EVALUATION OF FIVE INSECT-RESISTANT COTTON STRAINS ON BOLLWORM COMPLEX, COTTON FLEAHOPPER, AND PREDACEOUS ARTHROPODS

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1965

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1978

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PREFACE

This study was made as a contribution to the search for factors contributing to integrated pest control in cotton, which is one of the highest chemical insecticide consumers.

The primary objective was to evaluate the response of bollworm complex, cotton fleahopper and beneficial arthropods which feed on cotton pests, when insect resistant varieties were used.

I wish to express my appreciation to Dr. Jerry H. Young not only for being the major adviser on my committee, but also for his valuable guidance and opportune advices throughout my course work.

I would like to thank Dr. Don C. Peters, Head of the Entomology Department, and Dr. Richard Berberet for serving as members of my graduate committee. A special word of thanks is extended to Dr. William Drew not only for serving as a member of my graduate committee, but also for his friendship and moral support.

A special acknowledgement is given to Dr. Maurice J. Lukefahr, USDA-ARS, for introducing me to the field of host plant resistance, and to Dr. Everardo Villarreal F., INIA-MEX, for his fellowship and encouragement.

A note of thanks is also extended to Mr. V. L. Strickland, Foreman, Southwest Agronomy Research Station at Tipton, and to Mr. Ed Oswalt, Superintendent, South Central Cotton Research Station at Chickasha, and to their staff members for their assistance on my research.

Special appreciation is extended to Dr. Laval Verhalen, Cotton Breeder, Oklahoma State University, for his friendship and for allowing me to use the Cotton Quality Control Laboratory.

Thanks are also extended to Dr. Jerry H. Young, Dr. Richard Price and Kevin S. Mussett for their assistance in collecting data.

I wish to extend my appreciation to CONACYT (Consejo Nacional de Ciencia y Tecnologia, Mexico) for their financial support. I also would like to express my gratitude to the Instituto Nacional de Investigaciones Agricolas, Mexico, and the Patronato para la Investigacion, Fomento y Sanidad Vegetal for their financial aid.

I am specially grateful to those individuals who have instilled in me an inner confidence.

To my wife, Josefina, and to our daughters, Cris and Peque, who have given much and received little during the realization of this work, I am lovingly grateful.

This research was supported by the Oklahoma Agricultural Experiment Station.

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CHAPTER I

INTRODUCTION

Insect pests constitute one of the limiting factors in cotton crop production in the world. The bollworm complex, Heliothis zea (Boddie) and Heliothis virescens (Fabricius), is in most places the key pest, due to its well known resistance to several insecticides. Brazzel (1963) found that the Texas strain of tobacco budworm, H. virescens was resistant to DDT. He demonstrated this same resistance to DDT in bollworm, H. zea, in 1964. Lowry et al. (1965) confirmed the resistance of bollworm and tobacco budworm, determining that the tobacco budworm is 16.5 times more resistant to DDT than the bollworm. Adkisson (1968) found that the tobacco budworm had developed resistance to Endrin and carbaryl. The resistance to carbaryl may be an example of cross-resistance between carbamate and chlorinated hydrocarbon types.

The cotton bollworm has become the most destructive cotton pest in Oklahoma and tobacco budworm is generally a late season pest which usually represents less than 10% of the bollworm complex population (Kunz 1966a).

Quaintance and Brues (1905) found that each bollworm larva damages an average of 8 squares, 1-2/3 bolls, and 1 flower. Similar results were found by Kincade et al. (1967) with the tobacco budworm.

Knipling (personal communication with Lukefahr and Shaver 1972) developed population models indicating that if 80% of each generation of Heliothis could be suppressed, population levels would become static.

Host Plant Resistance

The need for alternative methods of insect control have made researchers look toward the use of plants with some insect resistant characters. Painter (1951) cites that the use of resistant varieties falls into three different groups: a) as a principal method of control, b) as an adjunct to other measures and c) as a safeguard against the release of more susceptible varieties than those in existence at the present time. Luginbill (1969) defines an insect resistant plant as a plant which has a degree of resistance to insect attack if it sustains less damage at a given level of infestation than the average of other plants grown in the same environment.

Resistance to pests exists throughout nature, it needs only to be discovered, identified and put to work to solve many of our most serious pest problems. The mechanisms of resistance described by Painter (1951) and Horber (unpublished) are: a) tolerance, which includes all plant responses resulting in the ability to withstand infestations and to support insect population which would severely damage susceptible plants, b) antibiosis is the presence of certain compounds in the plant which inhibits the buildup of certain insects, c) non-preference is an adverse effect on the insect behavior during orientation for oviposition, food or shelter. This last term has been discussed by Kogan and Ortman (1978) who have suggested the use of the word antixenosis instead of non-preference.

The use of host plant resistance in pest control should be implemented rapidly because current chemical control methods for some of the major pests contribute substantially to the accumulation of insecticide residues in our environment (Knipling, 1964). Traditionally, to control key insect pests, it is necessary to use a broad spectrum of insecticides, which have adverse effects on natural enemies.

The experiment discussed here was designed to test five cotton strains resistant to bollworm complex and cotton fleahopper, Pseudatomoscelis seriatus (Reuter), and to observe the behavior of some of their predators.

Characteristics of Resistance

The characteristics of resistance tested in this study are: nectariless, glabrous and gossypol content.

Nectariless

This characteristic, which is the lack of extrafloral nectaries (Lukefahr and Shaver, 1972), was the first trait found to have an influence on Heliothis populations. The nectaries are external glands which produce a sweetish fluid that serves as food for many insects. Cultivated upland cotton, Gossypium hirsutum L., has extrafloral and floral nectaries; the nectariless condition was transferred from Gossypium tomentosum N., a wild cotton from Hawaii (Meyer and Meyer, 1961). This is a recessive trait controlled by two pairs of genes.

Parson (1938) and Parson et al. (1938) found that Heliothis moths are interested in cotton only when the plant starts to bloom, and he also found that fertile eggs are not deposited unless the moth gets food from the nectar at regular intervals. Lukefahr and Rhyne (1960) observed that lack of food for adults reduced the number of eggs laid. Similar results were found by Wilson and Wilson (1976) on pink bollworm, Pectinophora gossypiella (Saunders), where the nectariless plots had a lower number at each sampling date than the nectaried plots. Lukefahr et al. (1965) report that the nectariless strain in prefloral and floral tests had significantly fewer eggs of five different lepidopterous species than the nectaried strains.

Maxwell (1977) reported that from several thousand acres of nectariless cotton grown commercially, the common green lacewing was the only predator significantly reduced by this condition.

Schuster et al. (1976) found that cotton fleahopper was significantly reduced in the nectariless plots in early season but not in late season. The ladybeetle, Hippodamia convergens (Guérin-Méneville), was significantly reduced throughout the season. Lacewings, tachinid flies and several predators including spiders were reduced in late season but not in early season. Differences in cotton fleahopper were significant at P=.05 when there were 99% and 96% pure lines, but not when the purity was 92%. Davis et al. (1973), in a study conducted over a 4-year period using cages to test Acala strain nectaried and nectariless, found that H. zea moths laid as many as 45% less eggs in nectariless Acala strains as in their normal hairy nectaried strains.

Glabrous

The reduction of trichomes on buds and leaves and its effects upon the insect pest population has been studied for many years. Scales and Stadelbacher (1972, 1973) observed that Heliothis spp. damaged a significantly higher number of fruits of Stoneville 213 than of other three varieties less pubescent than Stoneville 213. Also, the mean eggs laid on Stoneville 213 was significantly higher than on Niles Sm; and, in general, H. zea and H. virescens seemed to prefer the more hirsute varieties for oviposition. Lukefahr et al. (1971) found that glabrous cotton strains were effective in reducing the oviposition of *Heliothis* spp. Those reductions varied from 36% to 80% and the larval populations were from 41% to 67% lower.

Ellington (1976) in an experiment with semi-smooth nectariless cotton found a highly significant reduction of lygus, lacewing and lady-beetle adults. He did not find a significant reduction in collops beetles and cucumber beetles. He did not determine whether the beneficial complex suffered from a lack of prey or if plant resistance factors directly affected them.

Gossypol Content

Gossypol is the most active of the terpenoid compounds against *Heliothis* spp. It is toxic to non-ruminant animals (Eagle et al., 1948) because it reduces the oxygen-carrying capacity of blood cells. Dilday and Shaver (1976) found that the environmental factors have a great influence on the level of gossypol produced. The average content of gossypol in a stable line such as M-8 (doubled haploid) is about .48%, but the range is from 1.5% for the strains with the highest and .27% for those with the lowest gossypol content.

After gossypol was demonstrated to be responsible for the growth inhibition of *Heliothis* larvae, the main goal was to incorporate this compound into commercial varieties. The source most commonly used so far for gossypol is the wild cotton strains from Socorro Island, off the coast of Mexico.

Since there are several compounds released from internal glands of *Gossypium* spp. which are toxic to insects, Lukefahr et al. (1977) suggested that it is possible that a synergistic effect can exist. Shaver and Lukefahr (1969) found that other compounds present in the glands are about ½ as toxic to insects as gossypol.

Quaintance and Brues (1906) noticed that Egyptian cotton was less preferred by bollworm than upland cotton, and they believed that some chemical internal compounds were responsible for this effect. Wene and Sheets (1966), testing short staple cotton varieties (G. hirsutum L.) and long staple cotton varieties (G. barbadense L.) against bollworm, found that the infestation in G. hirsutum averaged 33 larvae/100 plants and 11 larvae/100 plants in G. barbadense, indicating that some factor which is present in long staple cotton inhibited bollworm population.

Other experiments conducted by Lukefahr and Houghtaling (1969) and Bottger et al. (1964), using resistant cotton strains with high gossypol, concluded that lines with high gossypol content in the squares produced the smallest Heliothis larvae and those producing the largest larvae averaged the lowest gossypol content. Bottger and Patana (1966) found great reduction on larval weight and an increase in development time for Spodoptera exigua (Hubner) and H. zea when fed on high gossypol diets.

The presence of glandless genes in cotton made it accepted to insects which normally do not cause damage to cotton (Maxwell et al., 1965; Murray et al., 1965; Oliver et al., 1970).

Since the same source which inhibits Heliothis larval growth is toxic for non-ruminant animals, this restricts the use of cotton as animal feed. Lukefahr and Fryxell (1967) found that in the genus Cienfuegosia, no gossypol is stored in the seeds, a small amount is stored in the flower buds, and a high concentration is present in the roots. This selectivity may make it possible to use cotton seed meal for feeding purposes of non-ruminant animals. Miravalle and Hyer (1962) worked on the identification of the $Gl_2gl_2Gl_3gl_3$ genotype for the glandless cotton seed, trying to find the point at which gossypol content tended to limit the usefullness of cotton seed meal as an animal food.

In regard to the influence of glandless genes, Wilson and Lee (1971) found that Gl_2 contributes more than Gl_3 to genetic addition, while Shaver and Garcia (1973) found that the Gl_3 genotype had more gossypol in the flower than plants with Gl_2.

Dealing with cotton containing combinations of resistant characteristics in suppression of <u>Heliothis</u> spp., Lukefahr et al. (1975) found differences in larval populations when they tested lines with glabrous and nectariless conditions and high gossypol content, and lines having combinations of these three characteristics. Since nectariless character was difficult to evaluate due to the small size of the plot, only the combination of glabrous and high gossypol was evaluated, showing a reduction from 60% to 80% on larval populations.

In prior studies on characteristics of strains resistant to <u>Heliothis</u> spp. and their effect on cotton fleahopper population, it has been found that nectariless traits as well as high gossypol content provide resistance against fleahopper, but the glabrous condition is highly susceptible to this pest. Lukefahr and Houghtaling (1975) demonstrated that high gossypol character imparts a high degree of antibiosis to the immature stages of fleahopper. They also found that nectariless conditions, when combined with high gossypol, reduce fleahopper populations by an additional 10%.

Brett et al. (1946) reported that cotton fleahopper, <u>P. seriatus</u>, is a factor which normally does not increase the shedding square cause, and they reported cases where varieties with more cotton fleahopper population yielded more than varieties which showed fewer. Kunz (1966b) reports that cotton fleahopper infestation may be serious enough to cause loss of a cotton crop, specially in the drier areas of Oklahoma.

