences in larval development and diapause incidence among populations. They demonstrated that photoperiod and temperature were instrumental in inducing diapause in all the borer populations studied. They suggested that temperature was a primary factor in diapause induction of the F<sub>1</sub> generation of borers in which the parental stock came from Massachusetts whereas photoperiod appeared to be the primary factor for the  $F_1$  progeny of all other geographical populations compared. They concluded that the adaptation of borer populations to different local environmental conditions resulted in the selection of divergent genetic compositions, thereby, producing geographical borer types.

The  $F_1$  generations of European corn borer whose parental stocks were collected in Minnesota, Iowa, and Missouri were studied in the field under caged conditions by Sparks et al. (1966b). Ten biological or behavioral parameters were observed for each population for two years at each of three locations; southern Minnesota, central Iowa, and southeastern Missouri. They found larger numbers

of emerged moths and larger numbers of diapausing larvae were produced by Missouri and Minnesota borer populations, respectively, at all experimental locations. The Iowa population, with regard to these parameters, was intermediate at all experimental locations. The authors concluded that at least two biotypes of the borer exist in the Midwest--a northern one, represented by Minnesota, and a southern one, represented by the Missouri population.

Sparks et al. (1966b) reported the survival of all biotypes the same at all locations. However, Chiang et al. (1968) determined that the biotype (Missouri) adapted to warmer conditions, did not survive as well in the north, and therefore, is more sensitive to temperature changes than the biotype (Minnesota) which is adapted to cooler conditions. Additionally, they found that the Missouri biotype had a higher rate of pupation when grown in the north and the Minnesota biotype had a higher rate of diapause when grown in the south. However, the increased pupation of the Missouri biotype was greater than the enhanced diapause of the Minnesota biotype. Chiang et al. (1968) concluded that the biotype adapted to short days (Missouri) is more sensitive to changes in photoperiod than is the biotype (Minnesota) adapted to long days.

Sparks et al. (1966a) conducted studies in which progeny of reciprocal matings of three Midwest biotypes of the

European corn borer were used. Progenies of matings in which at least one parent was of Minnesota origin exhibited a definite influence in incidence of diapause on populations from Iowa and Missouri under laboratory and caged field conditions. Sparks et al. (1966a, b) concluded that diapause in the European corn borer is governed by a multi-genetic makeup which responds to photoperiod and temperature. Sparks et al. (1966b) hypothesized that a gene pool represented by the Minnesota population may produce a high "titer" of genes favoring single-generation borers which is maintained through selection by the environment. The single-generation factor in a southern population (Missouri) would be diluted each year because the borers that diapause during the first generation are exposed to various hazards during the long, warm season.

Diapause, the Factor which Synchronizes Insect

Life Cycles with the Environment

Beck (1968) defines diapause as a genetically determined state of suppressed development, which may be induced by environmental factors. Diapause is an important adaptive mechanism for insect survival during periods of unfavorable environmental conditions; winter temperatures, summer heat, dryness, and low food requisites. Heat and cold torpor differ from diapause in that the dormant state is usually

a direct response to the immediate environment whereas diapause, typically begins long before the onset of unfavorable conditions and may not terminate until long after such conditions disappear. Danilevsky (1961) believes these characteristics result from the fact that an important part in the regulation of diapause is played by internal cyclic processes that modify the influence of the external environment. Danilevsky (1961) goes on to say that dual regulations by factors that are largely independent of one another, physiological and ecological, are characteristic of all seasonal-cyclical adaptations and is of importance in the synchronization of life cycles with the dynamics of the environment.

Diapause is distinguished from hibernation by Williams (1946, 1947, 1952) and Williams and Adkisson (1964) in that it is enforced by physiological mechanisms whereas hibernation is not. Another distinguishing characteristic according to Andrewartha (1952) and Lees (1956) is that diapause often occurs long before unfavorable weather conditions are present. Ushatinskaya (Danilevsky, 1961), however concludes that the onset of hibernation in insects is preceded by a physiological preparation and is terminated by a recuperative period. Danilevsky (1961) believes that the existing data indicates hibernation in insect species is not the direct result of unfavorable conditions but, like

diapause, is possible only at a specific stage of the life cycle of the species. Beck (1968) considers both estivation and hibernation as forms of diapause. Diapause may occur at any stage of the life cycle, however, it will occur only at a specific growth stage or instar (Lees, 1955; Danilevsky, 1961; Beck, 1968).

The condition of diapause has been divided into obligatory, every individual of every generation undergoes a period of diapause as part of its life history, and facultative, a diapause that may or may not be displayed by a given individual or population. This type of diapause depends on the environmental conditions prevailing during certain critical stages of the insect's development. Most insect species including the European corn borer manifest the facultative type of diapause (Beck, 1968). Finally, there are some species with homodynamic development which have no diapause. These species normally occur in tropical or sub-tropical areas where the annual range of temperatures remain within the limits effective for insect development (Danilevsky, 1961). The stage of growth of an insect in which diapause occurs, or whether diapause is obligatory or facultative, depends not on the systematic relationships of a species but on the particular ecology of the population (Danilevsky, 1961). In closely related species of a single genus diapause occurs in entirely different stages and in

some geographical populations appears as obligatory and in others as facultative.

The various environmental factors which influence diapause induction in insects have been definitively reviewed by Lees (1955, 1956). Two of the more important factors are temperature and photoperiod. Duclaux in 1869 (Danilevsky, 1961) was the first to observe the effect of temperature on the diapause processes of the embryo of the silkworm, Bombyx mori. Kogure (1933) also worked with the silkworm and was the first to show that photoperiod experienced by the female carrying the embryo was a major factor in the induction of embryonic diapause. Sabrosky, Larson, and Nabours (1933) reported the effect of photoperiodism on prevention of diapause in the adult and nymph of the pigmy grasshopper, Acrydium arenosum. Other environmental factors which affect the diapause processes (induction and reactivation) are humidity and dietary factors (Bull and Adkisson, 1960, 1962) and parental physiology and ecology (Lukefahr, Noble, and Martin, 1964; Phillips and Newsom, 1966). The knowledge of the effect of photoperiod on insect diapause has been summarized in the excellent reviews on photoperiodism and insects by Danilevsky (1961), de Wilde (1962), and Beck (1968). Time and again these authors stress the importance of the annually reoccurring environmental stimuli and their influence on the biology and physiology

of insects. Danilevsky (1961) believes the photoperiodic control of diapause is probably the most important aspect of the seasonal development phenomenon. Beck (1968) refers to photoperiodism as the response of an organism to the daily and seasonal rhythm of light and dark (or photoperiod). The light portion of the photoperiod is referred to as photophase and the dark period as the scotophase (Beck, 1962). Changes in the daily photoperiod follow an annual cycle which informs the organism as to the time of year (Danilevsky, 1961). The number of hours of light (including twilight) and dark is dependent on date and latitude. Within these restrictions there is very little deviation of the rhythm from year to year (Danilevsky, 1961; de Wilde, 1962; Beck, 1968).

Laboratory studies on the effect of photoperiod has shown that with some insects decreasing photophases were more effective than increasing or constant photophases in inducing diapause (Corbet, 1956; Lukefahr et al., 1964). Dickson (1949) Danilevsky (1961), and Adkisson, Bell, and Wellso (1963) reported that insects respond to the actual duration of the photophase, or according to Beck (1962) the scotophase, rather than to changes in the photoperiodic phases.

Although this review primarily pertains to the ecological side of voltinism and diapause, there are several

papers which discuss the physiological aspects of diapause which should be cited. Williams (1946) was able to terminate pupal diapause in the giant silkworm, Plateysamia cecropia by implantation of a nondiapause or chilled diapause brain whereas a nonchilled diapause brain or other tissue failed. Williams (1947, 1952) hypothesized pupal diapause resulted because the brain failed to secrete the hormone produced by the neurosecretory cells. Without this hormone the prothoracic glands fail to secrete ecdysone for molting and development stopped. Williams and Adkisson (1964) found a series of mechanisms was necessary for photoperiodic signals to influence the secretion and release of brain hormone. They concluded that the action of photoperiod was exerted directly on the brain. Cloutier et al. (1962) and Beck, Cloutier, and McLeod (1963) suggested that diapause in the European corn borer resulted from the presence of a brain barrier which blocks the release of brain hormone. Beck and Alexander (1964a, b) reported the existence of a hormone, proctodone, which is produced in the larval ileum and supposedly activates the endocrine centers of the larval brain. Beck (1964) reported the secretion of proctodone occurred at 8 hr intervals beginning with darkness and a similar rhythm initiated by light and expressed by the change in diameter of the lateral neurosecretory cells indicated a secretion by the brain. The secretions of these

two endocrine systems are in phase when larvae are reared under a 16 hr photophase and out-of-phase when larvae are reared under a 12 hr photophase. Beck (1964, 1968) suggests the in-phase situation is conducive to continued development while the out-of-phase situation allows the induction of diapause.

#### MATERIALS AND METHODS

Laboratory Study of the Effects of Regimes Typical for the Parent Types on Progeny of Reciprocal Matings Overwintering European corn borers obtained during the winter of 1966-67 from Autauga County, Alabama, Princess Anne County, Maryland, and Ottertail County, Minnesota were maintained under 24 hr illumination at 27° C. Once diapause was broken and pupation occurred each group of insects was placed in each of three mating cages described by Guthrie et al. (1965). Insects in the cages were maintained under 16 hr light at 18.3 to  $27^{\circ}$  C and were thoroughly sprayed with water twice daily. Upon emergence, and after mating, the females deposited egg masses on waxed paper strips. The strips were tagged with culture name, and date, and replaced daily. The egg masses were handled in the manner described by Guthrie et al. (1965) and egg masses used in the study were heat treated at 43.3° C for 30 min as described by Raun (1961) in order to reduce the incidence of infection by the microsporidian Perezia pyraustae. Each of 900 newly hatched first instar larvae were transferred into a 3-dram shell vial containing a 1.86 cm plug of corn leaf factor medium (Lewis and Lynch, 1969) and stoppered with cotton.

The vials, each containing a single larva, were placed in trays each holding 170 vials, and the trays were placed in a chamber maintained at 24 hr light and  $27^{\circ}$  C. When

the insects pupated, they were isolated in a  $2 \times 4$  cm jelly cup containing a moist filter paper, and capped with a paper bottle cap. In order to produce all possible reciprocal matings with the three parent types, 100 pairs of adults of each type were combined in each of nine mating cages and maintained under conditions previously described. The waxed sheets containing the egg masses were hung in a chamber maintained at 24 hr light and 27° C; the masses were allowed to hatch after which time masses were counted and a random sample of five masses from each day's production for each of the nine cultures were examined to determine the number of eggs laid and the percent hatched. Egg masses to be used to produce larvae for the experiment were selected from masses deposited the fourth day after initiation of deposition. Three hundred and six larvae that hatched from each reciprocal mating were individually placed in a 3-dram shell vial containing a 1.86 cm plug of wheat germ medium (Lewis and Lynch, 1969). Larvae from each reciprocal mating were randomized over rows, 17 vials per row, in each of 18 trays and trays were randomized over each of three bioenvironmental chambers, six trays per chamber.

The three chambers were Percival CE-2 Bioenvironmental Chambers identical in all general respects, programmed for photoperiod with Paragon 5 minute interval key-type clocks

accurate to  $\pm$  1 minute (Figure 1a). Light was furnished by three sets of one 40-watt Grolux flanked by two 40-watt cool white fluorescent tubes arranged vertically along the two sides and middle of each chamber. According to Dr. Robert Shaw (personal communication)<sup>1</sup> foot candle meters indicate nothing about spectral distribution, and very little about total intensity of light sources. They indicate apparent light intensity as seen by a human observer, therefore, respond chiefly to light in the yellow-green part of a visible spectrum. To obtain some idea of the actual spectrum and intensity of the light source in the chambers, an ISCO Model SRR spectroradiometer was used to spot check these parameters during the experiment. Figure 2 presents the adjusted light quality and quantity to which the insects were subjected.

Temperatures were programmed with Partlow cam-operated thermostats (Figure 1a). The temperature regimes were set to simulate a typical June 21 day at each of the collection sites of the three parent populations, i.e., central Albama, eastern Maryland, and west central Minnesota. The thermoperiods were developed by plotting on recorder charts mean, maximum, and minimum temperatures occurring

<sup>&</sup>lt;sup>1</sup>Dr. Robert Shaw, Professor of Climatology, Department of Agronomy, Iowa State University of Science and Technology, Ames, Iowa. Quality and quantity of light, Winter 1967-68.

Figure 1a. Paragon time clock and Partlow clock with plastic cam to regulate light and temperature, respectively

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Figure 1b. Hydrothermograph and chart which shows temperature and relative humidity typical for bioenvironmental chambers





Figure 2. Light quality and quantity furnished by three sets of one 40-watt Grolux flanked by two 40-watt cool white fluorescent tubes per bioenvironmental chamber



for four years on June 21 at the respective locations. Plots were sketched in originating at 4 p.m. (maximum temperature) with a rapid drop after sunset to sunrise (minimum temperature) and increased through the day to 4 p.m. To reproduce temperatures in the environmental chambers, plastic cams were cut to duplicate the temperature curves for each collection site.

Relative humidity was maintained at approximately 70 to 90 percent and temperature and humidity were carefully monitored throughout the experiment by hygrothermographs which were installed in each chamber (Figure 1b).

The photoperiod and thermoperiod of each regime is presented in Table 1. The term photoperiod denotes a 24 hr period divided into a photophase (light) and scotophase (dark) as described by Beck (1962).

To secure true replication of the experimental regimes, the experiment was run three times. Each time the individuals used in the reciprocal matings were reared under 24 hr light and  $27^{\circ}$  C on corn leaf factor medium, therefore, the F<sub>1</sub> progenies used in each run of the experiment came from parents that had not been exposed to the experimental regimes. The design of the experiment was a split plot with regimes as whole plots and reciprocal mating (egg source) as subplot. When sex was considered a factor it was sub-subplot. Trays within chambers were originally to be considered subsamples,

I	Photopha Ir N	ise Iin	Scotopha Hr N	ise J Min	Thermoperiod OC
	15	55	8	5	8.3-23.3
-	14	55	9	5	13.3-28.9
:	14	15	9	45	18.3-31.7

Table 1. Light and temperature regimes to which nine laboratory cultures of reciprocal matings were subjected

but because of uneven distribution of females and males within trays, they were ignored and lumped together in the analysis of variance. Heterogeneity of variance of biological counts or percentages is common (Steel and Torrie, 1960); therefore, count data were transformed to square root and the percentage to arcsin in order to approximate normal distribution for the analysis of variance. The data are illustrated in graphs by north to south latitudes showing the populations of each mating ( $\begin{array}{c} x & d \end{array}$ ) in the following order: Minn. x Minn., Minn. x Md., Md. x Minn., Minn. x Ala., Ala. x Minn., Md. x Md., Md. x Ala., Ala. x Md., and Ala. x Ala. Populations of  $F_1$  Reciprocal Matings Tested in the Field Handling of experimental material prior to infestation

Overwintering European corn borers were obtained during the winters of 1967-68 and 1968-69 from Autagua County, Albama, Princess Anne County, Maryland, and Ottertail County, Minnesota and held at the European Corn Borer Laboratory, Ankeny, Iowa. The procedures for breaking diapause, conditions for mating, and handling of egg masses were identical to those previously described except that the procedure to make water available for the moths, by spraying the mating cages twice daily, was discontinued, and 250 x 300 cm cotton pads were installed onto the fronts of all cages and soaked once daily. In 1968 egg masses laid on the fourth day after initiation of deposition were heat treated as previously described in order to reduce the incidence of P. pyraustae infection. Each of the three parent types were reared for one generation under 24 hr light and  $27^{\circ}$  C with 80 percent RH on wheat germ medium, and in 1969 a microsporidicide, Fumidil B, at 1500 ppm was incorporated into the diet (Lewis and Lynch, 1970) in order to eliminate the microsporidian P. pyraustae. Pupae were handled as previously described and in order to produce all possible reciprocal matings of the three parent types, upon emergence of adults, 100 pairs of each type were combined in each of nine mating cages, replicated three times for a total of

27 cages which were maintained at 15 hr photophase and cycling temperatures of 18.3 to  $27^{\circ}$  C and 70 to 80 percent RH over a 24 hr period. Egg masses to be used in the experiment were selected from those deposited on the fourth day after initial deposition and were handled as described by Guthrie et al. (1965). Briefly, disks of waxed paper each holding an egg mass, were punched out, impaled on 2.5 cm straight pins, and 200 disks pinned to each of two 15 x 25 cm fibre boards per reciprocal mating. The masses deposited the fifth day of deposition were used as a back-up supply, and were handled in the same manner. One fibre board with egg masses from each reciprocal mating, for a total of nine boards, were wrapped in wet paper toweling, placed in a polyethylene bag, and sealed in a cardboard box and held over night at  $15.6^{\circ}$  C to await transportation to the experimental site. This procedure was repeated each year for each experimental location.

Each year egg masses from each reciprocal mating deposited the third day after initial deposition were handled according to Guthrie et al. (1965) and a single egg mass was placed in each of 17 plastic jelly cups previously described, per reciprocal mating. Immediately after hatch a single larva was taken from each jelly cup and placed in a rearing vial previously described containing a 1.86 cm plug of non-Fumidil B wheat germ medium (Lewis and Lynch,

1969). These 17 vials per reciprocal mating were placed in a tray and held at 24 hr light and  $27^{\circ}$  C until after the larvae achieved the fifth instar, at which time each larva was observed for <u>P</u>. <u>pyraustae</u> infection. The larvae were rated noninfected, light, medium, or heavily infected and an infection index was developed from this information by the assignment of 0, 1.961, 3.922 and 5.883, respectively, per individual larva.

## Land preparation and seeding operations

An attempt was made to synchronize planting dates over years and locations so that corn plants would be at a similar stage of maturity upon manual infestation with European corn borer egg masses.

Ankeny, Iowa, 1968 The 100 x 180 ft experimental area was fertilized with 365 lb of 6-24-24 and plowed during the fall of 1967. The area was harrowed on April 27, 1968. On April 29, 1968 the area was sprayed with 3 lb actual of 80 percent w.p. Atrazine which was harrowed under for weed control. That afternoon an International Harvester 6-row planter set on a 30-inch spacing in a single operation placed 365 lb of 33.5 percent NH4NO<sub>3</sub>, 3 lb actual Ramrod for weed control, and 1 lb actual of Bux-10 granules per acre for rootworm control in the seed bed. Pioneer hybrid 3304 was planted in rows 1, 2, 5, and 6 and a European corn borer susceptible inbred, WF9, in rows 3, and 4 at

the rate of 18,000 seeds per acre. The experiment was planted out in nine 100-ft passes of the planter.

Morris, Minnesota, <u>1968</u> In the fall of 1967 the 100 x 180 ft experimental area was fertilized with 400 lb 6-24-24 and plowed. The area was harrowed on April 20, and on May 6, 1968, a 6-row planter set on a 30-inch spacing in a single operation placed 365 lb of 33.5 percent NH<sub>4</sub>NO<sub>3</sub>, 3 lb actual Ramrod, and 0.8 lb actual Bux-10 granules in the seed bed and planted 18,000 seed of Pioneer hybrid 3304 per acre. Twelve 100-ft passes were made by the planter. Nine days later on May 17, at 12-ft intervals, the seedlings in 6 ft of row in each of two rows were removed in each of the 12 swaths and WF9 was hand planted 3 seeds per hill, 3 hills per row, 20 inches apart.

Ankeny, Iowa, 1969 The experiment was run in the exact location as in 1968, the reason of which will be explained later. The fall of 1968 was so wet that fall plowing operations were not conducted. The spring of 1969 was very wet, therefore, it was May 26 before any land preparation was undertaken. Corn stalks of the previous year were cleared away by hand and the 100 x 180 ft area was spring-toothed twice during the day. On the morning of May 29, 1969 the area was sprayed with 3 lb actual 80 percent w.p. Atrazine for weed control. That afternoon the field was planted in the manner described for 1968 with the

exception that 365 lb of a 6-24-24 fertilizer was applied.

Morris, Minnesota, 1969 Fall plowing and fertilization and the spring fertilization, weed control, rootworm control, and planting procedures were identical to 1968. Planting and replanting operations were conducted May 8 and 16, respectively.

#### Cages used in the experiments

In 1966, two years prior to the Ankeny, Iowa initiation of the present experiments, heavy winds destroyed 33 plastic screen cages which were internally supported by 1-inch pipes and guy wires similar to the cages described by Sparks (1965). Consequently some experimental material was lost when the pipes ripped through the cages. To minimize the chances of wind damage to corn planted in cages in the event of high winds, the method of holding the cages was changed from internal to external support. Since cage design can influence experimental results, the system used is described in detail should similar research be attempted by other workers. Pentachlorophenol treated 5 in x 10 ft telephone posts were sunk 3 ft into the ground, 360 ft apart. Between each end post, at 20 ft intervals, 17 pentachlorophenol-treated 4 in x 4 in x 10 ft posts were sunk 3 ft into the ground. Four inches down from the top of each post, a 3/8 in x 6 in threaded J-bolt was inserted with the base of the bolt facing forward and the small part of
the angle upward. U.S. Government surplus 1/8 inch tow target cable was strung through the J-bolts and a 1/8 inch hole four inches down from the top of each end post and clamped with 1/8 inch cable clamps to a hook and hook-type 1/2 inch diameter galvanized turnbuckle which was secured at a 45° angle by a 3-foot earth anchor as illustrated by Figure 3a. After this part of the operation was completed each J-bolt was tightened to each post with a flat washer and 3/8 inch nut. Directly behind each post at precisely 8 ft the operation was repeated with the exception that each J-bolt faced to the rear rather than forward. Two 1/8 inch cable clamps were secured 8 ft apart on each cable within each 20-foot interval. This produced available spaces for 18 cages. Forty inches of 1/4 inch nylon cord, looped to expose a length of 18 inches, was sewed with carpet thread to the top of each corner of each  $6 \times 6 \times 6$  ft plastic screen cage. A cage was stationed in the center of each 20-foot interval and the nylon cords were tied to the 1/8inch cable clamps as shown in Figure 3b. Each cage was then secured with eight  $1/4 \times 18$  in metal stakes placed through grommets around the base of the cage. This overall procedure repeated eight times with precisely 8 and 12 ft alternating intervals between each line of posts (Figure 4) allowed available spaces for 72 cages of which 36 were used for the present experiment. This type of structure removed

Figure 3a. Position of cable through end post and fastened to turnbuckle which is attached to earth anchor

Figure 3b. Nylon cord which holds corner of cage upright, attached to cable, and secured by cable clamp





Figure 4. Overall view of cages in position



the factors which would cause ripping of the cages in the event of high winds. The thread which secured the nylon cords to the corners of each cage, in the event of high winds, would break and the cage would drop to the ground, thereby the experimental material would remain enclosed and intact. This system withstood 80 mph wind during the summer of 1969. The only disadvantage of this system is the nonmaneuverability of the cages. The experiment must be conducted in the same general location each year. However, the advantages of retaining the experimental material and cages intact after high winds outweigh this disadvantage.

Morris, Minnesota The 36 cages used both years at this site were similar to those with internal support described by Sparks (1965).

