AUGMENTATION OF NATURALLY OCCURRING LEPIDOPTEROUS LARVAE AND EGGS AS AN ATTEMPT TO CONTROL BOLL-WORM DAMAGE IN COTTON

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PREFACE

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CHAPTER I

INTRODUCTION

The cotton bollworm, Heliothis zea (Boddie), and the tobacco budworm, Heliothis virescens (Fabricius), are often damaging to Oklahoma cotton. The bollworm is generally the most prevalent species, especially early in the season, but is often found together with the budworm later in the season.

During the late 1940's it became necessary to add DDT to insecticides used for boll weevil control to prevent damage to cotton by larvae of the Heliothis complex. This started a trend toward routine addition of DDT to materials applied for boll weevil control. Bollworm control was effective when as little as 0.5 lb/acre of DDT was applied in combination with BHC, aldrin, chlordane, heptachlor or toxaphene (Third Memphis Report, Conference of Cotton Entomologists, 1952). Inadequate control of the bollworm with organochloride insecticides was observed as early as 1956 in Louisiana (Graves et al. 1964). The first report of tobacco budworm resistance to DDT was from Peru in 1956 (Boza Barducci et al. 1957). In 1961 DDT resistance was reported in tobacco budworms in the United States (Brazzel 1963). Since that time resistance of both the bollworm and the budworm to certain insecticides has increased as much as 2- to 33,000-fold as reported by many investigators including Brazzel et al. (1963), Brazzel (1964), Adkisson and Nemec (1966), Lincoln et al. (1967), Graves et al. (1963), Pate (1964), Harris (1970), Nemec (1970), and Lukefahr (1970).

The availability and widespread use and effectiveness of organic insecticides in the 1940's and 50's apparently prevented growers and many entomologists from realizing the full value of predaceous and parasitic arthropods in regulating Heliothis populations. There was, however, a limited amount of attention given to predator and parasite populations during this period by investigators such as Newsom and Smith (1949), Iglinsky and Rainwater (1950), Gaines (1954, 1955) and Ahmed et al. (1954). In the 1960's as a result of the development of insecticide resistance (Brazzel 1963, Adkisson 1965), pest resurgence after treatment, awareness of environmental pollution and increased cost to growers, a new focus was brought to predator and parasite effects on the Heliothis complex.

The number of arthropod predators and parasites known to attack Heliothis is large. Whitcomb and Bell (1964) recorded over 600 predators in Arkansas; van den Bosch and Hagen (1966) estimated over 350 predators and parasites in California cotton fields; and over 40 parasites of Heliothis have been reported by Muesebeck and Krombein (1951) and Stone et al. (1965). Regulation of Heliothis is probably accomplished by a complex of both predators and parasites which may vary with the crop, the time of year and locality.

Various species of predators such as spiders (Araneida), green lacewings (Chrysopidae), lady beetles (Coccinellidae), soft-winged flower beetles (Malachiidae) and hooded beetles (Anthicidae) are abundant in Oklahoma cotton fields and are an important segment of the predator complex which helps regulate Heliothis populations. One of the problems with any one predator is that they are not specific enough in their food sources under natural conditions to be used as the only control of a particular pest.

Parasites of Heliothis spp. are much more specific but the number of species is more limited. There are 10 to 15 families of important predators, but only 10 to 15 species of important parasites. Most species of parasites attack both the bollworm and the tobacco budworm. Some parasites of genera such as Trichogramma and Chelonus parasitize eggs, while others, such as Apanteles, Campoletis, and Microplitis and Chelonus attack early instar larvae. Other parasites, such as Cardiochiles, Eucelatoria and Lespesia prefer late instar larvae (Ridgway and Lingren 1972).

Another problem in depending on predators and parasites is that natural populations of these beneficial arthropods rarely reach a sufficient level to regulate the Heliothis complex until the Heliothis population size is large and causing heavy damage. Some workers, such as Ridgway and Jones (1969), have attempted to overcome this lag phase of the beneficial insects by augmenting predators such as Chrysopa carnea Stephens. Lingren (1970) also attempted to eliminate the lag phase by releasing large numbers of Trichogramma. Both of these and others show promising results in regulating the Heliothis complex.

This research is an attempt to remove the lag between the destructive Heliothis build-up and its predators and parasites. This study involves the rearing of the yellow-striped armyworm, Spodoptera ornithogalli (Guenee) and the fall armyworm, Spodoptera frugiperda (J. E. Smith) in the laboratory and seeding either larvae (1971) or eggs (1972) in the cotton field to supply greater sources of food and to provide additional hosts for parasites. This increase in food and host source should theoretically enable the natural populations of the beneficial arthropods to increase in number prior to the time when *Heliothis* populations become damaging.

The *Heliothis* populations were estimated by counting the number of damaged fruits each week.

Levels of beneficial insects were not sampled in 1971; however, in 1972 approximate densities of major beneficials were determined by whole plant examinations.

Evaluations of the effects of the levels and type of larvae or eggs seeded were made by comparing *Heliothis* damage and yield of cotton from each treatment.

CHAPTER II

REARING AND MANIPULATION OF SPODOPTERA ORNITHOGALLI (GUENEE) AND SPODOPTERA FRUGIPERDA (J. E. SMITH)

In any study involving the augmentation of naturally occurring organisms, several factors must be considered before selecting organisms to be seeded or released. The organism must lend itself to mass rearing in the laboratory or field cage situations; have a high reproductive potential; have a similar distribution as the pest species which are the target of suppression; reared organisms should support parasitoids of the pest species; have a similar length life cycle; and be readily available from the local area.

The yellow-striped armyworm, *Spodoptera ornithogalli* (Guenee), and the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), are the two insects selected for rearing in this study. They are related to *Heliothis zea* and *H. virescens* and fulfill the above desired traits. Both *S. ornithogalli* and *S. frugiperda* have been successfully reared on diets of natural plant material by Luginbill (1928), Crumb (1929), Revelo and Raun (1964), Bailey and Chada (1968) and others. Adkisson et al. (1960) developed an artificial medium based on wheat germ for the rearing of the pink bollworm. Since that time several variations, substitutions or modifications of the artificial diets by workers such as George et al. (1960), Vanderzant (1962), Berger (1963), Shorey (1963), Shorey and Hale (1965), Roberts (1965), Randolph and Wagner

(1966), Bowling (1967), Burton (1967, 1969), Bottrell (1968), Pantana (1969) and Ignoffo et al. (1970) has enabled the rearing of numerous lepidopterous larvae on artificial media.

Biology of *Spodoptera ornithogalli*

Crumb (1929), Shorey and Hale (1965) and Bottrell (1968) presented data on the biology of *S. ornithogalli*. Crumb (1929) was the most complete and will be used as the source for the following biology except where noted.

The yellow-striped armyworm, *S. ornithogalli*, is a common noctuid distributed from the most southern countries of South America through most of the continental United States.

The moths emerge from overwintering pupae in early April through the end of May. Mated female moths oviposit freely, with or without having fed, depositing large masses of eggs on foliage, walls of buildings, twigs of trees and other elevated objects. The masses consist of one or more, usually two, layers covered and intermingled with grayish scales from the moth's body. The potential number of eggs a female can lay and the size of the egg masses are somewhat greater than that of the fall armyworm. Walkden (1950) reported dissecting two females; one contained 2,189 eggs and the other 1,622. Crumb (1929) recorded two egg masses as having 950 eggs and about 500 eggs and that several similar masses could be deposited by one moth in a single night.

Crumb (1929) reported six instars but Bottrell (1968) reported six, seven or eight larval instars with six being the most common. The larvae feed on a great variety of plants, including cotton. The final instar of the larvae burrows into the ground and forms a chamber and pupates. There are generally several broods of larvae per year, with the last brood providing the overwintering pupae. The complete life cycle requires about 36 to 43 days at temperatures about 70° F.

Biology of Spodoptera frugiperda

Biology of Spodoptera frugiperda has been reported by numerous workers, a few of which are Dew (1913), Luginbill (1928), Hofmaster and Greenwood (1949), Walkden (1950), Metcalf et al. (1962), Randolph and Wagner (1966), Bowling (1967), Burton (1967), and Bailey and Chada (1968). Luginbill (1928) is the most complete and will be used as a source unless otherwise indicated.

The fall armyworm, Spodoptera frugiperda, is a semi-tropical armyworm which cannot overwinter in areas in which the ground freezes and, therefore, must migrate annually from the extreme southern USA and Mexico.

The fall armyworm overwinters in southern Florida and southern Texas and occasionally along the Gulf Coast (Hinds and Dew, 1915). The moths overwinter in the tropical life zones of Mexico and Central and South America and migrate northward when temperatures allow into the austral life zone and even into Canada.

The moth deposits her eggs in masses consisting of two or three layers superimposed on each other and covered with scales from her body. The several masses produced by the female range from a few to about 600 eggs and a total of about 1000 eggs are produced by each female. The average number of eggs is about 150 per mass (Metcalf 1962). The eggs are deposited usually before 10 p.m. (Dew 1913).

The larvae emerge and proceed through six or seven instars, feeding on a great variety of plants including cotton (Dew 1913, Luginbill 1928). The last instar burrows into the ground and forms a chamber and pupates. The entire life cycle requires approximately 33 days at a temperature of 80° F. (Randolph and Wagner 1966).

Methods and Materials

Larvae of the yellow-striped armyworm were collected from alfalfa in Payne, Lincoln, Noble and Grady counties and from mung beans in Kingfisher County (Oklahoma) to establish a laboratory colony.

The field collections of S. ornithogalli were begun about April 15, 1971, and continued through June 15 from alfalfa and mung beans. In the beginning sweeping was used in the alfalfa to collect the larvae, but relatively few larvae, less than 200 total, were collected by this method. The greatest number of larvae were found beneath the cut alfalfa which had been windrowed for three to four hours on a hot day (over 300 larvae were collected in less than 30 minutes). Large numbers of larvae were collected from mung beans on two different collection trips (about 270 larvae collected in less than 30 minutes). Some of these large collections were highly parasitized, up to 70 percent, primarily by a large Tachinid (Archytas apicifer (Wlk.)). The most reliable source of larvae was in freshly cut fields of alfalfa. Sufficient populations of larvae were collected to establish the colony in the laboratory by June 15, 1971.

Larvae of the fall armyworm were secured from R. L. Burton.[1]

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[1]Research Entomologist, USDA, Small Grains Laboratory, Oklahoma State University, Stillwater, Oklahoma 74074.

The larvae were reared in 1 oz. transparent plastic cups,[2] each supplied with about 10 ml. of modified pinto bean diet (Burton 1969). The larvae were allowed to pupate in the artificial media and the moths emerge.

Approximately 10 pairs of moths were placed in a breeding chamber which consisted of a one gallon freezer carton with paper toweling fitted to the walls of the chamber and paper toweling used as a top. The moths were fed a sucrose solution (80 grams of sucrose in 1000 ml. of distilled water) in a cotton filled 1 oz. plastic cup.

The eggs and/or larvae were collected as demanded and prepared for release or seeding. In 1971 larvae were placed on a small amount of media in a 1 oz. plastic cup to be transported from the laboratory at Stillwater to the field near Tipton, Oklahoma. Larvae were placed in 1 oz. cups and a plot treatment package was prepared. Each plot was replicated four times in the field so four plot treatment packages were made for each of the treatments (1, 10, and 100 larvae per 10 feet of row on 80 feet of each plot). For the treatment with one larva per 10 feet, one larva was placed in each of eight cups. For the treatments with 10 and 100 larvae per 10 feet, 10 larvae were placed in each of 8 and 80 cups, respectively, and placed in each plot package. The larvae were released by placing the open cup at the base and in the shade of the cotton plants.

In 1972 eggs of both species were collected on paper toweling which lined the sides and top of the cartons. The egg masses of both species were separated by the method reported for separating fall armyworm egg

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[2]Premium Plastics, 465 Cermak Road, Chicago, Illinois 60616.

masses by McMillian and Wiseman (1971). However, due to a shortage of labor and time, this procedure was abandoned. Instead, the eggs on the paper toweling were collected every other day and stored in a refrigerator at about 45^{o} F to slow hatching. The eggs were counted by placing the egg masses under a grid and determining the number of eggs in the masses. Both species of Spodoptera were subjected to the same test. The masses of S. ornithogalli have about 250 eggs in a medium size mass, while S. frugiperda has only about 150 eggs in a medium size mass. The paper toweling was then stapled together in units of two or three towels and placed in treatment packages. A treatment package contained sufficient numbers of eggs or larvae to treat one plot. These were transported from Altus to the research plots (about 21 miles away) and placed in the plots between 6 p.m. and 9 p.m. The eggs were physically placed on the cotton plants at the treatment rates of 10 and 50 yellow-striped armyworms and 10 and 50 fall armyworm eggs per linear foot on 80 feet of each plot. These treatments, plus the check, totaled five treatments which were replicated five times in the 5 x 5 latin square. A total of about 48,000 eggs (24,000 of each species) were seeded each week for a period of eight weeks.

Results and Discussion

Colonies of both the fall armyworm and the yellow-striped armyworm were satisfactorily established and maintained for a period of two years. The larvae seemed to do well on the modified pinto bean diet and the resulting moths produced sufficient quantities of eggs and/or larvae throughout this study period.

Larvae which were released in 1971 were apparently consumed, parasitized, or other mortality factors came into play to the extent that only one yellow-striped armyworm and two fall armyworms were ever found to have reached the 5th instar. All of these were parasitized, the parasitic larvae being observed on the dorsum about the second or third segment of the body.

Eggs physically placed on the plants in 1972 were apparently consumed within three days by predators such as Chrysopa spp., Coccinellids, Collops beetles, Notoxus monodon, etc., and parasites. On several occasions the paper toweling on the cotton plant from the previous week was examined and found to serve as hiding places or resting places for lacewing larvae, lady beetle adults, and/or Collops beetles. No Spodoptera larvae were observed during the sampling periods.

Summary

Securing a sufficient quantity of yellow-striped armyworms from field collections required about 60 days because the parasitism rate was up to 70 percent in some collections. The primary parasite was a large Tachinid. Colonies of the fall armyworm were secured from an established laboratory culture and presented no problem.

Both species of Spodoptera are easily mass reared and with a limited amount of work can be increased to produce the desired larvae and/or eggs needed. A variety of diets will suffice for the larval stages of both species. Adults seem to produce the best egg lays when cages of 8 to 10 pair are placed in each cage.

The first and second instar larvae were transferred from the hatching compartments into 1 oz. transparent cups which were then transported from the laboratory at Stillwater to the field plots south of Tipton, Oklahoma. The larvae of both Spodoptera are positively phototrophic, and when placed at the base of a plant, will ascend that plant.

The separation of the eggs of the yellow-striped and fall armyworms was satisfactorily performed by the method reported by McMillian and Wiseman (1971). However, as stated before, it was abandoned because of the shortage of labor and the time consumed in preparing the eggs for placement in the cotton field. The method of determining the numbers of eggs by use of a grid appeared consistent and accurate enough that it was the technique used.

CHAPTER III

EFFECT OF AUGMENTATION WITH LARVAE OF SPODOPTERA ORNITHOGALLI (GUENEE) AND SPODOPTERA FRUGIPERDA (J. E. SMITH) ON HELIOTHIS DAMAGE AND COTTON YIELD

The cotton bollworm, *Heliothis zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (F.), both major pests of cotton in Oklahoma, are susceptible to attack by predaceous and parasitic arthropods according to Glover (1856), Comstock (1879), Quaintance and Brues (1905), Chamberlin and Tehnet (1926), Wene (1943), Grayson (1944), Wille (1951) and others. Ewing and Ivy (1943) and Fletcher and Thomas (1943) demonstrated the importance of beneficial arthropods in regulation of bollworm populations in cotton.

A large number of arthropod predators and parasites are known to attack *Heliothis*. Whitcomb and Bell (1964) recorded over 600 predators in Arkansas cotton fields; van den Bosch and Hagen (1966) estimated about 350 predators and parasites in California cotton fields; Muesebeck and Krombein (1951) and Stone et al. (1965) recorded over 40 parasites of *Heliothis*. Although many predators and parasites attack the *Heliothis* in cotton, the most important predators are probably limited to 10 to 15 families, most of which feed on the eggs or early instar (3rd instar or smaller) larvae. The parasites are probably limited to about 10 to 15 species in the cotton growing regions. Some of the families which are important larval predators are Lygaeidae (*Geocoris*), Nabidae (Nabis), Anthocoridae (Orius), Chrysopidae (Chrysopa), Coccinellidae (Coleomegilla, Hippodamia and Scymnus) and Araneida of the families Argiopidae, Oxyopidae, Salticidae and Thomiscidae. Some of the more important families of larval parasites are Braconidae (Apanteles, Microplitis, Cardiochiles and Chelonus), Ichneumonidae (Campoletis) and Tachinidae (Eucilatoria and Lespesia) (Ridgway and Lingren 1972).