CHAPTER II

MATERIALS AND METHODS

Insect Resistant Cotton Strains

Five cotton strains resistant to Heliothis spp. were used for this experiment and the cultivar, Stoneville 213, was used as a check.

The experimental strains were supplied by Dr. M. J. Lukefahr, USDA, ARS, Brownsville, Texas and Dr. W. P. Sappenfield, University of Missouri-Columbia. BW 73-51849, having only high gossypol content as a resistant factor, was supplied by Dr. Sappenfield. HG DDS-N-1, HG DDS-N-2, HG P-9-13 and HG NCSm10 were supplied by Dr. Lukefahr and all of them have three features for resistance against bollworm complex: they are nectariless, glabrous and have a high gossypol content. Stoneville 213 is a commercial variety used as control, with normal expression of nectaries and trichomes as well as gossypol content.

Methods Used

These materials were tested in 1977 and 1978 at Tipton, Oklahoma, at the OSU Agricultural Experiment Station and in 1978 at the OSU Experiment Station in Chickasha, Oklahoma. A randomized-complete-block design was used, replicated four times. The study area was divided into 24 plots each 12 rows per 15.24 meters on 1.02 meters row spacing. The seeding rate was 22.407 Kgs./Ha. to obtain a population between 98,000 to 148,000 plants per Ha. Planting dates were May 17, 1977, and June 13, 1978, at Tipton, and May 14, 1978 at Chickasha. The delay in planting date at Tipton, in 1978, was due to excessive rainfall during the normal planting season. Agricultural practices such as fertilization, planting and irrigation, were performed in accordance with the Extension Service in each area. Guthion (.280 Kgs./Ha.) was applied to control boll weevil on July 28, 1977, at Tipton. Methyl parathion was used twice at Tipton and Chickasha in 1978 to control boll weevil and predispose the varieties to Heliothis attack. Spraying dates for both locations were July 26 and August 2.

Sampling

Whole plant examination was practiced at both locations. Five 2.7 foot-row (1/5000 of an acre) samples were taken per plot per sampling date. Numbers of bollworm eggs and larvae, cotton fleahoppers and beneficial insects were recorded. D-Vac samples were also taken using one row 15.24 meters long per plot. In addition, 50 squares were collected at random from each plot and examined for bollworm and boll weevil damage. All of these samples were taken weekly.

Whole plant examinations were performed at Tipton in 1977, during nine weeks starting on June 28. D-Vac samples were taken during four weeks starting on June 29. Squares were collected on July 26 and the subsequent four weeks.

At the same location, in 1978, whole plant examination was practiced during nine weeks starting on June 28, and D-Vac samples were collected during seven weeks starting on June 28. At Chickasha, in 1978, only whole plant examinations were performed every week during six weeks starting on July 6. Due to the susceptibility of high gossypol content to thrips, counts of this insect were taken at Tipton, and 25 plants per plot were examined using the Berleese funnel method.

Yield data were collected at Tipton by picking 15.24 meters of row from each plot. Two pickings were made in order to determine earliness in the cotton strains tested. Fiber quality was determined at the cotton laboratory at OSU, Stillwater.

Data obtained from both years and for both locations were statistically analyzed at the Oklahoma State University Computer Center, using the Statistical Analysis System designed by A. Barr and J. Goodnight, from the Department of Statistics, North Carolina State University. These data include bollworm complex larvae and eggs, fleahopper, thrips, beneficial insects, spiders and fiber quality as well as yield obtained in 1977.

CHAPTER III

RESULTS AND DISCUSSION

Bollworm Complex

The results obtained on the behavior of the bollworm complex in cotton strains resistant to these insects, are in accordance with most of the studies carried out in different regions and by different researchers.

Even though populations in 1977 were not high enough to cause economic damage, significant differences were found in larval numbers and Stoneville 213 had the highest population (Table I). No significant differences were found among the strains which have three characteristics and the strain with only one characteristic, however, the lowest populations were in those strains with three resistance factors. Figure 1 shows the distribution of larvae populations in Stoneville 213, BW 73-51849 and HG DDS-N-1. The samplings were started on June 28, but the population was not increased until August 2, due to an insecticide application against boll weevil made on July 28, which stopped the action of beneficial insects.

In 1978, the results were similar to those obtained during the previous year. Stoneville 213 had significantly higher populations than the resistant strains; among which no significant differences were recorded (Table I). In 1978, populations appeared very late. Samplings were made during nine consecutive weeks, starting on June 28, and no populations were detected until the seventh week, on August 8. Two insecticide applications (Methyl parathion) were made on July 26 and August 2, which predisposed the plants for bollworm infestations. Figure 2 shows the distribution throughout nine sampling dates in three varieties with different resistance characteristics.

During 1978, differences were obtained in the number of eggs in the different strains (Table II). The number of eggs in Stoneville 213 was significantly greater and BW 73-51849 was second. There were no statistical differences at 5% level among the strains which posses a glabrous character, which has demonstrated its effectiveness in reducing egg populations. Figure 3 shows the egg fluctuation during the cycle in three different strains, of which Stoneville 213 maintained the highest populations and HG DDS-N-1 obtained as much as 10.50 times lower populations than Stoneville 213.

The results obtained at Chickasha in 1978 are not essentially different from those obtained at Tipton. In larval populations, again, Stoneville 213 proved to be statistically different from the resistant strains (Table I), among which no significant differences were recorded. Figure 4 shows that larval population in August was high enough to show significant differences among the resistant strains. In regard to the number of eggs, it was also detected that, statistically, Stoneville 213 was the preferred variety for oviposition (Table II), followed by BW 73-51849 which is pubescent, and HG NCSm10 which was less preferred. Figure 5 shows seasonal distribution of Stoneville 213 when compared with two strains, BW 73-51849, haired, and HG DDS-N-1, glabrous material.

In regard to the fruiting damage in 1977, since infestations were very low, no statistically significant differences were found.

In 1978, at Tipton, significant differences were found between Stoneville 213 and the resistant strains only on August 15 (Table III), but no differences were detected among the strains. Figure 6 shows the fluctuation of fruiting damage through the season and it also shows that on August 15, the three entries were over the economic threshold which is 5% squares infested for Oklahoma cotton, Pinkston et al. (1978).

At Chickasha in 1978, there were significant differences on August 30 and September 14, where Stoneville 213, the standard, was different from the resistant strains (Table IV). Figure 7 shows that Stoneville 213 reached economic levels of square damage on four out of five dates, while of the resistant strains, only HG DDS-N-1 was above the economic threshold on August 15.

Cotton Fleahopper and Thrips

Results obtained at Tipton in 1977 show that Stoneville 213 had significantly more fleahoppers than other strains (Table V), with a population 2.89 times higher than the next entry (BW 73-51849) and 10.23 times higher than the last (HG P-9-13). Even though the glabrous character is well known as being susceptible to fleahopper, this susceptibility is not shown with high gossypol content. Figure 8 shows the fluctuation of cotton fleahopper through the season, where the highest infestation was detected during the first three weeks; significant differences were found among the strains and Stoneville 213.

During 1978, similar results were obtained and once again BW 73-51849 showed 2.91 times less fleahopper than Stoneville 213 and HG DDS-N-2 had 10.66 times fewer insects than the check (Table V). No significant differences were found among the four entries with three resistant characters. Figure 9 shows the population for the check and two strains with different characters. In 1977, higher infestations were sampled at the beginning of the season; in 1978, populations were higher at the end of the season. It is not known whether these effects were caused by the fact that 1978 was dryer than 1977 or by insecticide applications which were made three and two weeks before the first high populations were detected.

Results for Chickasha did not differ much from those for Tipton in 1977 and 1978, and Stoneville 213 showed once again more susceptibility to attack of cotton fleahoppers than the resistant strains (Table V). Despite the fact that statistical differences were not found among the strains, BW 73-51849 had as much as 5.09 times fewer fleahoppers than Stoneville 213; and HG NCSm10 had 16.97 times less fleahoppers than the check. Figure 10 shows the fluctuation of the population on BW 73-51849 and HG DDS-N-1 through the season.

Data collected on thrips during 1977 and 1978 at Tipton, showed that the populations were low, and no significant differences were found.

Predaceous Insects and Spiders

Beneficial arthropods, mainly predator insects and spiders, play an important role in the natural control of bollworm complex and cotton fleahopper; therefore, an evaluation of their populations was made.

Big Eyed Bug, Geocoris Spp.

This insect was found only occasionally in Tipton and Chickasha in 1977 and 1978, and when monitored, the population was too low to show statistical differences.

Collops Beetles, Collops Spp.

Significant differences at 5% level were found at Tipton in 1977, where Stoneville 213 was not statistically different from BW 73-51849, but HG DDS-N-1 had the lowest population (Table VI). During this same year, collops constituted 8.2% of the total population of beneficial arthropods in BW 73-51849, 3.6% in HG DDS-N-1 and 9.2% in Stoneville 213. In 1978, at this same station, Stoneville 213 was significantly different from the treatments; the lowest population was for HG P-9-13 as shown in Table VI. Collops constituted 12% of the total beneficial arthropods (Table VIII).

At Chickasha, in 1978, differences were detected only between the resistant strains and Stoneville 213 (Table VI).

Green Lacewing, Chrysopa Spp.

Eggs, larvae and adults were counted individually in the whole plant examination practiced. In 1977, at Tipton, Stoneville 213 and BW 73-51849 were not significantly different in egg population (Table VII). In 1978, statistical differences were found between the check and the treatments. No differences were detected among treatments (Table VII). The data collected from Chickasha showed that Stoneville 213, HG P-9-13 and HG DDS-N-1 were not statistically different, even though these last two have no nectaries and are glabrous (Table VII).

One of the highest percentages in population of beneficial insects counted belonged to green lacewing eggs (Table VIII). Very few larvae and adults were found. But in 1978, at Tipton, the data collected for adults showed that Stoneville 213 and BW 73-51849 were significantly different from the other strains (Table IX).

Hooded Flower Beetle, Notoxus Sp.

Only at Tipton (in 1977 and 1978) Stoneville 213 was statistically different from the treatments. No differences were detected among treatments (Table X).

Ladybeetle, Hippodamia Spp.

In 1977, at Tipton, populations of ladybeetle were low and no differences were detected; but in 1978, at Tipton and Chickasha, Stoneville 213 was significantly different from the resistant cultivars, which were not statistically different among themselves (Table XI).

Nabids, Nabis Spp.

In 1977, data collected at Tipton showed that the standard variety was different from all treatments. As many as 13.4 times less nabids were found in HG P-9-13 and 2.2 times less population in BW 73-51849, as shown in Table XII.

Data collected at Chickasha in 1978, demonstrated that Stoneville 213 is not statistically different from HG P-9-13, HG DDS-N-2 and BW 73-51849 in nabid population (Table XII).

Spiders

Oxiopidae, Salticidae, Thomicidae and Theridiidae were the families more often detected in plant examinations. Spiders are very active predators; however, they sometimes destroy high numbers of beneficial insects. The results obtained at Tipton in 1977, show that apparently spider populations were not affected by the characteristics of resistance of the lines, and it can be noticed in Table XIII that no statistical differences were found in Stoneville 213, BW 73-51849, HG P-9-13 and HG NCSm10.

Populations in 1978 were lower than those in 1977 and no differences were found at Tipton; but at Chickasha, the results from data collected show that no differences were found between Stoneville 213 and BW 73-51849, and the other resistant cultivars were not significantly different among themselves, as shown on Table XIII. Personal observations made on cotton fields at Tipton and Chickasha showed that spiders are one of the most active predators on cotton fleahoppers and *Heliothis* spp. larvae.

Beneficial Complex

When the total of predaceous arthropods was considered as one factor, it was found that at Tipton, in 1977, Stoneville 213 was significantly different from the resistant strains, and BW 73-51849 was significantly different from the four three-characteristic strains (Table XIV). Figure 11 shows the fluctuation of beneficial arthropods during nine sampling dates in Stoneville 213, BW 73-51849 and HG DDS-N-1. Besides those found in the seasonal data, significant differences were also found in June 28, July 19, July 25 and August 9. During 1978, at this same location, Stoneville 213 was found to be significantly different from the other treatments and no difference was found among the resistant strains (Table XIV). Figure 12 shows the seasonal distribution for Stoneville 213 and two strains, having found differences at .05 level on July 7, July 18, July 25, August 15 and August 22.