## Experimental design

Each plot consisted of two rows of corn planted 30-inches apart with one plant of WF9 spaced 20 inches apart in each row for a total of six plants per plot. Approximately two weeks after planting each plot was covered by a 6 x 6 x 6 ft plastic screen cage in the manner described in the previous section. Four guard rows of Pioneer hybrid 3304 surrounded each caged plot. Each of nine plots was randomly assigned a treatment which consisted of three egg masses, approximately 60  $\pm$  2 eggs from each reciprocal mating placed into the whorl of each plant in the plot. In 1968 plants with

leaves extended ranged in height at time of infestation from 43 to 51 and 23 to 32 inches at Ankeny and Morris, respectively, and in 1969, 29 to 36 and 30 to 36 inches at Ankeny and Morris, respectively. The experiment was replicated four times as a randomized complete block at each location over each year.

The infestation date at both locations in 1968 was July 1. Preliminary examination of the 1968 data suggested the experiment could be refined by delay of infestation date, so in 1969 this portion of the experiment was infested on July 10 at both locations. The overall experiment was analyzed as a split-split plot with years as whole plots, locations as subplots, and the most important factor, egg sources, as sub-subplots. The data are presented in graphs as previously described.

## Handling of experimental material after manual infestation

Approximately three weeks after hatch each cage at each location over both years was checked daily for moth emergence. The sex of each adult was recorded and each specimen from each reciprocal mating was placed in a container filled with 70 percent ethanol. During the third week of September of each year at each location each corn plant of each plot was dissected and the location and number of tunnels, and forms of European corn borer were recorded.

## RESULTS

Laboratory Study of the Effects of Regimes Typical for the Parent Types on Progeny of Reciprocal Matings

In order to produce all possible reciprocal matings, upon emergence of adults, 100 pairs of each parent type, Alabama, Maryland, and Minnesota, were combined in each of nine mating cages. The mated females deposited egg masses on the undersides of two strips of waxed paper covering the top of each mating cage. These strips were changed daily and the egg masses were allowed to hatch on the waxed paper or in glass jars. The experiment was replicated over three generations, however, daily changes of some egg mass deposition sheets were overlooked during the first genera-Therefore, analysis was made on generations 2 and 3 tion. which were considered replicates 1 and 2, and are summarized in Table 27. Measurements were taken on the following variables: egg masses deposited, mean number of eggs per mass, and percent of eggs hatched per mass per mating per The data were analyzed as a split plot with egg source dav. as whole plots and days of egg deposition as subplots. In order to approximate normal distribution of the large variance which occurred in each reciprocal mating per day, the data were transformed to square root and the percentage The analysis is presented in Table 28. data to arcsin.

Females of each reciprocal mating were equal in the numbers of egg masses deposited, eggs per mass, and hatch per mass. Significant differences were entirely due to days of egg mass deposition with the highest number of masses occurring the 3rd or 4th day. The data show there were more egg masses produced in replicate 2. However, hatch per mass remained the same between replicates.

The laboratory experiment in which progenies of nine matings were used was conducted in bioenvironmental chambers programmed to simulate the photophase and thermoperiod typical of June 21 at each parent collection site: west central Minnesota 15 hr 55 min photophase,  $8.3-23.3^{\circ}$  C thermoperiod; Maryland 14 hr 55 min photophase,  $13.3-28.9^{\circ}$  C thermoperiod; and central Alabama 14 hr 15 min photophase,  $18.3-31.7^{\circ}$  C thermoperiod. True replication of the regimes was obtained by running the experiment over three generations. The individuals used in the reciprocal matings were reared under 24 hr light and  $27^{\circ}$  C, therefore, the progenies used in the experiment came from parents that had not been exposed to the experimental regimes.

The experiment was initiated with 102 freshly hatched larvae of each mating, within each regime per replicate. Percent survival, percent diapause, mean pupal weights, days to 80 percent pupation, days to 80 percent adult emergence, demonstration of negative phototaxis and the percentage of

males and females were the variables on which measurements and analysis for differences were made. The raw data for the five variables are presented in Tables 29 through 32, inclusively. Survival figures were obtained by subtracting larval mortality from the 102 individuals of each reciprocal mating per replicate that went into the experiment initially, and the diapause figures were arrived at by subtracting the numbers of pupae from the total survival figure of each mating colony per replicate. Diapause was assumed to have occurred for all individuals which had not pupated at the end of 52 days. Pupal weight, in milligrams, was obtained for each individual 1 day after the last larval skin was shed and tanning had occurred. Days to 80 percent pupation and adult emergence were arrived at by recording daily pupation and adult emergence and upon completion of each stage calculating the days on which 80 percent occurred. The 80 percent figure was used in order to eliminate the tailing effect which occurred at 100 percent in all mating colonies under each regime.

During the experiment it was noted that a majority of individuals which pupated spun a silk web near the cotton plug which stoppered each vial. However, some sealed themselves within the plug of medium and pupated in relative darkness.

Laboratory colonies maintained at the Iowa State Univer-

sity and United States Department of Agriculture, European Corn Borer Laboratory, Ankeny, Iowa produced 55-45 percent males to females. Therefore this character was tested among the mating colonies under two of the three regimes.

Ninety percent of the mortality occurred during the first and second day of the experiment. The analysis (Table 33) shows that percent of survival is due directly to egg source and regimes had no effect. This feature is shown by Table 2 and by the average larval mortality data presented in Figure 5 in which the data are plotted in a north (Minn. x Minn.) to south (Ala. x Ala.) arrangement. The data show that the progeny of the Alabama, Maryland, and Minnesota parents sustained the highest mortality. The fact that the progeny of the other matings had fewer deaths suggests hybrid vigor. Table 33 shows that regimes and egg sources produced very large F values, 530.36 and 102.73, respectively, for the variable, percent diapause, transformed to arcsin. With values of this magnitude, a significant regime x mating interaction would be expected. This interaction and a comparison between matings are summarized in Table 3 and the percent diapause on which the summarization is based is presented in Table 31. The magnitude of difference between the means of matings depends upon the regime. Among the parent types, Minn. x Minn. produced the highest percentage diapause, Ala. x Ala. was intermediate, and Md. x Md. was

Regime	Rep.	Percent Ala. x Md.	survi Md. x Ala.	val per Ala. x Minn.	Minn. X Ala.	ocal ma Md. x Minn.	ting (? Minn. x Md.	x ď) Ala. x Ala.	by re Md. x Md.	plicate Minn. x Minn.
Photophase	I	88	85	85	91	91	77	63	65	69
15 hr 55 min	II	68	78	62	65	75	75	53	46	63
Thermoperiod 8.3-23.3° C	III	93	89	90	91	95	96	84	88	75
Average		83	84	79	82	87	83	67	66	69
Photophase	I	95	88	82	96	89	97	73	73	70
	II	68	75	76	58 <sup>°</sup>	81	69	59	57	54
13.3-28.9° C	III	89	88	91	94	96	89	87	75	78
Average		84	84	83	83	89	85	73	68	67
Photophase	I	89	86	81	88	90	88	66	70	70
14 nr 15 min	II	72	90	.74	63	85	77	67	55	68
18.3-31.7° C	III	95	96	99	94	100	95	97	76	99
Average		85	91	84	50	92	87	76	67	79

Table 2. Percent survival per replicate for nine laboratory colonies of European corn borers reared under three photophases and thermoperiods

Figure 5. Larval mortality of progenies of nine matings reared under three photophases and thermoperiods, Ankeny, Iowa, 1968

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	Average percent diapause Regime						
Matings (♀ x ♂)	14 hr 15 min 18.3-31.7° C	14 hr 55 min 13.3-28.9° C	15 hr 55 min 8.3-23.3° C				
	, , , , , , , , , , , , , , , , , , ,	ang shi aya an ang sa ang sa ga sa ang sa ga sa					
Ala. x Ala.	92	60	12				
Minn. x Minn.	100	100	88				
Ala. x Minn.	100	. 98	43				
Minn. x Ala.	100	97	39				
Md. x Md.	69	19	2				
Minn. x Minn.	100	100	. 88				
Md. x Minn.	100	97	21				
Minn. x Md.	98	87	. 47				
Ala. x Ala.	92	60	12				
Md. x Md.	69	19	2				
Ala. x Md.	86	39	l				
Md. x Ala.	93	41	l				

Table 3. Comparison of percent diapause between nine laboratory colonies of European corn borer reared under three photophases and thermoperiods

the lowest under all three regimes. The 14 hr 15 min photophase and  $18.3-31.7^{\circ}$  C thermoperiod produced the highest percent diapause in all matings. In this regime percent diapause of F<sub>1</sub> progenies from Ala. x Minn., Minn. x Ala., Md. x Minn., and Minn. x Md. was not different from the 100 percent diapause of Minn. x Minn. Percent diapause of Ala. x Md. and Md. x Ala. was similar to the percentage recorded for Ala. x Ala. None of the reciprocals were similar to the Md. x Md. matings for this regime. The photophase and thermoperiod of this regime simulated a typical June 21 day in central Alabama. Therefore, the high percentage diapause, 92, expressed by the Ala. x Ala. mating was unexpected.

The 1- hr 55 min photophase and 13.3-28.9° C thermoperiod, which simulated a typical June 21 day in northern Maryland, realigned the reciprocal matings so that the percent diapause of Ala. x Minn., Minn. x Ala., and Md. x Minn. remained similar to Minn. x Minn. but the Minn. x Md. mating with 87 percent diapause was different from Minn. x Minn. which suggests a moderate paternal effect. Ala. x Ala. produced 60 percent diapause, however, the progenies of the Ala. x Md. and Md. x Ala. reciprocals were intermediates between Alabama and Maryland which suggests no maternal or paternal effect. The influence with regard to percentage diapause of the Minn. x Minn. mating was reduced drastically at the 15 hr 55 min photophase and 8.3-23.3° C thermoperiod. This regime simulated a typical June 21 day in west central Minnesota. The percent diapause of Ala. x Minn. and Minn. x Ala. was intermediate to those of Ala. x Ala. 12, and Minn. x Minn., 88, which suggests incomplete dominance

between the parent types. The percent diapause of Ala. x Md. and Md. x Ala. was similar to that of the Md. x Md. mating which was near 2 percent. The 47 percent diapause of the Minn. x Md. mating was intermediate between the two parent types. However, the Md. x Minn. mating had an average of 21 percent diapause which suggests a maternal effect of the Maryland female.

The data summarized in Table 3 show that within the three regimes studied, photophase or scotophase plays a major part in enhancing or reducing the incidence of diapause for all nine matings. The Minnesota parent type exerts the greatest influence with short photophase and high thermoperiod. However, as the photophase is lengthened and thermoperiod is lowered the Maryland parent type becomes most influential and the incidence of diapause is reduced. The Alabama parent type appears intermediate at all three regimes.

The shorter photophases, 14 hr 55 min and 14 hr 15 min, with  $13.3-28.9^{\circ}$  C and  $18.3-31.7^{\circ}$  C thermoperiods, respectively, enhanced diapause and, therefore, reduced pupation and adult emergence so drastically that these variables could not be measured for all matings under the former or for any at all under the latter regime. Mean pupal weight data presented in Table 4 were transformed to square root and the analysis is presented in Table 33. At the 15 hr 55 min photophase

Table 4. Mean weight in milligrams of 1-day-old pupae of nine laboratory colonies of European corn borer reared under different regimes of light and temperature

Regime	Rep	Ala. 2 9	Mean K Md. d	pupal Md. x º	weigh Ala. ơ	nts, ir Ala. 2 9	n mill K Minr d	ligrams 1. Minr 9	s, of 1.xAla. ď
Photophase	I	87.2	75.8	100.2	75.4	100.9	82.4	98.3	76.3
	II	98.5	78.4	94.1	70.0	98.6	77.9	103.8	87.6
Thermoperiod 8.3-21.3° C	III	91.3	79.7	95.0	74.9	101.9	82.3	114.7	87.7
Average		92.3	77.6	96.4	73.4	100.3	80.9	105.6	83.9
Photophase 14 hr 55 mi	I	107.4	91.0	116.5	82.7				
Thermoner's	II	109.2	91.5	110.6	82.7				
13.3-28.9°	C III	105.0	86.2	104.8	80.8				
Average		107.2	89.6	110.6	82.1				·

<sup>a</sup>Based on 5 to 39 \$ and 3 to 46 °, and 13 to 29 \$ and 13 to 27 ° per replicate in regimes 1 and 2, respectively.

fema	les and	males <sup>a</sup>	per m	ating (	(♀ x ♂)	by rep	licate	<b>)</b>	
Md.	x Minn.	Minn.	x Md.	Ala.	x Ala.	Ma. x	Ma	Minn. x	Minn.
¥	ර	Ŷ	ර	¥	්	¥	ď	Ŷ	ଟ 
			-					•	
98.	7 77.4	88.7	75.1	89.2	74.3	80.5	66.1	87.5	75.0
96.8	3 72.4	88.2	75.5	95.0	78.8	85.9	68.5	100.5	77.0
98.6	5 75.4	91.1	74.5	98.1	81.2	84.3	68.7	100.0	80.0
98.0	75.0	89.3	75.0	94.1	78.1	83.6	67.8	96.0	77.3
				0	0		_1 1		
				105.8	82.2	93.8	74.4		
				102.1	82.2	97.1	78.7		
				108.3	83.8	98.3	76.7		
				105.4	82.7	96.4	76.6		

and 8.3-23.3° C thermoperiod, the largest difference was between sex, females outweighed males an average of 18.52 However, there were significant differences between mg. egg sources when all matings were compared. The mating x sex interaction is presented in Figure 6. The progeny of Md. x Md. weighed significantly less and those of Minn. x Ala. weighed significantly more than progenies of all other matings. The males from the remaining matings are similar, however, the females produced from the Minn. x Md. and Ala. x Md. matings weigh less than the females of most of the other matings. Therefore, the magnitude of difference between females and males of these two matings is less. This difference may be interpreted as an effect of the Maryland male on the progenies of these matings. The magnitude of differences between females and males is highest among the progenies of the Minn. x Ala., Ala. x Minn., and Md. x This suggests that the females and males of the Minn. Alabama or Minnesota parentage may be exerting an equal effect on the weight of the first two progenies while the latter is due to the Minnesota female. The data show there is an apparent trend for the weight of male and female progenies to be affected by female and male parentage, respectively. The mean pupal weights and the analysis transformed to square root of four reciprocal matings under two regimes are presented in Tables 4 and 33.

Figure 6. Mean pupal weight, transformed to square root, of progenies of nine matings reared under 15 hr 55 min photophase and 8.3-23.3° C thermoperiod, Ankeny, Iowa, 1968

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Significant differences were due to sex, reciprocal matings, and regimes. The significant interactions of regime x sex and matings x sex are presented in Figure 7. The 14 hr 55 min photophase and  $13.3-28.9^{\circ}$  C thermoperiod increased the difference in the weight between females and males an average of 4.82 mg. The progenies of the Md. x Md. mating weighed less than the progenies of the other three matings under both regimes. The highest weight increase, 25.76 mg, between females and males occurred with the females of the Md. x Ala. mating. Why 1-day-old pupae of the female and male progenies of each of the four matings had significantly increased weight under the shorter 14 hr 55 min photophase and higher 13.3-28.9° C thermoperiod cannot be answered by this study because photophase and temperatures were confounded.

Days to 80 percent pupation and adult emergence data are presented in Table 5. These two variables were measured for all nine matings at 15 hr 55 min photophase and  $8.3-23.3^{\circ}$  C thermoperiod and for four matings at 14 hr 55 min photophase and  $13.3-28.9^{\circ}$  C thermoperiod. The analysis of variance of the two variables presented in Table 33 shows that the nine matings were similar. Table 5 shows on the average females attained 80 percent pupation in 37.04 days whereas males achieved this percentage at 35.74 days. However, the pupal period of the female was

Figure 7. Mean pupal weight, transformed to square root, of progenies of four matings reared under different photophases and thermoperiods, Ankeny, Iowa, 1968



		Ala.	X ·	Mđ.	х э	Ala. Min	<u>х</u>
Regime	Rep.	2 2	ਰ	Ŷ	ਰ	<u>\$</u>	ය ර
		Da	ys to 8	BO perce	ent pu	patic	n of
Photophase	I	39	38	40	39	42	38
15 hr 55 min	II	33	30	32	31	33	31
8.3-23.3° C	III	38	35	35	35	36	36
Average		36.7	, 34 <b>.</b> 3	32.3	35	37	35
Photophase	I	30	26	24	24		
14 nr 55 min	TT	25	24	25	23		
Thermoperiod 13.3-28.9° C	III	31	28	25	25		
Average		28.7	26	24.7	24		
		Days	to 80 <sup>.</sup>	percent	adult	emer	gence
Photophase	I	52	53	53	54	54	55
	II	48	48	48	48	49	48
8.3-23.3° C	III	56	56	53	54	52	55
Average		52	52.3	51.3	52	51.7	, 52 <b>.</b> 7

Table 5. Days to 80 percent pupation and adult emergence by replicate of nine laboratory colonies reared under different regimes of light and temperature

Minn. x Ala. x Md. x Minn. x Md. x Minn. x Md. 9 ď Md. ♀ Ala. 9 ď Ala. 9 ď Minn. Minn. \$ ď రి Ŷ d females and males per mating  $(9 \times 3)$  by replicate 40 40 42 41 41 40 42 41 43 41 39 44 35 35 31 33 33 33 30 31 29 34 33 30 38 34 34 38 36 39 38 39 39 40 35 33 36.3 36 38.3 37 39 37.7 35.7 35.7 35.7 37.3 35.7 37 27 26 30 30 26 25 26 27 30 33 27 31 27.7 29.7 26 29.3 <u>م</u> ، 1.

of.	females	and	males	$\mathtt{per}$	mating	(¥ X	ര്) by	repli	.cate		
54	54	55	55	53	54	56	56	56	55	52	56
50	52	49	46	46	45	51	50	51	47	52	47
52	53	56	56	56	57	57	57	57	58	52	53
52	53	53.3	3 53.3	51	•7 52	54.7	7 54.3	54.7	, 53 <b>.</b> 3	52	52

		Ala. x Md.		Md. Ala	Ala. x Minn.		
Regime	Rep.	Ŷ	ď	¥ 	<u>්</u>	¥.	්
Photophase	I	42	38	36	37		
	II	36	36	36	35		
13.3-28.9° C	III	41	38	35 .	36		
Average		39.1	7 37.3	35.7	36		

Table 5. (Continued)

Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala Al	a. x la.	Md Mo	. x 1.	Minn. Minn	<u>x</u>
ୁ ଦୁ 	ຊ ູ	<u></u> Ф о <sup>4</sup>	ę 	්	£ 		<u>ұ</u>	ۍ 
			41	39	41	42		
			38	37	37	39		
			42	38	44	41		
			40.3	3 38	40.'	7 40.7	<b>,</b>	

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shorter than that of the male so that on the average both sexes attained 80 percent adult emergence after 54 days. Where four matings were analyzed over two regimes, on the average, females lagged 1.42 days behind males in days to 80 percent pupation but there was not any differences between sexes for 80 percent adult emergence. However, in this analysis there were significant differences between matings and regimes. This information is presented in Figure 8 and Tables 5 and 33. Days to 80 percent pupation for  $F_1$ progenies of Md. x Ala. was different from Ala. x Md. which differed from both parent types, which were similar to one another at the 14 hr 55 min photophase and 13.3-28.9° C thermoperiod. On the average, 80 percent pupation occurred 9.67 days and adult emergence 14.54 days earlier at 14 hr 55 min photophase and  $13.3-28.9^{\circ}$  C thermoperiod than at the 15 hr 55 min photophase and 8.3-23.3° C thermoperiod. Before the data were scrutinized orthogonal comparisons were conducted on the 80 percent adult emergence data. The comparisons and analysis are presented in Table 6. Progenies of Md. x Ala. emerged earlier (Table 7) than Ala. x Md. progenies and both groups emerged earlier than either parent type.

Negative phototaxis is the movement away from light. Some individuals from all four matings exhibited this tendency during the experiment. They would web themselves

Figure 8. Average number of days to attain 80 percent pupation for progenies of four matings reared under different photophases and thermoperiods, Ankeny, Iowa, 1968

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Table 6. Orthogonal comparisons, coefficients, and analysis of variance of days to 80 percent adult emergence of four laboratory colonies of European corn borer reared under two photophases and thermoperiods

			Orthogo	onal comparis	arisons	
Mat	cings (º x ď)	Sums	cl	°2	°3	
	***************************************		**************************************			
1.	Md. x Ala.	525.00	+ 3	0	0	
2.	Ala. x Md.	543.99	<b>-</b> 1 <sup>-</sup>	+ 2	0	
3.	Md. x Md.	567.99	- 1	- 1	+ 1	
4.	Ala. x Ala.	561.99	- 1	- 1	- 1	

$$c_{1} = \frac{[3(525.00) + (-1) (543.99) + (-1) (567.99) + (-1) (561.99)]^{2}}{12[(3)^{2} + (-1)^{2} + (-1)^{2} + (-1)^{2}]} = 68.06$$

$$c_{2} = \frac{[2(543.99) + (-1) (567.99) + (-1) (561.99)]^{2}}{12[(2)^{2} + (-1)^{2} + (-1)^{2}]} = 24.50$$

$$c_{3} = \frac{[1(567.99) + (-1) (561.99)]^{2}}{12[(1)^{2} + (-1)^{2}]} = 1.50$$

Table 6. (Continued)

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Source	SS	ANC df	DV M.S.	F
Matings	94.06	3	Augura de augura de augura de la	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
l vs. 2, 3, and 4	68.06	1	68.06	37.186**
2 vs. 3 and 4	24.50	1	24.50	13.388**
3 vs. 4	1.50	1	1.50	. < 1
Error for matings	21.999	12	1.83	
		F values for	comparison	
	Level of	confidence 1 a	nd 12 degrees	of freedom
		*95 percent	4.75	
		**99 percent	9.33	

	Mean days	ent adult	; emergence	
		Mating	(♀ x ♂)	
Regime	Md. x Ala.	Ala. x Md.	Md. x Md.	Ala. x Ala.
Photophase 15 hr 55 min	51.67	52.17	54.00	54.50
Thermoperiod 8.3-23.3°C				
Photophase 14 hr 55 min	35.83	38.50	40.67	39.17
Thermoperiod 13.3-28.9°C				
Average	43.75	45.33	47.33	46.83

Table 7. Mean days to 80 percent adult emergence of four laboratory colonies of European corn borer reared under two photophases and thermoperiods

into the plug of medium and once sealed, pupate in relative darkness. The hypothesis (that the number of individuals which exhibited negative phototaxis would approximate 10 percent and would follow chi-square) was tested for each mating. All matings could not be evaluated for this phenomenon under the 14 hr 55 min photophase and 13.3-28.9° C thermoperiod and none could be examined under the 14 hr 15 min photophase and 18.3-31.7° C thermoperiod because of the low numbers which pupated. Table 8 presents the results of the

		Ма	ting (° x	ರೆ)
Regime	Rep.	Ala. x Md.	Md. x Ala.	Ala. x Minn.
			<u>, ,,,,,,,, - ,,</u>	Observed
Photophase	I	24	19	5
15 117 55 1111	II	17	12	б
8.3-23.3° C	III	10	8	l
Average		17	13	4
	_			Expected
	I	9	9	5
·	II	7	8	5
	III	9	9	3
Average		8	.9	4
	-		Co	ontribution
	T	25.00**	12.97**	• 0.01
	II	15.30**	2.00	0.09
	III	0.04	0.13	1.16

Table 8. Observed and expected values of negative phototaxis for individuals of nine laboratory colonies of European corn borer reared under different photophases and thermoperiods

 $a_X^2 = 3.84*$  at .05 and 6.63\*\* at .01 probability with 1 df.
		Mati	ng (° x ď)		
Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md.x Md.	Minn. x Minn.
values					
7	13	14	7	16	1
5	7	6	10	16	l
7	8	10	9	19	. l
6	9	10	9	17	l
values				•	
5	6	7	6	6	1
5	7	6	5	5	l
5	8	9	7	9 · · ·	l
5	7	7	6	7	1.
to chi-s	square <sup>a</sup>				
0.62	6.81**	• 6.71*	* 0.30	14.93**	0.27
0.03	0.02	0.01	5.00**	27.17**	0.01
0.47	0.01	0.26	0.45	11.11**	0.13

Table o. (Continue)	d,	)
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•				
		Ma	ting (? x	<b>ਰ</b> )
Regime	Rep.	Ala.x Md.	Md. x Ala.	Ala. x Minn.
			·	
Dhotophago	т	77	<u>6</u>	Observed
14 hr 55 min	Ŧ	7.44	0	
	II	11	10	
13.3-28.9° C	III	6	6	
Average		10	7	
				Expected
	I	1	6	
	II	6	5	
	III	5	5	
Average		4	5	
			Co	ntribution
	I	9.41**	0.03	
	II	7.59**	5.00*	
	III	0.67	0.30	

•

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•

	Mat	ing (♀ x ♂)		
Minn.x Md.x Ala. Minn.	Minn. x Md.	Ala. x Ala.	Md.x Md.	Minn. x Minn.
values				
		7	25	
		4	14	
		4	13	
		5	17	
values		<u>x</u>		
		3	6	
		3	5	
		2	5	
		3	6	
to chi-square				
		4.51*	57.01**	
		0.26	14.28**	
		1.26	11.70**	

matings and regimes under which this variable was measured. Each of the 39 observations, with 1 degree of freedom, was tested in order to determine the existence of a possible trend.