Recent investigations have demonstrated that naturally occurring predators and parasites play an important role in suppressing Heliothis populations according to Whitcomb (1967 a,b), Lincoln et al. (1967), Ridgway et al. (1967), Lewis and Brazzel (1968), Lingren et al. (1968 a, b), and Ridgway (1969). In a theoretical appraisal, Knipling (1967) assumed 75% control of Heliothis by insect predators and parasites and Ridgway and Lingren (1972) stated that a generalized average of the effects of predators and parasites on eggs and larvae of Heliothis would indicate that levels of natural control from 50% to 90% or more might be expected. Fletcher and Thomas (1943) reported a reduction of 13% to 60% of Heliothis larvae on cotton by predators. Whitcomb (1967 a, b) reported a 25% to 56% reduction in Heliothis larvae by predators. Reduction of Heliothis larvae by parasites has been reported to range from 0 to 51% on cotton by Quaintance and Brues (1905), Watson et al. (1966), Lewis and Brazzel (1968) and Bottrell et al. (1968). Quaintance and Brues (1905) and Watson et al. (1966) also reported a 1% reduction of Heliothis larvae on corn by naturally occurring parasites. Lewis and Brazzel (1968) reported a 76% reduction of Heliothis larvae on tomatoes by naturally occurring parasites. Wene (1943) and Grayson

(1944) reported 14% to 94% and 28% to 94%, respectively, reduction of *Heliothis* larvae by parasites.

The above investigations indicate that there is potential for suppression and/or control of *Heliothis* in cotton as well as some other crops by use of natural enemies. Although naturally occurring predators and parasites may be important in suppressing *Heliothis* populations, they frequently do not prevent populations of the pests from reaching economically damaging levels. This is particularly true in intense agro-ecosystems which frequently are monocultures or when insecticides are used to control other pests. Thus, augmentation of naturally occurring predators and parasites provides a means of producing the desired level of predator and/or parasite populations which in turn may regulate the *Heliothis* population. Augmentation may take the form of programmed releases of mass reared predators or parasites, adding additional food sources or host sources, or cultural practices which will result in increased parasite and/or predator populations (Ridgway and Lingren 1972). Recent investigations by Lingren et al. (1968) and Ridgway and Jones (1968, 1969) with programmed releases of *Chrysopa carnea* has provided effective control of *Heliothis* larvae on cotton in field cages and in the field. Inundative releases of *Apanteles marginventris* (Cresson) and *Campoletis predistinctus* (Vierick) have also provided promising results in the control of *Heliothis* in field cage or field test (Ridgway and Lingren 1972).

In a theoretical study on providing supplemental parasites, Knipling (1971) indicated that sustained releases of larval parasites (100 to 200 per acre) would achieve a high degree of suppression or even eventual elimination of the pests. Knipling and McGuire (1968) in another theoretical study suggested that food (in the form of eggs) could build up populations of naturally occurring parasites to a level at which *Heliothis* could be controlled. Parker (1971) demonstrated that suppression of the pest *Pieris rapae* (L.) could be achieved in field situations by release of the pest itself, an egg parasite and a larval parasite. The impact of supplemental food or hosts in field situations may potentially provide a more economically feasible method of suppressing field populations than mass rearing and release of predators and/or parasites. For the previous statement to have any validity one must consider the potential predators and parasites available and their food or host preferences. While most predators are generalists in that they feed on available food sources, parasites are more specific. Ridgway and Lingren (1972) compiled a list of principal parasites of *Heliothis* larvae in the southern United States which has been modified to include the yellow-striped armyworm, *Spodoptera ornithogalli*, and the fall armyworm, *S. frugiperda*, as hosts (Table I). This indicates the host potential that might be provided by releases of the *S. ornithogalli* or *S. frugiperda* larvae.

Our proposal for this study was to release larvae of *S. ornithogalli* or *S. frugiperda* in cotton at 0, 10, or 100 larvae per 10 linear feet on 80 feet of each plot, each species in its own test plots. The effects of these low density releases would be determined by *Heliothis* damage and cotton yield.

Materials and Methods

Eighty-four rows of Westburn 70 cotton were planted on May 18, 1971, at the Southwestern Agronomy Research Station in Tillman County, Oklahoma, utilizing 40 in. row spacing. The cotton was planted at the rate of 20 pounds per acre. The field was divided into two equal 4 x 4 latin square design test areas. Each plot was 60 feet long and 18 rows wide. Each plot contained a smaller sub-plot in the center which measured 20 feet long and 4 rows wide. In each of the sub-plots, larvae of S. ornithogalli (Guenee) or S. frugiperda (J. E. Smith) were released according to the test area and the randomized scheme of treatment levels.

Larvae of S. ornithogalli and S. frugiperda were transferred with a camel hair brush from laboratory colonies in Stillwater, Oklahoma, into transparent 1 oz. plastic cups,[1] each cup containing about 2 ml. of modified pinto bean artificial media (Burton (1969) and transported to the field plots south of Tipton, Oklahoma. The 1st and 2nd instar larvae were placed in cups at the rate of 1 or 10 larvae per cup and placed in paper bags in the numbers to be seeded in each plot. The treatments were seeded by placing cups of S. ornithogalli or S. frugiperda larvae at the base of the cotton plants at the low level rates of 0, 1, 10, and 100 larvae per 10 feet of linear space in the sub-plot area of each plot, treating a total of 80 feet in each plot. The S. ornithogalli larvae were placed in the test plots July 15 and 27, August 10 and 24, and September 9. Larvae of S. frugiperda were placed in the test plots July 7 and 20 and August 3, 17, and 31.

The effects of the treatments on Heliothis damage were evaluated by collecting 100 squares weekly from the top 1/3 of the plants in each of the main plots in each of the latin squares from July 7 through

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[1]Premium Plastics, 465 Cermak Road, Chicago, Illinois 60616.

September 7. An analysis of variance was performed by the Statistics Department utilizing the Statistical Analysis System program.[2]

Yield data were collected by hand gathering the cotton in each sub-plot (20 feet of 4 rows in the middle of each main plot). The cotton was harvested twice (October 2 and November 18, 1971). The yield data were recorded and then converted to lint cotton with a conversion factor of 0.23. An analysis of variance was performed on the data.

Results and Discussion

Damage to the cotton squares and small bolls by Heliothis in each of the replicates treated with the same levels of S. ornithogalli were recorded and averaged (Table II and Fig. 1). Analysis of these data revealed that there was no significant difference between treatments (Table III). However, there was a significant difference at the 1% level in the damage of this test area over the 10 week period (Table III). This difference in the damage indicates the population size, or generation cycles of the Heliothis population for this particular field in 1971. The increases in damage followed the periods of lunar activity described by Nemec (1971). The new moon occurred July 22 and August 20 (Almanac, 1971) and the damage peaks occurred between July 27 to August 3 and August 24 to August 31 (Fig. 3), about a week after the new moon. During these two peak periods square and small boll damage reached an average of about 2.5% and 7.0%, respectively, but was followed by a decrease in damage of over 50% of the peak. At no time was there evidence of foliage or fruit damage by S. ornithogalli, the

[2]Anthony J. Barr and James Howard Goodnight, North Carolina State University.

released larvae. Only one larva over the 3rd instar was ever observed and that larva was parasitized by a dipterous parasite (the small larva was observed on the dorsum of the second or third body segment).

Damage to the cotton squares and small bolls by Heliothis in each of the replicates treated with the same levels of S. frugiperda was recorded and averaged (Table IV and Fig. 2). Analysis of these data revealed that there was no significant difference between treatments (Table V). However, there was a significant difference in the damage over a 10 week period (Table V). There was a significant difference at the 1% level due to dates and a significant interaction at the 5% level for the variable treatment by dates. The differences in the damage indicate the population size, or generation cycles of the Heliothis population for this particular field in 1971. The increases in damage followed the periods of lunar activity described by Nemec (1971). The new moon occurred July 22 and August 20 (Almanac, 1971) and the damage peaks occurred between July 27 to August 3 and August 24 to August 31 (Fig. 3), about a week after the new moon. During these two peak periods square and small boll damage reached about 1.25% and 6.25%, respectively, but was followed by a decrease of over 50% of the peak. At no time was there evidence of foliage or fruit damage by S. frugiperda, the released larvae. Only two larvae over the 3rd instar were ever observed and those larvae were both parasitized by a dipterous parasite (the small larva was observed on the dorsum of the second or third body segment). There could be no statistical analysis comparing the two treatment areas due to the design but there appears to be no difference in the damage of the two areas (Fig. 3).

The cotton yield data were collected from each plot and recorded as burr cotton. These data were converted to lint cotton then to lint cotton per acre. The yield data collected from the area treated by the differing levels of _S. ornithogalli_ larvae (Table VI and Fig. 4) when subjected to an analysis of variance (Table VII) revealed that there was no significant difference between the treatment responses. The average yield for the area treated by released _S. ornithogalli_ was 651.5 pounds of lint cotton per acre.

Statistical analysis of the yield data collected from the area treated by the treatment levels of _S. frugiperda_ larvae (Table VIII and Fig. 5) revealed that there was no significant difference between the treatment responses (Table IX). The average yield for the area treated by released _S. frugiperda_ was 527.75 pounds of lint cotton per acre.

The yield of the two areas was not compared statistically due to the design of the experiment. There appears to be a difference in the averages of about 100 pounds throughout the field (Fig. 6). However, it is hypothesized that the difference is caused by disease (wilt) of which there were two large areas in the latin square treated by _S. frugiperda_ which caused a stunting of the plants and an observed difference in cotton yield.

Summary and Conclusions

The larvae of _S. ornithogalli_ and _S. frugiperda_ when released in cotton at low levels are apparently in themselves unable to provide sufficient host and/or food sources to adequately increase the parasite and predator populations of the _Heliothis_ complex. This is demonstrated by the nonsignificance between the damage and yield from plots in which no larvae were released and any of the other plots regardless of the species of *Spodoptera* utilized.

The potential for increasing the beneficial populations is evident. However, these data do not support my hypothesis that it could be done with this level of release and even possibly these organisms. Inundative releases of larvae might prove to provide the necessary food and/or host sources or, if not, there might be some other factor suppressing the *Heliothis* population.

CHAPTER IV

EFFECT OF AUGMENTATION WITH EGGS OF SPODOPTERA ORNITHOGALLI (GUENEE) AND SPODOPTERA FRUGIPERDA (J. E. SMITH) ON BENEFICIAL ARTHROPODS, HELIOTHIS LARVAL POPULATIONS AND DAMAGE, AND YIELD IN COTTON

The eggs of two major pests of cotton, the cotton bollworm, *Heliothis zea* (Boddie) and the tobacco budworm, *H. virescens* (F.) are susceptible to predation by a wide range of predators and parasitized by several species of egg parasites. Many of the predators which consume the eggs of the two *Heliothis* species will also feed on the eggs of the yellow-striped armyworm, *Spodoptera ornithogalli* (Guenee), and the fall armyworm, *S. frugiperda* (J. E. Smith). Some of the major predators found in cotton are Neuroptera of the genus *Chrysopa*, Coleoptera of the genera *Collops*, *Hippodamia*, *Scymnus*, and *Notoxus*, Hemiptera of the genera *Geocoris*, *Nabis*, *Orius* and *Zelus* (Lingren et al. 1968 a, b; Bell and Whitcomb 1962, 1964; Young 1969; and Ridgway and Lingren 1972).

Reduction of *Heliothis* eggs by predation has been reported by several workers: Fletcher and Thomas (1943) reported 15 to 33% reduction of eggs in cotton; Bell and Whitcomb (1962) found 6 to 38% reduction of eggs in cotton in a 12 hour time period; Whitcomb (1967 a, b) reported 12 to 26% reduction of eggs on cotton over a 24 hour period; and Harrison (1960 found a 25% reduction of *Heliothis* eggs on corn silk by predators. The predator complex varies to a degree with location, crop, and the growth stage of that crop (Ridgway and Lingren 1972).

Reduction of *Heliothis* eggs by parasites has been reported by several workers. Graham (1970) found 15 to 53% parasitism of eggs on cotton by *Trichogramma semifumatum* Perkins in the Rio Grande Valley of Texas. Lingren (1969) achieved 16 to 98% reduction of eggs on cotton with inundative releases of *Trichogramma* sp.

Several hymenopterous egg parasites which utilize *Heliothis* eggs as host also utilize eggs of *S. ornithogalli* and/or *S. frugiperda*, such as *Trichogramma* spp. and *Chelonus texanus* Cresson (Bottrell 1968, Graham 1970, Quaintance and Brues 1905, Fletcher and Thomas 1943, Walkden 1950, Luginbill 1928, and Crumb 1929).

Several species of *Trichogramma* have been reared and numerous attempts have been made to control several lepidopterous pests by periodic releases of large numbers of the parasites. De Bach and Hagen (1964) and Jaynes and Bynum (1941) reviewed these studies and stated that the results were inconclusive and required more study before any practical recommendation could be made. Knipling and McGuire (1968), in a theoretical study of the potential of *Trichogramma* in suppressing lepidopterous pests, suggested that releases of large numbers of the parasites (50,000 parasites per acre per parasite generation) would sufficiently suppress a *Heliothis* population. However, they also stated that a more economical method of building egg parasite populations in field situations might be to add sufficient host eggs to increase natural populations. Knipling (1970) suggested that host eggs on which *Trichogramma* could develop might be supplied by mass producing natural host eggs using the following methods. The host eggs could be sterilized and added to the natural environment in sustained additions.

Sufficient eggs of an alternate host that will not attack the crop could be mass produced and added to the environment. The males and females of the host could be sterilized so that large numbers of sterile eggs are produced which will serve as host for *Trichogramma* or other egg parasites.

Spodoptera ornithogalli and *S. frugiperda* are noctuids which are pests of cotton on occasion, although damage is usually minor. Both species produce large numbers of eggs in masses ranging in size from 60 to over 900 (Crumb 1929 and Luginbill 1928). The masses of *S. ornithogalli* average about 250 eggs, while those of *S. frugiperda* average about 150 eggs per mass (Metcalf 1951).

This study involves the sustained addition of *S. ornithogalli* or *S. frugiperda* eggs, from laboratory colonies, into the cotton agroecosystem at three different rates. The rates were a check, to which no eggs were added, 10 and 50 eggs of each species per linear foot on 80 feet of each plot. The eggs (approximately 50,000 per week) were added to the cotton plots in an attempt to supply sufficient food or host to increase and maintain the populations of those arthropods, which by means of predation and/or parasitism would suppress or control *Heliothis* populations. It is our hypothesis that *Heliothis* suppression can be achieved at one of the above two rates with one or both of the *Spodoptera* spp. eggs utilized.

Materials and Methods

Ninety-five rows of cotton, 520 feet long, were planted in a pre-irrigated field, utilizing Westburn 70 cotton at the rate of 23 pounds per acre and 40-inch row spacing. The cotton was planted May 24, 1972, on the Southwest Agronomy Research Station located three miles south of Tipton, Oklahoma, in Tillman County. A 5 x 5 latin square design was set up with each plot being 100 feet long and 18 rows wide.

The cotton was irrigated two times during the growing season, July 29 and August 9.

Laboratory colonies of S. ornithogalli and S. frugiperda, which were maintained at the cotton insect laboratory at Stillwater, Oklahoma, were transported and established in the laboratory at the Altus Irrigation Research Station at Altus, Oklahoma, in Jackson County. The colonies of S. ornithogalli maintained in Stillwater were established from field collected larvae found on alfalfa and mung beans in Payne, Lincoln, Noble, Grady, and Kingfisher counties. The colonies of S. frugiperda were acquired from R. L. Burton.[1] The adults were caged in a one gallon ice cream carton with paper toweling lining the sides and covering the top. The adults were fed on a sucrose and water solution.[2] The colony was maintained by collecting about 100 larvae per day with a camel hair brush and placing the larvae in one oz. plastic cups.[3] Each larva was provided with about 10 ml. of modified pinto bean diet (Burton 1969). Paper toweling with the deposited eggs was collected from the colonies at Altus and stored in a refrigerator at approximately 45° F. Five days prior to sampling the cotton except for the first sampling date, eggs were taken from the refrigerator, they were counted by the size of the egg masses, and the toweling with the

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[1]Research Entomologist, USDA, Small Grains Laboratory, Oklahoma State University, Stillwater, Oklahoma 74074.

[2]80 grams of sucrose in 1000 ml. of distilled water.

