EFFECTS OF STRIP CROPPING COTTON AND OTHER FIELD CROPS ON THE ABUNDANCE OF PREDATORY AND INJURIOUS INSECTS IN COTTON IN RELATION TO DAMAGE, YIELD, AND LINT QUALITY

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PREFACE

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CHAPTER I

INTRODUCTION

The cotton bollworm, *Heliothis zea* (Boddie) and tobacco budworm, *Heliothis virescens* (Fabricius), comprise a complex that causes much damage to Oklahoma cotton in most years. The bollworm is the dominant species, especially early in the season, but it is often found together with the budworm later in the season. The dependence on chemicals for controlling *Heliothis* has in the past resulted in resistance, resurgence of the pest after treatment, pollution of the environment, and increased cost to farmers. These factors have led to research for new methods of control by introducing or increasing natural populations of beneficial insects.

The primary objectives of this study were to plant five crops commonly grown in Southwestern Oklahoma in close association with cotton and determine their effects on the resulting insect populations in the cotton. The primary pest in the area is the cotton bollworm but levels of potential pests, such as thrips and fleahoppers, were determined while the plants were in susceptible stages of growth and production. Levels of predators were also determined throughout the season.

Evaluations of the effects of the selected alternate crops were made by comparing insect levels and damage, numbers of bolls reaching maturity, placement of bolls on the plants, yields, and lint quality.

CHAPTER II

STRIP CROPPING EFFECTS ON THE ABUNDANCE OF PREDATORY AND HARMFUL COTTON INSECTS IN OKLAHOMA

Many beneficial and harmful insects inhabit the cotton fields of Oklahoma during the cotton growing season. The role of predators and factors affecting their populations have become of prime interest in recent years. Prior studies have been directed at controlling the harmful insects with little regard for predators.

The primary purpose of this research was to determine the abundance of predators and harmful insects in cotton as affected by planting strips of alternate crops adjacent to cotton. Several authors, including van den Bosch and Hagen (1966), Whitcomb and Bell (1964) and several agricultural experiment station bulletins list and discuss cotton insect predators and harmful insects. These publications state their importance in control, hosts and stages attacked, time of greatest effectiveness, etc.

Beneficial Insects--Common predators and their benefits have been reported by several sources in recent years. Some of those present in Oklahoma are the lady beetles, primarily *Hippodamia* spp.; green lacewings, *Chrysopa* spp.; nabids or damsel bugs, *Nabis* spp.; the flower bug, *Orius insidiosus* (Say); soft-winged flower beetles, *Collops* spp.; and several species of spiders. Other beneficials that occur in the fields are parasites, ground beetles, assassin bugs, big-eyed bugs, hooded beetles, etc., which did not occur frequently enough to be included in the results.

Lady beetles, both larvae and adults, primarily feed on aphids and spider mites and may not be present in large numbers when the cotton does not harbor sufficient aphid or mite populations. They have also been observed feeding on various other soft-bodied insects.

Collops beetles feed on egg masses, small lepidopterous larvae, aphids, and plant bugs including fleahoppers. These small beetles are known to occur in very large numbers in some years.

The larval stage of green lacewings devour a variety of forms including bollworm eggs, aphids, mites and other soft-bodied insects.

Nabids feed on such hosts as aphids, spider mites, fleahoppers, leaf hoppers and small lepidopterous larvae.

Flower bugs, both immature and mature, attack and suck body juices from eggs and the larvae of various worms as well as fleahoppers, spiders, aphids and thrips. Orius is one of the most important insect predators found in the cotton field.

Destructive Insects--Thrips, primarily Frankliniella spp., are generally present each year on seedling cotton in Oklahoma. They injure the young seedlings by abrading foliage surfaces and sucking juices, thus causing malformed plants. King (1966) reviewed literature published from 1940 through 1965 and found that yields were increased in only 19 out of more than 152 tests when thrips were chemically controlled. He also found that, in the majority of tests, untreated cotton matured as early as treated cotton. That tends to indicate plants overcome early season thrips damage. In most cotton growing areas, thrips control is not recommended unless the population gets so high that stands are threatened. If that happens, chemical control may be warranted.