The exhibition of negative phototaxis by matings does follow chi-square except for the Md. x Md. mating within which 25.5 and 31.1 percent of the individuals pupated in the medium under the 15 hr 55 min photophase and  $8.3-23.3^{\circ}$  C thermoperiod and the 14 hr 55 min photophase and  $13.3-28.9^{\circ}$  C thermoperiod, respectively. There appears to be a trend toward increased pupation in darkness within the Ala. x Md. mating which suggests the parent Maryland male is exerting an influence which is expressed by this characteristic.

Colonies of European corn borer maintained under 24 hr photophase and constant temperature produced 55-45 percent males to females, respectively. The hypothesis to determine whether the progenies of the matings used in this study produced 55-45 percent males to females and followed chisquare was tested. Just four of the matings could be evaluated for this character under the 14 hr 55 min photophase and 13.3-28.9° C thermoperiod and none were evaluated under the 14 hr 15 min photophase and 18.3-31.7° C thermoperiod because of low adult numbers. The observed and expected values along with their contribution to chi-square are presented in Table 9. Again, each of the 39 observations,

Regime	Rep.	Ala M Ŷ	• x d. ď	Md. Al Ŷ	x a. రే	Ala Mi S	nn o
						Obser	ved
Photophase	I	45	43	45	34	23	21
	II	33	32	35	43	26	25
8.3-23.3° C	III	50	42	47	38	20	8
Average		43	39	42	38	23	18
						Expec	ted
	I	48	40	43	36	24	20
	II	36	29	43	36	28	23
	III	51	41	47	38	15	13
Average		45	37	44	37	22	9
					Cont	tribut	ion
	I	0.	41	0.	20	0.	09
	II	Ο.	56	2.	85	0.	32
	III	0.	04	0		3.	59

Table 9. Observed and expected values of males to females for nine laboratory colonies of European corn borer reared under different photophases and thermoperiods

 $a_{\rm X}{}^2$  = 3.84\* at .05 and 6.63\*\* at .01 probability with 1 df.

Min Al Ŷ	in. x .a. o <sup>7</sup>	Md Mi Ŷ	nn.	 Min M Ŷ	n.x Id. ő	Al A Ŷ	a 1	. x a. ď	 Md M P	d. ď	Minn Min º	. x n. 3
val	ues											
19	26	35	23	 46	34	30		24	 28	32	 4	2
23	19	41	30	33	22	21		23	24	17	0	10
24	22	42	31	31	45	33		29	52	29	3	4
22	22	39	28	37	34	28		25	35	26	2	5
val	ues			 - <u>n n</u>					 		 	
25	20	32	26	44	30	30		24	33	27	3	3
23	19	39	32	30	25	24		20	23	18	6	4
25	21	40	33	42	34	34		28	45	36	4	3
24	20	37	30	39	32	29		24	34	27	4	3
to	chi-so	luarea									 	
3.	24	0.	63	0.	20	0			 1.	68	 0.	67
0		٥.	23	0.	66	0	•	83	0.	10	15.	00**
0.	09	0.	72	6.	44 <b>*</b>	0	•	07	2.	45	0.	58

Table 9.	(Continued)
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Regime	Rep.	Ala.x Md. 9 d	Md.x Ala. 9 đ	Ala. x Minn. ? ď
			• • • • •	sentrod.
Photophase	I	37 25	28 21	serveu
14 nr 55 min	II	23 25	30 18	
Thermoperiod 13.3-28.9° C	III	22 21	24 24	
Average		27 24	27 21	
	_		Ex	pected
	I	34 28	27 22	
	II	26 22	26 22	
	III	24 19	26 22	
Average		28 23	26 22	
	I	0.59	Contri 0.08	bution
	II	0.76	1.34	
•	III	0.38	0.34	

.

Minn. x Ala. ♀ ♂	Md. x Minn. 9 ď	Minn. x Md. <sup>ç</sup> o <sup>r</sup>	Ala Al Ŷ	. x a. o	Md M P	. x d. ď	Minn.x Minn. ♀ d
ນລາມຄຣ							
Values			16	14	23	34	
			16	12	30	17	
			8	15	23	27	
			13	14	25	27	
values						·	
			17	13	31	26	
			15	13	26	22	
			13	10	28	22	
			15	12	28	23	
to chi-squ	are						
			0.	14	4.	53*	
			٥.	14	l.	75	
			4.	42*	2.	03	

with 1 degree of freedom, was tested in order to determine the existence of a possible trend. The progenies of the matings tested do produce 55-45 percent males to females and follow chi-square.

F<sub>1</sub> Progenies of Reciprocal Matings Tested in the Field

The objective of this experiment was to investigate, in the field, at two widely separated locations, west central Minnesota (Morris) and central Iowa (Ankeny), for two years, 1968 and 1969, the behavior of the  $F_1$  progenies of the same reciprocal matings which had been tested in the laboratory. Parental stocks were collected as overwintering larvae during the winters of 1967-68 and 1968-69 at Autauga County, Alabama, Princess Ann County, Maryland, and Ottertail County, Minnesota. Sixty  $\pm 2$  eggs from each of the nine matings were used to infest each of six WF9 corn plants within each of four 6 x 6 x 6' plastic screen cages at each location over two years.

Nineteen variables were measured during the study: total forms which survived per cage, percent survival based on total forms vs. 360 eggs used to infest each cage, larvae which diapaused, percent diapause, total tunnels in corn stalks in each cage, tunnels per borer form, location of tunnels on the corn stalk (above, on, and below the ear), number of forms which pupated, percent pupation, adults, male to female ratio, days to 80 percent adult emergence

(1969 omitted and Ankeny omitted), days to 80 percent adult emergence by sex (female and male), adults trapped in tunnels in corn stalks, and percent of adults trapped in tunnels in corn stalks.

The data by replicate, locations, and years on which these variables were observed are presented in Table 34. A summary analysis on 18 of the variables measured is presented in Table 10, and a more complete summation of the untransformed analysis for these variables is presented in Table 36. Mating (egg source), the factor of most concern, was significant at the 95 or 99 percent level of confidence for 14 of the 18 variables (Table 10). However, for many of the variables there were 2-way and for some 3-way interactions.

The mean number of forms which survived and the mean percent survival are summarized in Table 11. The percent and actual survival are presented in Tables 12 and 34. Years and locations affected survival of the progenies of the nine matings. The highest survival occurred at Ankeny in 1968, however, the lowest also occurred there in 1969. This phenomenon might be explained by microsporidium, <u>Perezia</u> <u>pyraustae</u>, infection and weather. Data on these factors are presented in Tables 13 and 35. Table 13 is a summary of percent survival in 1968 compared with an infection index which is the summation of individuals which were assigned indexes of 1.961, 3.922, and 5.883 for light, medium, and

					Co	mpon	ent	teste	d <sup>a,t</sup>	)				
Variable	Y	L	Ϋ́L	R/L	E	ΫE	LE	YIE	S	YS	LS	ES	YES	LES
Total forms	**		**		**	**		**						
Percent survival, x/360	**		**		**	**		**						
Diapausing larvae					**		**	**						
Percent diapause	**				**	**								
Total tunnels	**		**		**	**	**	*						
Tunnels per form	**		*		*	**								
Tunnels above the ear,														
1969		**			*		**							
Tunnels in the ear and														
shank, 1969		*												
Tunnels below the ear,														
1969		**												
Forms which pupated	**		**		**	**		**						
Percent pupation	**		**		**	**								
Adults emerged	**		**	**	**	**		**						
Days to 80 percent														
emergence														
1969 omitted		**												
Ankeny Omitted	*				**	**								

Table 10.	Summary of analysis of variance conducted on 18 variables at Morris,	
	linnesota and Ankeny, Iowa, 1968-1969	

a\*, \*\* Calculations based on 95 and 99 percent level of significance, respectively.

bY = years, L = locations, YL = years x locations, R/L = replicates per location, E = egg source, YE = years x egg source, LE = locations x egg source, YLE = years x locations x egg source, S = sex, YS = years x sex, LS = locations x sex, ES = egg source x sex, YES = years x egg source x sex, LES = locations x egg source x sex.

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Table 10. (Continued)

Nowichle	- 57		NPT-	- <del>19.71</del> -	Co	mpor	ent	teste	d <sup>a,b</sup>	770	<del> </del>		ধ্যানব	
	¥	ىل 	¥1.	к/ L		<u>ү</u> с		х L.C.	د 	12	<u></u> СЦ	<u>г</u> р	<u>тео</u>	<u>معيا</u>
Days to 80 percent emergence by sex 1969 omitted Ankeny omitted Adults tranned in		*			**	**	*		**	**		* *	**	
tunnels	*	**			**		**							
trapped	*	**		*	*		**							

			Mean forms which survived and percent survival per mating $(9 \times 4)$								
Year	Location	Variable	Ala. x Md.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md. x Md.	Minn. x Minn.
1968	Morris, Minn.	Mean Mean %	41 11	41 12	54 15	47 13	29 8	34 9	47 13	53 15	26 7
	Ankeny, Iowa	Mean Mean %	81 23	73 20	72 20	25 7	80 22	50 14	64 18	74 21	15 4
1969	Morris, Minn.	Mean Mean %	34 10	30 8	28 9	17 6	48 15	41 12	31 9	32 9	28 10
	Ankeny, Iowa	Mean Mean %	92	6 2	2	5 1	7 4	7 2	3 1	б 2	3 1

Table 11. Average number and percent of forms which survived for progenies of nine matings of European corn borer at two Midwest locations, 1968-69

		-				-					
			I	Percent survival per mating (9 x 3) by replicate							
Year	Location	Rep.	Ala. x Md.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md. x Md.	Minn. x Minn.
1968	Morris, Minn.	I II III IV	12 7 14 11	7 20 8 11	29 13 12 6	15 9 11 17	17 3 5 7	20 8 4 6	16 8 14 15	20 18 9 12	17 4 4 4
	Average		11	12	15	13	8	9	13	15	7
	Ankeny, Iowa	I II III IV	26 23 24 17	27 18 20 16	28 16 22 14	7 5 10 6	24 29 12 23	22 21 9 4	22 29 9 11	32 12 23 16	3 3 6 3
	Average		23	10	14	7	22	14	18	21	4
1969	Morris, Minn.	II II III IV	8 9 12 9	12 8 6 7	10 7 8 11	12 6 2 4	10 14 12 21	13 13 13 10	8 5 14 8	12 5 10 9	11 12 12 6
	Average		10	8	9	6	15	12	9	9	10

Table 12. Percent survival per replicate for progenies of nine matings of European corn borer at two Midwest locations, 1968-1969

Table 12. (Continued)

Year	Location	Rep.	Ala. x Md.	Md. Md. X Ala.	surviv Ala. x Minn.	Minn. X Ala.	Md. X Minn.	(♀ x ♂) Minn. x Md.	by re Ala. x Ala.	Md. Md. X Md.	.te Minn. x Minn.
1969	Ankeny, Iowa Average	I II III IV	2 1 3 3 2	1 1 2 2 2	1 0 0 1 0	1 1 1 2 1	3 1 1 12 4	2 1 1 4 2	1 0 1 1 1	2 0 2 3 2	1 1 0 1

Reciprocal mating (ද x ď)	Morris, Minr Mean % survival	P. pyraustae index <sup>a</sup>	Ankeny, Iowa Mean % survival
Ala. x Md.	11	1.961	23
Md. x Ala.	12	7.884	20
Ala. x Minn.	15	15.688	20
Minn. x Ala.	13	19.610	7
Md. x Minn.	8	31.376	22
Minn. x Md.	9	19.610	14
Ala. x Ala.	13	5.883	18
Md. x Md.	15	5.883	21
Minn. x Minn.	7	78.440	4

Table 13. Average percent of forms which survived for progenies of nine matings compared with infection index of <u>P. pyraustae</u> at two Midwest locations, 1968

<sup>a</sup>Index: 0 = none infected, 100 = all individuals heavily infected.

heavy <u>P</u>. <u>pyraustae</u> infection, respectively. Table 35 was developed by recording the maximum and minimum temperatures, the precipitation, and the photophase for each day from egg hatch until at least 45 days after egg hatch. After this period, on the average, 80 percent adult emergence for all nine matings had occurred. These two characters and day of average first adult emergence are included in the table along with a summation of borer degree days starting with day of hatch. Survival (Table 11) at Morris, Minn. of progenies of Ala. x Md., Md. x Ala., Ala. x Minn., Minn. x Ala., Md. x Md., and Ala. x Ala. was less in 1969 than in 1968. However, survival was greater between years for Md. x Minn., and Minn. x Md. but remained similar for Minn. x Minn. Scrutinization of Table 13 reveals that in 1968 the populations of these three matings had high P. pyraustae infection. The populations with the lowest survival at Ankeny were Minn. x Minn., Minn. x Ala., and Minn. x Md. with 4, 7, and 14 percent survival, respectively. Each population with low survival at each location had Minnesota parentage in common. The data suggests that P. pyraustae infection was responsible for the lower survival and that the effect exerted by the organism was more pronounced on populations with Minnesota parentage, but, the response was influenced by ecological conditions.

A comparison, between years, of the maximum and minimum temperatures which occurred at Ankeny during borer development show the first week in 1969 was very hot and although the amount of precipitation which fell during the first week was similar in both years, the days within which it occurred were not. Note that Table 33 shows that one day after hatch almost one inch of rain fell in 1969.

Reciprocal matings differed significantly for the total

number of corn borer tunnels and the number of tunnels per Table 14 presents a summation of the tunnels borer form. caused by the corn borer over years and locations. This table also presents the differences between the number of tunnels found in 1968 and 1969. Where the 1969 number is larger, the difference is prefixed with a plus (+) sign. In 1969, fewer or the same number of tunnels were produced at Morris for all matings except Minn. x Minn. and the two reciprocal matings of Minnesota and Maryland, and far fewer tunnels were produced at Ankeny. These results are dependent on the fact that on the whole there was less survival in 1969. Examination of the average tunnels per borer form shows that there was a slight trend for this variable to increase at both locations in 1969. The data on the location of tunnels on the corn plants; above the ear, in the ear and shank, and below the ear, were analyzed in 1969 (Table 36). Matings (egg source) produced significantly different numbers of tunnels above the ear at Morris, Minnesota. Those matings which showed a trend toward increased tunnel production above the ear were Minn. x Md., and Md. x Minn. which produced an average of 23.3 and 25.0 tunnels per six plants, respectively.

Percent diapause and incidence of diapause are presented in Tables 15 and 34. The summary analysis (Table 10) shows that matings and years were significantly different for

		Matin	ng (♀ x ♂)	
Year	Ala. x Minn.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.
				<u></u>
			Ave	rage number of
1968 1969 Mean dif-	52.5 41.2	50.0 39.2	42.5 41.5	36.0 33.2
ference	11.2	10.7	1.0	2.7
			Ave	rage number of
1968 1969 Maan dif	85.7 13.7	75.0 10.7	65.7 8.2	38.0 9.7
ference	72.0	64.2	57.5	28.2
			Average numb	er of tunnels
1968 1969	1.4 1.3	1.4 1.3	1.0 3.9	0.8 1.7
ference	0.1	0.2	+ 2.9	+ 0.9
			Average numb	er of tunnels
1968 1969 Maan dif	1.1 1.6	1.1 2.2	0.9 6.1	1.5 2.0
ference	+ 0.6	+ 1.1	+ 5.2	+ 0.5

Table 14.	Average tunnels per six plants and tunnels per borer form for nine matings of European corn borer at two Midwest locations, 1968-69

		Mating ( º x J	)	
Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md. x Md.	Minn. x Minn.
tunnels.	Morris, Minnes	ota		
41.2 53.0	36.7 53.2	39.7 39.0	49.0 36.2	39.5 53.5
-11.7	+16.5	0.7	12.7	+14.0
tunnels,	Ankeny, Iowa		·	
76.0 9.7	57.0 11.7	66.0 8.7	69.7 11.2	24.0 5.7
66.2	45.2	57.2	58.5	18.2
per bore:	r form, Morris,	Minnesota		
1.6 1.3	1.3 1.4	0.9 1.4	0.9 1.2	1.8 1.4
0.4	+ 0.1	+ 0.6	+ 0.3	0.4
per bore:	r form, Ankeny,	Iowa		
1.0 1.8	1.4 2.0	1.2 3.1	1.0 1.2	1.6 2.5
+0.8	+ 0.6	+ 1.9	+ 0.1	+ 0.9
<del></del>				

Year	Location	Rep.	Percent or Ala. x Md.	f surviving Md.x Ala.	larvae that Ala. x Minn.
1968	Morris, Minn.	I II III IV	13 7 0 5	4 1 0 5	19 17 10 35
	Average		б	3	20
	Ankeny, Iowa	I II III IV	0 0 1 2	0 0 1 0	9 5 2 8
	Average		0	0	6
1969	Morris, Minn.	I II III IV	7 3 14 12		46 46 54 62
	Average		9	0	52
	Ankeny, Iowa	I II III IV	62 0 33 36	0 20 11 0	50 0 100 100
	Average		33	8	62

Table 15. Percent of surviving larvae that entered diapause per replicate for progenies of nine matings of European corn borer at two Midwest locations, 1968-69

entered d	liapause per	mating (9	x c) by re	eplicate	
Ala.	Ma. X	Minn. x	Ala. X	Md. x	Minn. X
	Minn.	Md.	Ala.	Md.	Minn.
19	18	13	2	3	70
25	9	7	7	2	87
15	11	29	4	0	87
6	23	15	0	5	69
16	15	16	3	2	78
8	21	28	0	1	64
26	9	14	2	0	62
17	16	28	3	1	61
14	8	13	2	7	58
16	14	21	2	2	61
47	44	30	11	4	87
33	52	60	6	18	93
44	53	49	4	3	100
40	29	65	13	3	100
41	45	51	8	7	95
50	45	100	25	50	100
0	50	50	0	50	100
60	80	60	0	0	100
29	44	57	0	· 33	100
35	55	67	6	44	100 ·

these two variables. The percent diapause, by year, of the progenies for the nine matings was plotted in a north (Minn. x Minn.) to south (Ala. x Ala.) arrangement and is illustrated in Figures 9 and 10. The least significant difference method was used to determine the difference between two means (Steel and Torrie, 1960) within the same year and location. The difference was found to be 12.26 at the 5 percent level of confidence. The same method was used to determine the difference between two means within the same location but different years. The calculated figure is 7.23 at the 5 percent level of confidence. During 1968 the Minnesota parent exerted some influence on enhancement of diapause of progenies of every mating with which it was involved. However, conversely it can be said that when Alabama or Maryland parentage was involved with Minnesota parentage they exerted a greater influence on the reduction of the incidence of diapause of the  $F_1$  progenies. Incidence of diapause between reciprocal matings of Alabama and Maryland was similar to the parent types, very low. In 1969 a much greater influence was exerted by the Minnesota parentage on the incidence of diapause of  $F_1$  progenies. Climatological data presented in Tables 16 and 35 show that at hatch the average photophase was 11 min shorter in 1969 than in 1968 at Morris and Ankeny. By the date of average emergence of the first adult the difference had

Figure 9. The percent diapause of progenies of nine matings of European corn borer, Morris, Minnesota, 1968-69



Figure 10. The percent diapause of progenies of nine matings of European corn borer, Ankeny, Iowa, 1968-69





Location	Year	Day of development	Date	Temper (° Max	rature F) Min
Morris, Minn.	1968	34 35 36 78 39 41 42 44 56 78 90 41 456 78 90 55 55 55 55	Aug. 5678910112131415161718192223	91 876 98995301 928580 788768580 7514 979	649965362920784565987
	1969	36 35 36 37 38 39 41 42	12 13 14 15 16 17 18 19 20	89 92 85 88 90 83 78	62 695 557 561 554 556

Table 16. Temperature, moisture, and photophase during periods of pupation and adult emergence of progenies of nine matings of European corn borer at two Midwest locations, 1968-69

<sup>a</sup>Average 1st emergence.

<sup>b</sup>Average 80 percent emergence.

Accumulated borer degree days	Pre	cipitation (inches) Accumulated	Photo Hr	ophase Min
663.5 691.5 724.0 751.5 778.5 802.5 812.0 818.0 833.0 853.5 859.5 867.0 889.0 905.0 917.5 933.0 951.0 972.5 1002.5 1025.5	1.26 0.01 0.01 0.01 0.87 0.01 0.34 0.01	2.29 2.30 2.31 3.18 3.19 3.53 3.54	$\begin{array}{c} 14\\ 14\\ 14\\ 14\\ 14\\ 14\\ 14\\ 14\\ 14\\ 14\\$	385308529742853074185 555445
762.0 792.5 812.0 833.0 856.5 882.0 901.0 919.5 936.5	0.04	2.84	14 14 14 14 14 14 13 13	17 14 12 8 5 3 0 57 54

Location	Year	Day of development	Date	Temper (° Max	rature F) Min
Morris, Minn. (cont)	1969	43 44 45 46 47 48 49	Aug. 21 22 23 24 25 26 27	82 82 84 85 86 90	59 538 56 58 61
Ankeny, Iowa	1968	34 <sup>a</sup> 35 36 37 38 39 41 42 43 45 46	3 4 56 7 8 90 11 12 13 14 15	82 81 94 83 82 82 87 75 87 83	6614935216916 77655216916
	1969	34 35a 36 37 38 39 40 41 <sup>b</sup> 42	13 14 15 16 17 18 19 20 21	87 87 84 74 86 87 87 87 69	68 553 60 65 66 65 63

Accumulated borer degree days	Pre Daily	ecipitation (inches) Accumulated	Photo Hr	ophase Min
957.0 974.5 995.0 1015.0 1036.5 1060.5 1086.0			13 13 13 13 13 13 13	51 48 45 36 33
757.0 780.5 807.5 840.0 871.5 788.5 913.0 936.0 946.5 962.0 980.5 1004.5 1029.0	0.01	4.58	14 14 14 14 14 14 14 14 13 13 13	20 16 14 97 52 08 553 53
826.5 850.0 869.5 888.0 911.0 936.5 962.5 989.5 1005.5	0.05 0.08 0.14	5.95 6.03 6.17	13 13 13 13 13 13 13 13 13	58 553 48 44 398 38

.

increased to 22 min at Morris and 25 min at Ankeny.