[3]Premium Plastics, 465 Cermak Road, Chicago, Illinois 60616.

number of eggs required for each plot was placed in a group. The toweling was stapled together and taken to the field at Tipton, approximately 20 miles away. The paper toweling with the eggs was placed on the cotton plants by research personnel. The eggs were placed on approximately 40 feet of each of the middle two rows of each plot between 6 p.m. and 9 p.m. five days prior to each sampling date. The placement of the eggs late in the evening was an attempt to allow the eggs to acclimate to the high temperatures in southwestern Oklahoma.

The five treatments (addition of eggs) were replicated five times and were as follows:

Treatment 1 was the addition of 10 S. frugiperda eggs per linear foot on 80 feet of the plot.

Treatment 2 was the check in which no eggs were added to the plot.

Treatment 3 was the addition of 10 S. ornithogalli eggs per linear foot on 80 feet of the plot.

Treatment 4 was the addition of 50 S. frugiperda eggs per linear foot on 80 feet of the plot.

Treatment 5 was the addition of 50 S. ornithogalli eggs per linear foot on 80 feet of the plot.

Those treatments of which 10 eggs per linear foot on 80 feet of row in each plot were added had a total of 800 eggs added per plot each week. The five replicates would make the total 4,000 eggs and the two species would make a total of 8,000 eggs per week. Those treatments of which 50 eggs per linear foot on 80 feet of row in each plot were added had a total of 4,000 eggs per plot each week. The five replicates would make a total of 20,000 eggs per week for each species. The two species would make the total 40,000 eggs per week. The total eggs added to all of the plots in the 3.5 acre field was approximately 48,000 eggs per week. The egg addition was sustained for eight weeks (July 9, 16, 23, 30 and August 6, 13, 20, 27), making a total of approximately 384,000 eggs added to the field or approximately 109,000 eggs per acre.

During the first week eggs were separated from the toweling and each other by the method described by McMillian and Wiseman (1971). Although eggs of both S. ornithogalli and S. frugiperda could be separated by the above method it was found to be very time consuming. Due to a shortage of time and labor, an alternate method for counting and placing the eggs in the field was devised. The eggs were left on the paper toweling, and the egg masses were placed under a raised glass with circles on it. The eggs were counted by the number of layers and the size of the egg mass. Several masses of each species were counted before a size-number grid was established. The egg numbers were then rather easily determined, even though the egg masses of S. ornithogalli were usually larger than those of S. frugiperda.

A plant density check was taken on July 14. The average plant density was 38.4 plants per 10 feet of row, making a total of approximately 49,658 plants per acre.

Data on plant fruiting, Heliothis damage to cotton fruits, Heliothis eggs and larvae, and beneficial arthropods were collected on July 14, 20, 27 and August 3, 10, 17, 24, 31. All data were collected by whole plant examination of two plants per row on the middle 10 rows of each plot each week. Ten steps into the plot from either end were first taken then a guarded plant was selected at a random distance from the starting place. The plant fruiting and damage data consisted of counting the number of healthy and Heliothis damaged squares, blooms and bolls on each plant and recording them on field data sheets. The Heliothis egg and larva counts were made and recorded on the insect data sheets. The beneficial arthropod data consisted of counting green lacewing eggs and larvae (Chrysopa spp.), soft winged flower beetles (Collops spp.), lady beetles, both larval and adult stages, hooded beetles (Notoxus monodon (Fab.)), and spiders of several families. The arthropod data were collected first then the plant data.

Twenty feet of the middle 10 rows of each plot was hand stripped on October 14 to calculate the yield for that plot. The hand stripped cotton was converted to lint cotton by a factor of 0.23 and to a per acre basis by multiplying the plot yield by 13,068 square feet.

Analysis of variance was performed on the data by the Statistics Department of Oklahoma State University utilizing the Statistical Analysis System.[4]

Results and Discussion

Plant Fruiting

The fruiting pattern of the Westburn 70 cotton planted on May 24, 1972, indicated that peak squaring occurred about July 20, with approximately 325,000 squares per acre. The peak boll production was reached about August 10, with more than 250,000 bolls per acre. The highest number of blooms recorded was approximately 50,000 per acre (Fig. 7).

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[4]The system was designed and implemented by Anthony James Barr and James Howard Goodnight, Department of Statistics, North Carolina State University, Raleigh, North Carolina.

Heliothis Damage

Analysis of *Heliothis* damaged fruits (Tables XXXV, XXXVI, and XXXVII) indicate no difference between treatments, although there was a significant difference at the 1% level over the sampling dates. The amount of damage by treatments (Table XXXVIII) does not display any marked difference between the treatments. However, there is a difference among weekly intervals. The amount of damage in the plots treated with no addition of eggs and the plots treated with 50 *S. ornithogalli* eggs per linear foot both have totals of over 7,000 damaged fruits per acre, which is less than 1% of the total fruits. All the other plots and treatments have less *Heliothis* damage than the two previously mentioned. The *Heliothis* damage (Fig. 8 and Table XXXIX) never reached 1% of the total fruits at any time. The greatest amount of *Heliothis* damage was recorded as 0.7% on August 31 in plots treated with 50 *S. frugiperda* eggs per linear foot. The average *Heliothis* damage (Table XXXIX, Fig. 9, 10, 11, 12, 14, and 15) reached peaks on July 20, August 10, and August 31, with that of August 31 being the greatest at 0.4%. Damage to other cotton on the same research station reached 4 to 6% of the squares. Other research fields being subjected to biological control in the local area reported peak averages of 1.25 and 1.65% *Heliothis* damage.

Heliothis Eggs and Larvae

The greatest number of *Heliothis* eggs recorded during the eight weeks of sampling was on July 20 with a total of five eggs on 500 plants from a 3.5 acre field. There was a total of 19 *Heliothis* eggs recorded during the entire eight weeks of sampling. The percent infestation was 1% of the total number of plants infested or just under 500 *Heliothis* eggs per acre.

There were only seven *Heliothis* larvae recorded during the entire sampling period. The greatest number of *Heliothis* larvae recorded was four on August 31. No other sampling date produced more than one larva.

The numbers of eggs and larvae were so few that an analysis was not deemed necessary.

Green Lacewing Eggs

The impact of the beneficial predators was evident by the low rates of *Heliothis* damage throughout the growing period in this field.

Green lacewing eggs were sampled in an attempt to relate those numbers with adequate food supply being augmented in the field. The analysis of variance (Table X) of the lacewing eggs indicates that there was significance of 1% due to latitude. There is also a significant difference at 1% caused by time intervals. There was no significant difference between the number of lacewing eggs per acre resulting from treatments. The maximum number of eggs deposited was on August 17, in plots treated with 50 *S. frugiperda* eggs per linear foot (Tables XI and XII).

Green Lacewing Larvae

The lacewing larvae reached an average peak of over 1,900 larvae per acre on August 17 (Fig. 9 and Tables XIV and XV). Analysis of variance (Table XIII) for this insect indicated differences due to latitude. The greatest number of lacewing larvae (3,973 per acre) was recorded on August 17 in plots treated with 50 S. frugiperda eggs per linear foot. There were three population peaks, July 20, August 17, and August 31, approximately paralleling the Heliothis damage (Fig. 9).

Collops Beetles

Collops beetles had two population peaks during the sampling periods, August 3 and 24 (Tables XVII and XVIII A). The average number of Collops beetles on those dates were 12,911 and 3,873 per acre, respectively (Fig. 10). Analysis of variance (Table XVI) for the Collops beetles indicate a 1% significant difference due to latitude (Table XIII B) and date, indicating field differences and population cycling, respectively. The greatest number of Collops beetles was 16,844 per acre in plots treated with 50 S. frugiperda eggs per linear foot.

Lady Beetles

The entire complex of Coccinellidae, lady beetles, had three population peaks, July 20, August 3, and August 31 (Fig. 11 and Table XX). The average numbers of lady beetles was 9,534, 10,130, and 16,154 per acre, respectively. Analysis of variance for lady beetles indicates only date differences (Table XIX). The greatest number of lady beetles was: 10,925 per acre on July 20 in plots treated with 50 S. ornithogalli eggs per linear foot; 14,401 per acre on August 3 in the check plots; and 20,856 per acre on August 31 in plots treated with 10 S. ornithogalli eggs per linear foot (Table XXI).

Hooded Beetles

Hooded beetles had an early season population peak from July 14 through July 27, and a late season peak about August 24 (Fig. 12 and Table XXIII). The average number of hooded beetles at these peaks was between 4,767 and 5,760 per acre at the first population peak and 5,363 per acre for the second peak. The greatest number of hooded beetles was 8,938 per acre on July 20. These were in plots in which no eggs were added (Table XXIV). Analysis of the number of hooded beetles (Table XXII) indicate that only the sampling dates display any significant difference, indicating population cycles.

The three Coleoptera, Collops beetles, lady beetles, and hooded beetles, show an interesting relationship when the averages of each population is graphically displayed (Figure 13). The hooded beetle population is relatively small and does not seem to be related to the other two. However, the Collops population which is high in the early season and low in the late season is almost inverse to the lady beetle population.

Spiders

The spiders had an almost constant increase in numbers throughout the sampling period (Figure 14 and Table XXVI). The average number of spiders was at its highest peak on August 17, but there was little difference in the last three weeks' sampling (Table XXVII). Analysis of the numbers of spiders per acre indicate that only the sampling date produced significant differences, indicating the hatching of spider eggs and the ballooning of new spiders into the cotton field (Table XXV). The greatest number of spiders (24,332 per acre) was recorded on

August 17 in plots treated with 50 *S. ornithogalli* eggs per linear foot.

Total Beneficials

The beneficials (all of the above mentioned arthropods) were recorded as beneficial predators in Tables XXIX, XXX, XXXI, XXXII, and XXXIII by treatments. The numbers were then pooled and converted to a per acre basis in Table XXXIV. The average beneficial populations had two peaks, August 3 and 31 (Fig. 15). The greatest average number at both peaks was approximately 43,000 per acre (Table XXXIV). Analysis of the beneficial predators per acre (Table XXVIII) indicate only field differences and sampling dates. The greatest number of beneficials per acre (47,672 and 48,169) were recorded on August 3 and 31 in plots treated with 10 *S. frugiperda* eggs per linear foot and in the check plots, respectively (Table XXXIV). At the time of the average peak for the beneficials (43,000 per acre) in the field there was an average of 0.9 beneficials per plant.

Cotton Yield

The yield in lint cotton per acre (Table XLI) and analysis of the strip cotton per acre (Table XL) indicate only field differences and none due to treatments. The average lint cotton per acre ranged from approximately 607 pounds to 650 pounds. The average estimated yield of lint cotton was 633 pounds for the entire field. The actual total yield at the end of the year was 630 pounds of lint cotton per acre.

Summary

The colonies of *S. ornithogalli* and *S. frugiperda* were satisfactorily established and maintained in the entomology laboratory at the Altus Irrigation Research Station in Altus, Oklahoma. Twenty cages of each species were sufficient to supply the 48,000 eggs per week required for treating the cotton field at Tipton, Oklahoma. The eggs were removed each day and stored in a refrigerator at a cool, but not cold, temperature until five days prior to the sampling day each week. The eggs were then counted and taken to the field on the paper toweling on which they were deposited. The toweling with the eggs was physically placed on the cotton plants by research personnel.

The beneficial arthropods were present at high levels throughout the season, although no treatment differences were noted. Early in the season the beneficials were present at approximately one for every two plants and late in the season increased to approximately one per plant. The *Heliothis* damage throughout the season was light. This light infestation might have been due to low populations of the pest or other environmental factors. However, since other fields of cotton on the same station reached *Heliothis* damage levels of up to 6% of the squares, it is felt that the level of predators and or parasites was established and maintained at a sufficient level to suppress the damage.

In light of the last statement, the following facts need to be assimilated: *Heliothis* eggs and larvae were never in great numbers at any time in the season; *Heliothis* damaged fruits were less than 1% of the total fruits; no chemicals were used for insect control in these plots; beneficial arthropods increased throughout the growing season;

and yield for the field and plots was as great as or equal to the other cotton on the research station at Tipton. Therefore, it is felt that the possibility of suppression of the Heliothis damage was high in this test. The inability to depict the treatment differences was negated possibly by the small field (3.5 acres), the large number of eggs added, and the mobility of the beneficial predators and parasites.

CHAPTER V

SUMMARY

Spodoptera ornithogalli and S. frugiperda, both noctuids related to Heliothis zea and H. virescens, are easily field collected and reared in laboratory colonies. Both species of Spodoptera lay large numbers of eggs and the larvae can be reared on a variety of artificial and natural diets. The colonies can be established to supply almost any demand for larvae or eggs that is desired.

Most of the predators and many of the parasites of the two species of Spodoptera will also attack the Heliothis complex. The predator-parasite complex may provide suppression of the prime target species without the use of chemicals.

The sustained low level releases of larvae were apparently unable to provide sufficient food or host to allow beneficial arthropod populations to suppress Heliothis damage below the 5% square damage late in the season. The low level of larval treatments did not result in any difference in yield. However, Mr. V. L. Strickland, foreman of the research station where this study was done, reported that the cotton on the station treated with chemical insecticides did not produce as much per acre as the cotton used in this study. There was other Westburn 70 cotton on the same research station which was chemically treated that yielded only one bale of lint cotton per acre, while the Westburn 70 cotton to which the larvae were added produced 1½ bales of cotton per acre.

The sustained addition of 48,000 eggs per week to the cotton field did apparently increase the beneficial predator populations. However, the addition of the different species and/or levels of addition did not produce any statistical differences.

It was found by the researcher that the populations of beneficial organisms were manipulated in cotton to numbers great enough to suppress *Heliothis* populations. Damage by *Heliothis* in Oklahoma might be reduced by addition of about 13,700 eggs per acre per week (*S. ornithogalli* and/or *S. frugiperda*). Other species or artificial sources of food might be equally utilized.

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APPENDIX

TABLE I. PRINCIPAL PARASITES OF HELIOTHIS LARVAE IN THE SOUTHERN UNITED STATES AND THOSE WHICH ALSO PARASITIZE LARVAE OF SPODOPTERA ORNITHOGALLI AND SPODOPTERA FRUGIPERDA

Parasite	Hosts: Heliothis zea	Hosts: Heliothis vir.	Hosts: Spodoptera orn.	Hosts: Spodoptera fru.	Reference
HYMENOPTERA					
Braconidae					
Apanteles marginiventris (Cresson)	X	X		X	Muesebeck & Krombein (1951), Hofmaster & Greenwood (1949)
Microplitis croceipes (Cresson)	X[1]	X[1]			Bryan et al. (1969)
Cardiochiles nigriceps (Vierick)	X	X			Lewis et al. (1967)
Chelonus texanus (Cresson)	X[2]	X[2]	X[3]	X	Muesebeck & Krombein (1951), Lingren & Ridgway (1972), Bottrell (1968), Luginbill (1928)
Ichneumonidae					
Campoletis perdistinctus (Vierick)	X	X	X	X	Lingren et al. (1970), Bottrell (1968)
Trichogrammatidae					
Trichogramma spp.	X	X	X	X	Muesebeck & Krombein (1951), Crumb (1929), Luginbill (1928)
DIPTERA					
Tachinidae					
Eucelatoria armigera (Coquillett)	X[4]	X[4]			Jackson et al. (1969)
Lespesia archippivora (Riley)	X[5]	X[5]	X[6]	X	Bryan et al. (1969), Bottrell (1968)
Winthemia rufopicta (Big.)	X	X	X	X	Bottrell (1968), Hofmaster & Greenwood (1949)

[1]Most common Braconidae reared from Heliothis spp. in Oklahoma (Bottrell 1968).
[2]Second most common Braconidae reared from Heliothis spp. in Oklahoma (Bottrell 1968).
[3]Most common Hymenoptera parasite recorded in Oklahoma (Bottrell 1968).
[4]Most common Tachinidae parasite reared from Heliothis spp. in Oklahoma (Bottrell 1968).
[5]Second most common Tachinidae parasite reared from Heliothis spp. in Oklahoma (Bottrell 1968).
[6]Most common Diptera parasite recorded from Oklahoma (Bottrell 1968).

TABLE II. PERCENT *HELIOTHIS* DAMAGED SQUARES IN COTTON TREATED WITH BIWEEKLY RELEASES OF *SPODOPTERA ORNITHOGALLI* LARVAE, TIPTON, OKLAHOMA, 1971

NO. LARVAE PER LINEAR FT. ROW	DATE 7-07	7-15	7-20	7-27	8-03	8-10	8-17	8-24	8-31	9-09
0	*0.00	0.00	1.50	1.25	1.50	0.75	2.00	5.25	6.25	3.50
1	0.00	0.50	1.50	6.50	0.50	1.25	1.50	6.25	8.25	4.25
10	0.00	0.75	1.25	1.00	2.75	0.25	1.50	8.00	8.50	2.50
100	0.25	0.50	0.50	1.25	2.00	0.75	3.25	4.50	5.20	0.50
AVE	0.63	0.44	1.19	2.50	1.69	0.75	2.63	6.00	7.06	2.69

*EACH NUMBER IS BASED ON 100 SQUARES EXAMINED FROM EACH OF 4 PLOTS. TOTAL OF 80 FT. TREATED IN EACH PLOT.