The cotton fleahopper, Psallus seriatus (Reuter) and the black fleahopper complex, Spanogonicus albofasciatus (Reuter) and Rhinacloa forticornis (Reuter) occur in Oklahoma. Both nymphs and adults attack cotton while the plants are squaring. They suck juices from the tender portions of plants as well as young squares and may cause excessive blasting and shedding of the attacked fruit. If the population is large enough, it may even cause the loss of some top branches. The chemical control of fleahoppers appears to be more essential than that of thrips in a few areas. In general, experiments in the Eastern, Delta, and Western parts of the United States demonstrated no increases in yields from chemical control, although yields were increased in some tests in the Central region (King, 1966).

Much damage is usually attributed to the cotton bollworm, Heliothis zea (Boddie) and tobacco budworm, Heliothis virescens (Fabricius) during most years in Oklahoma. Those two species comprise a complex in which the bollworm is the dominant species early in the fruiting season but both may be found together later in the season. New control methods are being sought for the complex since chemical control in the past has resulted in resistance, resurgence of the pest after treatment, pollution of the environment, and increased production costs.

The boll weevil, Anthonomus grandis (Boheman), feeds and breeds in Oklahoma but during this study was not present in large enough numbers to be included. The boll weevil is not considered to be as destructive a pest in Oklahoma as Heliothis, although a great deal of damage is caused in some years. When the populations reach levels that can cause excessive damage, chemical control has been useful.

Materials and Methods

During the 1969 and 1970 cotton growing seasons tests were conducted on the Oklahoma State University Altus Irrigation Research Station at Altus, Oklahoma. Four rows of corn, soybeans, alfalfa, peanuts, sorghum, or no crop were planted along both sides of 8 rows of 'Delta Pine 16' cotton. Each plot contained 16 rows of 40 inch spacing and was 180 feet long. These plots were planted in a 6 x 6 Latin square design (Fig. 1). Analysis of variance tables containing mean squares and significance levels of variables studied are in the appendix.

Each plot was surrounded by a fallowed buffer area 25 feet in width (Fig. 2). All crops, with the exception of alfalfa, were planted each year at the end of May and were allowed to reach maturity in the field. The alfalfa was drilled in early April 1969 and alternate rows were cut regularly during each growing season to prevent mass migrations of harmful and beneficial insects from the alfalfa (Schlinger and Dietrick, 1960).

Thrips counts on cotton were made weekly for 4 weeks at the beginning of the growing season. Twenty plants were pulled out of the soil from each plot and immediately placed in a quart container. The containers were capped to prevent escape of the thrips. The samples were then taken to the laboratory and the contents placed in a Berlese funnel for one hour. The thrips collected were counted and the numbers recorded.

At the start of squaring, samples were collected weekly for 7 weeks with a D-VAC vacuum sweeper bolted to a platform carrier on the back of an International Cub tractor. The tractor was driven down two rows in each plot at approximately 3.5 miles/hour while the collecting apparatus was aimed to suck the insects from the terminal portion of the cotton plants. The opening at the point of collection was 6.5 inches. From these samples, all of the predatory insects as well as fleahopper counts were made.

The collecting net was removed from the machine in a manner to prevent the insects from escaping. The net was then stuffed into a quart ice cream container. Ethyl acetate was squirted into the carton to kill the insects. They were taken to the laboratory where the insects were counted and recorded.

At the start of the fruiting season and continuing weekly for eight weeks, 100 squares/plot were pulled at random from the top one third of the plants to obtain fruit in various stages of development. From the samples, the numbers of *Heliothis* damaged squares were determined and recorded.

Since no insecticides were applied to either the alternate crops or cotton, the populations of parasites, predators, and harmful insects were allowed to become established and regulated by the association of the cotton and the respective alternate crop.

Results and Discussion

Beneficial Insects--The mean numbers of predators collected from cotton are listed in Table I. In most instances, the average monthly predator level was at least as great or greater in 1970 than in 1969 for all the insects studied. Some insects were more predominant in July, others in August.

Lady beetles were present on cotton in all the treatments in higher numbers during July in both years. However, in July lady beetles were most abundant in cotton planted between sorghum and they were least abundant in the soybean treatment. Figure 3 shows the levels were about the same in all the treatments during August.