The data show that in 1968 with photophases of 14 hr 30 min to 13 hr 57 min and 14 hr 20 min to 13 hr 55 min and accumulated degree days of 751.5 to 933, and 757 to 1004.5 at Morris and Ankeny, respectively, most progenies of 8 of the 9 matings pupated and emerged as adults. However, in 1969, with photophases of 14 hr 8 min to 13 hr 42 min and 13 hr 55 min to 13 hr 39 min with accumulated degree days of 833 to 1015 and 850 to 989.5 at Morris and Ankeny, respectively, 50 percent of the individuals of each of the progenies which involved Minnesota parentage entered diapause. Accumulation of borer degree days in the 833 to 1015 range were not enough to overcome the effect of the short day length.

The differences in incidence of diapause that exist between progenies of Alabama or Maryland parentage at Ankeny in 1969, might be involved with the low survival at that location. However, an examination of Table 11 shows that the mean survival of Ala. x Ala., Md. x Md., and Ala. x Md. at Ankeny in 1969, was 3, 6, and 9 forms per six plants, respectively, but data in Table 17 shows that for the three matings, the mean number of borers that pupated per six plants was 3, 5, and 6, with percentages of 94, 79, and 67, respectively. The performance of the progenies of these three matings at both locations in 1968 and at Morris in 1969 would indicate that Alabama and Maryland types are

			Mean forms and percentage which pupated per mating ( q x ්)									
Year	Location	Variable (pupation)	Ala. x Md.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md. x Md.	Minn. x Minn.	
1968	Morris,	Mean	39	40	44	40	24	29	46	52	7	
	Minn.	Mean %	94	97	80	84	85	84	97	98	22	
	Ankeny,	Mean	81	73	68	21	70	39	64	74	6	
	Iowa	Mean %	99	100	94	84	86	79	98	99	39	
1969	Morris,	Mean	31	30	16	13	30	22	30	31	2	
	Minn.	Mean %	91	100	48	59	43	49	92	93	5	
	Ankeny,	Mean	6	5	1	3	3	2	3	5	0	
	Iowa	Mean %	67	92	38	65	45	33	94	79	0	

Table	17.	Average	number	and	perc	ent	of	pupae	for	progenies	of	nine	matings	of
		Europear	corn	borer	at	two	loc	ations	s, 19	968-69				

•

very similar. However, the results at Ankeny in 1969 indicate that under a photophase range of 13 hr 55 min to 13 hr 39 min with an average thermoperiod range of 61.7 to 85.1° F there may be developmental differences between the two. Table 18 summarizes and compares mean number and percent diapause between the nine populations over years and locations. At Ankeny, in 1969, diapause of the  $F_1$ progenies of Ala. x Minn. was intermediate between the parent types whereas the diapause response of the  $F_1$  population of Minn. x Ala. tends toward the lower percent diapause of the Alabama parent. Both F7 reciprocal progenies of Maryland and Minnesota show intermediate diapause response when compared to the parent types. The diapause response of the F<sub>1</sub> progenies of Alabama and Maryland differ, the Ala. x Md. response tend toward Md. x Md. and the Md. x Ala. response is similar to Ala. x Ala.

The adults which emerged within each cage at each location over both years were collected daily and recorded by sex. Since a laboratory experiment showed that the progenies and parents used in the study produced 55 to 45 percent males to females and followed chi-square, the hypothesis was tested on the adults collected at both field locations over both years. The observed and expected values along with the contribution to chi-square are presented in Table 19. Each of the 144 observations, with 1 degree of

	Moi 1968	ris, I Mean	Minneso 1969	ta Mean	1968	Ankeny, Mean	Iowa 1969	Mean
Matings (° x ď)	No.	%	No.	%	No.	%	No.	%
Ala. x Ala.	1	3	2	8	. 1	2	0.3	6
Minn. x Minn.	20	78	26	95	9	61	3	100
Ala. x Minn.	10	20	12	52	5	б	l	62
Minn. x Ala.	7	16	4	41	4	16	2	35
Md. x Md.	l	2	l	7	, <b>1</b>	2	2	21
Minn. x Minn.	20	78	26	95	. • 9	61	3	100
Md. x Minn.	5	15	18	45	14	14	4	54
Minn. x Md.	5	16	9	51	12	21	5	67
Ala. x Ala.	l	3	2	8	1	2	0.3	6
Md. x Md.	1	2	1	7	1	2	2	21
Ala. x Md.	3	6	3	9	1	1	3	33
Md. x Ala.	1	3	0	0	0.3	0.3	1	8

Table 18. Comparison of mean number and percent diapause between nine populations of European corn borer at two Midwest locations, 1968-69

		Reciprocal matings ( a d						
Toostion		Ala	. X	Md.	x	Ala	a. X	
and vear	Rep.	۱۳۱ ۲	ບ. ູ້	AIA Ŷ	്	1 <sup>1</sup> 1. 우	്	
						01	bserved	
Morris, Minn. 1968	I	14	20	10	10	29	53	
2,000	II	9	11	37	32	23	14	
	III	18	28	17	9	18	19	
	IV	21	16	13	19	7	5	
Average		16		19	- 0	19		
			19		18		23	
						E	xpected	
	I	19	15	11	9	45	37	
	II	11	9	38	31	20	17	
	III	25	21	14	12	20	17	
	IV	20	17	18	14	7	5	
Average		19	70	20	- 6	23	10	
			ΤO		17		19	
						Contr	ibution	
	I	2.98		0.	0.20		12.61**	
	II	0.	0.81		0.06		0.98	
	III	4.	29*	1.	39	• . (	0.43	
	IV	Ο.	11	3.	17	(	0	

Table	19.	Observed and expected values of males to females
		for nine matings of European corn borer at two Midwest locations, 1968-69

 $a_X^2 = 3.84*$  at .05 and 6.63\*\* at .01 probability with 1 df.

.
			R	ecipr	ocal	mating	s (º	х б)			
Min	n. x	Md.	X	Min	n. x	Ala	. X	Md.	x	Minr	1. X
б ЧТ	డ. ర్	Min Ŷ	മ. ര്	۲۹ ۱۹۱	.α. ດ້	AT Ş	ය. ර්	Pia S	ੱ	· 우	າກ. ຮ້
		· · · · · · · · · · · · · · · · · · ·		<u> </u>							
$\frac{\sqrt{21}}{17}$	23	15	26	27	31	27	27	28	33	11	7
11	11	2	8	12	14	10	15	26	33	l	1
19	12	7	4	4	5	19	22	12	13	2	0
26	31	9	10	5	8	24	25	21	18	2	2
18	19	8	13	12	15.	20	22	22	24	4	3
val	values										
22	18	23	18	32	26	30	24	36	27	10	8
12	10	6	- 4	14	12	14	11	32	27	l	l
17	<b>1</b> 4	6	5	5	4	22	18	1 <b>4</b>	11	1	l
31	26	10	9	7	б	27	22	21	18	2	2
21	17	11	9	15	12	23	19	26	21	4	3
to	chi-so	luare <sup>a</sup>	,								
2.	52	6.	34*	1.	74	0.	67	3.	11	0.2	22
٥.	18	6.	67**	٥.	62	2.	60	2.	46	0	
0.	0.52 0.37		Ο.	45	l.	30	0.65		2.00		
1.	76	٥.	21	1.	24	Ο.	74	0		0	

			Recip	procal matings (9 x d)				
Location		Ala M	. x d.	Md. Ala	x	Ala M'	inn.	
and year	Rep.	ę	ď.	Ŷ	්	Ŷ	්	
Ankeny, Iowa	Ĩ	42	51	45	51	57	34	
1968	II	35	47	33	31	26	27	
	III	36	48	31	4ı	38	40	
	IV	28	30	32	33	28	18	
Average		35	44	35	39	37	30	
						Ext	<u>pected</u>	
	I	51	42	53	43	50	41	
	II	45	37	35	29	29	24	
	III	46	38	40	32	43	35	
	IV	32	26	30	25	25	21	
Average		44	36	40	32	27	30	
	_					Contril	oution	
	I	3.	52	2.	69	2.	.17	
	II	4.	92*	0.	25	. 0.	.68	
	III	4.	80*	4.	55*	1.29		
	IV	1.	11	2.	69 <sup>.</sup>	0.	79	

Table 19. (Continued)

Min	n. x	Md.	Re x	cipro Minn	cal :	mating Ala	s (º . x	x ♂) Md.	x	Minn	. x
Al º	a. ో	Min Ŷ	n. ď	Md ₽	a. Al d P		a. ď	Md Ş	ీ. రీ	Min ♀	n. đ
val	1165										
14	10	27	42	29	28	37	42	54	59	2	2
6	8	56	38	33	31	51	52	22	22	0	5
14	15	10	25	8	14	17	12	25	56	4	4
8	9	38	37	8	4	16	24	21	33	2	3
11	11	. 33	36	20	19	30	33	31	43	2	4
val	ues										
13	11	38	31	31	26	43	36	62	51	2	2
8	6	52	42	35	29	57	46	24	20	3	2
16	13	19	16	12	10	16	13	45	36	4	4
9	8	41	34	7	5	22	18	30	24	3	2
12	10	28	31	21	18	35	28	40	33	3	2
to	chi-sq	uare							•		<u></u>
0.	17	7.	09**	0.	28	l.	84	2.	29	0	
1.	17	0.	69	0.	25	1.	41	٥.	37	7.	50**
0.	56	9.	32**	2.	93	0.	14	20.	00**	0	
0.	24	0.	48	0.	34	3.	64	6.	.07*	Ο.	83

Table 19. (	(Continued)	)
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		Reciprocal matings (9 x d)							
Togetion		Ala. x	Md. x	Ala. x					
and year	Rep.	۲ م. ۲ م.	Ala. ۶ م	۹ مراجع ۲					
				Obconvod					
Morris, Minn.	I	12 16	13 27	<u>14</u> 5					
1909	II	11 18	13 16	9 4					
	III	11 24	7 12	. 75					
	IV	12 13	12 10	87					
Average		12 18	11 16	10 5					
	_			Expected					
	I	15 13	55 18	10 9					
	II	16 13	16 13	76					
	III	19 16	10 9	75					
	IV	14 11	12 10	87					
Average		16 13	15 13	8 7					
	I	1.29	8.18**	Contribution 3.38					
	II	3.48	1.25	1.24					
	III	7.37**	1.90	0					
	IV	0.65	0	O					

			R	ecipr	ocal	mating	s (º	х б)			
Min	n.x	Md.	X	Min	n. x	Ala	. X	Md.	x	Minr	1. X
A L Q	а. ~	Min o	n. đ	Ó Ial	α. 	A1 Q	a.	рМ С	•	Mlr. Q	in. ď
+				+							
val	ues										
8	15	14	5	19	12	12	11	19	20	3	1
б	7	10	14	7	11	12	5	4	6	2	1
3	2	11	8	15	6	7	23	12	21	0	0
2	7	27	24	3	8	• 9	15	12	19	0	0
5	8	16	13	11	9	10	14	12	17	1	0
val	ues										
13	10	10	9	17	14	13	10	21	18	2	2
7	6	13	11	10	8	9	8	6	4	2	1
3	2	10	9	12	9	26	21	18	15	0	0
5	4	28	23	6	5	13	11	17	14	0	0
7	6	15	13	11	9	15	13	. 16	13	1	1
to	chi-so	luare									
4.	42*	3.	38	0.	52	0.	18	0.	41	1.0	00
0.	31	l.	51 .	2.	02	2.	12	1.	67	0	
0		٥.	21	l.	75	14.	07**	4.	40*	0	
4.	05*	0.	08	3.	30	2.	68	3.	26	0	

		H	Reci	orocal m	cocal matings (9			
Tocation		Ala	. X	Md.	x	Ala	• X	
and year	Rep.	ę	ਰ ਹ	ç Ç	ਿ	ç Ş	ే 	
Ankeny, Iowa	I	2	1	0	2	1	0	
1909	II	2	. 5	1	3	1	0	
	III	5	3	4	4	0	0	
	IV	5	2	5	2	0	0	
` Average		4	2	3	3	0.	5 0	
	т		<u> </u>		<del></del>	Ex	pected	
	Ţ	2	1	Ţ	T	Т	0	
	II	2	2	2	2	l	0	
	III	4	4	4	4	0	0	
	IV	4	3	4	3	0	0	
Average		3	3	3	3	0.	5	
	_					Contrib	ution	
	T	0		2.	00	0		
	II	0		1.	00	0		
·	III	0.5	50	· 0		0		
	IV	0.5	58	0.	58	0		

Table 19. (Continued)

Min	n. x	Md	Re	ecipro Min	ocal m	ating Ala	s (우	x ď) Md.	x	Mini	<u>n. x</u>
Al Ŷ	a. J	Mir Ş	nn. ơ	Mo P	d. 	Ala Ŷ	ā. oʻ	Md 9	్	Min Ŷ	nn. ď
val	ues										
1	1	3	3	0	0	0	3	1	2	0	0
0	3	0	l	0	l	l	0	0	0	0	0
1	1	0	l	l	1	1	2	3	3	0	0
3	2	4	l	3	3	2	3	3	5	· 0	0
1	2	2	2	1	2	l	2	2	3	0	0
val	ues										
1	1	3	3	0	0	2	1.	2	1	0	0
2	1	1	0	l	0	l	0	0	0	0	0
1	1	l	0	l	l	2	1	3	3	0	0
3	2	3	2	3	3	3	2	4	4	0	0
2	1	2	l	l	1	2	i	2	2	0	0
to	chi-so	luare									
0		0		0		5.9	90*	1.	50	0	
6.	00*	18.9	95**	18.	95**	0		0		0	
0		18.9	95**	0		1.	50	0		0	
0	0 0.83		33	0		0.8	33	0.50		0	

freedom, was tested in order to determine the existence of a possible trend. The differences which occurred might be construed as a slight trend for the populations with a low incidence of diapause to produce more females and those with a relatively high incidence of diapause to produce more males and therefore not to follow chi-square. The number of adults which emerged is presented in Tables 19 and 34. Statistical evaluation of the data (Tables 10 and 36) show that this variable responded differently over years and matings (egg source). More adult moths emerged at Ankeny in 1968, however, because of the poor survival at Ankeny, more moths were collected at Morris in 1969. Duncan's new multiple range (Snedecor, 1956; Steel and Torrie, 1960) is a test which allows a comparison between all treatment means. This test has been criticized, according to Dr. David Jowett (personal communication)<sup>1</sup> because it allows significant differences which are false. However, the analysis of variance (Tables 10 and 36) made on the numbers of emerged adults shows us that this variable is significant for egg source and interactions involving egg source. Therefore, it seems reasonably sound to use Duncan's procedure to test for differences between means,

<sup>&</sup>lt;sup>1</sup>Dr. David Jowett, formerly Experiment Station statistician, Iowa State University of Science and Technology, Ames, Iowa. Presently University of Wisconsin, Green Bay, Wisconsin. Duncan's New Multiple Range, March 1970.

of the matings, combined over locations but within years. Table 20 presents the results of ranked means tested by Duncan's method. Any two means not underscored by the same line are significantly different. In 1968, the Minn. x Minn. mating produced significantly fewer moths than any of the other mating combinations. Three of the matings in which there was Minnesota parentage produced similar results but when the Minnesota male was involved the  ${\rm F}_{\rm l}$  progenies tended to be more like the matings with Alabama or Maryland parentage. Both reciprocals of Maryland and Minnesota were intermediate to the parent types. In 1969, there was a realignment and both matings in which Alabama was involved with Minnesota were intermediate between the two parents but statistically similar to the progeny of both parents. This suggests that shorter day length allows the Minnesota type to exert greater influence on enhancement of the diapause response.

It was September before 100 percent adult emergence was achieved at either location in both years, therefore, to avoid the tailing effect characteristic of this variable, it was discarded in favor of date to 80 percent adult emergence. This variable was calculated by multiplication of the total number of emerged moths by 80 percent, the day of hatch to the time that number occurred was the day of 80 percent emergence. This variable was examined for

Year	Reciprocal mating (9 x d)										
	Minn. x Minn.	Minn. x Ala.	Minn. x Md.	Md. x Minn.	Ala. x Ala.	Md. x Ala.	Ala. x Minn.	Ala. x Md.	Md.x Md.		
1968	6.00	28.50	32.62	44.25	52.50	54.25	54.50	56.75	59.50		
	Minn. x Minn.	Ala. x Minn.	Minn. x Ala.	Minn. x	Ala. x	Md. x Minn.	Md.x	Md. x	Ala. x Md.		
1969	0.87	7.62	7.75	11.25	15.37	15.75	16.25	16.37	17.37		

Table 20. Array of means showing number of emerged adults, per six plants, by years

differences between populations with the number of each sex combined and separated. Because of the low numbers at Ankeny in 1969, this location for this year was dropped. There were significant interactions, namely; location x egg source and egg source x sex, in 1968. The average number of days to 80 percent emergence for progenies of all matings was 43.9 at Ankeny and approximately 4.5 days later, or 48.4 days at Morris. Figure 11 presents the mean number of days to 80 percent adult emergence at the two locations in 1968. The data were plotted in a north (Minn. x Minn.) to south (Ala. x Ala.) arrangement. Time of emergence appears much more erratic at Morris. However, the photophase and accumulated borer degree ranges for the two locations during this period (Table 16) were 14 hr 5 min to 13 hr 48 min with 889 to 1,002.5 degree days and 14 hr 2 min to 13 hr 55 min with 946.5 to 1,004.5 degree days at Morris and Ankeny, respectively. Accumulated precipitation for this period was 1.23 and 0 inches for Morris and Ankeny, respectively. Days to 80 percent emergence varied between years at Morris (Figure 12). In 1969 the number of days to 80 percent emergence dropped considerably for the progenies of Minn. x Minn. and the reciprocals in which Minnesota was a parent. The Alabama and Maryland parents and the reciprocals of the two remained similar over years. Table 16 shows that photophase and accumulated borer degree

Figure 11. Days to attain 80 percent adult emergence for progenies of nine matings of European corn borer, Ankeny, Iowa and Morris, Minnesota, 1968



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Figure 12. Days to attain 80 percent adult emergence for progenies of nine matings of European corn borer, Morris, Minnesota, 1968-69



days ranged from 14 hr 8 min to 13 hr 51 min and 867 to 972.5 degree days and 14 hr 0 min to 13 hr 36 min and 901 to 1,036.5 degree days for 1968 and 1969, respectively. When borer degree days are used as an index for comparison of parent types, the following becomes apparent (Figure 12 and Table 16): Eighty percent emergence for progenies of Minn. x Minn. occurred between 867 (1968) to 901 (1969), Md. x Md. between 889 (1968) to 1,015 (1969) and Ala. x Ala. between 917.5 (1968) and 1,060.5 (1969) borer degree days. The F<sub>1</sub> progenies of Md. x Minn. and Minn. x Md. showed the greatest difference, 7 and 8 days, respectively, between years in days to 80 percent emergence. When borer degree days are used as a measuring device to compare 80 percent emergence of these two sets of progenies, Minn. x Md. required 936.5 (1969) to 951 (1968) and Md. x Minn. required a very narrow range of 951 (1968) to 957 (1969) borer degree days.

Table 21 presents the mean number of days to 80 percent emergence of females and males for each mating. The difference in the length of time for males and females to attain this level of emergence was calculated for both years for Morris, if males took longer than females to attain 80 percent emergence the difference is expressed with a minus (-) sign. There are five such signs in 1968 and one in 1969. The difference in the time it took females and males

		Matings (° x ď)								
Year	Sex	Ala. x Md.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md. x Md.	Minn. x Minn.
1968	Female	43.00	49.50	47.00	45.75	53.00	50.00	49.75	46.50	44.25
	Male	46.75	46.50	48.25	46.00	48.75	50.50	48.00	46.00	47.50
Days	difference	- 3.75	3.00	- 1.25	- 0.25	4.25	- 0.50	1.75	0.50	- 3.25
1969	Female	46.25	49.50	46.25	49.29	43.75	43.00	47.50	47.00	43.00
	Male	46.25	45.00	44.50	40.00	43.00	41.25	48.50	45.25	37.00
Days	difference	0	4.50	1.75	9.29	0.75	1.75	- 1.00	1.75	6.00

Table 21. Mean number of days to 80 percent emergence of females and males at Morris, Minnesota, 1968 and 1969

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to reach this level increased sharply in 1969 for progenies of matings which involved Minnesota parentage. Progenies of the Minn. x Minn. mating attained 80 percent emergence six days earlier than in 1968. Progenies of reciprocal matings which involved Minnesota parentage also tended to take fewer days to attain this level of emergence in 1969. Figures 13 and 14 shows graphically that the days necessary to attain 80 percent emergence, exhibited by progenies of Minnesota parentage, is expressed primarily by the male.

The photophase and borer degree day accumulation ranges for females to attain 80 percent emergence were 14 hr 14 min and 13 hr 45 min with 853 to 1,025.5 degree days and 13 hr 51 min to 13 hr 33 min with 957 to 1,086 degree days in 1968 and 1969, respectively. A comparison of accumulated borer degree days for females of specific matings to attain 80 percent emergence indicates (Figure 15 and Table 16) that Minn. x Minn. required a range of 859.5 (1968) to 957 (1969), Md. x Md. 889 (1968) to 1,036.5 (1969), and Ala. x Ala. 933 (1968) to 1,036.5 (1969) degree days, respectively. The spread of the accumulated borer degree day ranges necessary to attain 80 percent emergence of females, were 97.5, 103.5, and 147.5 degrees for Minn. x Minn., Ala. x Ala., and Md. x Md., respectively. Females that developed from the reciprocal crosses of Minn. x Md. or Md. x Minn. required borer degree ranges of 951 (1968) to 957 (1969)

Figure 13. Days to attain 80 percent emergence for female progenies of nine matings of European corn borer, Morris, Minnesota, 1968-69



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Figure 14. Days to attain 80 percent emergence for male progenies of nine matings of European corn borer, Morris, Minnesota, 1968-69

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Figure 15. Borer degree day accumulations to attain 80 percent emergence for female progenies of nine matings of European corn borer, Morris, Minnesota, 1968-69



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and 957 (1969) to 1,025.5 (1968), respectively. Those females from Minn. x Ala. or Ala. x Minn. required 867 (1968) to 1.086 (1969) and 905 (1968) to 1.015 (1969) degree days, respectively. The spread of degree days within the ranges were 6 and 68.5 for Minn. x Md. and Md. x Minn., respectively, and 110 and 219 for Ala. x Minn. and Minn. x Ala., respectively. The degree day spread of both reciprocals was narrower than the spread for either the Minnesota or Maryland parents. However, the degree day spread of Ala. x Minn. was similar to that of both parents but the spread of Minn. x Ala. was much wider. The borer degree accumulations for  $F_1$  females of Md. x Ala. or Ala. x Md. were 933 (1968) to 1,086 (1969) and 853.5 (1968) to 1,015 (1969), respectively. The spread of degree days within the ranges were identical 151.5 and 153 for Ala. x Md. and Md. x Ala., respectively.