TABLE III. ANALYSIS OF VARIANCE FOR *HELIOTHIS* DAMAGE IN A 4X4 LATIN SQUARE DESIGN TREATED WITH BIWEEKLY RELEASES OF *SPODOPTERA ORNITHOGALLI* LARVAE, TIPTON, OKLAHOMA, 1971

SOURCE	DF	MS
TOTAL (CORRECTED)	159	
ROW	3	1.87
COLUMN	3	0.06
TREATMENT	3	10.57
DATE	9	86.94**
ROW X DATE	27	4.04
COLUMN X DATE	27	6.89
TREATMENT X DATE	27	6.21
RESIDUAL (ERROR)	60	7.41

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE IV. PERCENT *HELIOTHIS* DAMAGED SQUARES IN COTTON TREATED WITH BIWEEKLY RELEASES OF *SPODOPTERA FRUGIPERDA* LARVAE, TIPTON, OKLAHOMA, 1971

NO. LARVAE PER LINEAR FT. ROW	DATE									
	7-07	7-15	7-20	7-27	8-03	8-10	8-17	8-24	8-31	9-09
0	*0.25	0.00	1.25	1.25	2.00	1.00	1.00	6.50	5.00	2.25
1	0.00	0.25	0.00	1.50	0.75	0.25	0.75	10.50	8.50	6.00
10	0.50	0.25	1.50	2.75	6.00	0.75	1.50	4.25	4.25	2.00
100	0.00	0.75	0.00	2.75	0.50	1.50	2.00	4.25	6.50	4.50
AVE	0.19	0.31	0.69	2.06	2.31	0.88	1.31	6.38	6.06	3.69

*EACH NUMBER IS BASED ON 100 SQUARES EXAMINED FROM EACH OF 4 PLOTS. TOTAL OF 80 FT. TREATED IN EACH PLOT.

TABLE V. ANALYSIS OF VARIANCE FOR *HELIOTHIS* DAMAGE IN A 4X4 LATIN SQUARE DESIGN TREATED WITH BIWEEKLY RELEASES OF *SPODOPTERA FRUGIPERDA* LARVAE, TIPTON, OKLAHOMA, 1971

SOURCE	DF	MS
TOTAL (CORRECTED)	159	
ROW	3	5.38
COLUMN	3	6.11
TREATMENT	3	4.54
DATE	9	83.00**
ROW X DATE	27	4.83
COLUMN X DATE	27	5.30
TREATMENT X DATE	27	10.31*
RESIDUAL (ERROR)	60	6.05

*SIGNIFICANT AT THE 0.05 LEVEL.

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE VI. LINT COTTON PER ACRE FROM PLOTS TREATED WITH BIWEEKLY RELEASES OF SEVERAL RATES OF *SPODOPTERA ORNITHOGALLI* LARVAE, TIPTON, OKLAHOMA, 1971

NUMBER LARVAE PER 10 FT. ROW	ROW 1	2	3	4	AVE
0	*608	603	737	768	679
1	680	648	623	657	652
10	532	717	600	460	577
100	657	517	817	800	698
AVE	619	621	694	671	**652

*EACH NUMBER BASED ON STRIP COTTON FROM 20 FT. OF 4 ROWS PER PLOT AND CONVERTED TO LINT COTTON BY A FACTOR OF 0.23.

*TREATMENT AREA CONSISTED OF 20 FT. OF 4 ROWS FOR A TOTAL OF 80 FT. PER PLOT.

**AVERAGE FOR THE FIELD TREATED WITH *SPODOPTERA ORNITHOGALLI*.

TABLE VII. ANALYSIS OF VARIANCE OF COTTON YIELD FROM PLOTS TREATED WITH BIWEEKLY RELEASES OF SEVERAL RATES OF *SPODOPTERA ORNITHOGALLI* LARVAE, TIPTON, OKLAHOMA, 1971

SOURCE	DF	MS
TOTAL (CORRECTED)	15	
ROW	3	3.48
COLUMN	3	12.43
TREATMENT	3	6.98
RESIDUAL (ERROR)	6	4.36

TABLE VIII. LINT COTTON PER ACRE FROM PLOTS TREATED WITH BIWEEKLY RELEASES OF SEVERAL RATES OF SPODOPTERA FRUGIPERDA LARVAE, TIPTON, OKLAHOMA, 1971

NUMBER LARVAE PER 10 FT. ROW	ROW				
	1	2	3	4	AVE
0	*720	520	443	532	554
1	643	540	472	632	572
10	517	497	368	537	480
100	448	448	372	772	510
AVE	582	501	414	614	**529

*EACH NUMBER BASED ON STRIP COTTON FROM 20 FT. OF 4 ROWS PER PLOT AND CONVERTED TO LINT COTTON BY A FACTOR OF 0.23.

*TREATMENT AREA CONSISTED OF 20 FT. OF 4 ROWS FOR A TOTAL OF 80 FT. PER PLOT.

**AVERAGE FOR THE FIELD TREATED WITH SPODOPTERA FRUGIPERDA.

TABLE IX. ANALYSIS OF VARIANCE OF COTTON YIELD FROM PLOTS TREATED WITH BIWEEKLY RELEASES OF SEVERAL RATES OF *SPODOPTERA FRUGIPERDA* LARVAE, TIPTON, OKLAHOMA, 1971

SOURCE	DF	MS
TOTAL (CORRECTED)	15	
ROW	3	20.62
COLUMN	3	6.07
TREATMENT	3	4.44
RESIDUAL (ERROR)	6	4.75

TABLE X. ANALYSIS OF VARIANCE FOR LACEWING EGGS ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS AT 0, 10, OR 50 EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	21,720
LATITUDE	4	156,554**
TREATMENT	4	8,465
ERROR A (LONG X TRT - LAT)	12	11,147
DATE	7	2,056,797**
LONGITUDE X DATE	28	22,437
LATITUDE X DATE	28	32,502*
TREATMENT X DATE	28	21,230
RESIDUAL (ERROR B)	84	19,503

*SIGNIFICANT AT THE 0.05 LEVEL.

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XI. LACEWING EGGS ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS EACH WEEK FROM JULY 14 THROUGH AUGUST 31, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*4	19	15	89	100	142	123	127
S. ORNITHOGALLI	10	5	11	16	86	98	138	134	118
S. FRUGIPERDA	10	16	12	12	69	95	144	121	126
S. ORNITHOGALLI	50	5	23	15	125	104	150	150	85
S. FRUGIPERDA	50	3	6	9	73	83	155	153	134

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XII. LACEWING EGGS PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS FOR A PERIOD OF EIGHT WEEKS, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*1986	9435	7448	44195	49658	70514	61079	63066
S. ORNITHOGALLI	10	2482	5462	5945	42706	48665	68528	66542	58596
S. FRUGIPERDA	10	7945	5959	5959	34264	47175	71508	60086	62569
S. ORNITHOGALLI	50	2482	11421	7448	62073	51644	74487	74487	42209
S. FRUGIPERDA	50	1489	2979	4469	36250	41216	76970	75977	66542

*EACH NUMBER IS BASED ON 49,658 PLANTS PER ACRE.

TABLE XIII. ANALYSIS OF VARIANCE FOR LACEWING LARVAE ON COTTON TREATED WITH SUSTAINED ADDITION OF SPODOPTERA ORNITHOGALLI OR SPODOPTERA FRUGIPERDA EGGS AT 0, 10, OR 50 EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	904
LATITUDE	4	1,559*
TREATMENT	4	1,243
ERROR A (LONG X TRT - LAT)	12	447
DATE	7	742
LONGITUDE X DATE	28	490
LATITUDE X DATE	28	546
TREATMENT X DATE	28	486
RESIDUAL (ERROR B)	84	476

*SIGNIFICANT AT THE 0.05 LEVEL.

TABLE XIV. LACEWING LARVAE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS EACH WEEK FROM JULY 14 THROUGH AUGUST 31, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*2	3	1	2	5	2	0	4
S. ORNITHOGALLI	10	1	0	0	1	1	0	1	1
S. FRUGIPERDA	10	1	5	0	4	3	4	1	8
S. ORNITHOGALLI	50	0	1	0	0	4	6	1	1
S. FRUGIPERDA	50	1	2	7	2	1	8	2	3

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XV. LACEWING LARVAE PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS FOR A PERIOD OF EIGHT WEEKS, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*993	1490	497	993	2483	993	0	1986
S. ORNITHOGALLI	10	497	0	0	497	497	0	497	497
S. FRUGIPERDA	10	497	2483	0	1986	1490	1986	497	3973
S. ORNITHOGALLI	50	0	497	0	0	1986	2980	497	497
S. FRUGIPERDA	50	497	993	3476	993	497	3573	993	1490

*EACH NUMBER IS BASED ON 49,658 PLANTS PER ACRE.

TABLE XVI. ANALYSIS OF VARIANCE FOR *COLLOPS* BEETLES ON COTTON TREATED WITH SUSTAINED ADDIION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS AT 0, 10, OR 50 EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	719
LATITUDE	4	19,907**
TREATMENT	4	750
ERROR A (LONG X TRT - LAT)	12	1,860
DATE	7	33,747**
LONGITUDE X DATE	28	1,535
LATITUDE X DATE	28	4,192
TREATMENT X DATE	28	1,134
RESIDUAL (ERROR B)	84	1,269

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XVII. *COLLOPS* BEETLES ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS EACH WEEK FROM JULY 14 THROUGH AUGUST 31, TIPTON, OKLAHOMA, 1972

SPECIES	EGGS ADDED	DATE 7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*7	9	13	23	8	1	14	8
S. ORNITHOGALLI	10	2	7	15	29	7	6	9	7
S. FRUGIPERDA	10	5	10	13	23	4	3	5	3
S. ORNITHOGALLI	50	7	10	15	21	5	4	9	4
S. FRUGIPERDA	50	5	5	14	34	4	3	2	6

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XVIIIA. *COLLOPS* BEETLES PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS FOR A PERIOD OF EIGHT WEEKS, TIPTON, OKLAHOMA, 1972

SPECIES	EGGS ADDED	DATE 7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*3476	4460	6456	1142	13973	497	6952	3973
S. ORNITHOGALLI	10	993	3476	7449	14401	3476	2980	4469	3476
S. FRUGIPERDA	10	2483	4966	6456	11421	1986	1490	2483	1490
S. ORNITHOGALLI	50	3476	4966	7449	10428	2483	1986	4469	1986
S. FRUGIPERDA	50	2483	2483	6952	16884	1986	1490	993	2980

*EACH NUMBER IS BASED ON 49,658 PLANTS PER ACRE.

TABLE XVIIIB. COLLOPS BEETLES PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF 13,700 SPODOPTERA ORNITHOGALLI AND SPODOPTERA FRUGIPERDA EGGS PER ACRE PER WEEK, TIPTON, OKLAHOMA, 1972

	DATE							
LATITUDE	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
1	*2980	5462	14401	21850	4469	1986	5959	5959
2	1490	4469	8938	20360	4966	2979	2979	1986
3	1490	5462	4469	9932	2979	993	3973	3476
4	4469	1986	5959	5462	496	993	3476	1490
5	2483	2979	993	6952	993	1489	2979	993

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XIX. ANALYSIS OF VARIANCE FOR LADY BEETLES ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS AT 0, 10, OR 50 EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	8,373
LATITUDE	4	1,992
TREATMENT	4	8,042
ERROR A (LONG X TRT - LAT)	12	2,881
DATE	7	26,610**
LONGITUDE X DATE	28	4,405
LATITUDE X DATE	28	4,479
TREATMENT X DATE	28	3,598
RESIDUAL (ERROR B)	84	3,577

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XX. LADY BEETLES ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS EACH WEEK FROM JULY 14 THROUGH AUGUST 31, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*21	28	11	29	19	27	21	40
S. ORNITHOGALLI	10	21	18	4	19	15	23	17	42
S. FRUGIPERDA	10	12	9	6	26	15	20	31	27
S. ORNITHOGALLI	50	14	22	12	17	10	13	15	25
S. FRUGIPERDA	50	12	19	12	11	21	23	21	29

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XXI. LADY BEETLES PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF SPODOPTERA ORNITHOGALLI OR SPODOPTERA FRUGIPERDA EGGS FOR A PERIOD OF EIGHT WEEKS, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*10428	13904	5467	14401	9435	13408	10428	19863
S. ORNITHOGALLI	10	10428	8938	1986	9435	7449	11421	8442	20856
S. FRUGIPERDA	10	5959	4469	2980	12911	7449	9932	15394	13408
S. ORNITHOGALLI	50	6952	10925	5959	8442	9932	6456	7449	12241
S. FRUGIPERDA	50	5959	9435	5959	5462	10428	11421	10428	14401

*EACH NUMBER IS BASED ON 49,658 PLANTS PER ACRE.

TABLE XXII. ANALYSIS OF VARIANCE FOR HOODED BEETLES ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS AT 0, 10, OR 50 EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	4,497
LATITUDE	4	2,655
TREATMENT	4	343
ERROR A (LONG X TRT ÷ LAT)	12	1,471
DATE	7	7,210**
LONGITUDE X DATE	28	2,177
LATITUDE X DATE	28	2,141
TREATMENT X DATE	28	991
RESIDUAL (ERROR B)	84	1,326

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XXIII. HOODED BEETLES ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS EACH WEEK FROM JULY 14 THROUGH AUGUST 31, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*10	19	14	4	1	6	12	4
S. ORNITHOGALLI	10	14	11	11	7	4	3	11	4
S. FRUGIPERDA	10	16	8	11	5	2	6	9	6
S. ORNITHOGALLI	50	7	4	11	4	7	4	13	8
S. FRUGIPERDA	50	11	7	11	8	2	5	9	5

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XXIV. HOODED BEETLES PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS FOR A PERIOD OF EIGHT WEEKS, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*4966	8938	6952	1986	497	2980	5959	1986
S. ORNITHOGALLI	10	6952	5462	5462	3476	1986	1490	5462	1986
S. FRUGIPERDA	10	7945	3973	5462	2483	993	2980	4469	2980
S. ORNITHOGALLI	50	3476	1986	5462	1986	3476	1986	6456	3973
S. FRUGIPERDA	50	5462	3476	5462	3973	993	2483	4469	2483

*EACH NUMBER IS BASED ON 49,658 PLANTS PER ACRE.

TABLE XXV. ANALYSIS OF VARIANCE FOR SPIDERS ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS AT 0, 10, OR 50 EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	9,760
LATITUDE	4	12,457
TREATMENT	4	7,379
ERROR A (LONG X TRT - LAT)	12	5,632
DATE	7	47,846**
LONGITUDE X DATE	28	5,237*
LATITUDE X DATE	28	6,102*
TREATMENT X DATE	28	2,283
RESIDUAL (ERROR B)	84	3,478

*SIGNIFICANT AT THE 0.05 LEVEL.

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XXVI. SPIDERS ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS EACH WEEK FROM JULY 14 THROUGH AUGUST 31, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*23	30	19	25	40	33	32	41
S. ORNITHOGALLI	10	15	26	12	31	37	32	27	30
S. FRUGIPERDA	10	15	22	21	38	39	42	32	38
S. ORNITHOGALLI	50	23	32	19	36	38	49	30	44
S. FRUGIPERDA	50	21	19	11	35	31	44	32	42

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XXVII. SPIDERS PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS FOR A PERIOD OF EIGHT WEEKS, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*11421	14898	9435	12415	19863	16387	15891	20360
S. ORNITHOGALLI	10	7449	12911	5959	15394	18374	15891	13408	14898
S. FRUGIPERDA	10	7449	10925	10428	18870	19367	20856	15891	18870
S. ORNITHOGALLI	50	11421	15891	9435	17877	18870	24332	14898	21850
S. FRUGIPERDA	50	10428	9435	6456	17380	15394	21850	15891	20856

*EACH NUMBER IS BASED ON 49,658 PLANTS PER ACRE.

TABLE XXVIII. ANALYSIS OF VARIANCE FOR TOTAL BENEFICIALS ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS AT 0, 10, OR 50 EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	24,994
LATITUDE	4	102,008**
TREATMENT	4	16,948
ERROR A (LONG X TRT - LAT)	12	13,183
DATE	7	101,822**
LONGITUDE X DATE	28	20,299*
LATITUDE X DATE	28	23,151**
TREATMENT X DATE	28	6,671
RESIDUAL (ERROR B)	84	11,374

*SIGNIFICANT AT THE 0.05 LEVEL.