At Chickasha, in 1978, the data on Table XIV show that Stoneville

213 was significantly different at 5% level than the treatments; HG DDS-N-1, HG P-9-13, HG DDS-N-2 and BW 73-51849 are not different at the same level of significance; and BW 73-51849 is not different from HG NCSm10 which had the lowest population. Figure 13 shows that the highest population of beneficial arthropods appeared at the end of the season after two insecticide applications in July 26 and August 2. This same figure shows peaks where significant differences were found in July 11, July 21, July 25, August 1 and August 23.

Table VIII shows the predaceous insects sampled and the percentages obtained on each one at Tipton, in 1977 and in 1978 at Chickasha, in 1978. This same table shows that the higher percentages of predaceous arthropods were those of lacewing eggs, but for some reason this fact is not reflected in larval population which is one of the lowest in population percentages.

When analysis for correlation between predators and fleahoppers were made, from the average data of six varieties and nine dates, a high positive correlation (r= .617) was found. Figure 14 shows the straight line buildup from data obtained in Tipton during 1978.

Yield

Since no major pest infestations were present, Stoneville 213 seemed to have more yield potential than the insect resistant strains.

In seed cotton harvested, no differences were detected between Stoneville 213 and HG DDS-N-1.

In order to determine earliness, two pickings were made at Tipton in 1977, and Stoneville 213 was found to be the earliest material (Table XV); the lowest yield in the first picking was that of HG NCSm10.

Table XVI shows that the 28.45% cotton lint pulled and the 38.65% cotton lint picked in BW 73-51849 was not significantly different from the 28.05% cotton lint pulled and the 38.22% cotton lint picked in Stoneville 213.

Fiber Properties

Fiber length, which is one of the properties taken into consideration when determining the price per pound per lint, is reported in Table XVII. It was found that HG NCSm10, a three-characteristic resistant strain, had the longest fiber significantly different at 5% level from all the rest, when 2.5% span length was taken; but in 50% span length, Stoneville 213, with .524, was different from all the strains.

Table XVIII shows the uniformity index property, where Stoneville 213, with 48.5%, was not significantly different from BW 73-51849, with 48.3%. The same table shows coarseness or micronaire; the highest value for micronaire was that of Stoneville 213 with 5.3, and the lowest was that of HG NCSm10. Micronaire is acceptable anywhere between 3.5 to 4.9; the fiber is too fine when it is below 3.5 and too coarse when it is above 4.5.

Fiber strength, which for reading convenience is expressed in pounds per square inch in thousands, in Table XIX is given 1/8" gauge and 0" gauge. No significant differences were detected between BW 73-51849, with 45.5, and HG NCSm10, with 45.8, in 0" gauge. The lowest fiber strength was for Stoneville 213, with 40.2.

CHAPTER IV

SUMMARY

This study was undertaken to determine how some characteristics of resistance act on populations of bollworm complex, cotton fleahopper and some of the beneficial arthropods. Six varieties were used in this study: Stoneville 213 (the standard), BW 73-51849, HG DDS-N-1, HG DDS-N-2, HG P-9-13 and HG NCSm10. This research was conducted during 1977 and 1978 at Tipton, Oklahoma and in 1978 at Chickasha, Oklahoma, both locations under irrigated conditions.

At both locations, in 1977 and 1978, Stoneville 213 had the highest infestation of Heliothis spp. larvae. No differences were detected between strains with one resistant trait and those with three resistant traits.

Since the population was too low, no difference was found in square damage in 1977. In 1978, significant difference in fruiting damage was found at Tipton and Chickasha; Stoneville 213 had the highest level of squares damaged and no difference was found among the resistant strains.

At Tipton, in 1977 and 1978, fleahopper populations were found at different levels according to the three groups of varieties used. The highest population was found in Stoneville 213, a normal nectaried and hairy variety; the next lower population was found in BW 73-51849, a high gossypol and nectaried strain, and the lowest populations were found in the strains with glabrous, nectariless and high gossypol characteristics. At Chickasha, no difference was found among the resistant strains.

In regard to beneficial arthropods (insects and spiders), Stoneville 213 was the variety with consistently more population at both locations, in 1977 and 1978. BW 73-51849, a nectaried strain, was significantly different from nectariless strains in 1977. No difference was found among the strains in 1978, neither at Tipton nor at Chickasha.

In regard to the individual population counts made, and based upon personal observations in cotton fields, spiders seemed to be the most important single factor in controlling pest populations.

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APPENDIX A

TABLES

TABLE I

HELIOTHIS LARVAE
SEASONAL MEAN

Strains	Tipton 1977 Pop./Ha.	Tipton 1977 Times Reduced	Tipton 1978 Pop./Ha.	Tipton 1978 Times Reduced	Chickasha 1978 Pop./Ha.	Chickasha 1978 Times Reduced
Stoneville 213	3089 a*		5354 a*		3939 a*	
BW 73-51849	1784 b	1.73	1785 b	2.99	1003 b	3.93
HG NCSm10	1030 b	2.99	1373 b	3.90	927 b	4.25
HG P-9-13	961 b	3.21	2265 b	2.36	618 b	6.37
HG DDS-N-2	892 b	3.46	1304 b	4.10	927 b	4.25
HG DDS-N-1	687 b	4.50	1510 b	3.55	1236 b	3.19
LSD .05=	1051		1883		771	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE II

HELIOTHIS EGGS
SEASONAL MEAN

Strains	Tipton 1978 Pop./Ha.	Tipton 1978 Times Reduced	Chickasha 1978 Pop./Ha.	Chickasha 1978 Times Reduced
Stoneville 213	5766 a*		21698 a*	
BW 73-51849	3295 b	1.75	8107 b	2.68
HG NCSm10	1098 c	5.25	3165 c	6.85
HG DDS-N-2	1029 c	5.60	5715 bc	3.80
HG P-9-13	892 c	6.46	4092 bc	5.30
HG DDS-N-1	549 c	10.50	4710 bc	4.60
LSD .05 =	1853		4309	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE III

SEASONAL PERCENTAGE OF SQUARES
DAMAGED BY <u>HELIOTHIS</u>
TIPTON, 1978

Treatments	Dates					
	7-25	8-02	8-09	8-15*	8-23	8-31
BW 73-51849	0.0	0.0	0.5	6.5 b	4.5	1.0
HG DDS-N-1	0.0	0.0	0.5	9.5 b	7.5	0.0
HG DDS-N-2	0.0	0.0	0.5	6.0 b	3.5	1.5
HG P-9-13	1.0	0.5	1.5	8.0 b	3.0	1.5
HG NCSm10	0.0	0.0	0.5	5.0 b	4.5	0.5
Stoneville 213	1.5	0.5	0.5	21.5 a	10.5	3.5
LSD .05 =	1.9	0.9	1.58	9.7	5.64	2.8

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE IV

SEASONAL PERCENTAGE OF SQUARES
DAMAGED BY HELIOTHIS
CHICKASHA, 1978

Treatments	Dates 8-15	8-23	8-30*	9-06	9-14*
BW 73-51849	4.0	3.0	5.0 b	4.0	2.5 b
HG DDS-N-1	7.0	4.5	3.5 b	0.0	0.0
HG DDS-N-2	4.5	4.0	3.5 b	1.5	0.0
HG P-9-13	9.0	5.0	8.0 b	1.5	2.5 b
HG NCSm10	6.5	1.0	3.5 b	0.5	1.5 b
Stoneville 213	11.0	6.5	16.0 a	10.5	6.0 a
LSD .05 =	7.3	5.4	7.8	7.3	3.4

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE V

COTTON FLEAHOPPER
SEASONAL MEAN

Strains	Tipton 1977 Pop./Ha.	Tipton 1977 Times Reduced	Tipton 1978 Pop./Ha.	Tipton 1978 Times Reduced	Chickasha 1978 Pop./Ha.	Chickasha 1978 Times Reduced
Stoneville 213	9128 a*		6589 a*		3936 a*	
BW 73-51849	3158 b	2.84	2265 b	2.91	773 b	5.09
HG DDS-N-2	2676 bc	3.41	618 c	10.66	385 b	10.22
HG NCSm10	2402 bc	3.80	824 c	7.99	232 b	16.97
HG DDS-N-1	1646 cd	5.55	686 c	9.60	385 b	10.22
HG P-9-13	892 d	10.23	1029 c	6.40	541 b	7.28
LSD .05 =	1263		1169		1072	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE VI

COLLOPS BEETLES
SEASONAL MEAN

	Tipton				Chickasha	
	1977		1978		1978	
Strains	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced
Stoneville 213	1922 a*		3648 a*		3630 a*	
BW 73-51849	1371 ab	.71	1784 b	2.04	2009 b	1.80
HG DDS-N-2	687 bc	2.80	1029 bc	3.54	1236 b	2.94
HG P-9-13	687 bc	2.80	412 c	8.83	927 b	3.92
HG NCSm10	413 c	4.65	1784 b	2.04	1312 b	2.76
HG DDS-N-1	343 c	5.60	1236 bc	2.94	1236 b	2.94
LSD .05 =	855		1226		1559	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE VII

GREEN LACEWING EGGS
SEASONAL MEAN

	Tipton				Chickasha	
	1977		1978		1978	
Strains	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced
Stoneville 213	5629 a*		7619 a*		32432 a*	
BW 73-51849	5011 ab	1.12	3981 b	1.91	20618 c	1.57
HG DDS-N-2	3707 bc	1.52	4256 b	1.79	24787 bc	1.31
HG P-9-13	3089 c	1.82	4324 b	1.76	29267 ab	1.11
HG DDS-N-1	2950 c	1.91	4256 b	1.79	28958 ab	1.12
HG NCSm10	2266 c	2.48	4599 b	1.66	18842 c	1.72
LSD .05 =	1572		2058		5903	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE VIII

ABUNDANCE OF PREDACEOUS INSECTS AND SPIDERS
AT TIPTON AND CHICKASHA, POP./HA.
SEASONAL MEAN

Predators	Tipton				Chickasha	
	1977	%	1978	%	1978	%
Big eyed bug	12	.2	148	1.1	52	.1
Collops beetle	904	6.8	1645	12.0	1724	4.7
Green lacewing eggs	3772	28.4	4817	35.2	25807	69.8
Green lacewing larvae	240	1.8	252	1.8	269	.7
Green lacewing adults	605	4.5	684	5.0	1312	3.6
Hooded flower beetle	914	6.9	1853	13.5	25	.1
Ladybeetle	948	7.1	1988	14.5	3228	8.7
Nabids	1119	8.4	674	4.9	217	.6
Spiders	4779	35.9	1645	12.0	4323	11.7
Totals	13293	100.0	13706	100.0	36957	100.0

TABLE IX

GREEN LACEWING ADULTS, SEASONAL MEAN
TIPTON, 1978

Treatments	Pop./Ha.	Times Reduced
Stoneville 213	1647 a*	
BW 73-51849	1167 a	1.41
HG DDS-N-1	412 b	3.99
HG DDS-N-2	412 b	3.99
HG P-9-13	275 b	5.99
HG NCSm10	206 b	7.99
LSD .05 = 680		

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE X

HOODED FLOWER BEETLE
SEASONAL MEAN

	Tipton			
	1977		1978	
Strains	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced
Stoneville 213	2197 a*		6178 a*	
BW 73-51849	823 b	2.67	1236 b	5.00
HG DDS-N-2	756 b	2.91	892 b	6.93
HG NCSm10	756 b	2.91	480 b	12.87
HG DDS-N-1	479 b	4.59	1304 b	4.74
HG P-9-13	479 b	4.59	1029 b	6.00
LSD .05 =	833		1777	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE XI

LADYBEETLE, SEASONAL MEAN

Strains	Tipton 1978 Pop./Ha.	Tipton 1978 Times Reduced	Chickasha 1978 Pop./Ha.	Chickasha 1978 Times Reduced
Stoneville 213	5697 a*		7334 a*	
BW 73-51849	1853 b	3.07	2627 b	2.79
HG NCSm10	1167 b	4.88	2162 b	3.39
HG P-9-13	1167 b	4.88	2009 b	3.65
HG DDS-N-2	1167 b	4.88	2703 b	2.71
HG DDS-N-1	892 b	6.39	2548 b	2.88
LSD .05 =	2540		1950	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE XII

NABIDS, SEASONAL MEAN

	Tipton 1977		Chickasha 1978	
Strains	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced
Stoneville 213	2745 a*		232 ab*	2.00
BW 73-51849	1236 b	2.20	232 ab	2.00
HG DDS-N-2	1030 bc	2.60	309 ab	1.50
HG DDS-N-1	756 bc	3.60	77 b	6.04
HG NCSm10	756 bc	3.60	-	-
HG P-9-13	205 c	13.40	465 a	-
LSD .05 =	919		289	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE XIII

SPIDERS, SEASONAL MEAN

	Tipton 1977		Chickasha 1978	
Strains	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced
Stoneville 213	6178 a*		7722 a*	
BW 73-51849	5972 a	1.03	5366 ab	1.44
HG P-9-13	5216 ab	1.18	2471 b	3.13
HG NCSm10	4393 ab	1.41	2703 b	2.86
HG DDS-N-2	3707 b	1.67	3553 b	2.17
HG DDS-N-1	3227 b	1.91	4015 b	1.92
LSD .05 =	1890		2876	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE XIV

BENEFICIAL ARTHROPODS
SEASONAL MEAN

	Tipton				Chickasha	
	1977		1978		1978	
Strains	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced	Pop./Ha.	Times Reduced
Stoneville 213	21004 a*		28760 a*		53977 a*	
BW 73-51849	16954 b	1.24	13110 b	2.19	32279 bc	1.67
HG DDS-N-2	11463 c	1.83	9953 b	2.89	34209 b	1.58
HG P-9-13	11189 c	1.88	9335 b	3.08	36989 b	1.46
HG DDS-N-1	9679 c	2.17	10913 b	2.63	38765 b	1.39
HG NCSm10	9541 c	2.20	10364 b	2.77	25637 c	2.11
LSD .05 =	3173		4813		6736	

* Means not followed by the same letter within columns are significantly different at the 0.05 level of probability according to Duncan's test.