At Morris, Minnesota, the photophase and borer degree day accumulations for males to reach 80 percent emergence were 14 hr 5 min and 13 hr 54 min with 889 to 951 degree days and 14 hr 8 min to 13 hr 36 min with 833 to 1,060.5 degree days in 1968 and 1969, respectively. Figure 16 and Table 16 can be referred to for a comparison of accumulated borer degree days necessary for males of the various matings to attain 80 percent emergence. The males of Minn. x Minn., Md. x Md., and Ala. x Ala. required borer degree accumulations

Figure 16. Borer degree day accumulations to attain 80 percent emergence for male progenies of nine matings of European corn borer, Morris, Minnesota, 1968-69



of 833 (1969) to 905 (1968), 889 (1968) to 995 (1969), and 917.5 (1968) to 1,060.5 (1969), respectively, and the spread in accumulated degree days for the males was 72, 106, and 143, respectively. A comparison of accumulated borer degrees between females and males revealed that Minnesota males have a narrower spread than females, and that the size of the borer degree spread for Alabama and Maryland males actually exchange with the respective females. The borer degree accumulations for  $F_1$  males of Minn. x Md. or Md. x Minn. are 919.5 (1969) to 951 (1968) or 917 (1968) to 957 (1969) and the spread of degree days within the ranges are 31.5 and 40, respectively. A comparison of degree day accumulations between females and males of these two reciprocals show that the males required fewer borer degree days to attain 80 percent emergence. The accumulated degree days for  $F_1$  males of Minn. x Ala. or Ala. x Minn. to reach this level ranged from 889 (1968) to 901 (1969) and 1917.5 (1968) to 974.5 (1969) with a spread of 12 and 57 degrees, respectively. A comparison of degree day accumulations between  $F_1$  females and males of these reciprocals show that fewer degrees are needed for the males to attain 80 percent emergence, and that the range in accumulated borer degree days is less. The borer degree accumulations for  $F_1$ males of Md. x Ala. or Ala. x Md. matings were 889 (1968) to 995 (1969) or 889 (1968) to 1,015 (1969) with spreads

of 106 and 126 degrees, respectively. A comparison of  $F_1$  females and males of these two reciprocals indicate the sexes are very similar.

It seemed advisable to make specific paired comparisons of means among females and males based on the days to 80 percent emergence data presented in Figures 13 and 14, respectively. The means of the borer degree accumulation ranges for females and males of all matings presented in Figures 15 and 16, respectively, were calculated and are presented in Table 22. We can infer from the comparison presented in Table 23 that females of Minn. x Minn. require an accumulation of fewer borer degrees to attain 80 percent emergence than females of either Minn. x Md. or Md. x Minn. (Figure 15). The two reciprocals appear to require degrees of temperature accumulations similar to that required by the Md. x Md. parent. Since  $F_1$  females of Minn. x Ala. required accumulations of borer degree days similar to those required for Md. x Minn. we can infer that both Minn. x Ala. and Ala. x Minn. require a greater accumulation of day degrees to attain 80 percent emergence than Minn. x Minn., and that both reciprocals are similar to the Ala. x Ala. parent. Ala. x Md. and Md. x Ala. are different and require an average of 934.25 and 1,009.5 borer degrees to attain 80 percent emergence (Table 23). The Alabama and Maryland parent type requirements are just significantly

Ala. x Md.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.	Md. x Minn.	Minn.x Md.	Ala.x Ala.	Md.x Md.	Minn. x Minn.
				Females				
934 <b>.2</b> 5	1,009.50	960.00	976.50	991.25	954.00	999.62	962.75	908.25
				Males				
952.00	942.00	946.00	895.00	937.00	935.25	989.00	942.00	869.00

Table 22. Average number of borer degree days for populations of nine matings to attain 80 percent emergence at Morris, Minnesota

	Mean number of borer degrees					
Reciprocal mating (9 x d)	Female	Male				
		. <u></u>				
Minn. x Md. Minn. x Minn.	954.00 908.25	935.25 869.00				
Difference	45.75*	66.25*				
Md. x Minn. Minn. x Ala.	991.25 976.50	937.00 895.00				
Difference	14.75	42.00*				
Md. x Ala. Ala. x Md.	1,009.50 934.25	942.00 952.00				
Difference	75 <b>.</b> 25*	- 10.00				
Ala. x Ala. Md. x Md.	999.62 962.75	989.00 942.00				
Difference	36.87*	47.00*				

Table 23. Paired comparison of mean number of borer degrees to obtain 80 percent emergence for  $F_1$  populations of eight reciprocal matings at Morris, Minnesota

\* \$ standard error of difference =  $\sqrt{2(922.72)/9}$  = 14.32, d standard error of difference =  $\sqrt{2(1,042.10/9)}$  = 15.22 with 8 df,  $t_{05}$  d  $\bar{x}$  \$ = 2.306 (14.32) = 33.021 and  $t_{05}$  d  $\bar{x}$  d = 2.306 (15.22) = 35.092.

different from one another at the 95 percent level of confidence (Table 23).

A study of the data presented in Figure 16 and the means and comparison between means in Tables 22 and 23, respectively, show that males of Minnesota require fewer borer degrees to obtain 80 percent emergence than those of either Minn. x Md. or Md. x Minn. The similarities of borer degree requirements of the males of these two reciprocals to those of the males of Md. x Md. are more striking than were those for the females of these three matings. However, because Minn. x Ala. require fewer borer degrees than Md. x Minn. to attain 80 percent emergence (Table 23) it can be inferred that the  $F_1$  males of the Minn. x Ala. mating also require an accumulation of fewer degrees than Ala. x Minn. or Ala. x Ala. The  $F_1$  males of Md. x Ala. and Ala. x Md. require an average of 942 and 952 borer degree days, respectively, which are similar to each other and to the Md. x Md. parent, average requirement of 942 degrees. The male borer degree requirements of Ala. x Ala., 989, are significantly higher than those of Md. x Md., 942.

Therefore, the results presented in Figures 12, 13, and 14 when compared with the climatological data presented in Table 16 and expressed in Figures 15 and 16 show a close correlation at Morris, Minnesota for 1968 and 1969 between 80 percent emergence and specific ranges of borer degree days. The progenies of Minn. x Minn. require fewer degrees while  $F_1$  females of reciprocals of Minnesota parentage require degrees in the neighborhood of the Ala. x Ala. or Md. x Md. parents. This is also true of the  $F_1$  males of reciprocals of Minnesota, however, there are varying borer degree requirements for the  $F_1$  males of

Alabama and Minnesota. The requirements of fewer degree days to attain 80 percent emergence is primarily expressed by the males of all matings except Ala. x Ala.

Table 24 presents the averages of the number of individuals which pupated and emerged as adults for each reciprocal mating. The difference between the two variables is much sharper at the Morris location over both years. Most of this difference can be accounted for by the average number of adults which were trapped in tunnels in the corn stalks. In September, each corn stalk within each cage at each location over both years was dissected in order to obtain counts of larvae in diapause and tunnels produced. This procedure revealed that not all individuals that pupated and attained adulthood emerged from tunnels in the corn stalks. The actual numbers are presented in Table 34 and mean numbers and percentages are summarized in Table 25. The percentages were arrived at by dividing the numbers found in the tunnels by the total number of adults, emerged and trapped, and multiplied by 100. There were significant differences between years, locations, and matings (egg source). A higher percentage of adults from progenies of Maryland matings remained in the tunnels. A paired comparison of these five matings between years at Morris, Minnesota was conducted. The standard error of difference for a splitsplit plot was arrived at according to Cochran and Cox (1957)

			Mating (° x ď)								
Year	Location	Variables	Ala. x Md.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md. x Md.	Minn. x Minn.
1968	Morris, Minn.	Pupae Adults Difference	39 34 4	40 37 3	44 42 2	40 36 4	24 20 4	29 27 3	46 42 4	52 46 6	7 7 0
	Ankeny, Iowa	Pupae Adults Difference	81 79 1	73 72 1	68 67 1	21 21 0	69 68 1	40 39 1	64 63 1	74 73 1	6 6 0
1969	Morris, Minn.	Pupae Adults Difference	31 29 2	30 27 2	16 15 1	13 13 0	30 28 2	22 20 2	30 28 2	31 28 3	220
	Ankeny; Iowa	Pupae Adults Difference	6 6 0	5 5 0	1 1 0	3 3 0	3 3 0	2 2 0	3 3 0	5 5 0	0 0 0

Table 24. Average number of pupae and emerged adults for nine matings of European corn borer at two Midwest locations, 1968-69

Table 25. Mean number and percent of adults trapped in tunnels in corn stalks for progenies of nine matings of European corn borer at two Midwest locations, 1968-69

			Mean number of adults and percentage of adults in tunnels per mating (9 x d)								trapped
Year	Location	Variable	Ala. x Md.	Md. x Ala.	Ala. x Minn.	Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md. x Md.	Minn. x Minn.
1968	Morris, Minn.	Number Percent	3 9	3 10	1 5	1 4	3 10	26	2 5	4 9	0 0
	Ankeny, Iowa	Number Percent	1 1	1 1	0 0	0 0	1 1	0 2	0 2	1 1	0 3
1969	Morris, Minn.	Number Percent	8	28	0 3	0 0	2 6	2 10	1 3	2 10	0 0
	Ankeny, Iowa	Number Percent	0 0	0 0	0 0	0 0	0 0	0	0 0	0 0	0 0

from the analysis of variance presented in Table 36. The significant differences presented in Table 26 show that a higher percentage of progenies of three of the five types remained trapped in the tunnels during 1968 over 1969, however, the reverse was true for the progenies of Minn. x Md. The percentage trapped adults of the progenies of the Maryland parent remained the same both years.

Table 26. Paired comparison for percent of adults of matings (9 x 3) trapped in tunnels in corn stalks, Morris, Minnesota, 1968-69

Year	Md. x Ala.	Minn. x Md.	Ala. x Md.	Md. x Minn.	Md. x Md.
1968	10.48	6.44	8.70	9.79	8.90
1969	7.66	9.80	6.26	6.44	9.81
Difference	2.28*	+ 3.36*	2.44*	3.35*	0.91

\*Standard error of difference =  $\sqrt{2[(9-1)16.71 + 8.47]/72}$  = 1.405 with 81 df, t .05 d  $\overline{x}$  = 1.079 (1.405) = 1.5159.
# DISCUSSION

Laboratory Study of the Effects of Regimes Typical for the Parent Types on Progeny of Reciprocal Matings The primary purpose of egg production during this study was to obtain egg masses to start the colonies that were to go into the experimental regimes. Sparks et al. (1966a) in the absence of a statistical analysis of the data, empirically suggested a trend toward higher egg production when Minnesota adults were crossed with adults of other geographical origin. However, this trend did not appear during the egg production phase of this study. Females of each mating were equal in the numbers of egg masses deposited, eggs per mass, and hatch per mass. There were no difficulties in obtaining large numbers of egg masses from each of the reciprocal matings. These results strengthened Sparks' et al. (1966a) explanation that the difficulties incurred by Barber (1928) and Arbuthnot (1944) may have been due to less sophisticated techniques.

Ninety percent of the mortality of progenies of the matings occurred within the first two days of the experiment. This may be explained by the fact that moisture from the medium plug condensed around the interior of many of the vials. It was observed that soon after each newly hatched larva was placed on the plug of medium and the vial stoppered, many larvae would wander off of the plugs and onto the walls and into the droplets of moisture. The

data collected showed that percent survival was not significantly influenced by regimes and that the parent types, Alabama, Maryland, and Minnesota, sustained the highest mortality. Apparently fewer of the  $F_1$  progenies of the reciprocals wandered off of the medium plugs, or if they did, they were able to find their way back to the food supply.

Mutchmor and Beckel (1959) in laboratory studies with an Ontario population of European corn borer, found a very high incidence of diapause among borers exposed to 9.5 to 14 hr light for 24 hr and  $18.3^{\circ}$  C (65° F). Beck and Hanec (1960) conducted laboratory experiments with a Wisconsin population of European corn borer and found diapause was most effectively induced at a photoperiod range of 9 to 15 hr light. Mutchmor and Beckel (1959), Beck and Hanec (1960), Beck and Apple (1961), and Sparks (1965) showed that the diapause-inducing effect of photoperiod is temperature sensitive. Beck (1962) suggests that the temperature of the scotophase, rather than the photophase, is more important in inducing diapause in the European corn borer. The high incidence of diapause of the nine colonies, in the present study, indicates that thermoperiods of 13.3 to 28.9° C and 18.3 to 31.7° C are not high enough to offset the diapauseinducing effect of the 14 hr 55 min and 14 hr 15 min photophases, respectively.

The incidence of diapause, expressed as percent, was the character which showed the greatest difference in this experiment. In fact, incidence of diapause was so high for progenies of any matings which involved Minnesota parentage that other characters such as percent pupation, pupal weight, and days to 80 percent pupation and adult emergence could not be measured except in the 15 hr 55 min photophase and 8.3-23.3° C thermoperiod. The 14 hr 15 min photophase and 18.3-31.7° C thermoperiod was below the critical point for 50 percent diapause induction for all of the nine colonies. This regime simulates a typical June 21 day in central Alabama. Therefore, the high percentage diapause, 92, expressed by the Alabama parent type was unexpected. If this occurred during June in nature, only 8 percent of the population would contribute to the next generation. However, Eden (1956, 1959) reported that the European corn borer produced three generations a year in northern Alabama. The first developed during June, and less than 5 percent of the larvae went into diapause. Therefore, if an error has not been made in the initial handling of these nine colonies, factors other than summer photoperiods are responsible for the low incidence of diapause in central Alabama. The 14 hr 55 min photophase and 13.3-28.9° C thermoperiod simulated a typical June 21 day in Maryland. This regime was below the critical

photoperiod for the progenies of all of the nine colonies except for the Maryland parent type and two reciprocals in which Alabama was the other parent. The results show that under conditions of this regime the progenies of the Maryland type are more sensitive to photoperiod and temperature than the Alabama type and that this parental sensitivity is expressed in the  $F_1$  progenies of the two reciprocal matings. The 15 hr 55 min photophase and 8.3-23.3° C thermoperiod simulated a typical June 21 day in west central Minnesota. This regime was above the critical photoperiod for the progenies of all matings, except the Minnesota parent type. The reduced incidence of diapause of the progenies of the matings is the direct effect of the longer photophase or shorter scotophase. The high incidence of diapause of progenies of Minn. x Minn., under this regime, suggests that in nature, the Minnesota borer would normally produce one generation per year.

For the other variables tested, the largest differences were sex related. It was found for example that females outweighed males as 1-day-old pupae, female and male parents tended to affect the weight of the opposite sex of the progenies, males became pupae before females, however, the two sexes attained 80 percent adult emergence simultaneously. However, there were significant differences among the progenies of the matings. One-day-old pupae of Md. x Md.

weighed less and Minn. x Ala. more than any of the other progenies. The progenies of the four matings (Ala. x Ala., Ala. x Md., Md. x Ala., and Md. x Md.) tested under two regimes showed differences between regimes for days to 80 percent pupation and adult emergence. The reciprocals of the Alabama and Maryland parent types pupated and emerged as adults earlier than their parent types under the 14 hr 55 min photophase and 13.3-28.9° C thermoperiod. This indicates a high sensitivity by the reciprocals to light and temperature. The 1-day-old pupae of all four matings weighed more under the 14 hr 55 min photophase and 13.3-28.9° C thermoperiod. Why this was so cannot be pinpointed because light and temperature were confounded in this study. However, Sparks (1965) found an increase in weight of 10-day-old larvae of European corn borer with increased photophase and constant 28° C temperature. The weight increase in his experiment may have been attributable not to photophase, but to the increased radiant heat from the light source which would occur with the longer photophase. If this were true, then the weight increase in the present experiment which occurred in the regime with the shorter photophase but higher thermoperiod might also be attributable to heat.

During the experiment, a relatively high degree of negative phototaxis was exhibited by the pupae of Md. x Md. and Ala. x Md. matings which suggests that the parent

Maryland male is exerting an influence which is expressed by this variable. Just what this characteristic denotes in the behavior of the Maryland borer and how it would be expressed under field conditions is unknown.

The male to female ratio is 1.2:1 for all nine colonies studied under one regime and four colonies under two regimes of light and cycling temperatures. This ratio coincides with that which has been observed by this investigator for standard laboratory colonies reared under 24 hr photophase and constant temperature at the European Corn Borer Laboratory, Ankeny, Iowa.

F<sub>1</sub> Populations of Reciprocal Matings Tested in the Field

Sparks et al. (1966a) found no difference in survival between  $F_1$  populations of reciprocal matings within the same year and location. The present study demonstrated that in 1968 at Ankeny, Iowa, survival of most populations was near 20 percent except the populations of Minn. x Minn. and two reciprocals, in which the parent female was Minnesota, where less than 14 percent of each population survived. There was, in general, less survival of most populations at Morris, Minnesota in 1968. This agrees with the results of Sparks et al. (1966b) and Chiang et al. (1968) in which they found higher survival among populations at the most southern location in the experimental area. At Morris, there was a slight trend for lower percent survival for the

populations of Minn. x Minn. and the two reciprocals of Maryland and Minnesota. In 1969, however, the survival of populations of all nine matings ranged from 1 to 4 percent and 8 to 15 percent at Ankeny and Morris, respectively.

Chiang et al. (1968) suggest conditions responsible for survival difference may include temperature, moisture, and host development in the relation to insect development. In the present study, because of the later infestation date at both locations in 1969, temperatures were slightly warmer than in 1968 during insect development. Precipitation was slightly less in 1969 at Morris and similar between years at Ankeny. However, up to the date of average first moth emergence the amount of precipitation which fell was 0.5 inch and 1.32 inch higher in 1969 at Morris and Ankeny, respectively.

The wandering behavior exhibited by newly hatched larvae mentioned in the discussion of the laboratory study was also observed in the field. This behavior would place the small larvae in an immediate situation in which high temperatures and sudden heavy rainfall could cause high mortality by desiccation from the former and drowning or washing off of the plants by the latter. At Ankeny, in 1969, the temperatures the day of hatch, and for several days later, were very high and one day after hatch approximately 1 inch of rain fell. All of these factors, behavior

of newly hatched larvae, high temperatures, and heavy precipitation could have caused low survival of all populations at Ankeny in 1969. A change in the infestation procedure of placing 3 egg masses on each plant in 1 day to placing 1 egg mass on each plant over 3 days might avoid this situation in future experiments of this type. At Morris, in contrast to 1968, most populations had decreased survival. However, the three populations that had lower survival in 1968, Minn. x Minn., Minn. x Md., and Md. x Minn., had increased survival in 1969. The  $F_1$  populations of the reciprocal matings, Ala. x Minn., and Minn. x Ala. sustained the largest drop in survival. These facts might suggest that a population from Alabama will exert influence on one from Minnesota, while one from Maryland will be influenced by populations from Minnesota. However, these facts could also suggest that the effect of the infection of the microsporidian P. pyraustae on the populations in 1968, under the conditions at Morris, was not as severe for Ala. x Minn. or Minn. x Ala. as it was for Md. x Minn., Minn. x Md., and Minn. x Minn., but with the control of the infection in the  $P_1$  generation in 1969 through the use of Fumidil B in the diet (Lewis and Lynch, 1969) the populations of the latter three matings increased in numbers. This hypothesis would also explain the decreased survival in 1968 under the conditions at Ankeny of the

populations of Minn. x Minn., Minn. x Ala. and Minn. x Md., and would suggest that the influence exerted by the microsporidian was more severe when the parent Minnesota female was involved. <u>P. pyraustae</u> as a factor responsible for survival difference was ignored by Chiang et al. (1968) because they assumed heat treatment of the P<sub>1</sub> egg masses removed the microsporidian from the test populations of European corn borer.

Adults trapped in tunnels contributed more to higher mortality at Morris than at Ankeny during 1968 and 1969. Chiang (1959) showed that this phenomenon is produced by the elongation of the internode which shifts the tunnel opening so that after the borer pupates, and emerges as an adult there is no escape from the tunnel. Because of the cooler conditions at Morris, the corn plants did not elongate as rapidly as they did at Ankeny. The fact that significantly more individuals of populations with Maryland parentage were trapped in the tunnels leads to speculation of three possibilities why. The individuals of these populations tunneled into the corn stalks sooner than the other populations, or they tunneled in at approximately the same time as the other populations but the period spent in the tunnels lasted longer, and the plants elongated thereby trapping them. The third possibility would be a combination of the first two.

The fact that there were less tunnels produced at Morris, Minnesota in 1968 than in 1969 by populations of Md. x Minn., Minn. x Md., and Minn. x Minn. and that the average tunnels produced by all populations follows survival, strengthens the hypothesis that <u>P. pyraustae</u> influenced survival of these three populations. There was a trend for increased tunnels per borer form in 1969 at both locations. This might suggest that with decreased survival there is a change in the feeding habits of the survivors. However, another possibility is the one expressed by Chiang et al. (1968) in which the increased number of tunnels may be related to the higher percent of larvae entering diapause.

The conditions in 1968 were such that the populations of all crosses behaved similarly at Ankeny and Morris. Very few individuals of the populations of Alabama, Maryland, and reciprocals of the two, diapaused. Approximately 14 to 20 percent of the individuals of the  $F_1$  populations of the reciprocals of Alabama or Maryland with Minnesota diapaused. Averages of 61 and 78 percent of the populations of Minn. x Minn. diapaused at Ankeny and Morris, respectively. Therefore, very little influence was exerted by the Minnesota parentage on the reciprocal  $F_1$  populations. The fact that there was a high incidence of diapause for populations of Minn. x Minn. agrees with Sparks et al. (1966a, b) and Chiang et al. (1968). However, the fact that there were

no differences between locations or that the incidence of diapause of  $F_1$  populations was just modestly influenced by Minnesota parentage disagrees with Sparks et al. (1966a) and Chiang et al. (1968), respectively. It is well documented that photoperiod is primary and temperatures secondary for inducing diapause in most populations of the European corn borer (Mutchmor and Beckel, 1959; Beck and Hanec, 1960; Beck and Apple, 1961; Beck, 1962; Sparks et al., 1966a). Therefore, the reason for the results obtained in 1968 is that the photophase ranges were sufficiently long and the temperatures adequate to allow most of the individuals of 8 of the 9 populations to develop into adults at both Ankeny and Morris.

In 1969, the date of infestation at both locations was approximately 10 days later than 1968 in order to intensify any differences between locations and matings (egg source). The photophase at Morris in 1969 was 24 min shorter at first emergence than during the same period of insect development in 1968. There was a 25 min decrease in photophase between 1968 and 1969 at Ankeny. However, in 1969 the photophase of 13 hr 55 min at first adult emergence was also 13 min shorter than Morris and well below the critical photophases of 14 hr 30 min to 14 hr 45 min determined for specific borer populations by Beck (1962), Beck and Apple (1961), Beck and Hanec (1960), and Mutchmor

(1959). The actual date and photophase of first pupation is not known for this study. However, laboratory results discussed earlier in this manuscript showed that at a photophase of 14 hr 55 min and thermoperiod of 13.3-28.9° C there were approximately 12 days between pupation and emergence. The temperatures which occurred at Morris and Ankeny in 1969 were within this range so it can be assumed that first pupation occurred 12 days before first emergence. Therefore, the triggering mechanisms for diapause or pupation were in effect at photophases between 14 hr 41 min to 14 hr 8 min at Morris and 14 hr 22 min to 13 hr 55 min at Ankeny. However, at Morris, populations of Alabama, Maryland, and reciprocals of the two, diapaused in a manner similar to 1968. The same was true at Ankeny for populations of Ala. x Ala. and Md. x Ala., but the incidence of diapause of the populations of Ala. x Md. and Md. x Md. increased significantly over 1968. This indicates the critical photophase for these two populations is being approached but is lower than 13 hr 55 min. Unless the low numbers at Ankeny in 1969 are interfering with the results, Alabama and Maryland are not truly alike and the critical photophase for Ala. x Ala. and Md. x Ala. is much lower than 13 hr 55 min and the difference in response between the two parent types is expressed by the parental male.