Wene and Sheets (1962) concluded that lady beetles migrated from alfalfa fields infested with aphids to cotton but the numbers diminished when aphid populations were not present. Examinations of the sorghum plants during July of both years revealed the presence of 1-2 lady beetles/plant. Lady beetles may have been attracted to the sorghum treatments to feed on the fairly high levels of aphids present on sorghum in July. The cotton in the treatments may well have benefited from the presence of the beetles on the sorghum planted contiguous to the cotton, resulting in low aphid populations. As the sorghum matured in August the quantity of lady beetles present dropped drastically.

Collops beetles were present in greater numbers in 1970 than in 1969. In many instances up to 5 times more beetles were collected in 1970. The numbers detected in the cotton of each treatment were greater in July than in August (Fig. 3). The populations of _Collops_ present in July were nearly halved during August in each treatment. That was probably due to the decrease in available food. Since they are known to attack a variety of hosts and in some cases all stages of development, they are not as limited as the lady beetle. More _Collops_ were found in cotton planted contiguous to alfalfa and to sorghum than in the other treatments.

Lacewing larvae and adults were present in greater numbers in 1970 than in 1969 but, unlike the Collops and lady beetles, were more abundant in August than July. In 1969, it was difficult to determine the period of greatest abundance but in 1970 with larger populations it was evident that more were present from late July through August when lepidopterous eggs, small larvae and other soft-bodied insects served as their food source. Cotton planted between sorghum harbored more lacewings (Fig. 4b) than cotton in any of the other treatments. In August the levels present in the corn and alfalfa treatments were higher than the check, soybean or peanut treatments.

Nabid populations were greater in 1970 and July in all treatments. Averaged over both years, more were present in the check and sorghum treatments in July and slightly more in the sorghum treatment than the check, peanut, alfalfa, soybean, and corn treatments in August (Fig. 4a).

Information concerning population levels of the flower bug was available for the 1970 season only. Figure 5a shows that more were present in cotton during August in all treatments. Some size difference was noted between population levels of treatments. The peanut treatment appeared to harbor more flower bugs than the soybean, alfalfa, check, or sorghum treatments and considerably more than corn during August.

Spiders were more abundant during the 1970 season in all treatments and in August there were more spiders present in the corn, soybean, alfalfa and sorghum treatments than in July (Fig. 5b). The levels were about the same both months in the peanut and check treatments. All treatments had about the same levels in August with the exception of soybean treatment which contained fewer spiders. The peanut and check treatments had more spiders present in July. Although spiders occur at fairly high levels throughout the season, their true value as a predator is questionable. Wene and Sheets (1962) and others found spiders feeding on plant bugs as well as several species of predators trapped in their webs, indicating nonselectivity of predatory species.

The average numbers of predators present in the fields during July of both years combined ranged from 3.4/360 feet of cotton row in the soybean treatment to 5.1 in the sorghum treatment (Fig. 6). During August of both years combined, the range was from 2.5 in the soybean treatment to 3.3 in the sorghum treatment. The average of both months together over both years ranged from 3.0 in the soybean treatment to 4.2 in the sorghum treatment. Averaged over both months in both years, the cotton in the soybean treatment contained fewer predators than cotton in the other treatments (Fig. 6). During the same periods, the cotton in the sorghum treatment had more predators present than the other treatments.

Of the remaining, the alfalfa, peanut, and check treatments contained about the same levels averaged over both months; in July they were 4.3, 4.3 and 4.5, respectively; in August they were 2.9, 2.7 and 2.6; and over both years they were 3.6, 3.5 and 3.6. The corn treatment predator population was consistently above the soybean and below the alfalfa, peanut or check treatments.

Destructive Insects--The numbers of thrips found/20 plants are listed in Table II. The populations were of sufficient size both years to cause leaf curling and malformed plants although the levels present were not large enough in any treatment to reduce the stand.