TABLE XV

YIELD, TIPTON, 1977

Strains	Seed Cotton Kg./Ha.			Lint Harvested Kg./Ha.		
	1st Picking	2nd Picking	Total	1st Picking	2nd Picking	Total
Stoneville 213	3555 a*	504 c	4060 a	1345 a	203 c	1549 a
HG DDS-N-1	2629 b	982 ab	3610 ab	880 b	338 ab	1218 b
BW 73-51849	2394 b	841 abc	3236 bc	947 b	313 b	1261 b
HG P-9-13	2028 bc	638 bc	2666 c	722 b	230 c	962 c
HG DDS-N-2	1960 bc	1005 ab	2965 c	652 bc	356 a	1009 bc
HG NCSm10	1436 c	1167 a	2601 c	412 c	366 a	778 c
LSD .05 =	747	367	614	289	41	242

* Means not followed by the same letter within columns are significantly different at the .05 level of probability according to Duncan's test.

TABLE XVI

LINT PERCENTAGE, TIPTON, 1977

Strains	Cotton Lint % Pulled			Cotton Lint % Picked		
	1st Picking	2nd Picking	W. Avge.	1st Picking	2nd Picking	W. Avge.
BW 73-51849	30.22 a*	23.57 bc	28.45 a	39.15 a	37.15 b	38.65 a
Stoneville 213	29.90 a	28.05 a	29.57 a	38.00 ab	40.27 a	38.22 a
HG DDS-N-1	25.50 b	23.40 c	24.85 b	33.40 c	34.40 d	33.82 b
HG P-9-13	25.37 b	25.17 b	25.17 b	35.42 bc	35.87 c	35.57 b
HG DDS-N-2	24.52 b	23.92 bc	24.30 b	33.22 c	35.52 c	34.12 b
HG NCSm10	20.95 c	20.40 d	20.70 c	28.70 d	31.37 e	29.90 c
LSD .05 =	.026	.015	.021	.030	.005	.021

* Means not followed by the same letter within columns are significantly different at the .05 level of probability according to Duncan's test.

TABLE XVII

FIBER LENGTH, TIPTON, 1977

Strains	2.5% Span Length 1st Picking	2nd Picking	W. Avge.	50% Span Length 1st Picking	2nd Picking	W. Avge.
HG NCSm10	1.164 a*	1.091 a	1.132 a	.511 b	.441 b	.479 c
HG DDS-N-1	1.093 b	1.014 b	1.071 b	.510 b	.438 b	.490 b
HG DDS-N-2	1.091 b	1.037 b	1.073 b	.504 b	.439 b	.481 c
Stoneville 213	1.088 b	1.044 b	1.081 b	.533 a	.466 a	.524 a
HG P-9-13	1.071 b	1.009 b	1.054 b	.494 b	.428 c	.476 c
BW 73-51849	1.023 c	.966 c	1.007 c	.503 b	.445 b	.487 b
LSD .05 =	.034	.041	.021	.015	.015	.005

* Means not followed by the same letter within columns are significantly different at the .05 level of probability according to Duncan's test.

TABLE XVIII

UNIFORMITY INDEX, MICRONAIRE
TIPTON, 1977

Strains	Uniformity Index			Micronaire mg./in.		
	1st Picking	2nd Picking	W. Avge.	1st Picking	2nd Picking	W. Avge.
BW 73-51849	49.2 a*	46.1 a	48.3 a	5.1 a	4.7 b	5.0 ab
Stoneville 213	49.1 a	44.7 ab	48.5 a	5.4 a	5.2 a	5.3 a
HG DDS-N-1	46.7 b	43.2 bc	45.8 b	4.8 a	4.3 bc	4.7 bc
HG DDS-N-2	46.2 b	42.3 c	44.8 b	4.7 ab	4.2 c	4.5 c
HG P-9-13	46.1 b	42.5 c	45.2 b	4.6 ab	4.3 bc	4.5 c
HG NCSm10	43.9 c	40.5 d	42.3 c	3.8 b	3.6 d	3.9 d
LSD .05 =	1.611	1.684	1.724	.906	.387	.407

* Means not followed by the same letter within columns are significantly different at the .05 level of probability according to Duncan's test.

TABLE XIX

FIBER STRENGTH
TIPTON, 1977

Strains	Stelometer 1/8" Gauge GF/tex			Stelometer 0" Gauge GF/tex		
	1st Picking	2nd Picking	W. Avge.	1st Picking	2nd Picking	W. Avge.
BW 73-51849	22.6 a*	19.9 a	21.9 a	45.9 a	44.6 a	45.5 a
HG NCSm10	22.6 a	19.2 ab	21.1 ab	46.5 a	45.1 a	45.8 a
HG DDS-N-1	21.6 b	18.3 bc	20.7 bc	44.9 ab	38.4 c	42.5 b
HG P-9-13	20.8 c	17.3 c	20.0 c	42.8 bc	40.6 b	42.2 b
HG DDS-N-2	20.8 c	19.1 ab	20.2 bc	44.7 ab	40.8 b	43.4 b
Stoneville 213	20.7 c	17.8 c	20.3 bc	40.7 c	37.6 c	40.2 c
LSD .05 =	.847	1.016	.871	2.823	1.568	1.753

* Means not followed by the same letter within columns are significantly different at the .05 level of probability according to Duncan's test.