Diapause incidence of  $F_1$  populations of the reciprocals

of Alabama or Maryland with Minnesota was heavily influenced by Minnesota at both Ankeny and Morris in 1969. This response is in close agreement with Sparks et al. (1966a, b) and Chiang et al. (1968). A comparison of the temperatures and photophases which occurred at first adult emergence at both locations over both years indicates the temperatures were modestly higher and the photophases approximately 25 min shorter in 1969. The fact that few individuals of these populations diapaused in 1968 but approximately 50 percent did in 1969 suggests the critical photophase lies between 14 hr 20 min (Ankeny, 1968) and 14 hr 8 min (Morris, 1969). The high incidence of diapause of populations of Minn. x Minn. suggests the critical photophase for these populations is longer than the photophases which occurred at both locations over both years. The results of the present study in which a wide range of diapause response was observed are consistent with the conclusion of Beck and Hanec (1960) that diapause in the European corn borer is entirely facultative. The data indicate that Sparks et al. (1966a, b) might be correct in their hypothesis that the mechanism for inheritance of this character is something more than a single pair of genes. However, according to Dr. W. F. Hollander (personal communication) $^{\perp}$ , although there may be

Dr. W. F. Hollander, Professor, Department of Genetics, Iowa State University of Science and Technology, Ames, Iowa. Interpretation of diapause and (Continued on the next page)

many genes involved, there is evidence that one sex-linked recessive gene may be important. The diapause data under Ankeny conditions in 1969 bring this out and the results are consistent with those of Arbuthnot (1944).

The hypothesis is that Maryland and Minnesota females may have a sex-linked recessive gene. Figure 17 illustrates the expected hypothetical genotypes and phenotypes. The incidence of diapause of the  $F_1$  of Minn. x Ala. should be similar to or approach the Ala. x Ala. response. However, the  $F_1$  of the reciprocal, Ala. x Minn., would have a higher incidence of diapause because the females should be like the Minnesota females. The incidence of diapause of the  $F_1$ population of Md. x Ala. should be similar to or approach Ala. x Ala. However, the  $F_1$  of the reciprocal mating, Ala. x Md, would have a higher incidence of diapause because the females should be like the Maryland females. The incidence of diapause of  $F_1$  populations of Md. x Minn. or Minn. x Md. should be intermediate to that of Minnesota and Maryland, respectively, which would suggest incomplete dominance between the recessive parent types. The data on diapause of the field experiments follow this hypothesis quite closely. The hypothesis could be proved or disproved by further experimentation in which all diapausing individ-

(Continued from the previous page) adult emergence data of European corn borer. August 27 and September 8, 1970.

Figure 17. The expected hypothetical genotypes and phenotypes for progenies of nine matings of European corn borer

♀ ALA x of ALA ₽ MD ×♂MD 9 MINN × MINN A-AA a- . a'a'a' aa 0 ¶ † a-₽ A-0 ¦-0 aa o\* AA ďa'a' RECIPROCALS  $\frac{9}{4}$  ALA x of MINN 9 MINN x JALA ♀MDxo\*ALA ♀ALA×MD a'- ↓ AA A- a'a' a- ↓ AA A- ↓ aa ♀ A-♂ Aa 0 Ta'-0" Aa' ♀ A-♂ Aa' 9 4 а-б<sup>#</sup> Аа <sup>9</sup> MD xo<sup>\*</sup> MINN ♀ MINN × ♂ MD a'- | a- | a'a' aa 0 Ta'-0 Ta-0 aa' 0aa '

PARENT TYPES

uals of each reciprocal mating would be saved, allowed to break diapause, pupate, emerge, and then sexed to determine whether the females and males react as hypothesized.

The discrepancies in the data on diapause between the laboratory and the field would lead one to believe that the Alabama laboratory colony might actually be the Maryland colony and vice versa. Tight control was maintained to avoid any mix-up of colonies for both the laboratory and field experiments. However, had a mix-up between colonies occurred initially in the laboratory experiment, due to the nature of the experimental procedures, the error would have been carried through the three runs of the experiment.

The populations of the nine laboratory colonies produced 55 to 45 percent males to females. This 1.2:1 ratio was tested for the populations of the nine matings at both field locations over both years and it was found that there was a modest trend away from this ratio among populations with low incidence of diapause.

The actual moth emergence data combined over locations but compared between years show that Minnesota parentage exerted a greater effect in the production of fewer moths in 1969. This agrees with Sparks et al. (1966a, b) and Chiang et al. (1968) and is directly attributable to shorter day lengths.

The variable 80 rather than 100 percent adult emergence was observed in order to avoid the tailing effect of the latter. What appear as typically valid differences for this variable between populations of the nine matings changed dramatically when accumulated borer degree days were used as the measuring device. Populations of Minnesota parentage show a large range while those of Alabama, Maryland, and the reciprocals of the two, produced a modest range of days to 80 percent emergence between years. However, the borer degree accumulations for 80 percent emergence of the various populations show the reverse. The borer degree procedure of measurement is not only accurate, but more realistic. It tells us that when a specific range of accumulated degrees is attained the population, under the proper photophase, will emerge as adults irregardless of the number of days which have elapsed since hatch. Sparks et al. (1966a) did not find any significant difference in time to 80 percent emergence during the one year their reciprocal mating experiment was conducted. However, if the experiment had been run for two years and borer degree day accumulations calculated, the true differences might have been expressed.

The 80 percent emergence data of the present study, measured by borer degrees, illustrate the progenies of Minn. x Minn. require fewer degrees while  $F_1$  females of reciprocals of Minnesota parentage require degrees in the

neighborhood of the Ala. x Ala. or Md. x Md. parents. This is also true of the  $F_1$  males of reciprocals of Maryland and Minnesota; however, there are mixed borer degree requirements for the  $F_1$  males of the reciprocals of Alabama and Minnesota. The data on 80 percent emergence also show that as photophase decreases from 14 hr 41 min to 13 hr 55 min, with the borer degree accumulations present at Morris and Ankeny during the summers of 1968-69, progenies of the Alabama and Maryland parent types continue, while those of Minnesota cease, development.

The requirement of fewer degree days to attain 80 percent emergence is primarily expressed by the males of all matings except Ala. x Ala. What the 80 percent emergence data mean genetically is not clear.

#### SUMMARY

The biology and behavior of  $F_1$  populations of reciprocal matings of southern fringe (Alabama), east coast (Maryland), and northern fringe (Minnesota) populations were studied in the laboratory and field.

The following points summarize the findings with respect to survival, diapause, and moth emergence.

1. Photoperiod and temperatures did not affect survival in the laboratory. Microsporidian <u>Perezia pyraustae</u> infection affected survival in the field particularly of  $F_1$  populations with Minnesota parentage. In 1969, high temperatures and/or heavy rainfall during the first and second day after hatch reduced survival of all populations at Ankeny, Iowa. Host development in relation to insect development affected the survival of populations with Maryland parentage at Morris, Minnesota.

2. Two of the regimes of light and temperature used in the laboratory study placed most individuals of many of the populations into diapause. The laboratory and field data suggest that difference between the diapause response of the populations studied is in degree of sensitivity to photoperiod and temperatures. The diapause response effect of photoperiod and temperatures on populations of Alabama and Maryland was reversed in the laboratory and the field. A hypothesis has been projected that although many genes may

be involved in the mechanism of inheritance of diapause, one sex-linked recessive gene may be important. The data suggest that the Alabama, Maryland, and Minnesota populations are distinct from one another and appear to be pure.

3. The variable, 80 percent moth emergence, was not very useful for distinguishing differences between  $F_1$  populations under the experimental conditions of the laboratory, however, it proved to be quite valuable in the field. The criterion, days to 80 percent moth emergence, is not as accurate a measurement as borer degree days to 80 percent moth emergence. The Minnesota population requires fewer borer degrees to attain emergence than any of the other populations. Males of all populations, except Alabama, require fewer borer degrees than do females to attain moth emergence.

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# APPENDIX

	Reciprocal			Range			
Rep.	mating (	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch	
т	Md. x Ala.	1	123	5-53	3-49	60-100	
		2	69	19 <b>-</b> 35	8-35	32-100	
		3	224	3-33	0-29	0-88	
		4	380	1-13	0-12	0-100	
		5	181	6-25	0-1	0-9	
		6	150	4-24	0-20	0-100	
		7	ב7	1-31	0-18	0-75	
		8	117	6-45	0-25	0-78	
		9	57	1-7	0-3	0-43	
		10	30	2-48	0-48	0-100	
		11	28	2-36	0-35	0-97	
	Average		131	5-32	1-25	8-81	

Table 27. Summarization, by replicate, of egg masses per day, eggs per mass, hatch per mass, and percent hatch for females of nine laboratory matings of European corn borer

	Reciprocal mating (९x ४)	Day of egg deposition	Egg masses per day	Range		
Rep.				Eggs per mass	Hatch per mass	Percent hatch
*****		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,				
	Minn. x Ala.	l	122	6-24	4-22	36-100
		2	73	3-42	2-40	31-9
		3	248	1 <b>-</b> 58	0-48	0-100
		4	225	3-49	2-49	50-100
		5	236	2-40	0-35	0-88
		6	189	1-32	0-27	0-84
		7	149	<b>2-</b> 36	1-35	3-100
		8	126	3-30	0-29	0-97
		9	109	1 <b>-</b> 25	0-25	0-100
		10	50	7-30	0-27	0-100
		11	67	5-33	0-17	0~52
	Average		145	3-36	1-30	11-85

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	Reciprocal			Range			
Rep.	mating ( ° x J)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch	
	Minn v Md	1	77	10-47	5_27	11-100	
Т	MIIII, A MG.	2	74	-9-+1 5 <b>-</b> 27	2-24	9-96	
		3	151	8 <b>-</b> 50	0-15	0 <b>-</b> 67	
		4	164	1-38	0-29	0-100	
		5	174	1-28	0-25	0-90	
·		6	245	3-47	0-33	0-70	
		7	166	1-30	0-30	0-33	
		. 8	208	1-12	0-9	0-75	
		9	194	5 <b>-</b> 35	0-35	0-31	
		10	91	3-14	0-2	0 <b>-</b> 67	
		11	140	1 <b>-</b> 33	0-27	0-82	
	Average		153	4-33	1-23	2-74	

	Reciprocal			Range			
Rep.	mating (१x ४)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch	
<u></u>			<i></i>	2.05		0 100	
	Ala. X Ma.	Ţ	41	5-25	0-24	0-100	
		2	45	20-33	6-20	21-100	
		3	167	3-15	0-0	0-0	
		4	189	1-20	1 <b>-</b> 19	0-100	
		5	154	8 <b>-</b> 15	2-15	0-100	
		6	166	1-25	0-20	0-80	
		7	106	2 <b>-</b> 16	0-9	0-60	
		8	168	4-40	0-10	0-100	
		9	119	1-18	0-2	0-14	
		10	81	2-33	0-31	0-100	
		11	41	1-27	0-0	0-0	
	Average		116	4-24	1-14	2-68	

Table 27. (Continued)

Table	27.	(Continued)
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	Reciprocal			Range			
Rep.	mating (♀x♂)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch	
т.				7 06	4.00	40.100	
1	Ala. x Minn.	1	73	(-20	4-22	40-100	
		2	41	8-32	0-30	0-94	
		3	207	2-19	0-10	0-67	
		4	278	3 <b>-</b> 55	2-52	33-100	
		5	229	3-22	0-19	0-100	
		6	171	4-41	0-41	0-100	
		7	90	2 <b>-</b> 36	1-30	17-90	
		8	140	9 <b>-1</b> 7	0-15	0-94	
		9	112	1-7	0-7	0-100	
		10	48	7-21	0-7	0-100	
		11	33	4-30	0 <b>-</b> 26	0-87	
	Average		129	5 <b>-</b> 28	124	8-85	

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				Denne			
Rep.	Reciprocal mating (۹ x ه)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch	
	<u></u>						
	Md. x Md.	l	118	15-33	15 <b>-</b> 29	79 <b>-1</b> 00	
		2	77	8 <b>-</b> 25	4-21	20-84	
		3	357	1-48	0-31	0-76	
		4	339	3-33	0-23	0-70	
		5	230	15 <b>-</b> 50	0-37	0-74	
		6	132	2-21	0-7	0-75	
		7	152	8-27	4-26	31 <b>-</b> 96	
		8	108	3-33	0-17	0-52	
	•	9	88	8-28	2-18	22 <b>-</b> 67	
		10	45	<b>1-</b> 27	0-0	0-0	
		11	24	5-29	0-3	0-23	
	Average		153	7-32	2-19	14-63	

Table 27. (Continued)

Mahla	07 I	Continued
Table	27. (	(Continued)

	Reciprocal			Range			
Rep.	mating (º x ď)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch	
I	Ala. x Ala.	1	161	5-25	1-25	0-100	
		2	79	11-20	0-19	0-100	
		. 3	236	1-46	0-40	0-87	
		4	229	8-35	7-21	60-95	
		5	171	7-16	0-10	0-83	
		б	200	3 <b>-2</b> 5	0-6	0-37	
		7	135	1 <b>-</b> 38	0-14	0-93	
		8	131	8-30	0-23	0-83	
		9	114	2-11	0-20	0-100	
		10	51	15 <b>-</b> 21	1-17	0-81	
		11	29	4-30	0-5	0-56	
	Average		140	6-18	1-18	5 <b>-</b> 83	

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	Reciprocal			Bange		
Rep.	mating (° x ď)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch
	Md. x Minn.	1	138	5-36	0 <b>-</b> 35	0-97
		2	72	<b>6-</b> 36	0-17	0-93
		3	274	1-20	0-12	0-75
		4	424	1-23	0-23	0-100
		5	359	6 <b>-</b> 31	0-30	0-100
		6	256	3-25	0-17	0-75
		7	158	2-31	0-25	0-82
		8.	168	3-35	0-27	0-80
		9	141	4-23	0-23	0-100
		10	70	6-14	0-14	0-100
		11	42	10-25	1-15	0-91
	Average		196	4-27	0-22	0-90

Table 27. (Continued)

	Reciprocal				Range	
Rep.	mating (१x ४)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch
		<u></u>			***************************************	
I	Minn. x Minn.	1	47	8-38	8-30	79 <b>-</b> 100
		2	44	1 <b>-</b> 33	0-29	0-87
		3	243	3 <b>-</b> 19	0-5	<b>0-</b> 26
		4	245	1-26	0-21	0-100
		5	203.	1 <b>-</b> 35	0 <b>-</b> 35	0-100
		6	185	3-66	0-66	0-100
		7	136	1-25	0-28	0-100
		8	160	3-25	0-10	0-100
		9	147	3-40	2-40	0-100
		10	54	5-40	1-28	11-96
		11	77	7-25	0-10	0-40
	Average		140	3-34	1-27	8-86

Table 27. (Continued)

4

	Reciprocal			Bange			
Rep.	$\begin{array}{c} \text{mating} \\ ( \text{P x d} ) \end{array}$	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch	
			_				
II	Md. x Ala.	1	128	3 <b>-</b> 69	0-69	0100	
		2	239	2-33	0-31	0-97	
		3	316	1 <b>-</b> 51	0-41	0-96	
		4	292	11-66	1 <b>-</b> 63	3-100	
		5	268	2 <b>-</b> 52	0-50	0-100	
		б	227	8-25	8-25	100	
		7	237	2 <b>-</b> 35	0-35	0-100	
·		8	122	2-32	0-29	0-96	
		9	86	4-32	1-32	0-100	
		10	78	2-33	0 <b>-</b> 33	0-100	
		11	55	1-32	0-32	0-100	
	Average		186	3-42	1-40	0-98	

Table 27. (Continued)

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Table 27.	(Continued)
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	Reciprocal			Range		
Rep.	mating (	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch
ττ	Minn v Ala	1	ם לנים	5-46	1_15	20-100
<u>+</u> <del>+</del>	MILINI, A AIG.	1	141	9=40	1-+5	20-100
		2	190	2-20	0-20	0-100
		3	121	<b>10-</b> 59	10-59	81-100
		4	195	8-42	0-42	0-100
		5	124	13 <b>-</b> 25	0-26	0-100
		6	154	4-21	0-21	0-100
		7	121	7-28	6-28	91 <b>-</b> 100
		8	142	7 <b>-</b> 21	6-19	86-100
		9	71	5-16	0-9	0-100
		10	60	8-19	6-19	41-100
		11	35	15 <b>-</b> 23	2-19	9-100
	Average		120	8-24	3-29	30-100

	Reciprocal				Range	
Rep.	mating (♀x♂)	Day of egg deposition	Egg masses per dav	Eggs per mass	Hatch per mass	Percent hatch
				·····		
	Minn. x Md.	1	147	1-37	0-36	0-97
		2	174	<b>1-</b> 34	0-34	0-100
		3	208	12-41	8-17	39 <b>-</b> 86
		4	187	5-23	0-17	0-100
		5	206	2-26	0-26	0-100
		6	151	2-26	0-14	0-54
		7	163	4-19	0-19	0-100
		8	135	14-48	0-47	0-100
		9	114	1 <b>-</b> 34	0-34	0-100
		10	102	4-21	0-21	0-100
		11	88	1 <b>-</b> 38	0-20	0-95
	Average		152	4-32	1 <b>-</b> 26	4-94

<b>Mabl</b> a	07 1	Continued	1
Table	27. (	continued	)

	Reciprocal				Range	
Rep.	mating (१x४)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch
<u></u>						
II	Ala. x Md.	l	79	6-42	3-42	50-100
		2	97	3 <b>-</b> 31	0-28	0-100
		3	165	18 <b>-</b> 43	18-30	51-100
		4	196	3-46	2-42	67-96
		5	110	6-22	6-22	94-100
		6	222	6-39	0-30	0-92
		7	177	2-15	0-14	0-100
		8	222	1-21	0-20	0-95
		9	160	10 <b>-</b> 35	0-34	0-100
		10	167	1-17	0-11	0-100
		11	112	2-20	0-13	0-100
	Average		155	5-30	2-26	24-98

Table	27. (	Continued	)
TCOTC	- · ·	( oono mucu )	,

	Reciprocal			Range		
Rep.	mating (१x ४)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch
			<i>c</i> o	- 0		
	Ala. x Minn.	1	168	1-28	0-28	0-86
		2	250	6 <b>-</b> 39	0-33	0-100
		3	213	1 <b>-</b> 32	1-31	9 <b>0-</b> 100
		4	215	10-27	10-27	44-100
		5	186	3-37	0-37	0-94
		6	152	10-26	0-26	0-100
		7	155	1-21	0-21	0-100
		8	97	8 <b>-</b> 41	6 <b>-</b> 39	27-100
		9	64	3 <b>-</b> 26	0-25	0-100
		10	60	4-34	4-28	59-100
		11	19	8-28	0-28	0-100
	Average		<b>1</b> 44	5-31	2-30	20-91

Table	27.	(Continued)
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	Reciprocal				Range	
Rep.	mating (♀ x ♂)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch
II	Md. x Md.	1.	208	1-48	0-41	0 <b>-</b> 85
		2	271	1-50	0-50	0-100
		3	307	1 <b>-</b> 36	0-36	0-100
		4	285	3-25	0-14	0-67
		5	245	4-20	0-20	0-100
		6	233	2-30	0-25	<b>0-</b> 84
		7	153	3-21	0-17	0-100
		8	188	1 <b>-5</b> 3	0-41	0-92
		9	144	2-37	0-32	0-86
		10	97	2-11	0-10	<b>0-</b> 91
		11	55	1-28	0-21	0 <b>-</b> 93
	Average		199	2 <b>-</b> 33	0-28	0-91

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	Reciprocal				Range	
Rep.	mating (° x ď)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Percent hatch
				<u>, , , , , , , , , , , , , , , , , , , </u>	***************************************	
	Ala. x Ala.	1	135	9-31	4-10	15 <b>-</b> 59
		2	187	17 <b>-</b> 39	16-52	91-98
		3	232	1-28	0-28	0-100
		4	270	9 <b>-</b> 29	0-28	0-97
		5	110	11-18	9 <b>-1</b> 8	69 <b>-</b> 100
		6	202	0-21	0-16	0-76
		7	145	3-33	1 <b>-</b> 33	33-100
		8	134	3-33	<b>0-3</b> 3	0-100
		9	125	5 <b>-</b> 26	2-56	40-100
		10	112	5-25	2-24	19-100
		11	89	3-23	0-23	0-100
	Average		158	6-28	. 3-26	24-94

Table 27. (Continued)

Table	27.	(Continued)	)
10010		( oon oanaca)	1

Reciprocal				Range	
mating (१x ४)	Day of egg deposition	Egg masses per day	Eggs per mass	Hatch per mass	Fercent hatch
BAJ BAJ				1.09	F0 100
Ma. X Minn.	Ţ	90	2-35	1-20	20-100
	2	149	12-22	7-21	44 <b>-</b> 89
	3	231	10-32	0-30	0-100
	4	216	3-28	0-28	0-100
	5	250	7-19	0-12	0-100
	6	203	10 <b>-</b> 29	1-28	10-100
	7	174	<b>11-</b> 30	1-19	9-100
	8	185	<b>4-</b> 48	0-47	0-100
	9	138	8-28	4-28	50-100
	10	111	5 <b>-</b> 25	0-25	0-100
	11	69	3-25	0-25	0-100
Average		165	7 <b>-</b> 36	1-26	15 <b>-</b> 99
	Reciprocal mating (f x d) Md. x Minn.	Reciprocal mating (f x d) Day of egg deposition Md. x Minn.  Md. x Minn.  Average	Reciprocal (\$ x \$)         Day of egg deposition         Egg masses per day           Md. x Minn.         1         90           2         149           3         231           4         216           5         250           6         203           7         174           8         185           9         138           10         111           11         69           Average         165	Reciprocal mating (9 x 3)         Day of egg deposition         Egg masses per day         Eggs per mass           Md. x Minn.         1         90         2-35           2         149         12-22           3         231         10-32           4         216         3-28           5         250         7-19           6         203         10-29           7         174         11-30           8         185         4-48           9         138         8-28           10         111         5-25           11         69         3-25           Average         165         7-36	$\begin{array}{c c c c c c c c c c c c c c c c c c c $

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Rep.	Reciprocal mating (약xď)	Day of egg deposition	Egg masses per day	Eggs per mass	Range Hatch per mass	Percent hatch
<del> </del>				<del> </del>	<u></u>	
	Minn. x Minn.	l	133	1-22	0-22	0-100
		2	191	10-64	0-58	0-96
		3	210	4-21	0-21	0-100
		4	222	4-23	0-17	0-74
		5	170	12-22	0-22	0-100
		6	202	21 <b>-</b> 54	2-38	10-100
		7	188	4-17	0-17	0-100
		8	175	1-32	0-13	0-100
		9	164	1 <b>-</b> 37	0-29	0-100
		10	113	9 <b>-</b> 27	0-24	0-100
		11	88	2-30	0-30	0-100
	Average		168	6-32	0-26	1-97

Table 27. (Continued)

Variable	Source	df	MSa	Fb
Egg masses per day	Replications Egg source Error a Days egg masses laid Egg x day Error b	1 8 10 80 90	42.614 8.439 8.107 118.684 3.533 3.583	5.30* 1.15 ns 33.12** < 1 ns
Average number of eggs per mass	Replications Egg source Error a Days egg masses laid Egg x day Error b	ר 8 10 80 90	2.467 0.745 0.581 1.738 0.470 0.392	4.25 ns 1.20 ns 4.43** 1.20 ns
Average percent hatch per mass	Replications Egg source Error a Days egg masses laid Egg x day Error b	1 8 10 80 90	3.469 0.117 0.081 0.135 0.056 0.060	42.82** 1.46 ns 2.24* < 1 ns

Table	28.	Summary of analysis of variance for egg mass production by females of
•		nine laboratory matings of European corn borer

<sup>a</sup>Data expressed as counts or percentage transformed to square root or arcsin, respectively.