No treatment appeared to have either positive or negative effects on population sizes. There was a significant difference at the 0.01 level between the two years indicating that the 1969 populations were statistically larger than the 1970 populations. There was also a significant difference noted at the 0.01 level between the various weeks of the study. The number of thrips present each week ranged from 26.9/20 plants during the first week of the test to 12.1/20 plants during the fourth week. Thrips are quite responsive to environmental conditions and cases were noted where population levels dropped drastically or increased sharply from 1 week to the next. Great temperature changes from day to day and rainfall are not uncommon early in the season in Southwestern Oklahoma. Instances were observed both years in which population levels were affected by the weather.

By the fourth week of the tests, the plants were getting so large that it was difficult to get 20 plants into the container. At that time, the test was terminated due to the large size of the seedlings, production of new leaves and apparent recovery from the damage.

Fleahopper populations were present in all treatments each year. The cotton fleahopper comprised about 87% of the overall population in the study. Since the black fleahopper populations were so small and somewhat erratic at various times, the total numbers of cotton and black fleahoppers collected were added and analyzed together (Table III).

In 1969 the corn treatment showed a statistical difference, at the 0.05 level, from the other treatments (Table IV). In 1970 there was a treatment difference at the 0.08 level. When averaged over both years, there again was a significant difference between treatments at the 0.05 level. The fleahopper population in the corn treatment was shown to be statistically larger than the soybean, alfalfa and sorghum but not larger than the peanut or check treatments. At the same time there was no difference noted between the soybean, alfalfa, peanut, check or sorghum treatments. None of the populations reached levels that were expected to inflict economic damage, as measured by excessive fruit loss or visible plant damage.

The populations in the treatments were of about the same magnitude each year. The overall mean in 1969 was 2.84 fleahoppers/360 feet of row as compared to 3.23 in 1970. There was also considerable variation in the population sizes from week to week. It is thought that environmental conditions affect the numbers of fleahoppers that remain in the terminal area of the plants. It was noted especially after a rain that the numbers collected in the vacuum machine were reduced greatly.

Table IV shows treatment averages of the various levels of harmful insects, predators, damaged squares and cotton yields. The percent damaged squares resulting from Heliothis will be discussed in more detail in another chapter but is included here to aid in the discussion of harmful insect effects.

In 1969, the seasonal average of predators was less than the average of fleahoppers but in 1970 the levels reversed with more predators present than fleahoppers. Averaged over both years the number of predators was about equal to or more abundant than fleahoppers. It may appear that the fleahoppers had a detrimental effect in the corn treatment since the yield of cotton was significantly lower than the other treatments but after examining the levels in the other treatments it was concluded that the fleahoppers did not cause the reduction.

There was no statistical difference at the 0.05 level between the average numbers of fleahoppers present in the corn, peanut, or check treatments averaged over both years. Included in those 3 are the lowest yielding treatment, corn, and 2 of the higher yielding treatments, peanut and check. It is believed the major effect on total yield was due to the loss of fruit caused by Heliothis.

There were statistical differences at the 0.05 level of significance in percent damaged squares in 1969 but none in either 1970 or averaged over both years. The greater levels of square damage in 1969 was due to a larger population of ovipositing moths and probably fewer predators present in the treatments. In 1970 a combination of fewer ovipositing females in the area and increased numbers of predators combined to reduce the numbers of squares damaged to the point that there were no treatment differences detected. Fruit production by the plants neutralized the losses of squares due to larval damage and natural fruit shedding resulting in statistically equal yields.

The averages of seed cotton/acre in treatments shows that the corn harbored sufficiently more Heliothis which could cause an overall reduction in yield. At the 0.05 level of significance the cotton yield from the corn treatment was statistically less than all other treatments. The sorghum treatment yielded more seed cotton than the others but was not significantly different from the check or peanut treatment but was significantly different from the soybean, alfalfa, or corn treatments.

Conclusions

Based on the data collected over the 2 year period, it appears that irrigated farms of Southwestern Oklahoma may be able to produce from 1.6 - 1.8 bales/acre if early season populations of thrips and fleahoppers can be contained below economic levels. Thrips and fleahopper populations do not appear to be affected adversely by the adjacent plantings of alternate crops and most likely do not decrease the yield. Recent investigations in Oklahoma indicate that any insecticide application will reduce the beneficial insects and in many cases forces the farmer into a season-long insecticide program. Young and Price (1970) recommended that farmers not spray for early season insects, thrips, and fleahoppers, unless very large numbers of the pests are present. In tests dating back to 1931, no one has been able to show increased cotton yields by spraying for early season cotton pests.