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XXIX. BENEFICIAL PREDATORS ON COTTON TREATED WITH NO AUGMENTATION OF EGGS, CHECK PLOTS, TIPTON, OKLAHOMA, 1972

PREDATORS	DATE 7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
LACEWING EGGS	*4	19	15	89	100	142	123	127
LACEWING LARVAE	7	9	13	23	8	1	14	8
<u>COLLOPS</u> BEETLES	2	3	1	2	5	2	0	4
LADY BEETLE LARVAE	0	0	0	0	0	0	0	0
LADY BEETLE ADULTS	21	28	11	29	19	21	21	40
HOODED BEETLES	10	19	14	4	1	12	12	4
SPIDERS	23	30	19	25	40	32	32	41
TOTAL PREDATORS	67	108	73	172	173	211	202	224

*BASED ON 20 PLANTS PER REPLICATE FOR A TOTAL OF 100 PLANTS.

TABLE XXX. BENEFICIAL PREDATORS ON COTTON TREATED BY AUGMENTING NATURALLY OCCURRING LEPIDOPTEROUS EGGS WITH 10 _S. ORNITHOGALLI_ EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

	DATE							
PREDATORS	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
LACEWING EGGS	* 5	11	16	86	98	138	134	118
LACEWING LARVAE	1	0	0	1	1	0	1	1
COLLOPS BEETLES	2	7	15	29	7	6	9	7
LADY BEETLE LARVAE	1	0	0	0	0	0	0	0
LADY BEETLE ADULTS	21	18	4	19	15	23	17	42
HOODED BEETLES	14	11	11	7	4	3	11	4
SPIDERS	15	26	12	31	37	32	27	30
TOTAL PREDATORS	59	73	58	173	162	202	199	202

*BASED ON 20 PLANTS PER REPLICATE FOR A TOTAL OF 100 PLANTS.

TABLE XXXI. BENEFICIAL PREDATORS ON COTTON TREATED BY AUGMENTING NATURALLY OCCURRING LEPIDOPTEROUS EGGS WITH 10 S. FRUGIPERDA EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

	DATE							
PREDATORS	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
LACEWING EGGS	*16	12	12	69	95	144	121	126
LACEWING LARVAE	1	5	0	4	3	4	1	8
COLLOPS BEETLES	5	10	13	23	4	3	5	3
LADY BEETLE LARVAE	1	0	0	0	0	0	0	0
LADY BEETLE ADULTS	12	9	6	26	15	20	31	27
HOODED BEETLES	16	8	11	5	2	6	9	6
SPIDERS	15	22	21	38	39	42	32	38
TOTAL PREDATORS	66	66	63	165	158	219	199	208

*BASED ON 20 PLANTS PER REPLICATE FOR A TOTAL OF 100 PLANTS.

TABLE XXXII. BENEFICIAL PREDATORS ON COTTON TREATED BY AUGMENTING NATURALLY OCCURRING LEPIDOPTEROUS EGGS WITH 50 _S. ORNITHOGALLI_ EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

	DATE							
PREDATORS	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
LACEWING EGGS	*5	23	15	125	104	150	150	85
LACEWING LARVAE	0	1	0	0	4	6	1	1
COLLOPS BEETLES	7	10	15	21	5	4	9	4
LADY BEETLE LARVAE	0	0	0	0	0	0	0	0
LADY BEETLE ADULTS	14	22	12	17	10	13	15	25
HOODED BEETLES	7	4	11	4	7	4	13	8
SPIDERS	23	32	19	36	38	49	30	44
TOTAL PREDATORS	56	92	72	203	168	226	218	167

*BASED ON 20 PLANTS PER REPLICATE FOR A TOTAL OF 100 PLANTS.

TABLE XXXIII. BENEFICIAL PREDATORS ON COTTON TREATED BY AUGMENTING NATURALLY OCCURRING LEPIDOPTEROUS EGGS WITH 50 S. FRUGIPERDA EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

	DATE							
PREDATORS	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
LACEWING EGGS	*3	6	9	73	83	155	153	134
LACEWING LARVAE	1	2	7	2	1	8	2	3
COLLOPS BEETLES	5	5	14	34	4	3	2	6
LADY BEETLE LARVAE	0	1	0	0	0	0	0	1
LADY BEETLE ADULTS	12	19	12	11	21	23	21	29
HOODED BEETLES	11	7	11	8	2	5	9	5
SPIDERS	21	19	11	35	31	44	32	42
TOTAL PREDATORS	53	59	64	163	142	238	219	220

*BASED ON 20 PLANTS PER REPLICATE FOR A TOTAL OF 100 PLANTS.

TABLE XXXIV. BENEFICIAL PREDATORS PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS FOR A PERIOD OF EIGHT WEEKS, TIPTON, OKLAHOMA, 1972

SPECIES	EGGS ADDED	DATE 7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*31285	43699	28802	41216	36251	34264	39230	48169
S. ORNITHOGALLI	10	26319	30788	20856	43203	31781	31781	32278	41713
S. FRUGIPERDA	10	24333	26816	25326	47672	31285	37244	38734	40720
S. ORNITHOGALLI	50	25326	34264	38305	38734	36747	37740	33768	40720
S. FRUGIPERDA	50	24829	25822	28305	44692	29298	41216	32774	42210

*EACH NUMBER IS BASED ON 49,658 PLANTS PER ACRE.

TABLE XXXV. ANALYSIS OF VARIANCE FOR *HELIOTHIS* DAMAGED SQUARES ON COTTON TREATED WITH SUSTAINED ADDITION OF 0, 10, OR 50 *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	43
LATITUDE	4	143
TREATMENT	4	158
ERROR A (LONG X TRT - LAT)	12	192
DATE	7	246**
LONGITUDE X DATE	28	199
LATITUDE X DATE	28	97
TREATMENT X DATE	28	95
RESIDUAL (ERROR B)	84	122

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XXXVI. ANALYSIS OF VARIANCE FOR *HELIOTHIS* DAMAGED BLOOMS ON COTTON TREATED WITH SUSTAINED ADDITION OF 0, 10, OR 50 *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	4.62
LATITUDE	4	4.62
TREATMENT	4	4.62
ERROR A (LONG X TRT - LAT)	12	7.19
DATE	7	5.28
LONGITUDE X DATE	28	6.38
LATITUDE X DATE	28	6.38
TREATMENT X DATE	28	6.38
RESIDUAL (ERROR B)	84	6.02

TABLE XXXVII. ANALYSIS OF VARIANCE FOR *HELIOTHIS* DAMAGED BOLLS ON COTTON TREATED WITH SUSTAINED ADDITION OF 0, 10, OR 50 *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	199	
LONGITUDE	4	103
LATITUDE	4	149
TREATMENT	4	41
ERROR A (LONG X TRT - LAT)	12	193
DATE	7	344**
LONGITUDE X DATE	28	75
LATITUDE X DATE	28	50
TREATMENT X DATE	28	39
RESIDUAL (ERROR B)	84	115

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XXXVIII. *HELIOTHIS* DAMAGED FRUITS (SQUARES, BLOOMS, AND BOLLS) PER ACRE ON COTTON TREATED WITH SUSTAINED ADDITION OF *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS EACH WEEK FROM JULY 14 THROUGH AUGUST 31, TIPTON, OKLAHOMA, 1972

SPECIES	EGGS ADDED	DATE 7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*497	1987	0	993	1490	497	994	993
S. ORNITHOGALLI	10	497	1980	0	497	497	0	497	993
S. FRUGIPERDA	10	0	0	0	0	993	1490	497	1490
S. ORNITHOGALLI	50	497	1490	497	497	1490	1490	497	993
S. FRUGIPERDA	50	497	0	0	0	0	497	994	2484

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XXXIX. PERCENT *HELIOTHIS* DAMAGE TO COTTON FRUITS (SQUARES, BLOOMS, AND BOLLS) IN PLOTS TREATED WITH SUSTAINED ADDITION OF 0, 10, OR 50 *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

		DATE							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*.206	.557	.000	.248	.411	.115	.251	.302	.261
S. ORNITHOGALLI	10	.247	.568	.000	.139	.127	.000	.161	.311	.194
S. FRUGIPERDA	10	.000	.000	.000	.000	.241	.388	.143	.414	.148
S. ORNITHOGALLI	50	.244	.453	.148	.137	.395	.446	.144	.307	.284
S. FRUGIPERDA	50	.249	.000	.000	.000	.000	.130	.261	.789	.179
AVERAGE		.186	.329	.026	.109	.232	.214	.196	.422	.213

*EACH NUMBER IS BASED ON WHOLE PLANT EXAMINATION OF 100 PLANTS.

TABLE XL. ANALYSIS OF VARIANCE FOR YIELD OF WESTBURN 70 COTTON TREATED WITH SUSTAINED ADDITION OF 0, 10, OR 50 *SPODOPTERA ORNITHOGALLI* OR *SPODOPTERA FRUGIPERDA* EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

SOURCE	DF	MS
TOTAL (CORRECTED)	249	
LONGITUDE	4	6,618,993**
LATITUDE	4	2,826,005*
TREATMENT	4	322,734
ERROR A	12	832,889
(LONG X TRT - LAT)		
DIRECTION	1	24,659
DIRECTION X LONGITUDE	4	167,083
DIRECTION X LATITUDE	4	460,087
DIRECTION X TREATMENT	4	19,493
ERROR B	12	212,950
(DIR X LONG X TRT - DIR X LAT)		
ROW	4	211,647
ROW X LONGITUDE	16	54,130
ROW X LATITUDE	16	139,922
ROW X TREATMENT	16	60,342
ROW X DIRECTION	4	63,894
ROW X DIR X LONG	16	46,006
ROW X DIR X LAT	16	96,832
ROW X DIR X TRT	16	94,164
RESIDUAL (ERROR C)	96	247,107

*SIGNIFICANT AT THE 0.05 LEVEL.

**SIGNIFICANT AT THE 0.01 LEVEL.

TABLE XLI. LINT COTTON PER ACRE OF WESTBURN 70 COTTON TREATED WITH SUSTAINED ADDITION OF 0, 10, 50 SPODOPTERA ORNITHOGALLI OR SPODOPTERA FRUGIPERDA EGGS PER LINEAR FOOT ON 80 FEET PER PLOT, TIPTON, OKLAHOMA, 1972

		ROW							
SPECIES	EGGS ADDED	7-14	7-20	7-27	8-03	8-10	8-17	8-24	8-31
CHECK	0	*642		625	663	640		652	644
S. ORNITHOGALLI	10	622		628	619	604		628	620
S. FRUGIPERDA	10	598		659	637	661		676	646
S. ORNITHOGALLI	50	578		606	643	591		619	607
S. FRUGIPERDA	50	618		641	648	663		682	650
AVERAGE		612		632	642	632		651	633

*EACH NUMBER, EXCLUDING AVERAGES, IS BASED ON COTTON HAND STRIPPED FROM 20 FEET OF 10 ROWS PER PLOT.

*EACH NUMBER CONVERTED TO LINT COTTON PER ACRE BY A FACTOR OF 0.23 AND 49,658 PLANTS PER ACRE.

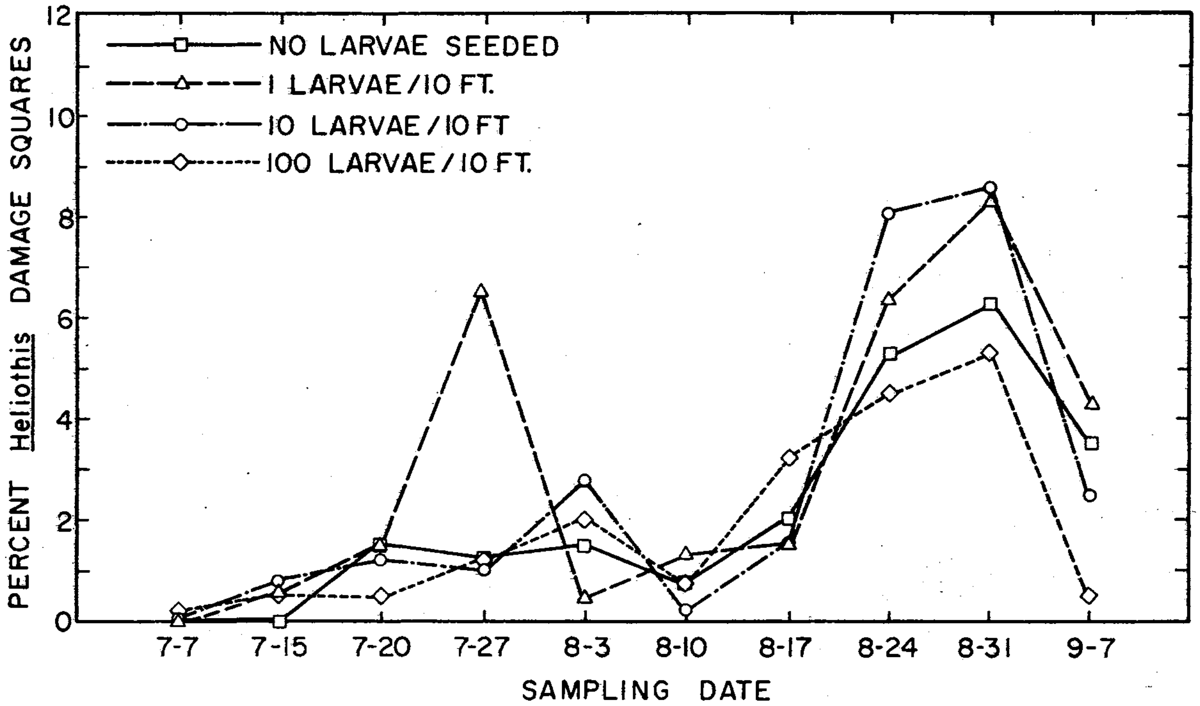

Figure 1. Percent Heliothis damage to Westburn 70 cotton in plots treated with biweekly releases of several rates of Spodoptera ornithogalli larvae, Tipton, Oklahoma, 1971.[a]

[a]Each point is based on 400 squares.

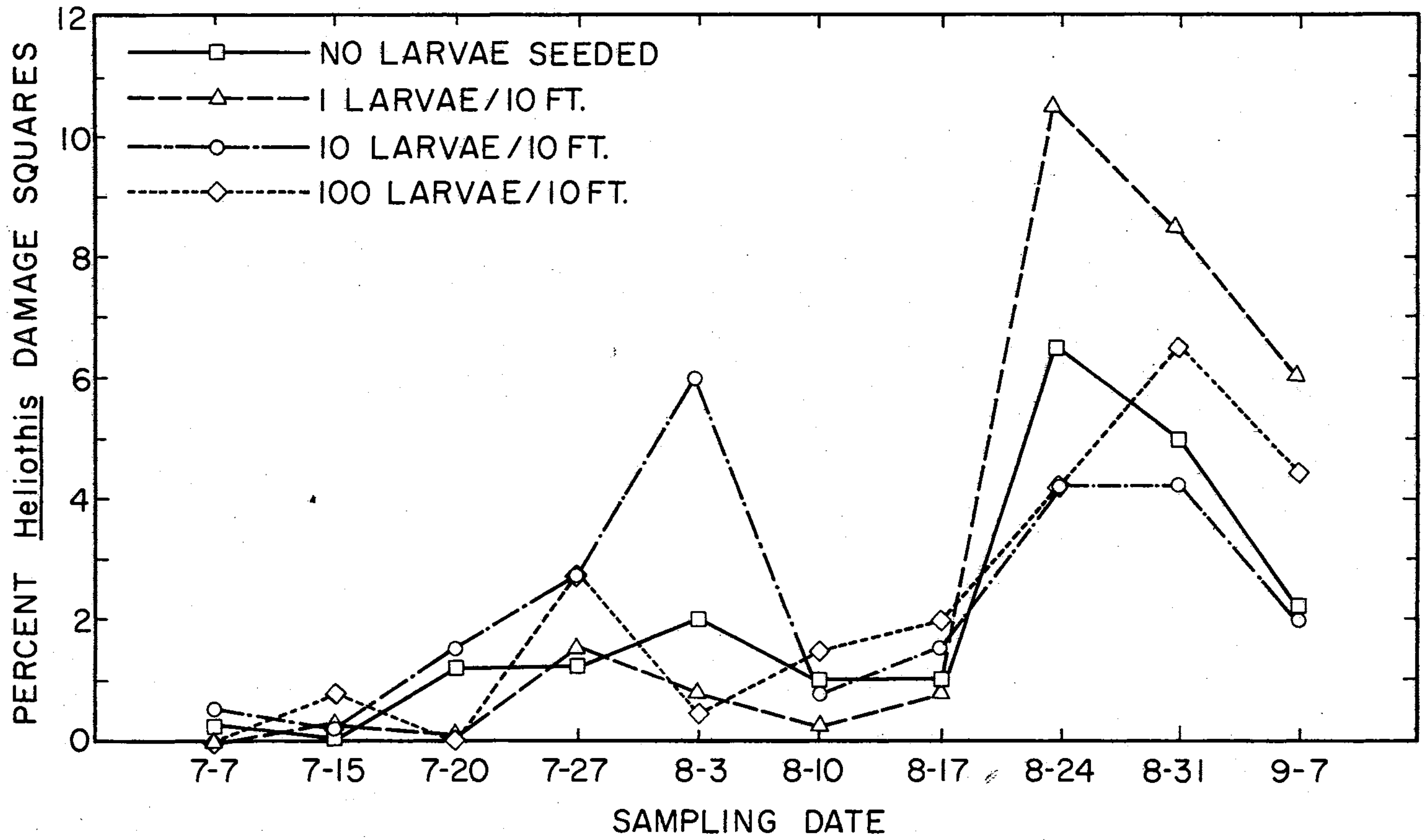

Figure 2. Percent *Heliothis* damage to Westburn 70 cotton in plots treated with biweekly releases of several rates of *Spodoptera frugiperda* larvae, Tipton, Oklahoma, 1971.[a]

[a]Each point is based on 400 squares.