<sup>b</sup>\*Significant 95 percent level, \*\*significant 99 percent level, ns = non-significant.

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		Number of	individuals	per mating
Regime	Rep.	Ala. X Md.	Ma.x Ala.	Ala. X Minn.
Photophase	I	90	87	87
10 III. 00 IIITU	II	69	80	63
Thermoperiod 8.3-23.3°C	III	95	91	92
Average		85	86	81
				<u>c</u> h
Photophase 14 hr 55 min	· I	97	90	84
	II	69	76	78
13.3-28.9° C	III	91	90	93
Average		86	85	85
Dhatashaga	Ŧ	01	00	80
14 hr 16 min	T	91	00	03
Mhormoroniod	II	73	92	75
18.3-31.7° C	III	97	92	93
Average		87	91	84

Table 29. Individuals, which survived, per replicate of nine laboratory colonies of European corn borer reared under three photophases and thermoperiods

<sup>a</sup>Remainder of 102 individuals per reciprocal mating per replicate.

(° x ď)	per replicate	that surv	ived larval	mortality	
Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md.x Md.	Minn.x Minn.
			Ch	66	
93	93	79	64	00	70
66	77	76	54	47	64
93	97	98	86	90	77
84	89	84	68	68	70
98	91	99	74	74	71
59	83	70	60	58	61
96	98	91	88	77	80
84	91	87	74	70	71
90	92	90	67	71	71
64	87	79	68	56	69
98	98	95	89	83	84
54	92	88	75	70	75

				•
Regime	Rep.	Number of Ala. x Md.	individuals Md. x Ala.	that entered Ala. x Minn.
Photophase	I	0	2	39
15 hr 55 min	II	1	0	10
Thermoperiod 8.3-23.3° C	III	1	0	64
Average		0.6	0.6	38
Photophase	I	34	38	84
14 nr 95 min	II	20	26	76
Thermoperiod 13.3-28.9° C	III	48	42	91
Average		34	35	84
Photophase	I	71	80	83
14 nr 15 min	II	63	84	74
18.3-31.7° C	III	92	88	93
Average		75	84	31

Table 30.	Individuals, in diapause, per replicate of nine
	laboratory colonies of European corn borer
	reared under three photophases and thermoperiods

diapause	per mating	(° x ď)	by replicate		
Minn. x Ala.	Md. x Minn.	Minn. Md.	x Ala.x Ala.	Md.x Md.	Minn.x Minn.
		······································			
41	29	8	7	3	64
20	11	18	4	0	53
39	18	13	14	0	70
33	19	13	8	l	62
94	89	84	42	12	71
57	79	63	29	5	61
96	96	78	65	25	80
82	88	75	45	14	71
90	92	89	62	41	71
64	87	79	59	41	69
98	98	90	86	63	84
84	92	86	69	48	75

Regime	Rep.	Ala. x Md.	Percent Md. x Ala.	diapause Ala. x Minn.	per
Photophase 15 hr 55 min Thermoperiod	I II	0 1	2 0	45 16	
8.3-23.3° C Average	III	1 1	0 1	70 43	
Photophase 14 hr 55 min Thermoperiod 13.3-28.9° C Average	I II III	35 29 53 39	42 34 47 41	100 97 98 98	
Photophase 14 hr 15 min Thermoperiod 18.3-31.7° C Average	I II III	78 86 95 86	91 91 96 93	100 99 100 100	

Table 31. Percent diapause per replicate for nine laboratory colonies of European corn borer reared under three photophases and thermoperiods

mating (9	nating (♀ x ♂) by replicate							
Minn. x Ala.	Md. x Minn.	Minn. x Md.	Ala. x Ala.	Md.x Md.	Minn.x Minn.			
					~ 7			
44	31	TO		5	91			
30	14	24	7	0	83			
42	19	13	16	0	91			
39	21	47	12	2	88			
96	98	85	57	16	100			
96	95	90	48	8	100			
99	97	86	74	32	100			
97	96	87	60	19	100			
100	100	99	93	58	100			
100	100	100	87	73	100			
100	100	95	97	76	100			
100	100	98	92	69	100			

Regime	Rep.	Number of Ala. x Md.	individuals Md. x Ala.	that attained Ala. x Minn.
Photophase	I	90	85	48
10 III. 99 IIIIII	II	68	80	53
Thermoperiod 8.3-23.3° C	III	94	91	28
Average	_	71	89	43
Photophase	I	63	52	0
14 nr 99 min	II	49	50	2
Thermoperiod 13.3-28.9° C	III	43	48	2
Average		52	50	1
Photophase	I	20	8	0
14 hr 15 min	II	10	8	1
Thermoperiod 18.3-31.7° C	III	5	4	0
Average		12	7	0.3

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Table 32.	Pupae per replicate for nine laboratory colonies
	of European corn borer reared under three photo-
	phases and thermoperiods

pupation Minn. x Ala.	per mating Md. x Minn.	(약 x ♂) by Minn. x Md.	replicate Ala. x Ala.	Md.x Md.	Minn.x Minn.
50	6/1	71	57	62	6
92 Дб	66	58	50	05 47	ט ור
54	79	85	72	90	7
51	70	108	60	67	8
4	2	15	32	62	0
2	4	7	31	53	0
0	2	13	23	52	0
2	3	12	29	56	0
0	0	1	5	30	0
0	0	0	9	15	0
0	0	0	3	20	0
0	0	0.3	6	22	0

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Variable	Source	dſ	msa	Fpb
Survival based on 102 individuals per rep.	Nine sources Replications Regimes Error a Egg source Reg. x egg Error b	of eggs 2 2 4 8 16 48	under three 10.302 0.270 0.235 1.820 0.022 0.131	regimes 43.83** 1.15 ns 13.93** < 1 ns
Percent survival	Replications Regimes Error a Egg source Reg. x egg Error b	2 2 4 8 16 48	0.510 0.011 0.014 0.091 0.001 0.006	36.43** < 1 ns 14.71** < 1 ns
Larvae in diapause	Replications Regimes Error a Egg source Reg. x egg Error b	2 2 4 8 16 48	11.357 184.474 0.540 22.570 4.771 0.426	21.00** 341.62** 53.04** 11.21**

Table 33.	Summary of	analysis of	variance	for s	survival	and	development	of	progenies
	of various	laboratory	matings of	f Euro	opean co	rn bo	orer		

<sup>a</sup>Data expressed as counts or percentage transformed to square root or arcsin, respectively.

<sup>b</sup>\*Significant 95 percent level, \*\*significant 99 percent level, ns = non-significant.

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Table	33. (	(Continued)
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Variable	Source	đf	MSa	F.p
Percent diapause	Replications Regimes Error a Egg source Reg. x egg Error b	2 2 4 16 48	0.049 5.834 0.011 0.847 0.090 0.008	4.45 ns 530.36** 102.73** 10.86**
Number of pupae	Replications Regimes Error a Egg source Reg. x egg Error b	2 2 4 8 16 48	1.906 189.973 1.372 32.534 4.593 0.848	1.39 ns 188.00** 38.38** 5.42**
Percent pupation	Replications Regimes Error a Egg source Reg. x egg Error b	2 2 4 8 16 48	0.049 5.654 0.010 0.816 0.089 0.008	4.94 ns 576.98** 107.16** 11.66**
Mean pupal weight	Nine sources Replications Egg source Error a Sex Egg x sex Error b	of eggs 7 2 8 16 1 8 18	under one reg 0.187 0.479 0.060 13.393 0.050 0.014	ime 3.17 ns 7.99** 942.58** 3.23*

Variable	Source	df	MS <sup>a</sup>	ър
Number of days to 80 percent	Replications	2	2.226	85.62**
pupation	Egg source Error a	8 16	0.036	1.39 ns
	Egg x sex Error b	8 18	0.104 0.007 0.015	< 1 ns
Number of days to 80 percent adult emergence	Replications Egg source	2816	1.060 0.027 0.024	44.17** 1.16 ns
	Error a Sex Egg x sex Error b	1 8	0.000 0.005	< 1 ns < 1 ns
	Four sources	of eggs	under two	regimes
Mean pupal weight	Replications Regimes Error a	2	0.023 3.960	< 1 ns 80.80*
	Egg source Reg. x egg	33	0.829	16.92**
	Error D Sex	15	13,157	1315.47**
	Reg. x sex	ī	0.112	11.18**
	Egg x sex	3	0.138	13.82**
	reg. x egg x sex Error c	د 16	0.006	<1 ns

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Table 33. (Continued)

Variable	Source	df	MS <sup>a</sup>	Fb
Number of Joing to 80 percent	Depliestiens		0.000	2 /12 mg
pupation	Regimes Error a	1	8.679	33.12*
	Egg source Reg. x egg	3	0.260	17.33** 4.40*
	Error D Sex Beg y sex	12	0.189	21.31**
	Egg x sex Reg. x egg x sex	100 0	0.014	1.63 ns
	Error c	ıĞ	0.009	
Number of days to 80 percent	Replications Regimes	2	0.572	7.13 ns
	Error a	2	0.080	
	Egg source	3	0.178	18.00**
	Reg. x egg	_3	0.032	3.00 ns
	Error b	12	0.010	0.50
	Sex Der mont	1	0.028	3.52  ns
	Reg. X Sex	2		1.95  ns
	Reg x egg x sev	2	0.014	1 81 ng
	Error c	16	0.008	

95 percent	99 percent
18.51 4.75 4.49 4.41 19.00 6.94 3.63 3.49 3.24 2.59 2.51 2.15	98.50 9.33 8.53 8.29 99.00 18.00 6.23 5.95 5.29 3.89 3.71 2.96
	95 percent 18.51 4.75 4.49 4.41 19.00 6.94 3.63 3.49 3.24 2.59 2.51 2.15 1.87

				Emer	red adult	S
Year	Location	Mating (9 x d)	Rep.	Females	Males	Total
1968	Morris,	Md. x Ala.	I	10	10	20
	Minn.		II	32	37	69
			III	9	17	26
			IV	19	13	32
			Total	70	77	147
			Average	e 18	19	42
	Minn. x Ala.	I	23	17	40	
			II	11	11	22
			III	12	19	31
			IV	31	26.	57
			Total	77	73	150
			Average	e 19	18	38
		Minn. x Md.	I	31	27	58
			II	14	12	26
			III	5	4	9
			IV	8	5	13
			Total	58	48	106
			Average	e 15	12	27

Table 34. Summary of tunnels and forms of European corn borer found at two Midwest locations, 1968-69

	Found i	n the plan	its		
Tunnels	Larvae	Pupae	Trapped ?	adults J	Total forms
62	٦	0	Л	0	25
35	1	1	1	0	-) 72
37	-	-	-	0	29
66	2	1	4	l	40
200	4	2	12	l	166
50	l	0.5	3	0	42
68	10	3	0	l	54
29	8	l	0	l	32
30	6	l	· l	l	40
17	4	0	0	0	61
144	28	5	l	3	188
36	7	l	0	1	47
56	9	2	l	1	71
37	2	l	l	0	30
16	4	l	0	0	14
38	3	l	3	0	20
147	18	5	5	l	135
37	5	l	l	0	34

				Emerged adults		
Year	Location	Mating (º x ď)	Rep.	Females	Males	Total
1968	Morris,	Ala. x Md.	I	20	14	34
	Minn.		II	11	9	20
			III	28	18	46
			IV	16	21	37
			Total	75	62	137
			Average	e 19	16	34
		Ala. x Minn.	I.	53	29	82
	r.		II	14	23	37
			III	19	18	37
			IV	5	7	12
			Total	91	77	168
			Average	e 23	19	42
		Md. x Md.	I	33	28	61
			II	33	26	59
			III	13	12	25
			IV	18	21	39
			Total	97	87	184
			Average	e 24	22	46

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	Tourd	the min			
Tunnels	Larvae	Pupae	Trapped P	adults d	Total forms
56	6	1	3	1	45
56	2	2	0	3	27
41	0	2	2	l	51
57	2	0	l	l	41
210	10	5	6	6	164
53	3	1	2	2	41
59	20	1	2	0	105
28	8	0	l	0	46
35	4	0	l	0	42
48	8	1	1 <sup>.</sup>	0	23
170	40	2	5	0	216
43	10	0.5	1	0	54
75	2	4	3	3	73
61	1	2	l	2	65
37	0	0	l	5	31
23	2	0	1	0	42
196	5	6	6	10	211
49	l	2	2	3	53

Table 34. (Continued)

				Emerged adults			
Year	Location	Mating (♀ x ♂)	Rep.	Females	Males	Total	
1968.	Morris,	Ala. x Ala.	I	27	27	54	
	Minn.		II	15	10	25	
			III	22	19	41	
			IV	25	24	49	
1-			Total	89	80	169	
			Average	e 22	20	42	
		Md. x Minn.	I	26	15	41	
			II	8	2	10	
			III	4	7	11	
			IV	10	9	19	
			Total	48	33	81	
			Average	e 12	8	20	
		Minn. x Minn.	I	7	11	18	
			II	l	· 1	2	
			III	0	2	2	
			IV	2	2	4	
			Total	10	16	26	
			Average	<b>e</b> 3	4	7	

	Found	in the plar	its		
Tunnels	Larvae	Pupae	Trapped 9	adults d	Total forms
42	1	1	0	0	56
28	2	0	1	0	28
52	2	4	l	0	50
37	0	1	3	2	55
159	5	6	5	2	189
40	1	2	l	0.5	47
72	11	4	5	1	62
23	l	0	0	0	11
37	7	2	2	l	18
33	6	0	l	0	26
165	25	6	8	2	117
41	6	2	2	0.5	29
71	43	0	0	0	61
30	13	0	0	0	15
34	13	0	0	0	15
23	9	0	0	0	13
158	78	0	0	0	104
40	20	0	0	0	26

Table 34. (Continued)

.

				ts		
Year	Location	Mating (? x d)	Rep.	Females	Males	Total
	***************************************			<u> </u>	······	
1968	Ankeny, Towa	Md. x Ala.	I	51	45	96
	TOMO		II	31	33	64
			III	41	31	72
			IV	23	32	55
			Total	146	141	293
			Average	e 37	35	73
		Minn. x Ala.	I	10	14	24
			II	8	6	14
			III	15	<b>1</b> 4	29
			IV	9	8	17
			Total	42	42	84
			Average	e 11	11	22
		Minn. x Md.	I	28	29	57
			II	31	33	64
			III	14	8	22
			IV	4	8	12
			Total	77	78	155
			Average	e 19	20	39

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	Found i	n the plar	nts		
Tunnels	Larvae	Pupae	$\operatorname{Trapped}_{\widehat{\mathbb{P}}}$	adults 3	Total forms
80	0	1	0	0	97
72	0	1	0	0	65
73	1	1	l	0	75
75	0	0	l	0	56
300	l	<sup>.</sup> 3	2	0	293
75	0	l	0.5	0	73
38	2	0	0	0	26
27	5	0	0	0	19
42	6	0	0	0	35
45	3	l	0	0	21
152	16	1	0	0	101
38	4	0	0	0	25
71	23	0	0	0	80
72	10	0	0	0	74
51	9	l	0	0	32
34	2	0	1	0	15
228	44	l	l	0	201
57	11	0	0	0	50

				Emerged adults				
Year	Location	Mating (° x ď)	Rep.	Females	Males	Total		
		ـــــــــــــــــــــــــــــــــــــ						
1968	Ankeny, Towa	Ala. x Md.	I	51	42	93		
	10110		II	47	35	82		
			III	48	36	84		
			IV	30	28	58		
			Total	176	141	317		
			Average	e 44	35	<b>7</b> 9		
		Ala. x Minn.	I	34	57	91		
			II	27	26	53		
			III	40	38	78		
			IV	18	28	46		
			Total	119	149	268		
			Average	e 30	37	67		
		Md. x Md.	I	59	54	113		
		II	22	22	44			
			III	56	25	81		
			IV	33	21	54		
			Total	170	122	292		
			Average	e 43	31	73		
Found in the plants								
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Tunnels	Larvae	Pupae	Trapped ç	adults o	Total forms			
94	. 0	0	0	O	93			
77	0	1	0	l	84			
105	1	l	l	1	88			
67	1	0	0	l	60			
343	2	2	l	3	325			
86	0.5	0.5	0	l	81			
83	9	0	Ο	0	100			
57	3	0	0	0	56			
71	2	l	0	0	81			
52	4	l	0	0	51			
263	18	2	0	0	288			
66	5	0.5	0	0	72			
77	l	1	0	0	115			
52	0	0	0	0	44			
80	l	l	1	0	83			
70	1	0	l	0	56			
279	3	2	2	0	298			
70	l	0.5	0.5	0	75			

Table 34. (Continued)

				Emer	ged adu	lts
Year	Location	Mating (♀ x ♂)	Rep.	Females	Males	Total
1968	Ankeny,	Ala. x Ala.	I	42	37	79
	Iowa		II	52	51	103
			III	12	17	29
			IV	24	16	40
			Total	130	121	251
			Average	33	30	63
		Md. x Minn.	I	42	27	69
			II	38	56	94
			III	25	10	35
			IV	37	38	75
			Total	142	131	<b>2</b> 73
			Average	36	33	69
		Minn. x Minn.	Ī	2	2	4
			II	5	0	5
			III	4	4	8
			IV	3	2	5
			Total	14	8	22
			Average	4	2	6

	Found i	n the plar	its		
funnels	Larvae	Pupae	Trapped Ŷ	adults o	Total forms
····					
70	0	1	0	· 0	80
81	2	0	0	0	105
55	l	0	l	1	32
58	l	. 0	0	0	41
264	4	1	l	1	258
66	l	0	0	0	65
93	18	0	0	0	87
72	10	0	1	l	106
65	7	2	0	0	44
74	7	l	0	0	83
304	42	3	l	l	320
76	11	1	0	0	80
٦٩	7	0	0	0	
10	1	0	0	U	11
28	8	0	0	0	13
35	14	0	0	0	23
15	7	0	0	0	12
96	36	0	0	0	59
24	9	0	0	0	15

Tracha	Teechieu		Der	Emer	ged adu	lts
year	Location	Mating (+ x d)	кер.	remates	Males	Total
1969	Morris,	Md. x Ala.	I	27	13	40
	Minn.		II	16	13	29
			III	12	7	19
			IV	10	12	22
			Total	65	45	110
			Average	16	11	27
		Minn. x Ala.	I	15	8	23
			II	7	6	13
			III	2	3	5
			IV	7	2	9
			Total	31	19	50
			Average	8	5	13
		Minn. x Md.	I	12	19	31
			II	11	7	18
			III	6	15	21
			IV	8	3	11
			Total	37	44	81
			Average	9	11	20

<u></u>	Found i	n the plan	ts Trapped	adults	Total
Tunnels	Larvae	Pupae	<u></u>	්	forms
FO		٦	٦	0	, Jo
29	Ū	т. Т	1		+2
49	0	0	0	1	30
19	0	1	0	2	22
30	0	0	3	l	26
157	0	2	4	4	120
39	0	0.5	1	1	30
49	20	0	0	0	43
37	7	l	0	0	21
20	4	0	0	0	9
27	6	0	0	0	15
133	37	l	0	0	88
33	9	Ο	0	0	22
50	14	0	1	1	47
61	28	0	l	0	47
48	23	0	2	l	47
54	24	0	l	l	37
213	89	0	5	3	178
53	22	0	l	1	45

Table	34.	(Continued)
20020	<u> </u>	(••••••••••

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			_	Emerged adults			
Year	Location	Mating (P x 3)	Rep.	Females	Males	Tota1	
1969	Morris,	Ala. x Md.	I	16	12	28	
	Minn.		II	18	11	29	
			III	24	11	35	
			IV	13	12	25	
			Total	71	46	117	
			Average	18	12	29	
	Ala. x Minn.	I	5	14	19		
		II	4	9	13		
			III	5	7	12	
	۲		IV	7	8	15	
			Total	21	38	59	
			Average	5	10	15	
		Md. x Md.	I	20	19	39	
			II	6	4	10	
			III	21	12	33	
			IV	19	12	31	
			Total	66	47	113	
			Average	17	12	29	

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	Found 1	n the plar	nts		
Tunnels	Larvae	Pupae	Trapped Ŷ	adults d	Total forms
40	2	0	0	0	30
37	1	0	2	0	32
50	б	0	1	2	44
38	4	0	1	2	32
165	13	0	4	4	138
41	3	0	1	1	35
49	17	0	0	1	37
31	12	1	0	0	26
34	15	0	0	l	28
52	24	0	0	0	39
166	68	1	0	2	130
42	17	0	0	·0.5	33
43	2	1	2	l	45
23	3	1	l	2	17
39	l	0	0	l	35
40	l	0	l	1.	34
145	7	2	4	5	131
36	2	0.5	· l	l	33

				Emerged adults			
Year	Location	Mating (♀ x ♂)	Rep.	Females	Males	Total	
1969	Morris,	Ala. x Ala.	I	11	12	23	
	Minn.		II	5	12	17	
			III	23	7	47	
			IV	15	9	24	
			Total	54	40	94	
			Average	14	10	24	
		Md. x Minn.	I	5	14	19	
			II	14	10	24	
			III	8	11	19	
			IV	24	27	51	
			Total	51	62	113	
			Average	13	16	29	
		Minn. x Minn.	I	1	3	4	
			II	1	2	3	
			III	0	0	0	
			IV	0	0	0	
			Total	2	5	7	
			Average	0.5	l	1.5	

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Found in the plants								
Tunnels	Larvae	Pupae	Trapped \$	adults đ	Total forms			
<u>и</u> р	З	0	2	0	28			
+ <b>∠</b> 07	ך ר	0	0	0	18			
2   )  ]	т О	0	U 1	0	50			
41	2	0	T	2	52			
46	4	2	0	0	30			
156	10	2	3	2	128			
39	3	0.5	l	0.5	32 ,			
44	16	0	l	0	36			
56	27	Ō	0	1	52			
47	24	0	2	0	45			
65	22	0	l	3	77			
212	89 ·	0	4	4	210			
53	22	0	l	1	53			
57	35	l	0	0	40			
62	42	0	0	0	45			
58	42	0	0	0	42			
37	21	0	0	0	21			
214	140	1	0	0	148			
54	35	0	0	0	37			

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Table 34. (Continued)

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				Emerged adults			
Year	Location	Mating (♀x♂)	Rep.	Females	Males	Total	
1969	Ankeny,	Md. x Ala.	I	2	0	2	
	Iowa		II	3	1	4	
			III	4	4	8	
			IV	2	5	7	
			Total	11	10	21	
			Average	3	2	5	
		Minn. x Ala.	I	l	l	2	
			II	3	0	3	
			III	l	1	2	
			IV	2	3	5	
			Total	7	5	12	
			Average	2	1	3	
		Minn. x Md.	I	0	0	0	
			II	l	0	1	
			III	l	l	2	
			IV	3	3	6	
			Total	5	4	9	
			Average	l	1	2	

	Found i	n the plan	its		
Tunnels	Larvae	Pupae	Trapped ç	adults d	Total forms
6	0	0	0	0	2
12	l	0	0	0	5
10	1	0	0	0	9
15	0	0	0	0	7
43	2	0	0	0	23
11	0.5	<b>O</b> .	0	0	6
7	2	0	0	0	4
7	0	0	0	0	3
8	3	0	0	0	5
17	2	0	0	0	7
39	7	0	0	0	19
10	2	0	0	0	5
11	7	0	0	0	7
6	l	0	0	0	2
11	3	0	0	0	5
19	8	0	0	0	14
47	19	0	0	0	28
12	5	0	0	0	7