Many of the beneficial insects present are enemies of Heliothis and should be protected by growers. Since the bollworm is the primary pest of cotton, in most years in Southwestern Oklahoma, it seems feasible that control can be accomplished to a great degree by natural enemies. The utilization of natural enemies may help solve such problems as resistance, resurgence, environmental pollution and profits may even exceed those that might result from increased yields resulting from chemical control.

CHAPTER III

STRIP CROPPING EFFECTS ON THE ABUNDANCE OF *HELIOTHIS* DAMAGED COTTON SQUARES, BOLL PLACEMENT, TOTAL BOLLS, AND YIELDS IN OKLAHOMA

The bollworm, *Heliothis zea* (Boddie), and tobacco budworm, *H. virescens* (Fabricius), are serious pests of cotton grown in Oklahoma. The bollworm is the dominant species, especially in early season, but the 2 are often found together comprising a *Heliothis* complex. The use of chemicals for controlling *Heliothis* has often resulted in pest resistance and resurgence, pollution of the environment, and increased cost to farmers. These factors have led to research for new methods of control that would introduce or increase natural populations of beneficial insects.

The purpose of this research was to plant in close association with cotton certain other field crops that are known to attract moths and determine if the close plantings affected square damage, numbers and placement of bolls, or yields. The test crops used in this study were selected for being known host plants of *Heliothis* and for their ability to grow, flower, and mature under the growing conditions of Southwestern Oklahoma. The fact that moths are attracted to these crops has been correlated to odors emitted by the plants and to lushness of succulent growth. Oviposition was timed with flowering and the presence of an ample food supply for the larvae (Quaintance and Brues, 1905; Thomas and Dunnam, 1931; Gaines, 1933; Parsons, 1940; Fletcher, 1941; Adkisson, 1958; and Coaker, 1959). Parsons (1940) also concluded that for practical purposes egg-laying may be considered as confined to the period of florescence in 21 short-flowering and 8 long-flowering crops that attracted moths of *Heliothis*.

Corn has received the majority of attention to date for trapping feeding larvae or diverting moths away from cotton and has been reported by several studies (Quaintance and Brues, 1905; Young, 1925; Parsons and Ullyett, 1934; Isley, 1935; Sloan, 1938; Parsons, 1939; Willie, 1951; Simon, 1954; Coaker, 1959; and Reed, 1965). Lincoln and Isley (1947) found that corn in silk appeared to be effective in attracting moths away from cotton but if scattered stalks or single rows of corn were planted in cotton fields they attracted moths which deposited eggs not only on the corn but also on nearby cotton plants. Others have not found corn to be a trap crop. Thomas and Dunnam (1931) found no relation between the proximity of corn to cotton and the infestation in cotton, and Coaker (1959) found no evidence of population efflux from one crop to another nor of maize being more attractive to moths than cotton.

In view of these conflicting reports, it seemed apparent that work should be done to determine the effects of planting crops in close association with cotton. An evaluation of the effects of the selected crops was made by comparing the percent damaged squares, average number of bolls reaching maturity, position of bolls on the plant, and the yield in pounds of seed cotton harvested.

Materials and Methods

During the 1969 and 1970 cotton growing season, tests were conducted on the Oklahoma State University Altus Irrigation Research Station at Altus, Oklahoma. Four rows of corn, soybeans, alfalfa, peanuts, sorghum, or no crop were planted along both sides of 8 rows of 'Delta Pine 16' cotton. Each plot contained 16 rows of 40 inch spacing and was 180 feet long. These plots were planted in a 6 x 6 Latin square design (Fig. 1). Analysis of variance tables containing mean squares and significance levels of variables studied are in the appendix.

Each plot was surrounded by a fallowed buffer area 25 feet in width (Fig. 2). All crops, with the exception of alfalfa, were planted at the end of May and allowed to reach maturity in the field. The alfalfa was drilled in early April 1969 and alternate rows were cut regularly during each growing season to produce renewed vegetative growth and periodic blooming. The cutting of the alternate rows prevented mass migrations of harmful and beneficial insects from the alfalfa that generally occur when the entire plots are cut (Schlinger and Dietrick, 1960).