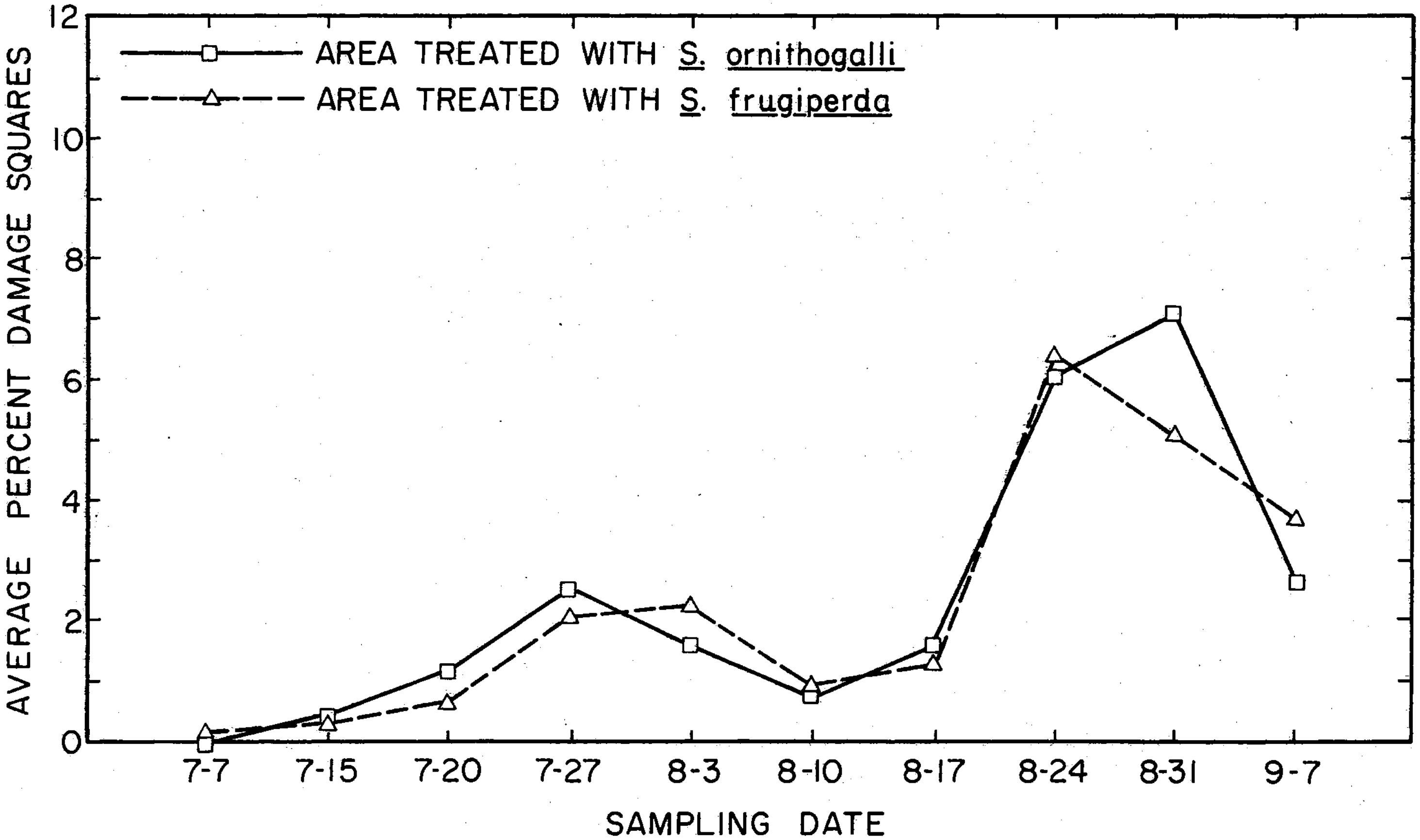

Figure 3. Average *Heliothis* damage to Westburn 70 cotton in fields treated with biweekly releases of *Spodoptera ornithogalli* or *S. frugiperda* larvae, Tipton, Oklahoma, 1971.[a]

[a]Each point is based on 1,600 squares.

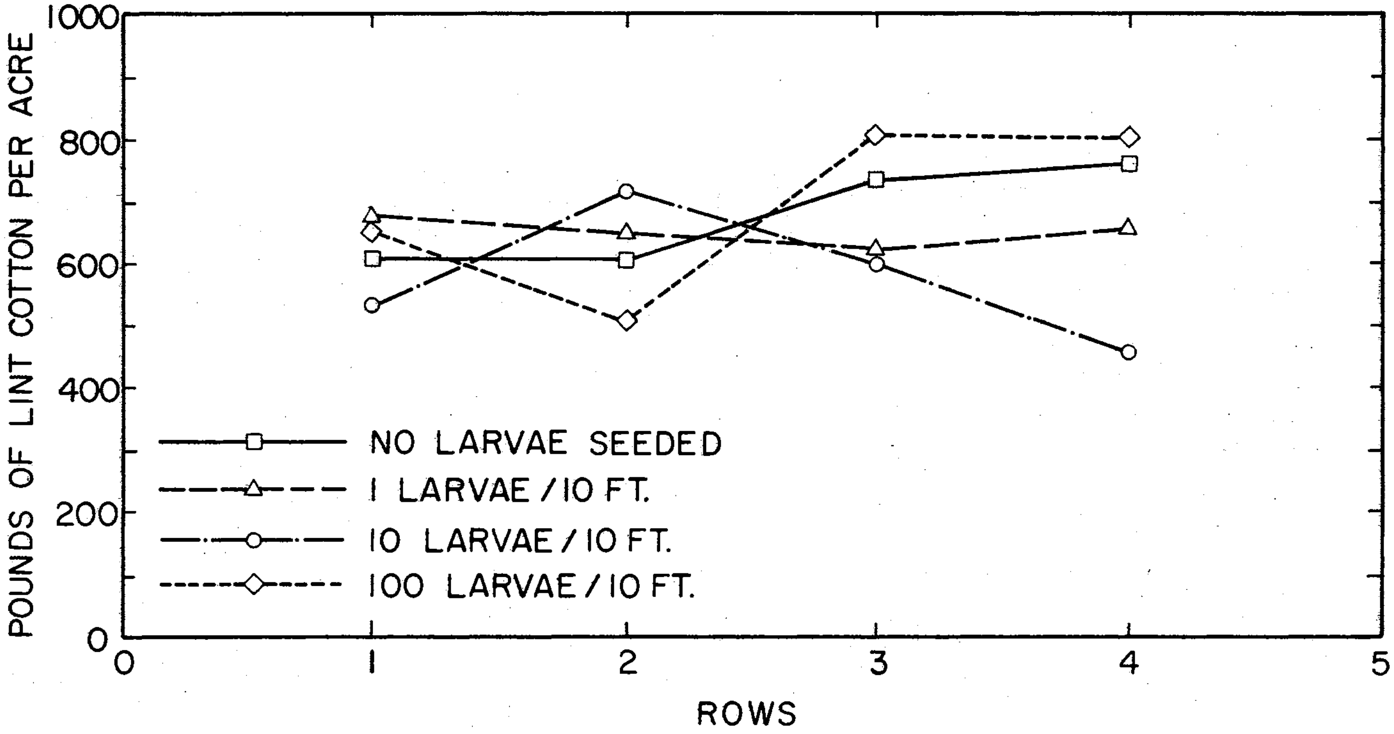

Figure 4. Average cotton yield of Westburn 70 cotton treated with biweekly releases of several rates of Spodoptera ornithogalli larvae, Tipton, Oklahoma, 1971.[a]

[a]Each point is based on cotton harvested from 20 feet of four rows.

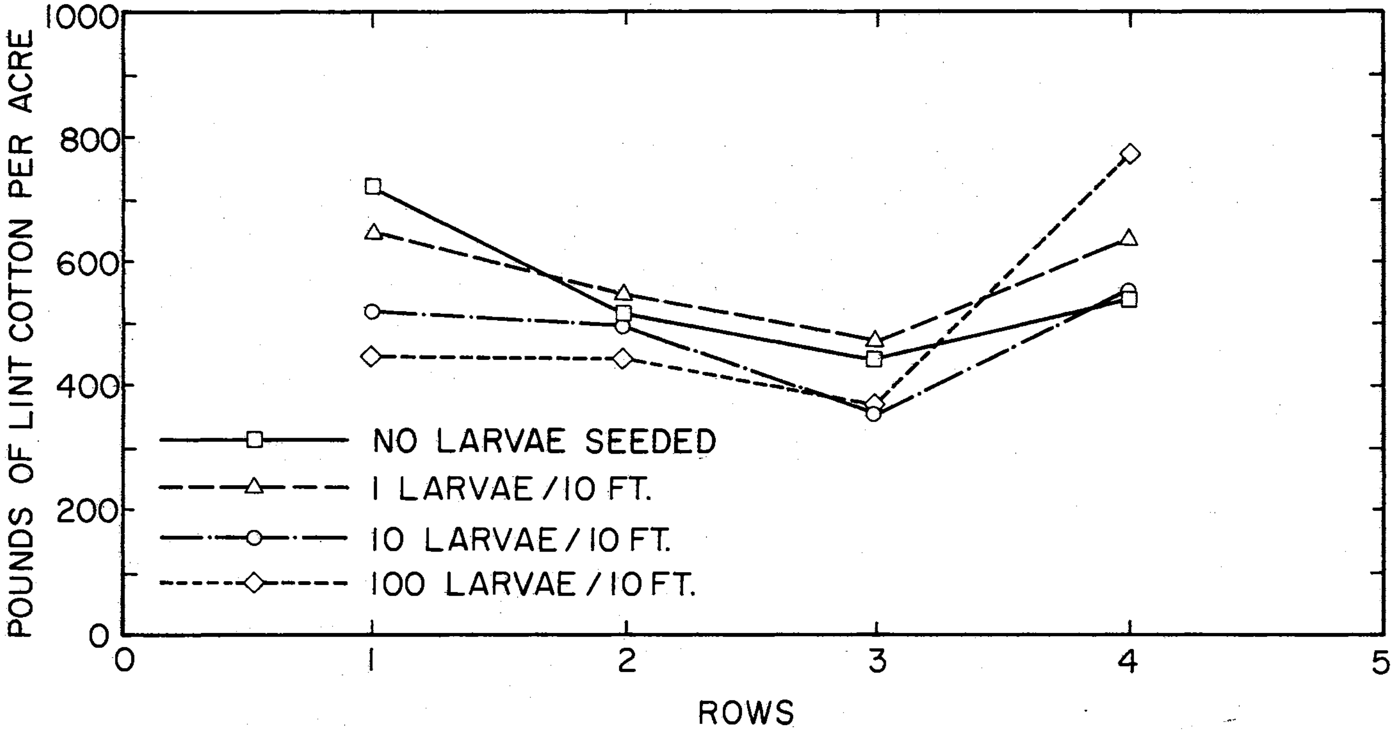

Figure 5. Average cotton yield of Westburn 70 cotton treated with biweekly releases of several rates of Spodoptera frugiperda larvae, Tipton, Oklahoma, 1971.[a]

[a]Each point is based on cotton harvested from 20 feet of four rows.

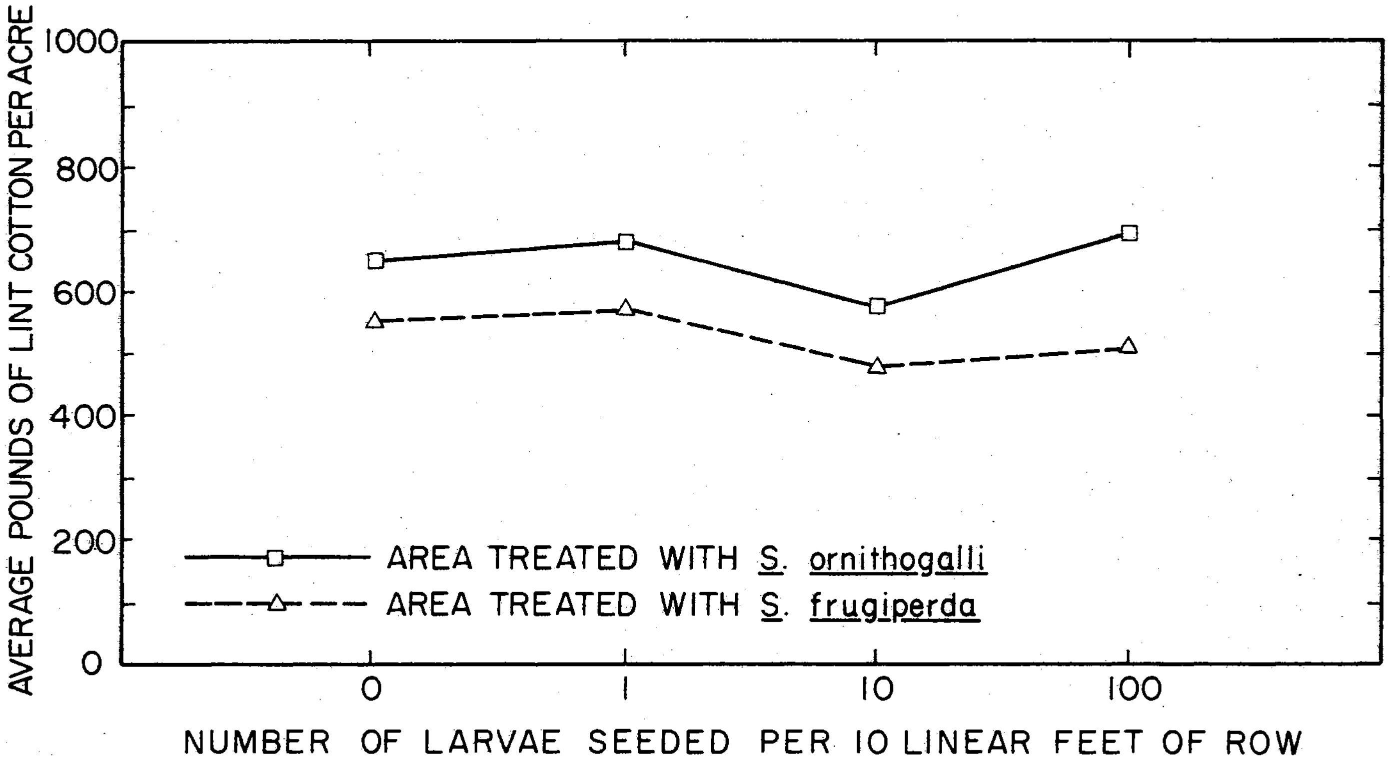

Figure 6. Average cotton yield in fields treated with biweekly releases of *Spodoptera ornithogalli* and *S. frugiperda* larvae, Tipton, Oklahoma, 1971.[a]

[a]Each point is based on cotton harvested from 20 feet of 16 rows.