				Emer	ged adu	lts
Year	Location	Mating (° x ď)	Rep.	Females	Males	Total
			_	_		
1969	Ankeny, Iowa	Ala. x Md.	I	1	2	3
			II	2	2	4
			III	3	5	8
			IV	2	5	7
			Total	8	14	22
			Average	2	4	6
		Ala. x Minn.	I	0	l	1
			II	0	1	1
			III	0	0	0
			IV	0	0	0
			Total	0	2	2
			Average	• <b>O</b>	0.5	0.5
		Md. x Md.	I	2	l	3
			II	0	l	l
			III	3	3	6
			IV	5	3	8
			Total	10	8	18
			Average	3	2	5

	Found	in the plant	ts		
Tunnels	Larvae	Pupae	f. f. f. f. f. f. f. f. f. f. f. f. f. f	adults o	forms
···•			<u></u>		<del>,,,</del>
7	5	0	0	0	8
9	0	0	0	0	4
20	4	0	0	0	12
19	7	0	0	0	11
55	16	0	0	0	35
<b>1</b> 4	4	0	0	0	9
6	٦.	0	0	0	2
ц Ц	0	0	0	0	-
12	1	0	0	0	-
11	2	0	0	0	- 2
33	4	0	0	0	" 6
8	7	0	0	0	2
Ū.	_	-			
7	3	0	0	0	6
5	· 0	0	0	0	י ב <sup>:</sup>
9	0	0	0	0	6
24	4	0	0	0	12
45	7	0	0	0	25
11	2	0	0	0	6

				Emer	ged adul	ts
Year	Location	Mating (9 x d)	Rep.	Females	Males	Total
1969	Ankeny,	Ala. x Ala.	I	3	0	3
	Toma		II	0	1	l
			III	2	1	3
			IV	3	2	5
			Total	8	4	12
			Average	2	1	3
		Md. x Minn.	I	3	3	6
			II	l	0	1
			III	l	0	l
			IV	l	4	5
			Total	6	7	13
			Average	2	2	3
		Minn. x Minn.	I	0	0	0
			II	0	0	0
			III	0	0	0
			IV	0	0	0
			Total	0	0	0
			Average	0	0	0

			Trapped	adults	Total	
Funnels	Larvae	Pupae	ę 	d <sup>7</sup>	forms	
13	l	0	0	0	4	
5	0	0	0	0	1	
6	0	0	0	0	3	
11	0	0	0	0	5	
. 35	1	0	0	0	13	
9	0	0	0	0	3	
9	5	0	0	0	11	
6	1.	0	0	0	2	
9	4	0	0	0	5	
15	4	0	0	0	9	
39	14	0	0	0	27	
10	4	0	0	0	7	
4	3	0	0	0	3	
6	4	0	0	0	4	
7	5	0	0	0	5	
6	l	0	0	0	1	
23	13	0	0	0	13	
6	3	0	0	0	. 3	

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Day of development	Date	Temper o Max	rature F Min	Accumulated borer degree days	Rair (inc Daily A	nfall ches) Accumulative	Photo Hr	ophase Min
Hatch 1 2 3 4 5 6 7 7-day average	July 2 3 4 5 6 7 8	61 69 81 81 82 88 70 76.0	46 49 53 55 58 58 58 58 54.3	Morri 3.5 12.5 29.5 47.5 67.5 90.5 106.0	s, Minnesot 0.01 0.02	ta, 1968 0.01 0.03	15 15 15 15 15 15 15	37 37 36 34 34 33 31 35
8 9 10 11 12 13 14 7-day average	9 10 11 12 13 14 15	77 72 83 74 84 93 88 81.6	48 59 66 67 66 66 60.6	118.5 130.5 151.5 171.5 197.5 226.5 253.5	0.15 0.07	0.18 0.25	15 15 15 15 15 15 15	30 29 28 26 24 23 21 26
15 16 17 18 19 20 21 7-day average	16 17 18 19 20 21 22	93 89 84 79 85 87 76 87 84.7	71 66 53 60 50 63 51 0	285.5 313.5 336.5 352.5 375.0 400.0 413.5	0.15 0.01 0.05	0.40 0.41 0.46	15 15 15 15 15 15 15 15	19 17 16 14 12 10 8 14

Table 35. Temperatures, rainfall, and photophases under which progenies of nine matings developed at two Midwest locations, 1968-69

Table	35. (	Continued	)
TONTO	$\mathcal{I}$	Conternaca	/

Day of development	Date	Temper O Max	ature F Min	Accumulated borer degree days	Rainfa (inche Daily Acc	ll s) umulative	Photo Hr	ophase Min
22 23 24 25 26 27 28 7-day average	July 23 24 25 26 27 28 29	80 85 76 81 82 71 75 78.6	63 57 58 61 58 50 53 57.1	Morris 435.0 456.0 473.0 494.0 514.0 524.5 538.5	, Minnesota, 0.01 0.34 0.22	1968 0.47 0.81 1.03	15 15 15 15 14 14 14 14	64 20 55 55 50
29 30 31 Aug 32 33 34 35 7-day average	30 31 9.2 3 4 5	80 82 73 82 93 91 87 84.0	62 53 49 52 64 69 59.7	559.5 577.0 588.0 608.5 636.0 663.5 691.5	1.26 0.01	2.29 2.30	14 14 14 14 14 14 14 14 14	51 45 43 43 43 35 43
36 37 <sup>a</sup> 38 39 40 41	6 7 9 10 11	96 89 85 73 70	69 66 65 46 42	724.6 751.5 778.5 802.5 812.0 818.0	0.01	2.31	14 14 14 14 14 14 14	33 30 28 25 22 19

aAverage 1st emergence.

Day of development	Date	Temper Max	ature F Min	Accumulated borer degree days	Rai (in Daily	nfall ches) Accumulative	Photo Hr	ophase Min
42 7-day average	Aug. 12	81 83.3	49 57.1	833.0	Morris,	Minnesota,	1968 14 14	17 25
43 44 45 46 47 48 49 <sup>b</sup> 7-day average	13 14 15 16 17 18 19	89 72 68 85 78 70 75 76.7	52 40 47 55 55 55 55 57 7	853.5 859.5 867.0 889.0 905.0 917.5 933.0	0.87 0.01 0.34	3.18 3.19 3.53	14 14 14 19 14 13 14	14 12 5 3 57 57
50 51 52 53 54 55 56 7-day average	20 21 22 23 24 26 27	81 84 92 79 95 67 69 81.0	55 59 67 61 45 45 57.1	951.0 972.5 1002.5 1025.5 1053.5 1059.5 1066.5	0.01	3.54 3.55	13 13 13 13 13 13 13 13	54 518 52 452 336 345
Hatch 1 2	<b>July</b> 10 11	85 85	62 60	23.5 46.0	Morris,	Minnesota,	1969 15 15	29 28

<sup>b</sup>Average 80 percent emergence.

Day of development	Date	Temper O Max	ature F Min	Accumulated borer degree days	Rai (in Daily	nfall ches) Accumulative	Photo Hr	ophase Min
3 4 5 6 7 7-day average	July 12 13 14 15 16	90 93 93 89 85 88.6	68 77 65 69 68 67.0	75.0 110.0 139.0 168.0 194.5	Morris, 0.30 0.33	Minnesota, 1 0.30 0.63	.969 15 15 15 15 15 15	26 24 23 21 19 24
8 9 10 11 12 13 14 7-day average	17 18 19 20 21 22 23	83 75 81 78 80 80 80.0	65 59 67 56 57 58 58 50.4	218.5 235.5 260.5 279.0 296.5 317.0 336.0	0.01 0.03 0.47	0.64 0.67 1.14	15 15 15 15 15 15 15	17 16 14 12 10 8 6 12
15 16 17 18 19 20 21 7-day average	24 25 26 27 28 29 30	77 85 85 84 75 82 86 82 0	59 593 56 58 58 58 59 59 4	354.0 376.0 400.0 420.0 436.5 456.5 481.0	0.04 0.02 0.01	1.18 1.20 1.21	15 15 14 14 14 14 14	4 2 0 8 5 5 3 5 5 5 5 5 5 5 5 5

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Table	35. (	Continued)
10010	$\mathcal{I}$	( oon oan aca )

Day of development	Date	Temper O Max	rature F Min	Accumulated borer degree days	Rai (in Daily	nfall ches) Accumulative	Photo Hr	ophase Min
22 23 Aug 24 25 26 27 28 7-day average	July 31 5.1 2 3 4 5 6	85 73 76 82 86 88 88 88 82.6	56 54 58 65 61 67 59.1	501.5 515.0 529.5 549.5 575.0 599.5 627.0	Morris, 1.46 0.13	Minnesota, 1 2.67 2.80	.969 14 14 14 14 14 14 14 14 14	48 45 41 35 33 40
29 30 31 32 33 34 35 7-day average	7 8 9 10 11 12 13	90 80 85 83 89 89 92 86.9	57 52 60 63 62 69 60.4	650.5 666.5 689.0 710.5 736.5 762.0 792.5			14 14 14 14 14 14 14 14 14	30 28 25 29 17 14 22
36 37 38 39 40 41 42 7-day average	14 <sup>a</sup> 15 16 17 18 19 20	84 85 90 82 83 78 84.3	55 57 59 561 564 56 56 56 9	812.0 833.0 856.5 882.0 901.0 919.5 936.5	0.04	2.84	14 14 14 14 13 13 14	128 530 542 552

Day of development	Date	Temper o Max	rature F Min	Accumulated borer degree days	Rain (inc Daily A	fall hes) ccumulative	Photo Hr	ophase Min
43 44 45 46 47 48 49 7-day average	Aug. 21 22 23 <sup>b</sup> 24 25 26 27	82 84 84 85 86 90 84.7	59 53 58 56 58 61 58.1	957.0 974.5 995.0 1015.0 1036.5 1060.5 1086.0	Morris,	Minnesota, 19	969 13 13 13 13 13 13 13 13	51 48 45 42 36 33 42
Hatch 1 2 3 4 5 6 7 7-day average	July 2 3 4 5 6 7	86 74 76 78 83 86 82 80.7	59 48 58 59 59 62 55 9	22.5 33.5 48.5 61.5 82.5 106.0 128.0	Ankeny, 1.70	Iowa, 1968 1.70	15 15 15 15 15 15 15	8 77 77 4 36
8 9 10 11 12 13 14 7-day average	8 9 10 11 12 13 14	84 88 78 78 84 91 89 84.6	68 63 55 56 72 67 764.0	154.0 179.5 196.0 213.5 238.5 267.5 298.0	0.22 0.15	1.92 2.07	15 15 14 14 14 14 14	310 5986 559 59

Table	35. (	Continued)

Day of development	Date	Temper Max	ature F Min	Accumulated borer degree days	Rai (in Daily	nfall ches) Accumulative	Photo Hr	ophase Min
15 16 17 18 19 20 21 7-day average	July 15 16 17 18 19 20 21	90 86 80 84 85 80 83 83 .0	73 71 68 69 59 58 67 66.4	329.5 358.0 382.0 408.5 430.5 449.5 474.5	Ankeny, 1.19 0.42	Iowa, 1968 3.26 3.68	14 14 14 14 14 14 14 14 14	54 521 49 47 45 49
22 23 24 25 26 27 28 7-day average	22 23 24 25 26 27 28	90 82 87 84 84 83 81 81.4	66 69 65 65 67 52 64.3	502.5 528.0 554.5 579.0 603.5 628.5 644.0	0.57 0.01	4.25 4.26	14 14 14 14 14 14 14 14	43 39 37 36 32 32 37
29 30 31 32 Au 33 34a 35 7-day average	29 30 31 2g. 1 2 3 4	79 82 84 71 77 82 81 79.4	56 62 53 55 66 59.6	661.5 684.5 707.5 719.5 735.0 757.0 780.5	0.01 0.30 0.01	4.27 4.57 4.58	14 14 14 14 14 14 14 14 14	30 28 26 23 20 18 24

Day develo	of opment	Date	Temper o Max	ature F Min	Accumulated borer degree days	Rain (in Daily	nfall ches) Accumulative	Photo Hr	<u>phase</u> Min
7-day	36 37 38 39 40 41 42 average	Aug. 5 7 8 9 10 11	83 91 94 93 82 84 70 85.3	71 74 69 65 65 65 51 65.0	807.5 840.0 871.5 899.5 913.0 936.0 946.5	Ankeny, 0.49 0.23 0.44 0.47	Iowa, 1968 5.07 5.30 5.74 6.21	14 14 14 14 14 14 14 14 14	16 14 12 9 7 5 2 9
4-day	43 44 45b 46 average	12 13 14 15	75 78 87 83 80.7	56 59 61 66 60.5	962.0 980.5 1004.5 1029.0	0.01	6.22	14 13 13 13 13	0 58 55 53 57
Hatch	12 <sup>:</sup> 34 56	July 11 12 13 14 15	89 88 94 93 94	66 70 67 75 74	27.5 56.5 87.0 121.0 155.0	Ankeny, 0.92	Iowa, 1969 0.92	14 14 14 14 14	5986 55555555555555555555555555555555555
7-day	7 average	17	92 91.6	70 70.9	218.5	0.93	1.85	14 14 14	52 51 55

Table	35.	(Continued)
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Day of development	Date	Temper o Max	ature F Min	Accumulated borer degree days	Ra (1 Daily	Rainfall (inches) Daily Accumulative		ophase Min
8 9 10 11 12 13 14 7-day averag	July 18 19 20 21 22 23 24 3e	84 87 78 81 81 85 84 82.9	70 70 67 61 65 61 64.9	245.5 274.0 296.5 317.0 338.0 363.0 385.5	Ankene 0.08 2.03 0.51	ey, Iowa, 1969 1.93 3.96 4.47	14 14 14 14 14 14 14 14 14 14	49 47 47 45 43 41 39 44
15 16 17 18 19 20 21 7-day averag	25 26 27 28 29 30 31 31	82 95 88 75 79 84 82.1	61 68 59 58 60 61 65 61.7	407.0 433.5 457.0 473.5 493.0 515.5 539.0	0.82	5.29	14 14 14 14 14 14 14 14 14	37 36 32 30 28 28 28 28 28 28
22 A 23 24 25 26 27 28 7-day averag	ug. 1 2 3 4 56 7 se	79 77 80 80 88 88 88 81.6	56 55 55 57 57 70 70 59.4	556.5 572.5 588.5 606.0 624.0 657.0 686.0	0.01	5.30	14 14 14 14 14 14 14 14	23 22 20 18 16 14 12 18

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Table	35.	(Continued)
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Table 35.	(Continued)	
	Temperature	Accumula

Day of development	Date	Tempera <sup>O</sup> E Max	ture Min	Accumulated borer degree days	Rai (ir Daily	nfall iches) Accumulative	Photo Hr	ophase Min
29 30 31 32 33 34 35 <sup>a</sup> 7-day average	Aug 9 10 11 12 13 14	83 87 83 84 85 87 87 85.1	56 64 561 65 66 60 61.7	705.5 731.0 751.5 774.0 799.0 826.5 850.0	Ankeny, 0.60	Iowa, 1969 5.90	14 14 14 14 14 13 13 14	97520852 552
36 37 38 39 40 41 <sup>b</sup> 42 7-day average	15 16 17 18 19 20 21	84 74 87 87 87 69 82.0	55 60 64 65 67 63 62.4	869.5 888.0 911.0 936.5 962.5 989.5 1005.5	0.05 0.08 0.14	5.95 6.03 6.17	13 13 13 13 13 13 13 13	53 48 44 398 45

Variable	Source	df	MS	F <sup>a</sup>
Total forms	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 3 9 8 8 8 8 24 72	36195.05 715.56 18382.82 1029.08 830.56 1127.55 795.83 329.42 847.92 197.27 239.78	43.58** 2.98 ns 22.13** 1.24 ns 4.70** 3.32** 1.37 ns 3.54** < 1 ns
Percent survival, x/360 days	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 3 9 8 8 8 8 24 72	2449.01 83.19 1548.61 121.15 50.34 81.19 74.21 35.67 52.01 18.63 17.45	48.98** 1.66 ns 30.96** 2.42 ns 4.65** 4.25** 2.04 ns 2.98** 1.07 ns

Table 36. Summary of analysis of variance for survival and development of progenies of nine matings of European corn borer under caged conditions in the field

a\*Significant 95 percent level, \*\*significant 99 percent level, ns = non-significant.

Table 36. (	Continued)	l
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Variable	Source	df	MS	F <sup>a</sup>
Larvae in diapause	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 3 9 8 8 8 8 8 8 2 4 7 2	5.84 564.06 410.06 10.17 177.68 405.17 9.98 119.70 106.98 11.66 30.18	<pre>&lt; 1 ns     3.17 ns     2.31 ns &lt; 1 ns     13.43** &lt; 1 ns     3.97**     3.55** &lt; 1 ns</pre>
Percent diapause	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 72 1 1 3 9 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	18771.90 197.38 1494.27 360.37 401.72 10176.12 920.44 138.09 135.64 166.17 152.17	46.81** < 1 ns 3.73 ns < 1 ns 66.87** 6.05** < 1 ns < 1 ns 1.09 ns
Total tunnels	Years Locations Y x L Replications	1 1 1 3	23973.36 1892.25 24596.66 869.51	58.22** 4.59 ns 59.73** 2.11 ns

## Table 36. (Continued)

Variable	Source	dſ	MS	Fa
Total tunnels (cont)	Error a Egg source Y x E L x E Y x L x E R x E Error b	9 8 8 8 24 72	411.78 628.41 652.61 409.22 252.63 89.35 112.25	5.60** 5.81** 3.65** 2.25* < 1 ns
Tunnels per form	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 3 9 8 8 8 8 8 8 2 4 72	266857.56 61628.06 70004.13 34282.54 13294.54 47697.66 61467.39 6726.17 6965.48 15306.71 17008.04	20.07** 4.64 ns 5.27* 2.58 ns 2.80* 3.61** < 1 ns < 1 ns < 1 ns
Tunnels above the ear, 1969	Locations Replications Error a Egg source L x E Error b	1 3 8 8 48	4278.11 37.61 69.16 52.31 48.87 19.02	61.86** < 1 ns 2.75* 2.57*

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Table 36. (Continued)

Variable	Source	df	MS	F <sup>a</sup>
Tunnels in the ear and shank, 1969	Locations Replications Error a Egg source L x E Error b	1 3 3 8 48	6.72 0.04 0.31 0.87 0.91 0.75	21.35* < 1 ns 1.17 ns 1.21 ns
Tunnels below the ear, 1969	Locations Replications Error a Egg source L x E Error b	1 3 8 8 48	5635.68 28.12 73.46 32.85 24.24 27.57	76.72** < 1 ns l.19 ns < 1 ns
Forms which pupated	Years Locations Y x L Replications Error a Egg source Y x E L x E L x E Y x L x E R x E Error b	1 1 39 8 8 8 8 8 24 72	37797.82 1.56 13708.49 1085.50 409.23 2248.76 752.76 219.64 776.86 184.77 192.05	92.36** < 1 ns 33.50** 2.65 ns 11.71** 3.92** 1.14 ns 4.05** < 1 ns
Percent pupation	Years Locations	1 1	22488.24 315.63	177.10 <b>**</b> 2.48 ns

Table	36. (	(Continued)
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Variable	Source	df	MS	Fa
Percent pupation (cont)	Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 3 9 8 8 8 8 24 72	1872.50 182.63 127.30 9857.93 936.03 267.67 247.97 259.76 234.43	14.74** 1.43 ns 42.05** 3.99** 1.14 ns 1.06 ns 1.11 ns
Adults emerged	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 3 9 8 8 8 8 8 24 72	34906.67 124.69 14399.96 1066.35 396.15 2036.32 715.14 225.24 758.51 183.23 182.71	88.11** < 1 ns 36.35** 2.69 ns 11.14** 3.91** 1.23 ns 4.15** 1.00 ns
Number of days to 80 per- cent emergence, 1969 omitted	Locations Replications Error a Egg source L x E Error b	1 3 3 8 8 8 48	369.01 6.72 7.01 2.78 8.51 5.00	52.64** < 1 ns < 1 ns 1.70 ns

Table 36.	(Continued)
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Variable	Source	df	MS	F <sup>a</sup>
Number of days to 80 per- cent emergence, Ankeny omitted	Years Replications Error a Egg source Y x E Error b	1 3 3 8 8 48	177.34 5.94 7.87 19.03 19.25 4.81	22.53* < 1 ns 3.96** 4.00**
Number of days to 80 per- cent emergence by sex, 1969 omitted	Locations Replications Error a Egg source L x E Error b Sex L x S E x S L x E x S Error c	1 3 8 8 48 1 1 8 54	548.34 37.39 50.50 12.44 30.38 11.02 9.51 7.56 12.17 7.33 5.51	10.85* < 1 ns 1.13 ns 2.76* 1.73 ns 1.37 ns 2.21* 1.33 ns
Number of days to 80 per- cent emergence by sex, Ankeny omitted	Years Replications Error a Egg source Y x E Error b Sex Y x S E x S	1 3 3 8 8 48 1 1 8	286.17 27.41 66.78 39.87 47.54 10.38 70.84 65.34 15.05	4,29 ns < 1, ns 3.84** 4.58** 11.13** 10.27** 2.37*

Variable	Source	df	MS	F <sup>a</sup>
Number of days to 80 per- cent emergence by sex, Ankeny omitted (cont)	Y x E x S Error c	8 54	20.27 6.36	3.19**
Adults trapped in tunnels	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 3 9 8 8 8 8 8 8 24 72	12.84 85.56 1.56 2.30 1.30 5.14 0.65 3.40 0.81 1.04	9.88* 65.82** 1.20 ns 1.77 ns 4.93** < 1 ns 3.27** < 1 ns < 1 ns < 1 ns
Percent of adults trapped in tunnels	Years Locations Y x L Replications Error a Egg source Y x E L x E Y x L x E R x E Error b	1 1 3 9 8 8 8 8 8 24 72	52.88 1004.88 0.34 35.31 8.47 42.64 3.66 50.51 9.03 16.40 16.71	6.50* 125.50** < 1 ns 4.37* 2.55* < 1 ns 3.02** < 1 ns < 1 ns

Level of confidence	95 percent	99 percent
F-values for comparison		
F1, 3 F1, 9 F1, 54 F3, 3 F3, 9 F8, 48 F8, 54 F8, 72 F24, 72	10.13 5.12 4.00 9.28 3.86 2.15 2.11 2.10 1.70	34.12 10.56 7.08 29.46 6.99 2.96 2.83 2.82 2.12

The laboratory and field data on incidence of diapause of progenies of the Alabama and Maryland parent types produced discrepancies which led to the speculation that a mixup between colonies might have occurred in the laboratory experiment. A similar laboratory experiment, replicated four times as previously described, was conducted during the summer of 1969 in which progenies of Alabama and Maryland parent types were reared under a 14 hr 15 min photophase and 18.3-31.7° C thermoperiod. A comparison, by replicate, of percent diapause between the two populations is presented in Table 37.

Table 37. Percent diapause per replicate for two laboratory colonies of European corn borer reared under one photophase and thermoperiod

Percent $\frac{(9 x)}{(1 + 1)^2}$			diapause per mating		
vegtue	nep.	Ala X Ala	Ma x Ma		
Photophase	I	53	94		
	II	49	95		
Thermoperiod 18.3-31.7°C	III	46	94		
	IV	60	100		
Average		52	96		

The data suggest that there might have been a mix-up between the Alabama and Maryland colonies in the 1968 laboratory experiment.