APPENDIX B

FIGURES

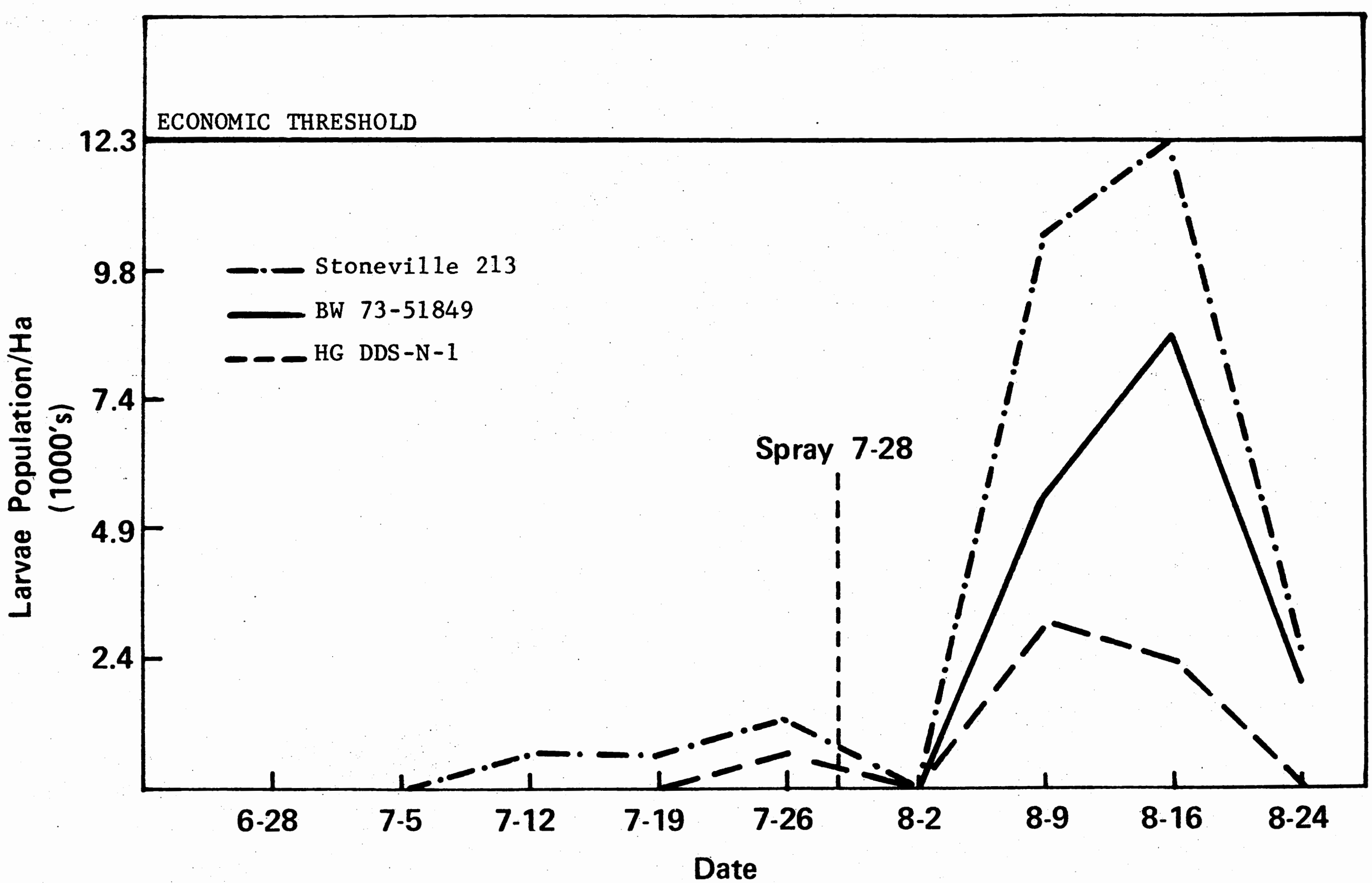

Figure 1. Heliothis Larvae Population, Seasonal Distribution, Tipton, 1977

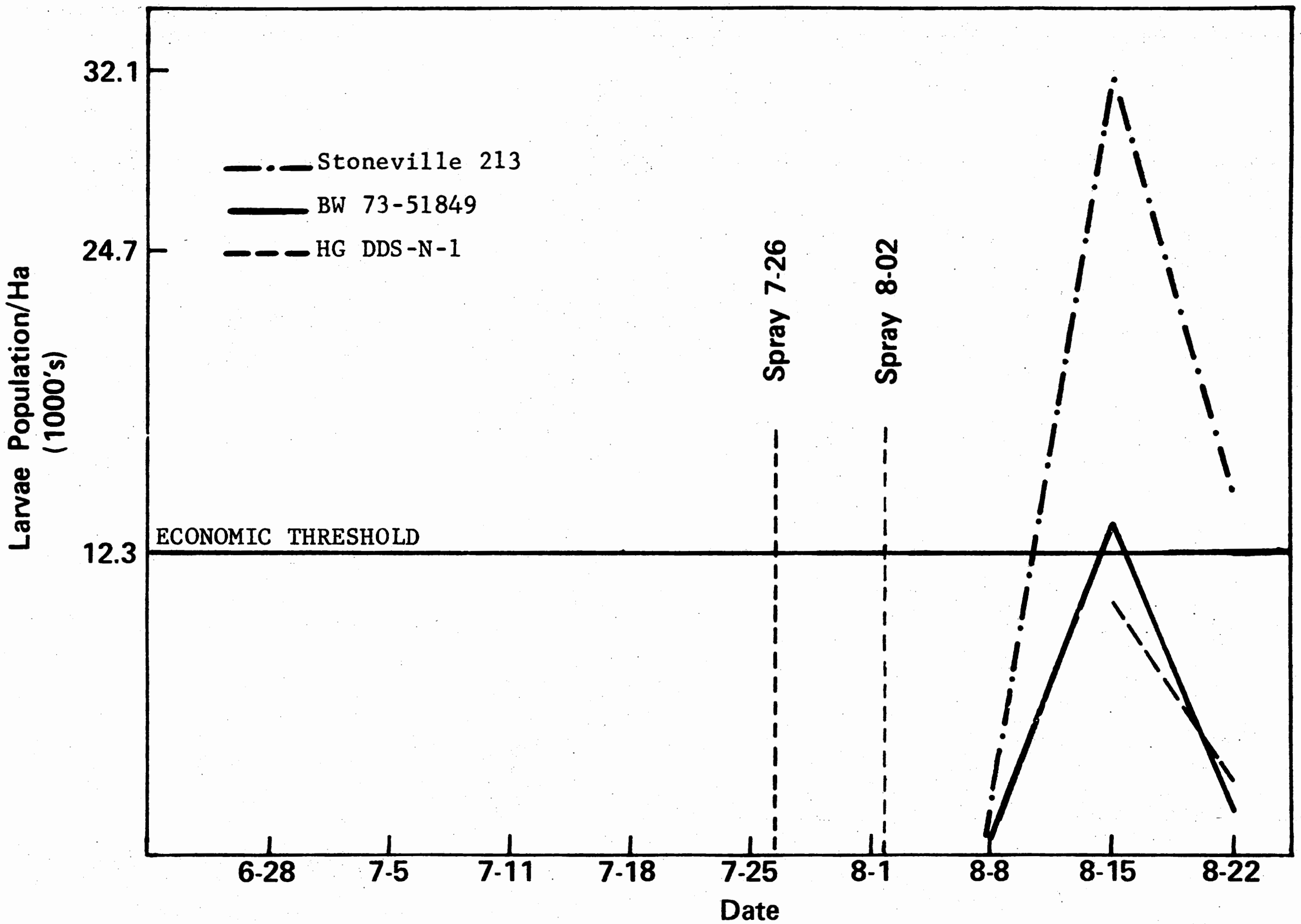

Figure 2. Heliothis Larvae Population, Seasonal Distribution, Tipton, 1978

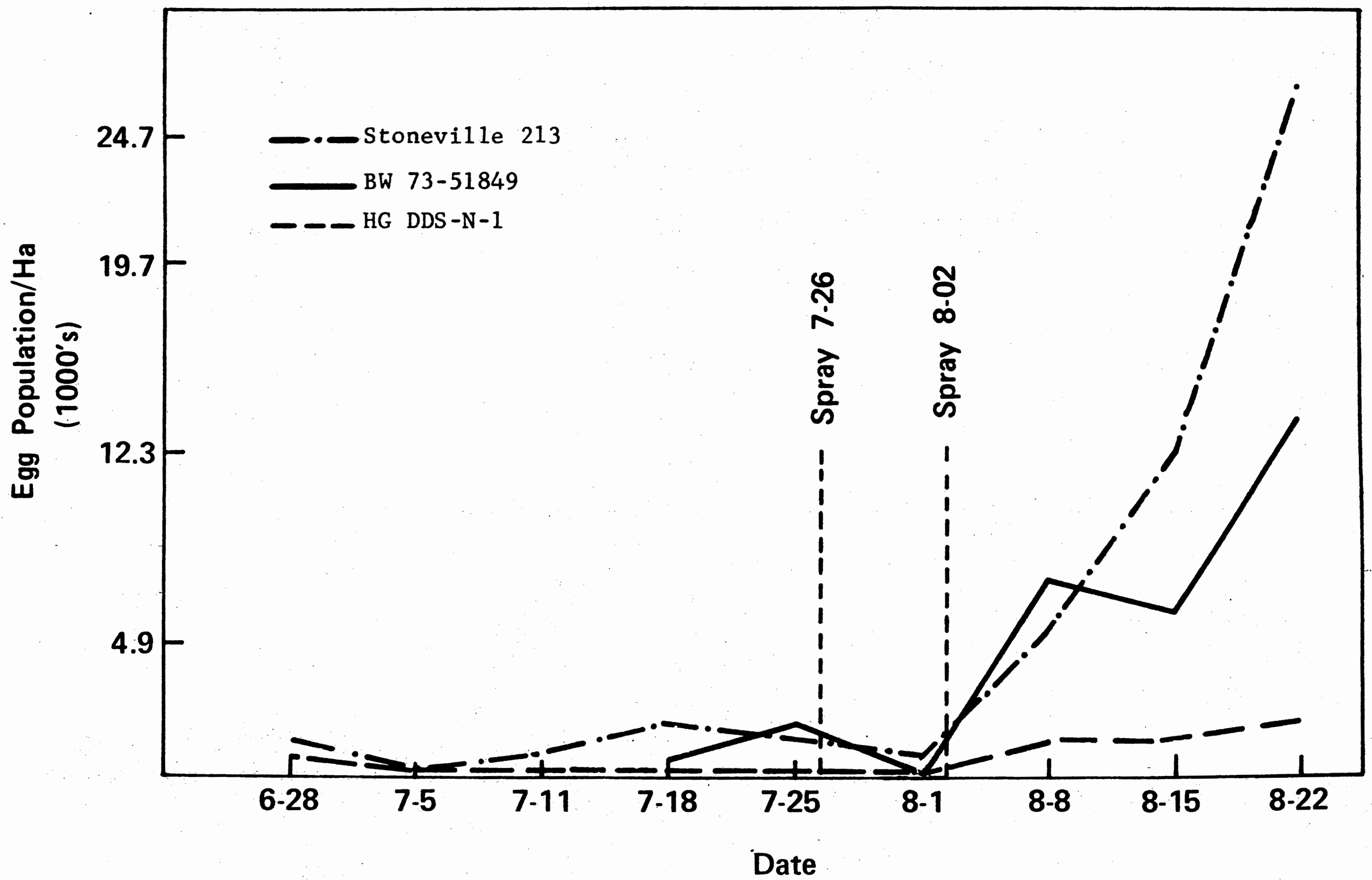

Figure 3. Heliothis Eggs, Seasonal Distribution, Tipton, 1978

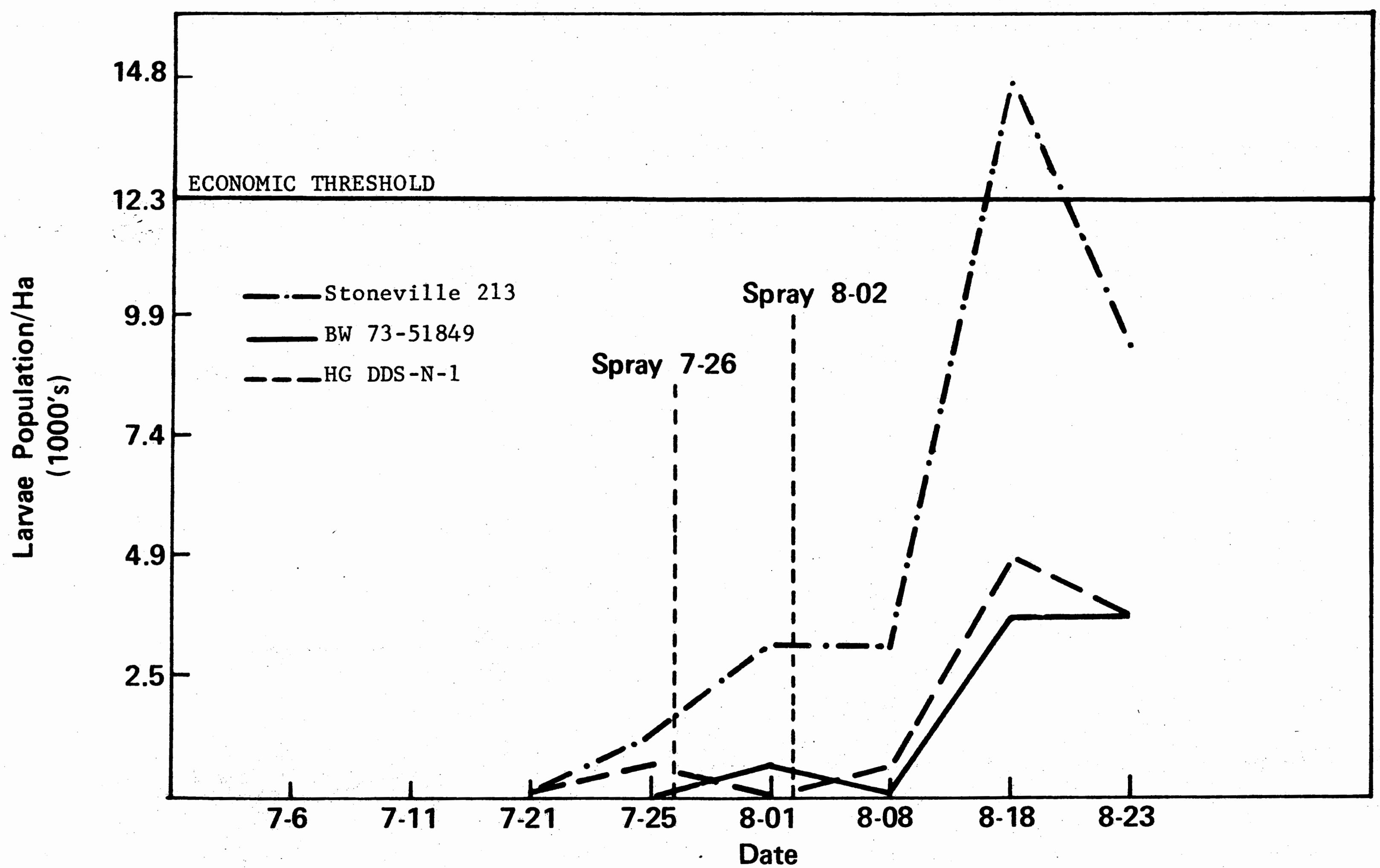

Figure 4. Heliothis Larvae Population, Seasonal Distribution, Chickasha, 1978