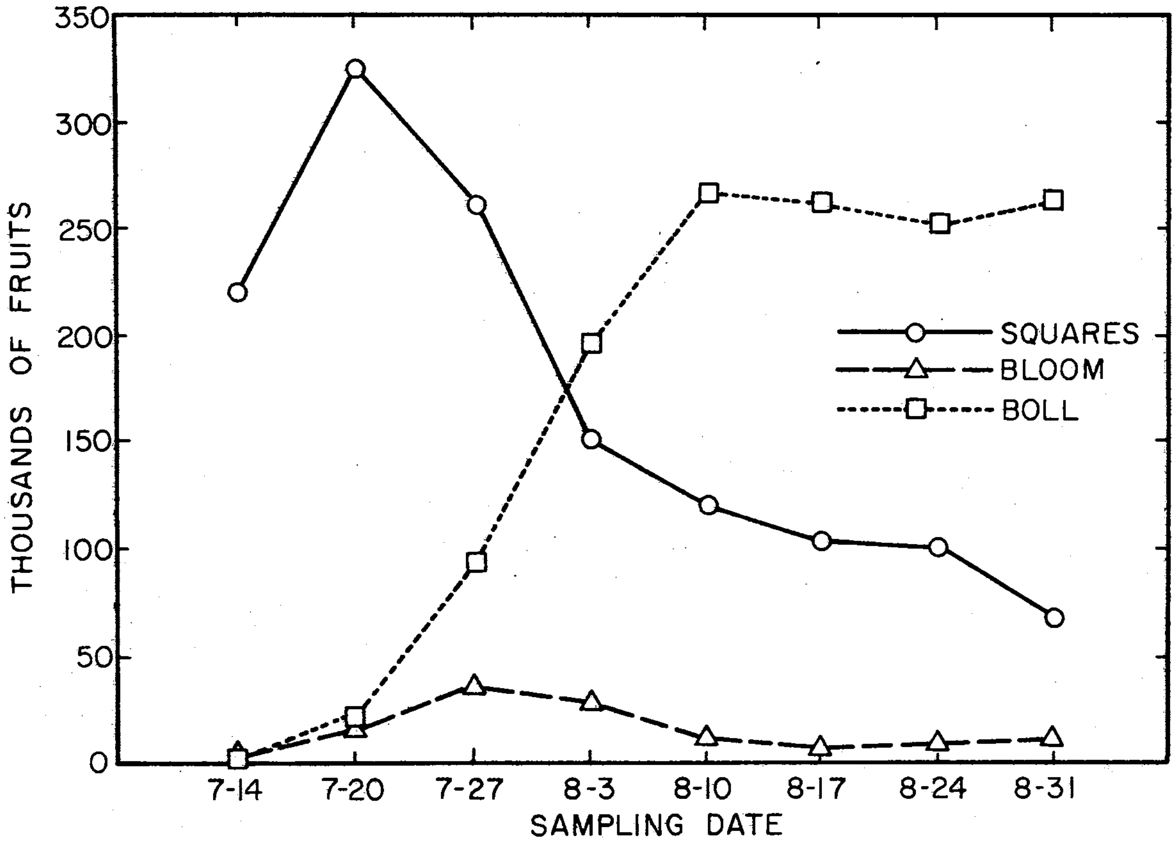

Figure 7. Fruiting of irrigated Westburn 70 cotton in southwestern Oklahoma, Tipton, 1972 (per acre).[a]

[a]Each point is based on whole plant examination of 500 plants and 49,658 plants per acre.

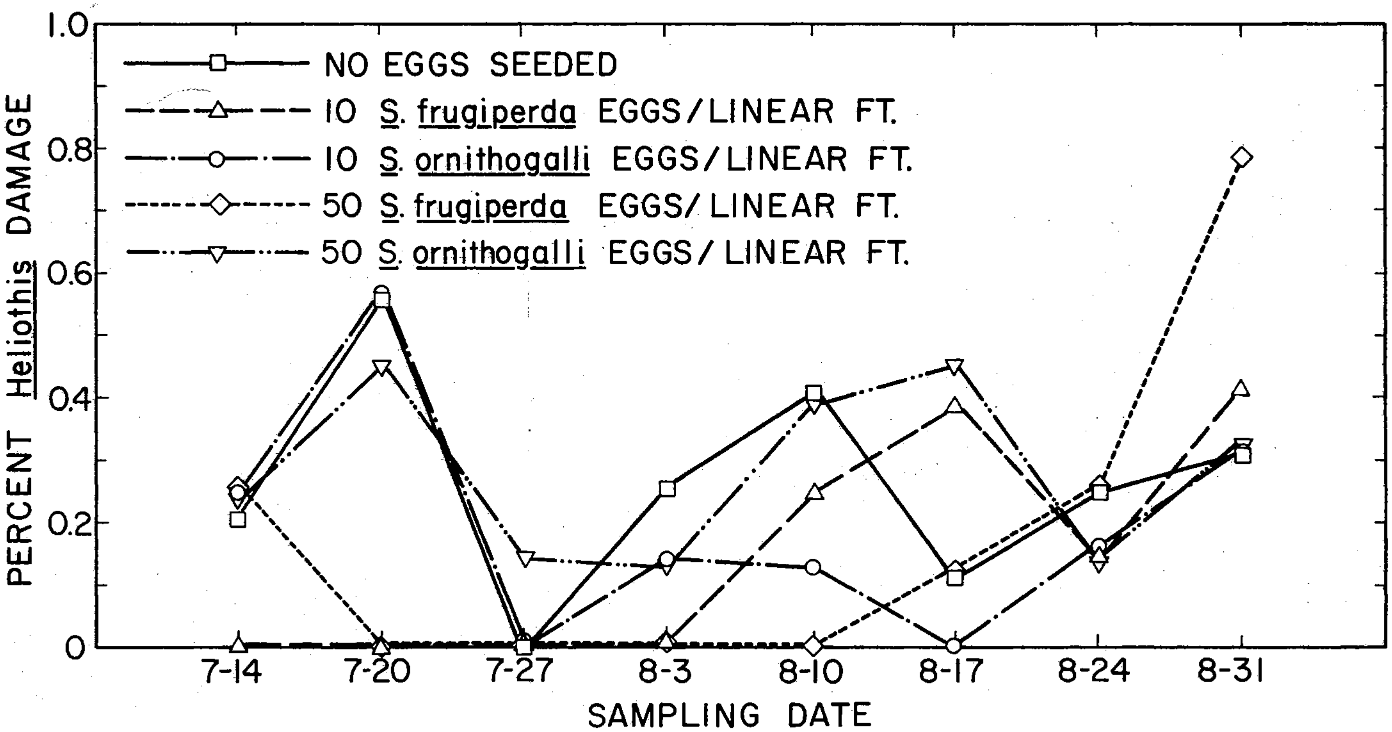

Figure 8. Percent Heliothis damage to cotton fruits (squares, blooms, and bolls) in plots treated with sustained addition of 0, 10, or 50 Spodoptera ornithogalli or S. frugiperda eggs per linear foot on 80 feet per plot, Tipton, Oklahoma, 1972.[a]

[a]Each point is based on whole plant examination of 100 plants.

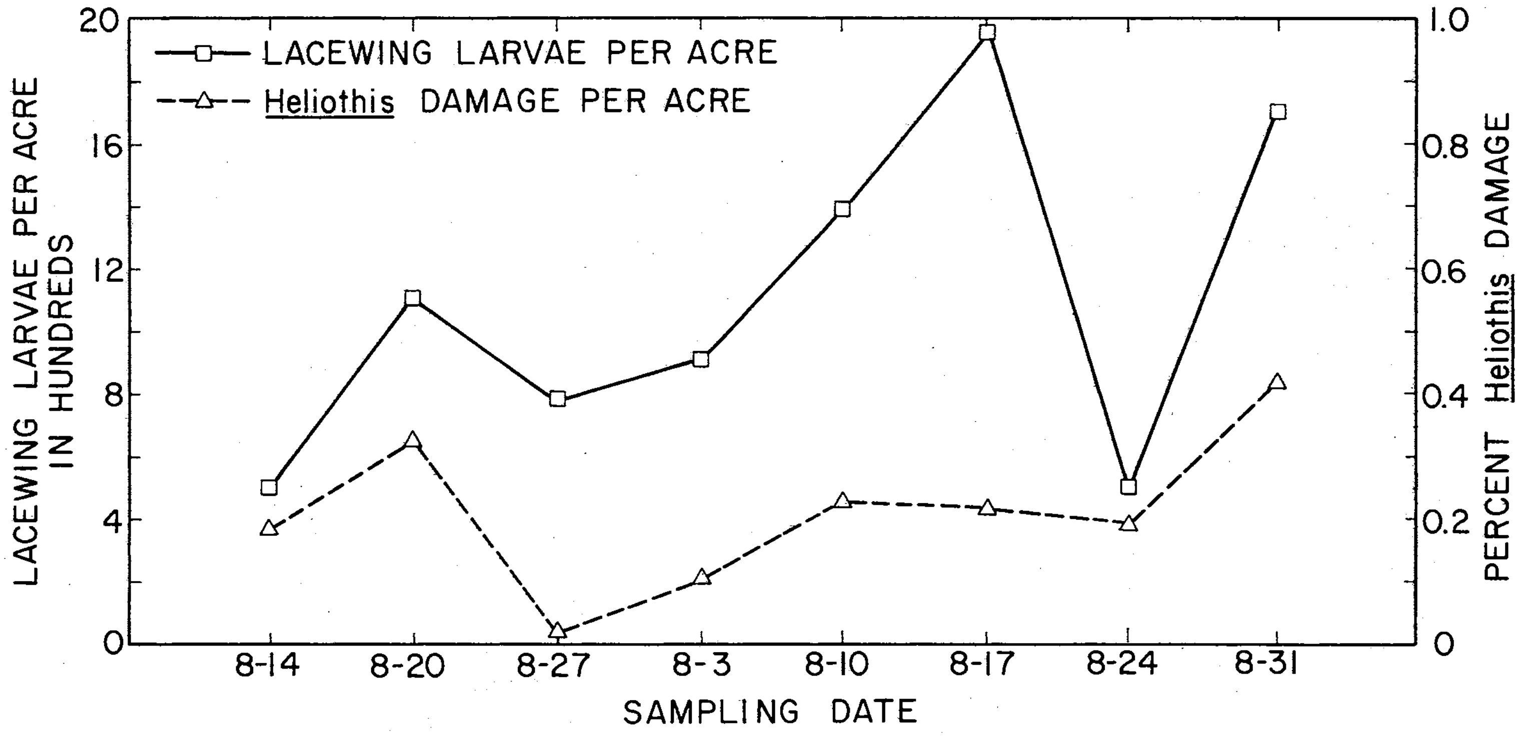

Figure 9. Average number of lacewing larvae per acre on cotton treated with sustained addition of lepidopterous eggs as compared to the average percent of Heliothis damaged cotton fruits per acre in southwestern Oklahoma, Tipton, 1972.[a]

[a]Each point is based on whole plant examination of 500 plants.

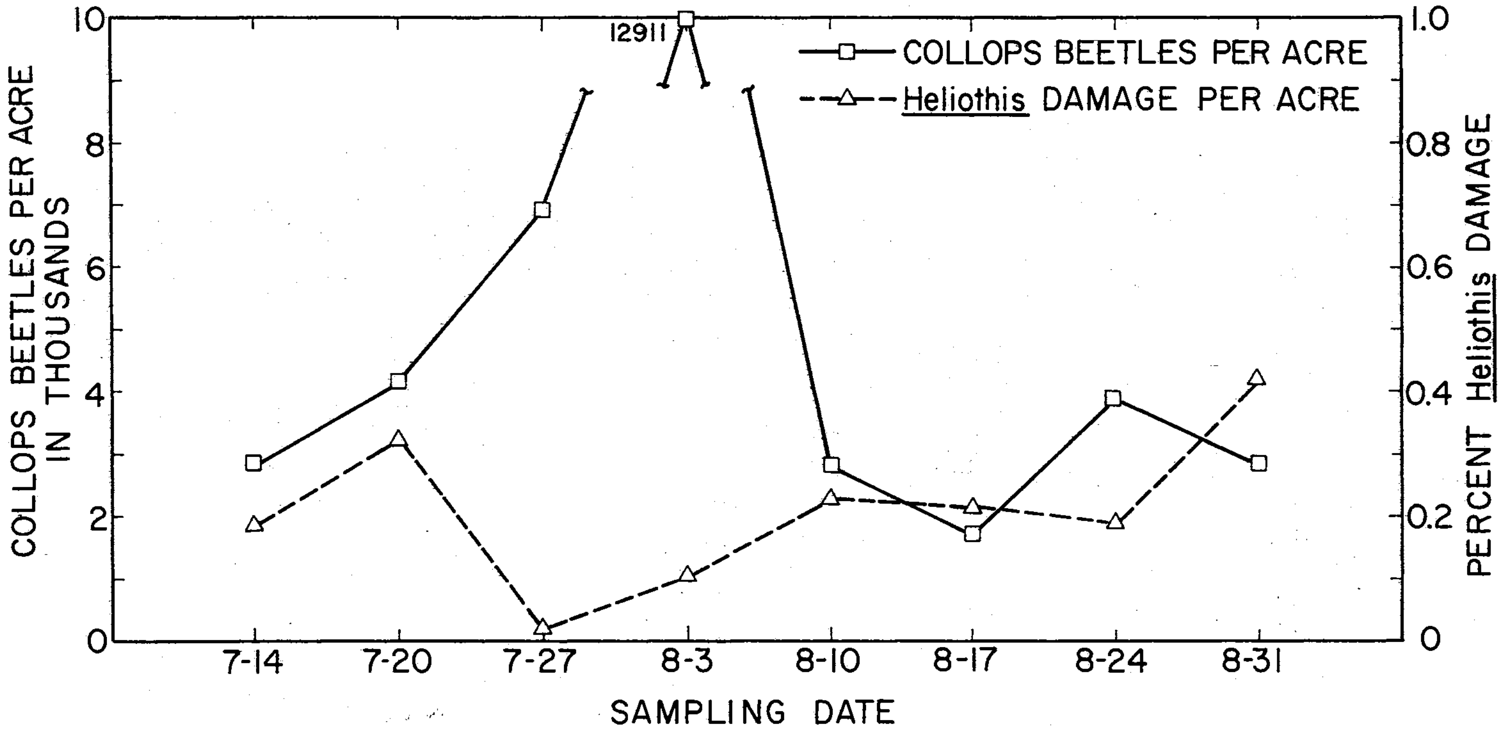

Figure 10. Average number of Collops beetles per acre on cotton treated with sustained addition of lepidopterous eggs as compared to the average percent of Heliothis damaged cotton fruits per acre in southwestern Oklahoma, Tipton, 1972.[a]

[a]Each point is based on whole plant examination of 500 plants.

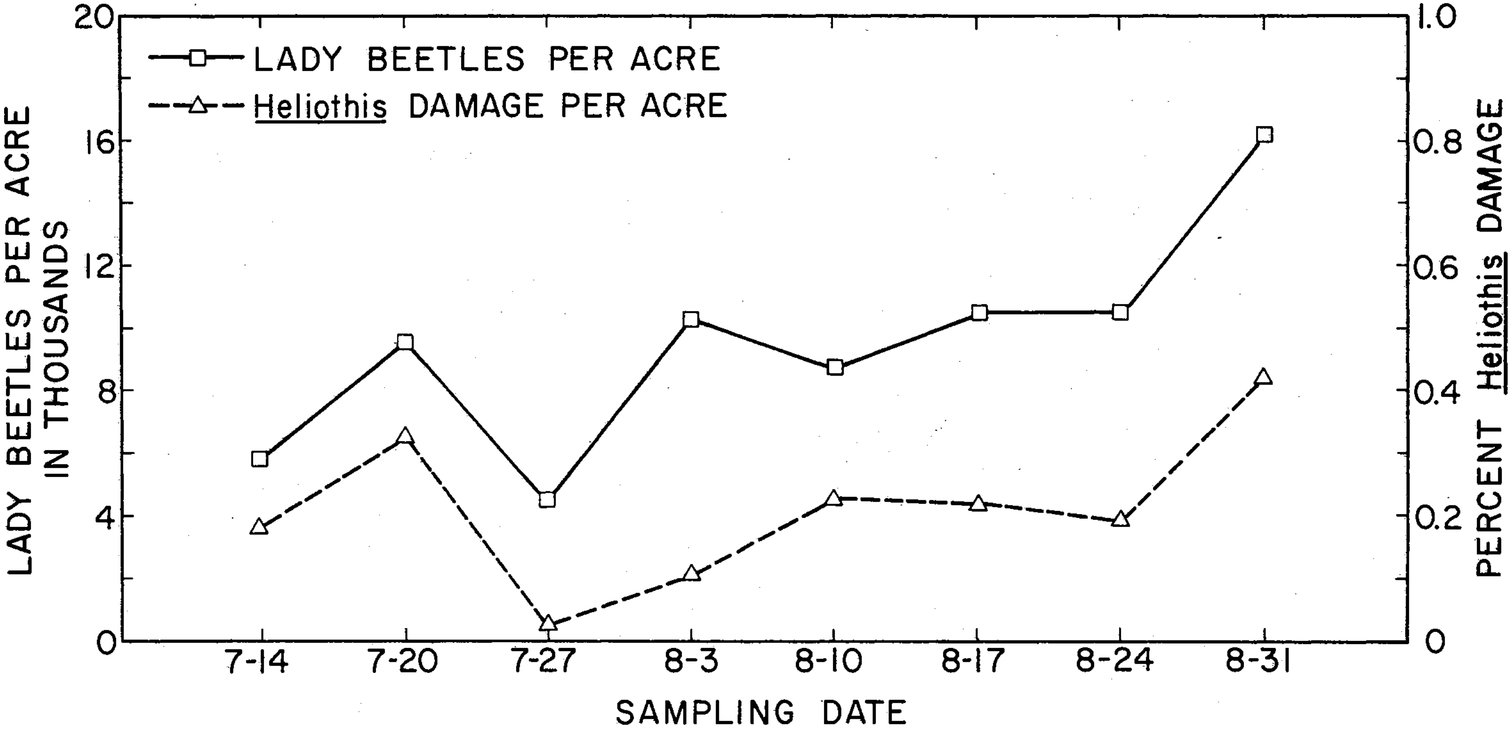

Figure 11. Average number of lady beetles per acre on cotton treated with sustained addition of lepidopterous eggs as compared to the average percent of *Heliothis* damaged cotton fruits per acre in southwestern Oklahoma, Tipton, 1972.[a]

[a]Each point is based on whole plant examination of 500 plants.