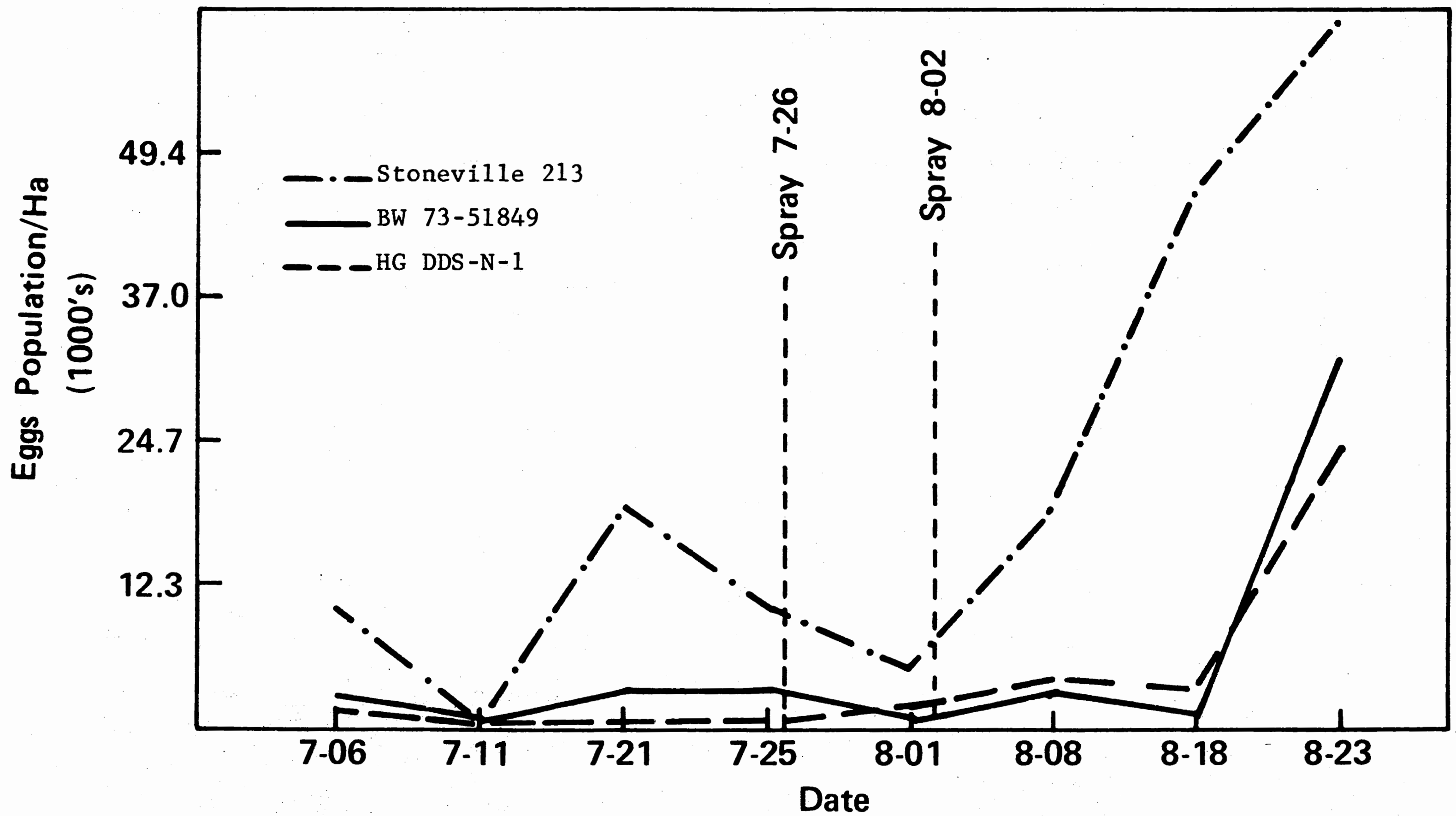

Figure 5. Heliothis Eggs Population, Seasonal Distribution, Chickasha, 1978

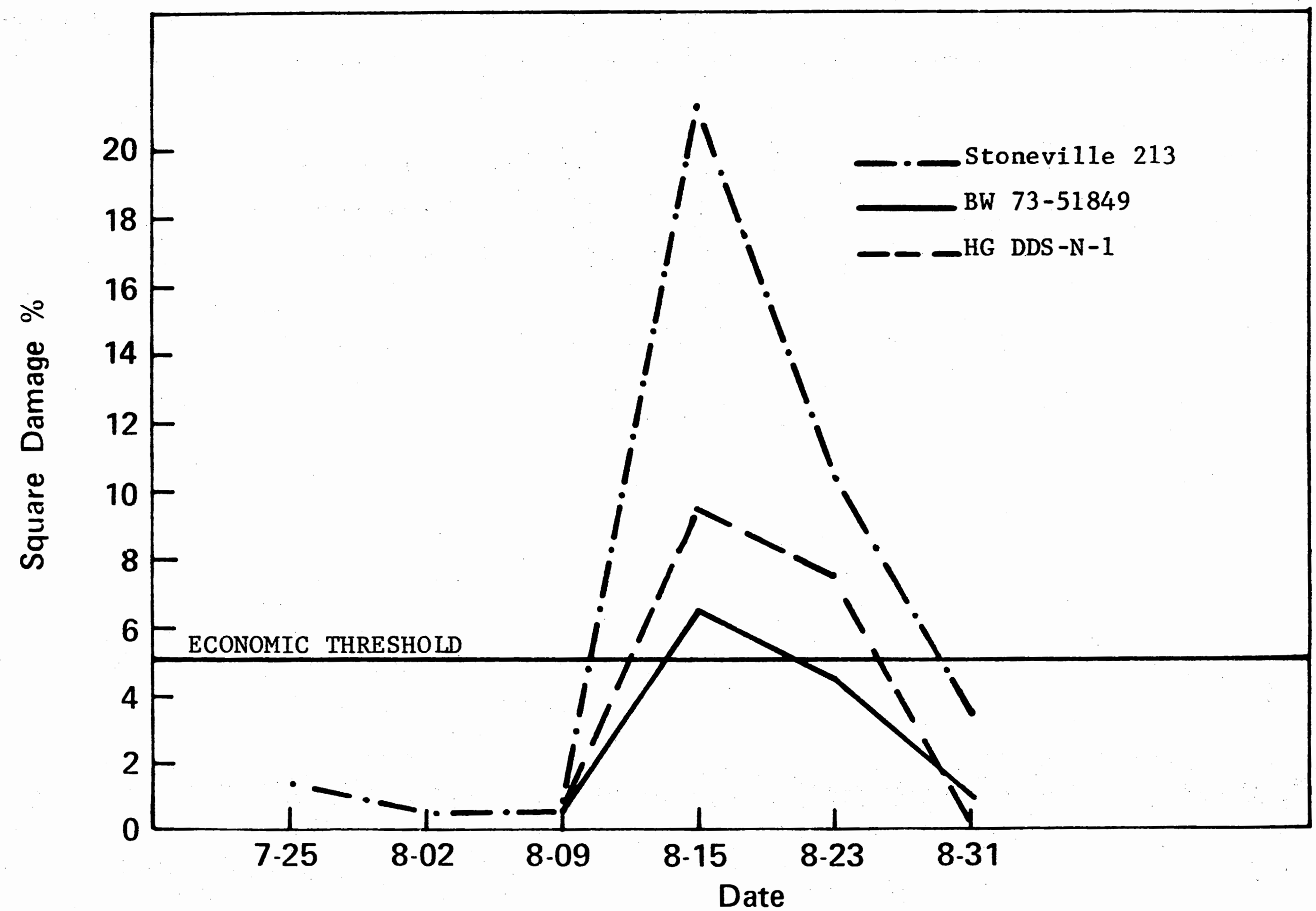

Figure 6. Seasonal Distribution of Square Damage by Heliothis, Tipton, 1978

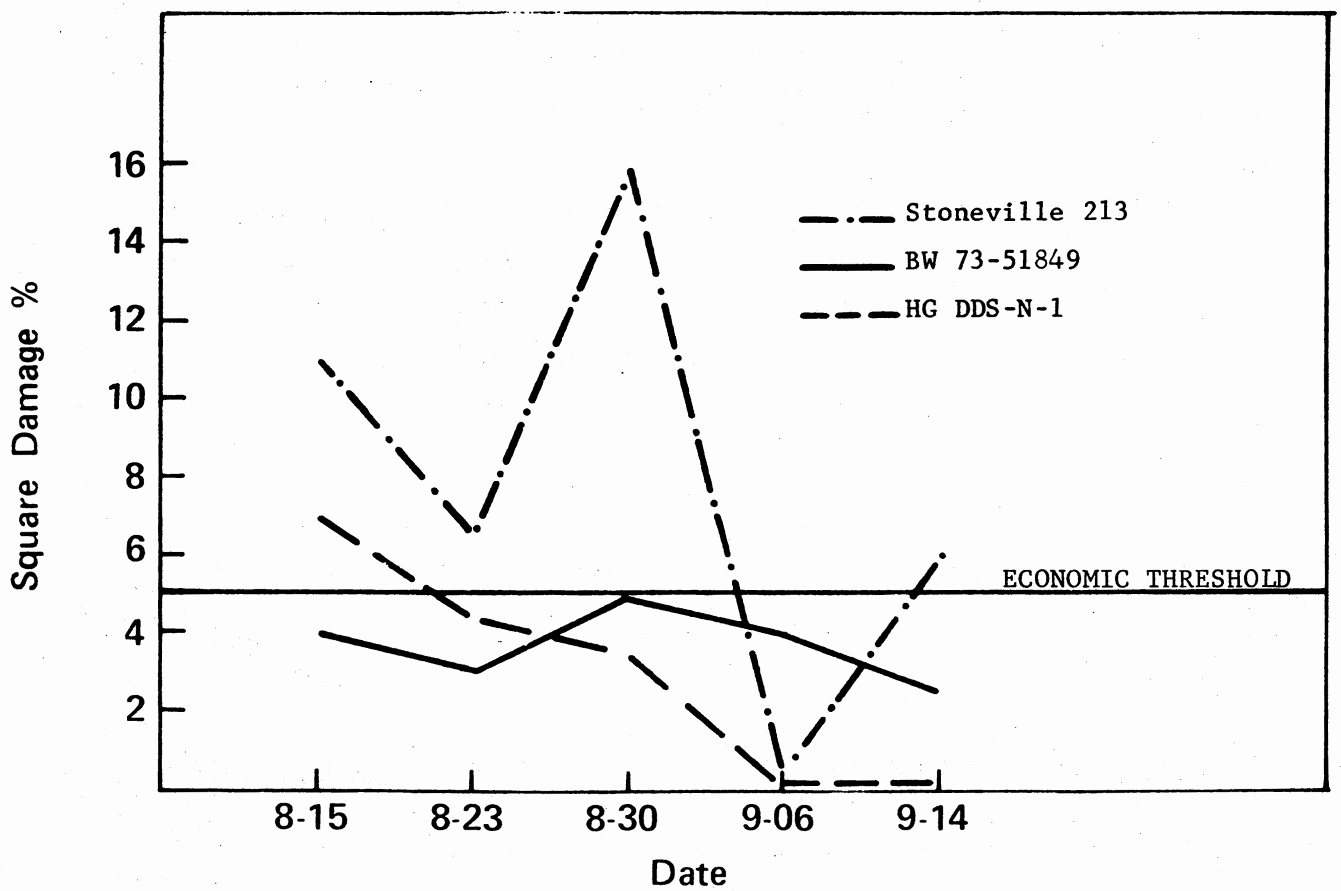

Figure 7. Seasonal Distribution of Square Damage by Heliothis, Chickasha, 1978

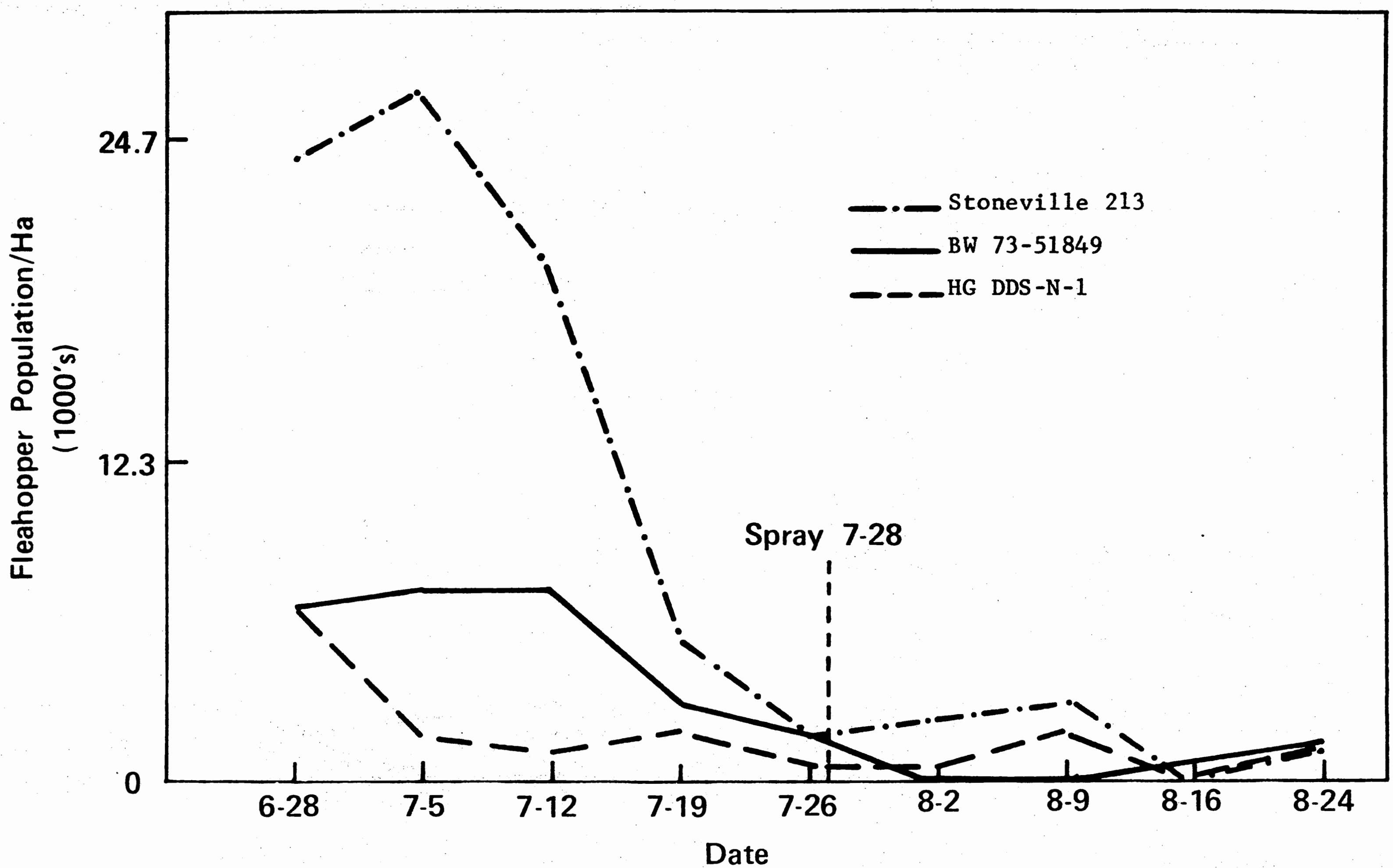

Figure 8. Fleahopper Population, Seasonal Distribution, Tipton, 1977

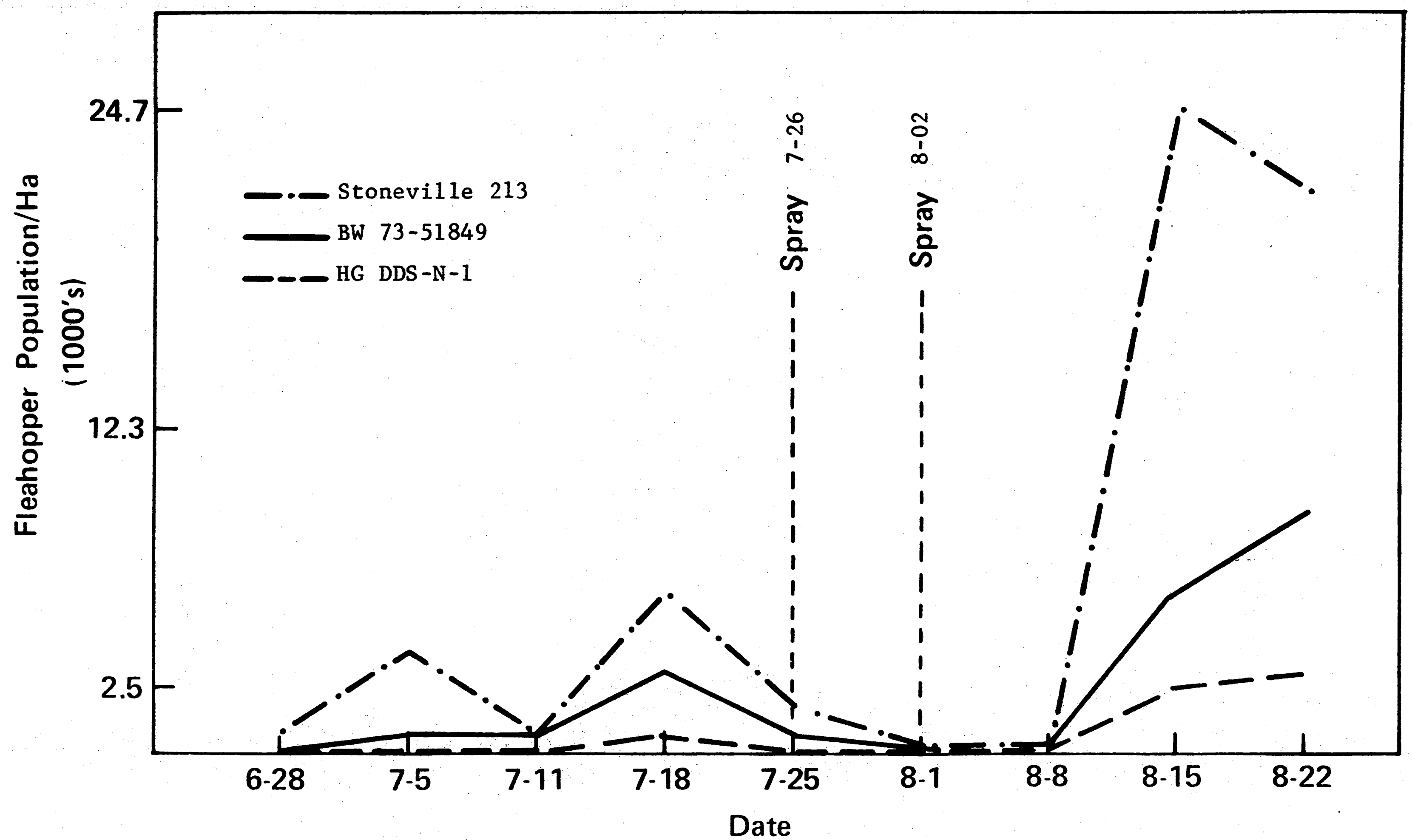

Figure 9. Fleahopper Population, Seasonal Distribution, Tipton, 1978

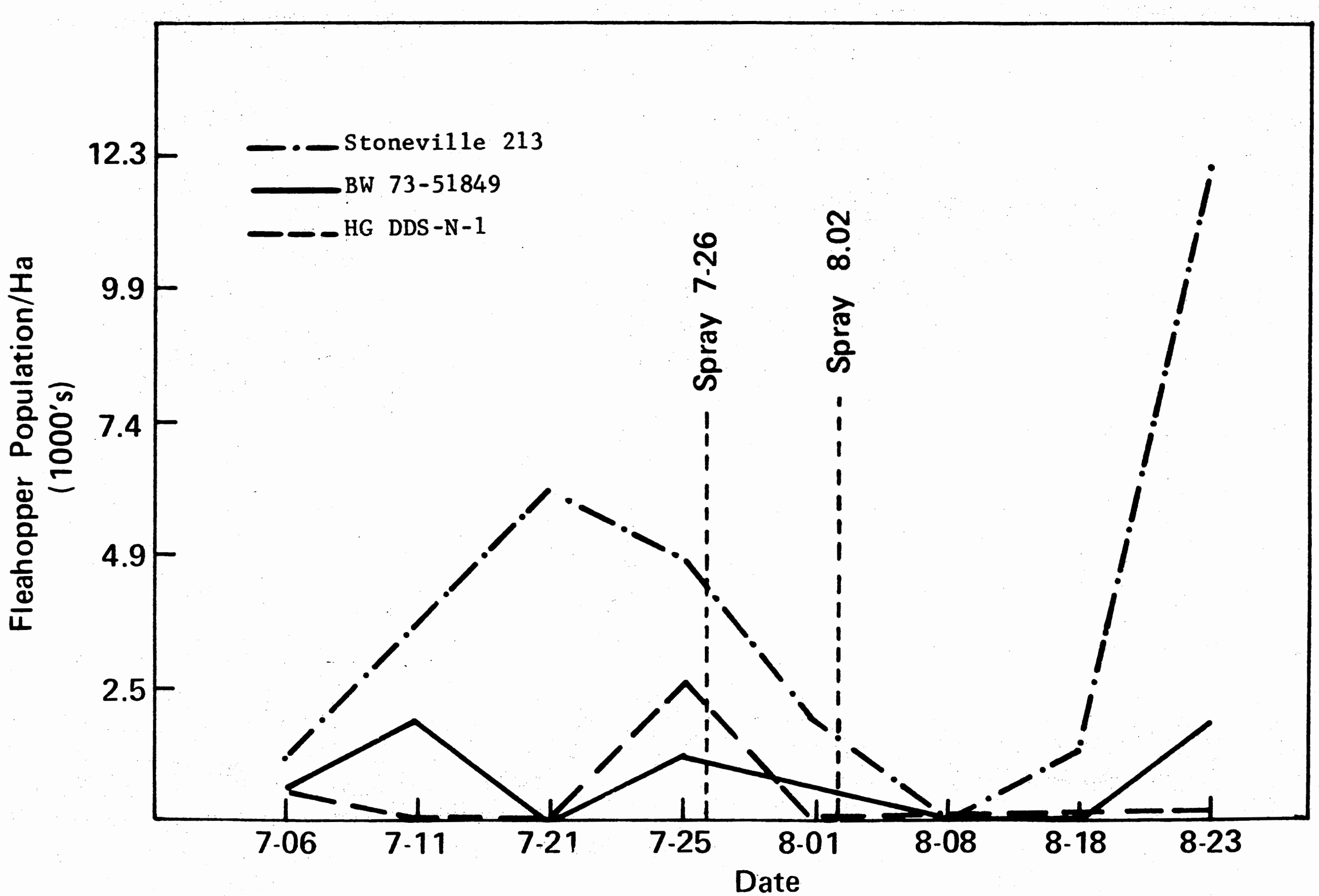

Figure 10. Fleahopper Population, Seasonal Distribution, Chickasha, 1978

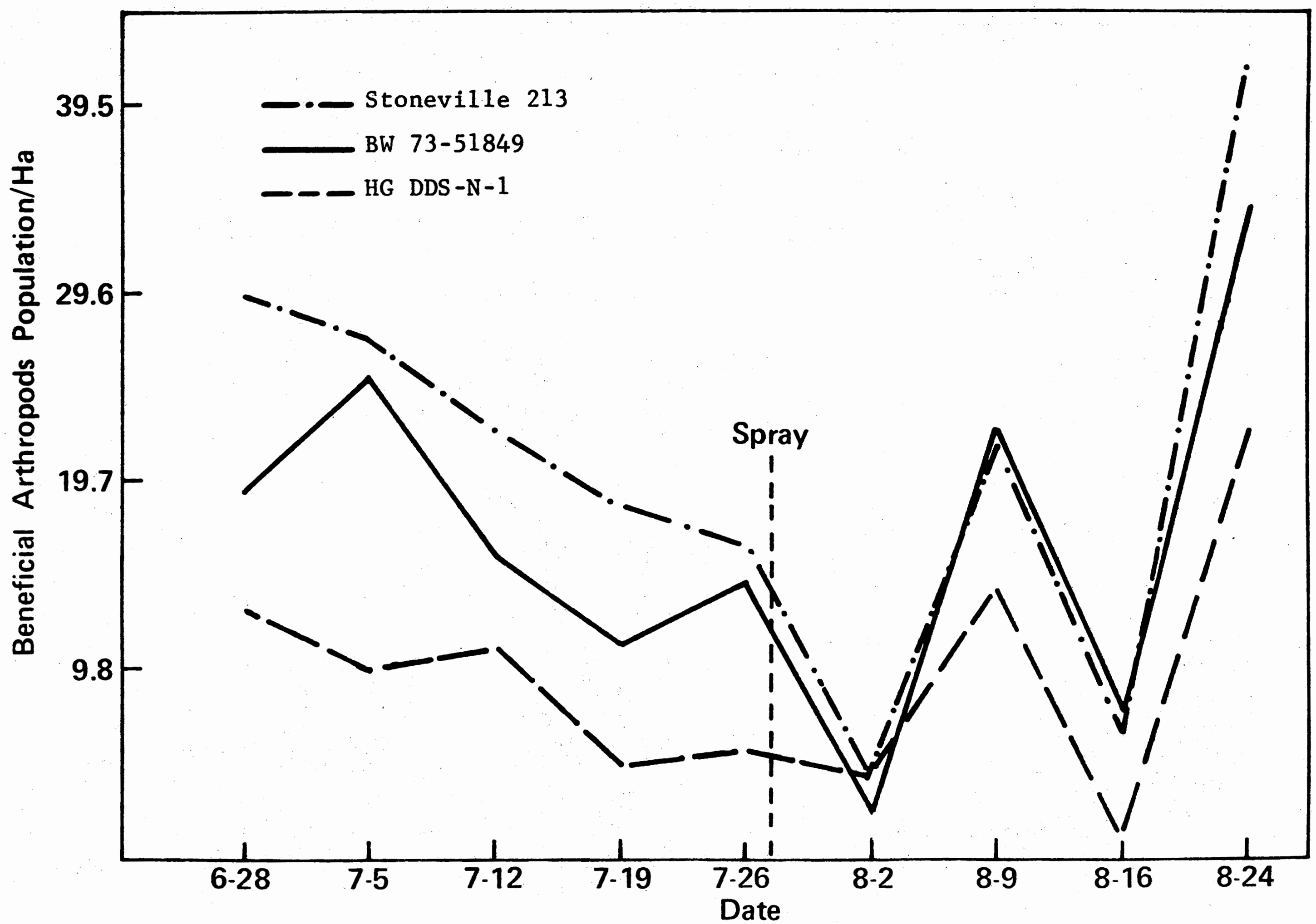

Figure 11. Beneficial Arthropods Population, Seasonal Distribution, Tipton, 1977

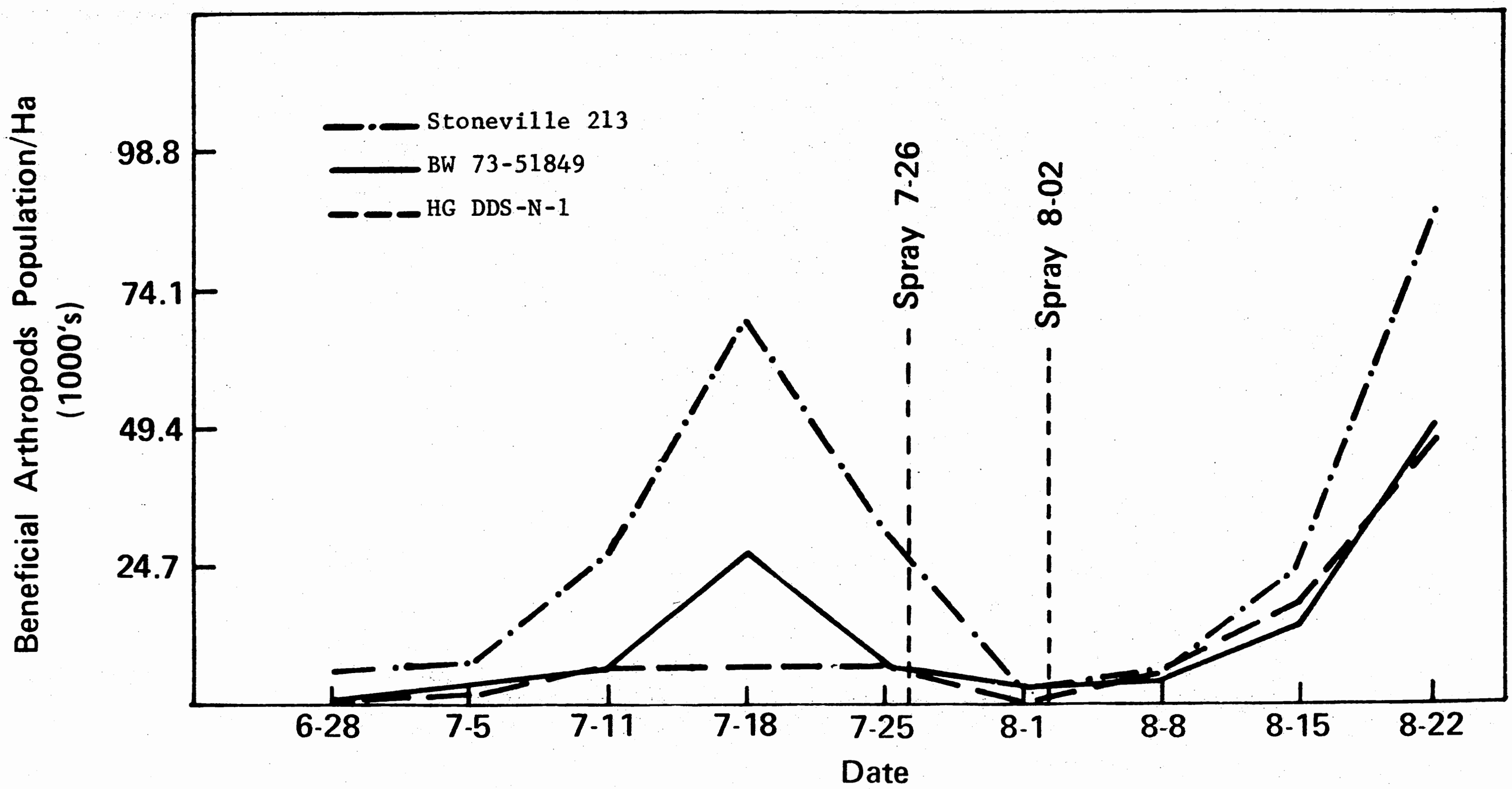

Figure 12. Beneficial Arthropods Population, Seasonal Distribution, Tipton, 1978