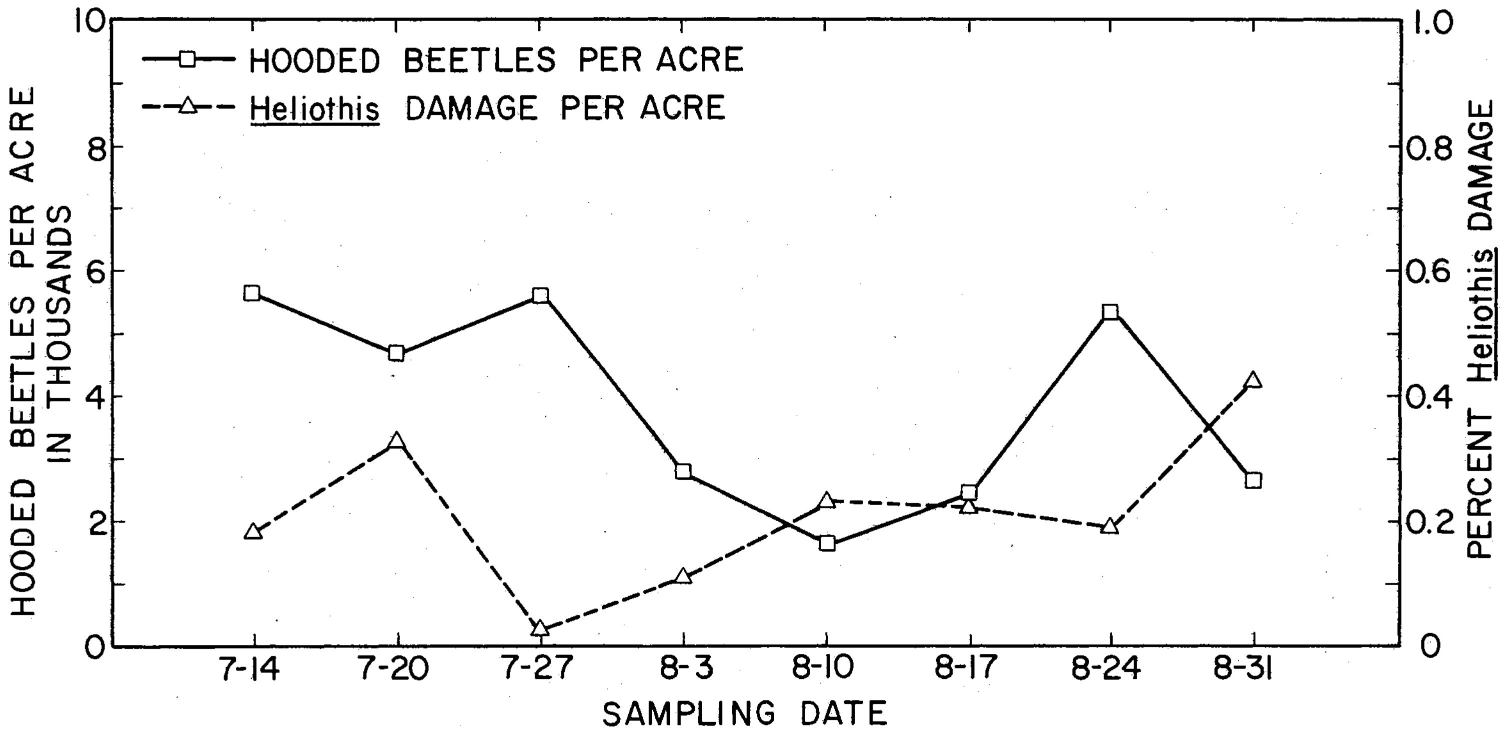

Figure 12. Average number of hooded beetles per acre on cotton treated with sustained addition of lepidopterous eggs as compared to the average percent of *Heliothis* damaged cotton fruits per acre in Southwestern Oklahoma, Tipton, 1972.[a]

[a]Each point is based on whole plant examination of 500 plants.

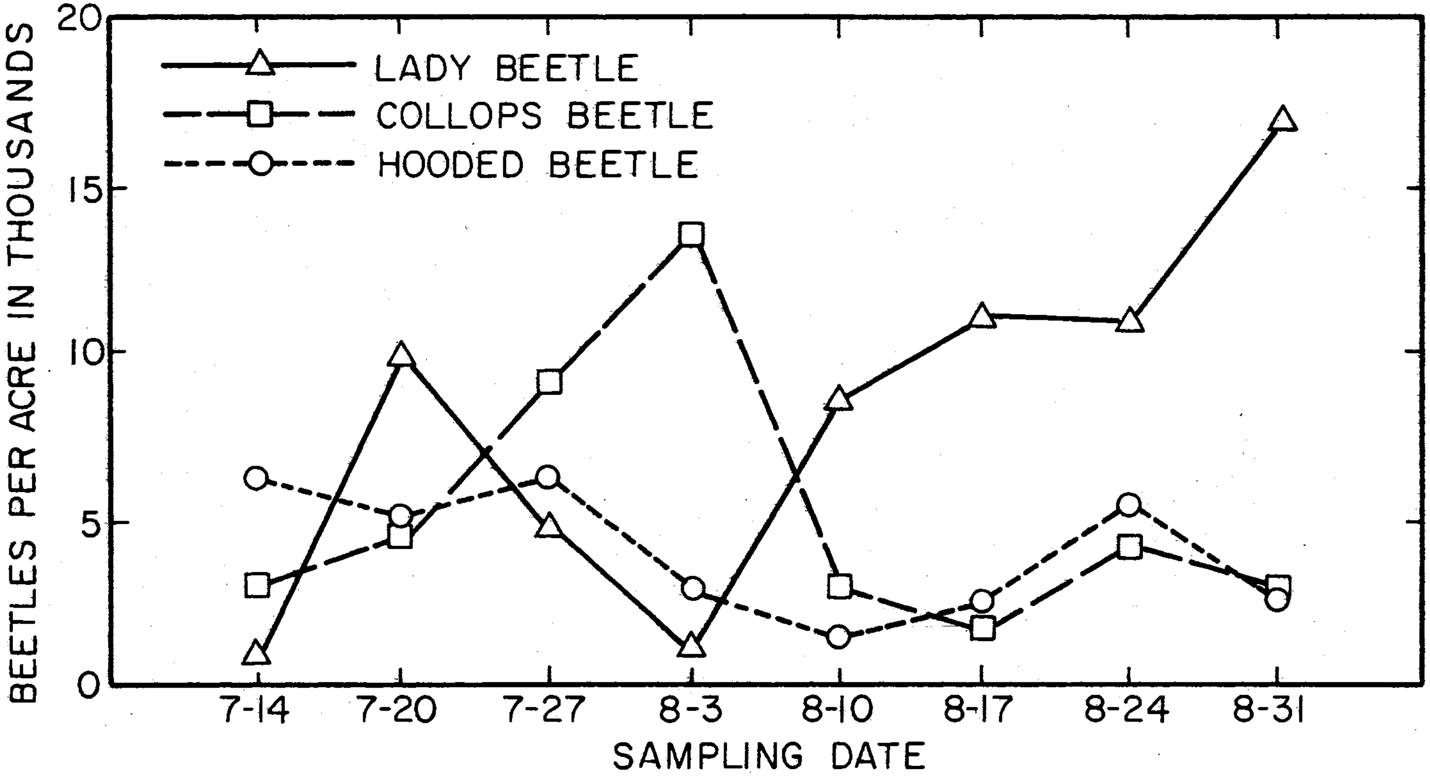

Figure 13. Lady beetles, _Collops_ beetles, and hooded beetles per acre on cotton in southwestern Oklahoma, Tipton, 1972.[a]

[a]Each point is based on whole plant examination of 500 plants.

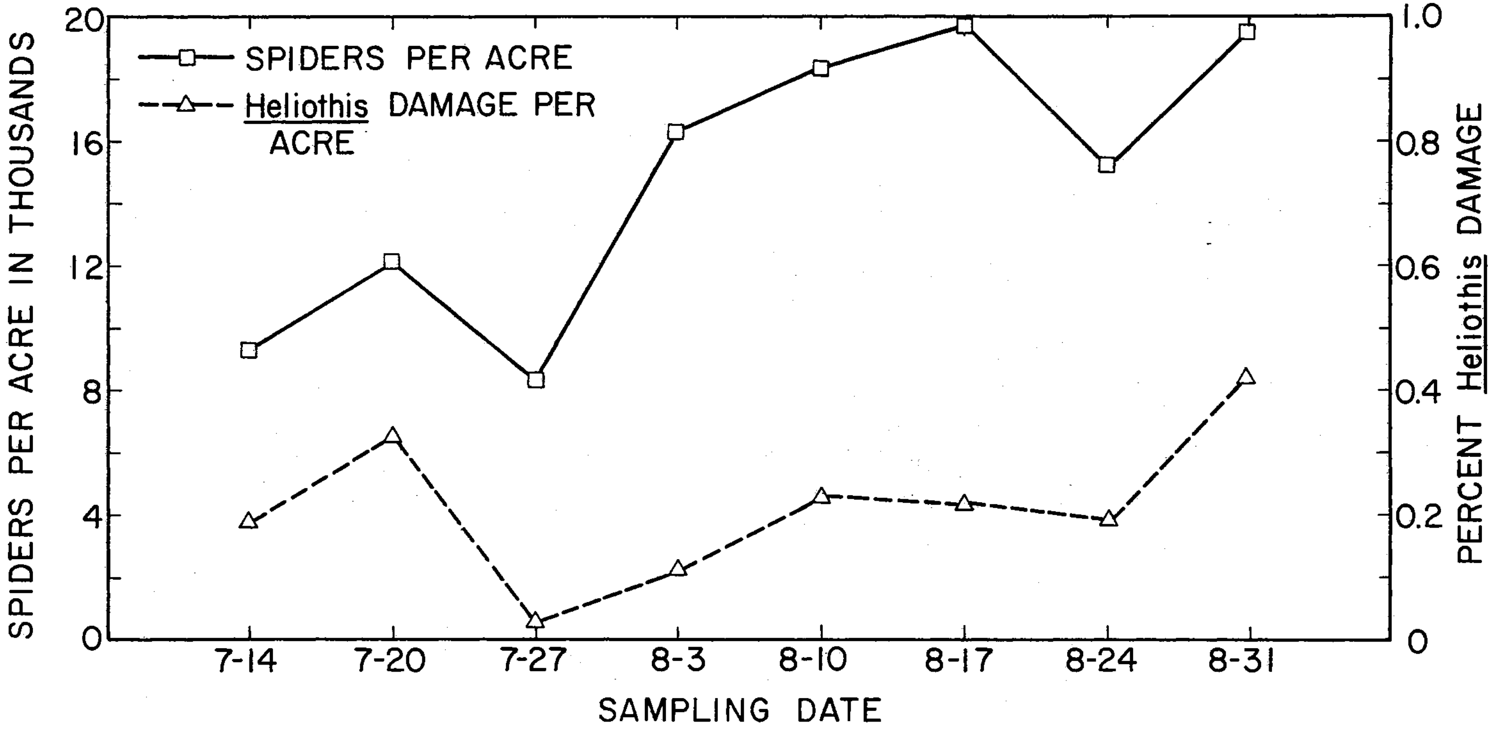

Figure 14. Average number of spiders per acre on cotton treated with sustained addition of lepidopterous eggs as compared to the average percent of Heliothis damaged cotton fruits per acre in southwestern Oklahoma, Tipton, 1972.[a]

[a]Each point is based on whole plant examination of 500 plants.

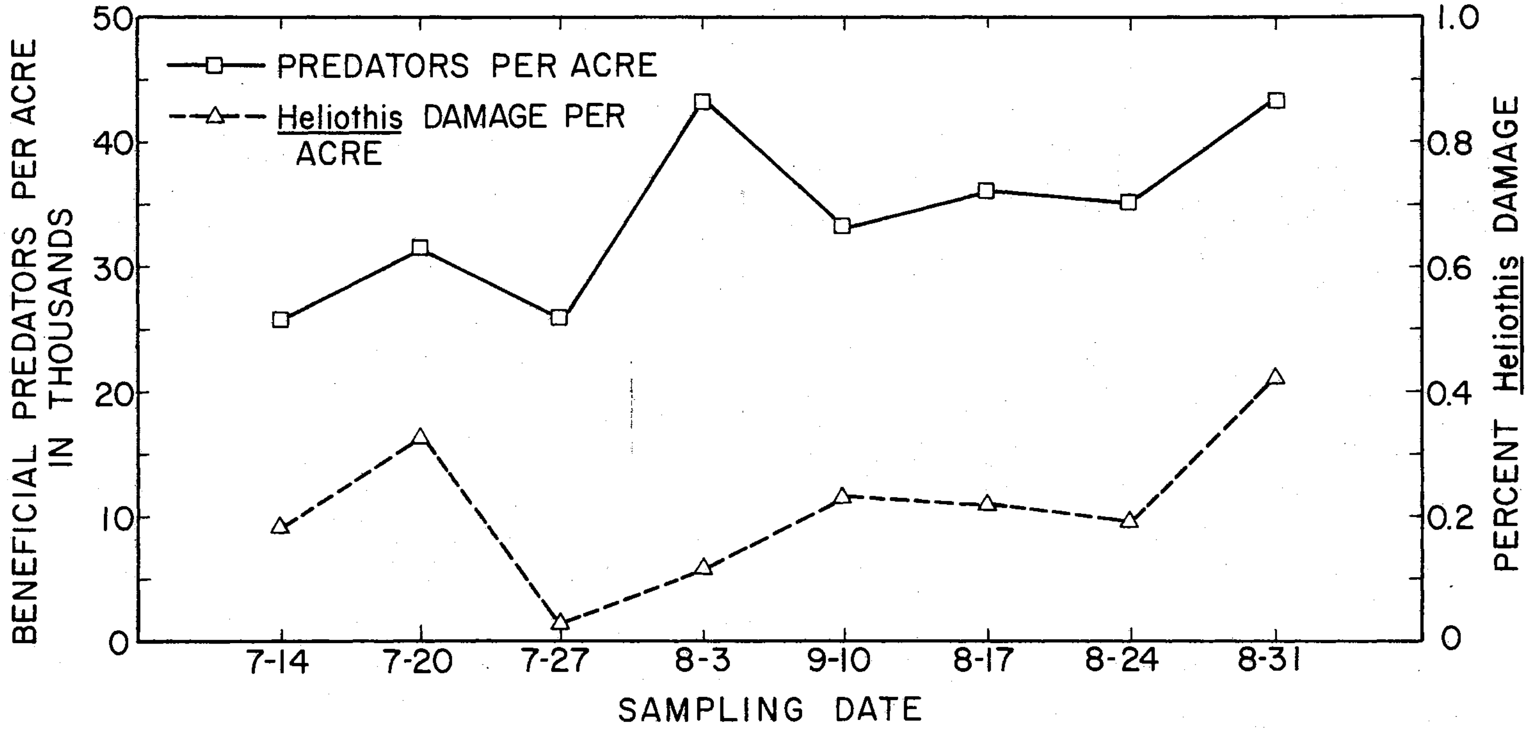

Figure 15. Average number of beneficial predators per acre on cotton treated with sustained addition of lepidopterous eggs as compared to the average percent of Heliothis damaged cotton fruits in southwestern Oklahoma, Tipton, 1972.[a]

[a]Each point is based on whole plant examination of 500 plants.

VITA

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Doctor of Philosophy

Thesis: AUGMENTATION OF NATURALLY OCCURRING LEPIDOPTEROUS LARVAE AND EGGS AS AN ATTEMPT TO CONTROL BOLLWORM DAMAGE IN COTTON

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