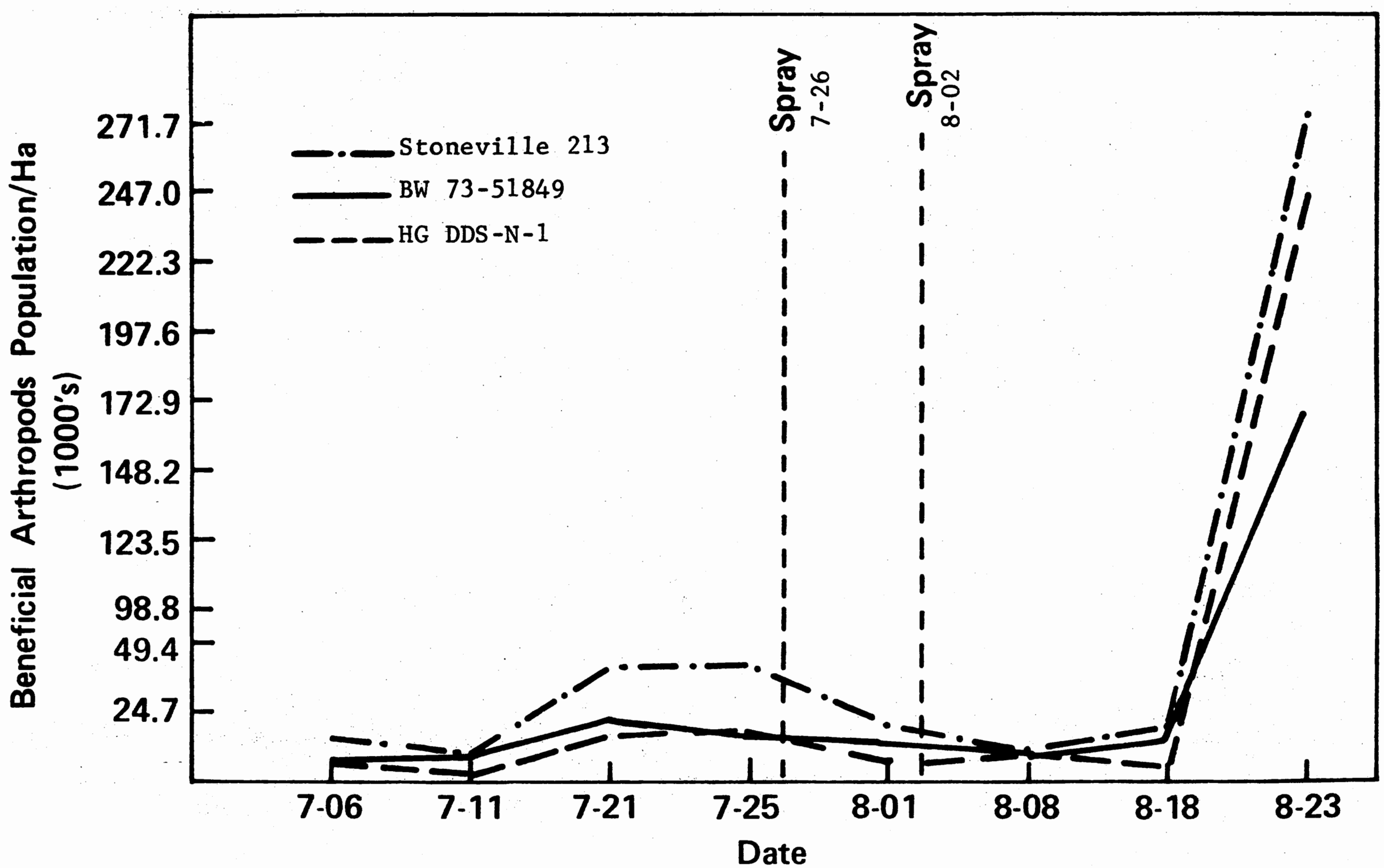

Figure 13. Beneficial Arthropods Population, Seasonal Distribution, Chickasha, 1978

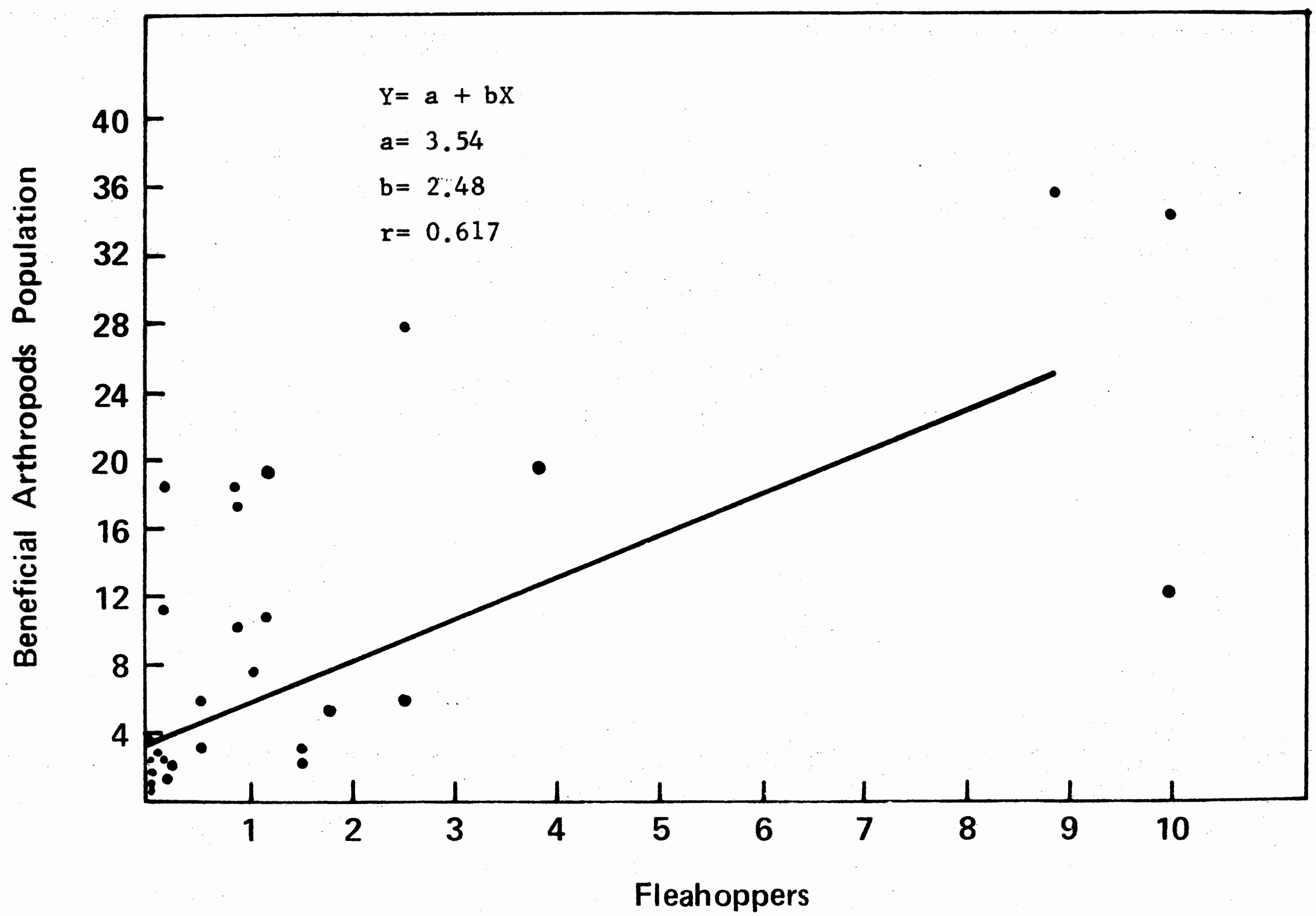

Figure 14. Relationship Between Beneficial Arthropods and Fleahopper, Through Nine Sample Dates, Tipton, 1978

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VITA

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Master of Science

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