Fruiting began prior to the first collection of squares but practically no eggs or larvae were observed in any of the treatments. One hundred squares/plot were pulled at random from the top one third of the plants to obtain fruit in various stages of development, beginning the fourth week of July and once weekly through the third week of September. The numbers of *Heliothis* damaged squares were counted and recorded.

Prior to harvest, 18 plants were selected at random from each plot. The number of open bolls and those expected to open occurring on either the top or bottom half of the plant were recorded. Later the average number of bolls/plant was determined for each treatment.

The middle 6 cotton rows from each plot were harvested twice by a 2-row mechanical harvester. Afterwards the cotton on the ground was picked up and the total pounds of seed cotton/treatment was determined.

Since no insecticides were applied on either the alternate crops or cotton, the populations of parasites, predators, and harmful insects were allowed to become established and regulated by the association of the cotton and the respective alternate crop.

Results and Discussion

Square Damage--Results from the 8 weekly square collections and examinations are listed in Table V.

In 1969 sorghum heads, corn tassels and alfalfa flowers were present in the middle of July which was the time cotton started to put on squares. According to Parsons (1940), those 4 crops were then capable of drawing moths and were susceptible to oviposition. The combined weekly abundance of damaged squares from all treatments indicates that egg-laying started about the middle of July. Figures 7 through 10 show that 2 generations of larvae developed in the cotton during the fruiting season. The first generation shows a peak period of damage on the third collection date, in the second week of August, and damage due to the second generation appeared at the end of the fruiting season during the middle part of September (Fig. 7).

A comparison of the weekly damage (Figs. 8a - 10b) indicates that corn, alfalfa, and sorghum treatments contained a higher percentage of damaged squares than the no crop, peanut, or soybean treatments during the development of the first generation of larvae. None of the treatments escaped infestation injury during that period. Parsons (1940) reported that cotton does not occupy a high place in the scale of attraction, and when grown in a community of alternative food plants may not attract ovipositing moths. The higher incidence of square damage in the corn, alfalfa, and sorghum treatments was probably due to moths being drawn to the attracting alternate crop and ovipositing on the cotton because of its close proximity.

The second generation larvae caused increasing damage to the cotton from the last few days in August until the test was terminated at the end of the fruiting period. During that time the peanuts, soybeans, alfalfa and cotton had been in flower. Soybean, peanut, and no crop treatments showed a higher degree of infestation of second generation larvae than these same crops during the first generation in August. The damage in the sorghum treated plots was about the same for both generations while corn and alfalfa plots showed a smaller level of infestation by the second generation larvae. The alternate crops that flowered later in the season, peanut and soybean, did not contain infestations as large as those that flowered earlier. As a result the damaged square levels were not as great. The peanut treatment harbored about the same rate of infestation as the other treatments and the soybeans contained the lowest number of damaged squares at the peak of infestation. The effect of the alfalfa on damaged squares did not seem to be as great during the latter part of the season as it was during the earlier part. The flowering cotton appeared to be the dominant attraction from late August until the end of the season.

Weekly averages of damaged squares indicated that when alternate crops were planted so the tasseling, heading, or initial flowering period coincided with the beginning of cotton flowering, square damage due to treatments were significantly different at the 0.05 level (Tables V and VI). There were no significant differences between the treatments for the period of flowering occurring later in the season and after cotton fruiting started. The peanut treatment did contain larvae in numbers large enough toward the end of the season to increase overall damage to the extent that it was not significantly different from any other treatment. The planting of corn or alfalfa next to cotton caused square damage to increase to a significant level above only the soybean and no crop treatments.

In 1970, first generation bollworms caused the greatest degree of damage during the second week of square collections. The averages increased from less than 1.00% damage the date prior to the first collection to 6.80% the first date and then up to 10.02% the second date (Fig. 7). After that the counts dropped to low levels and remained there until the sixth week of the study. At that time the damage increased to 5.11% then peaked at 13.72% the seventh date. By then, square production was beginning to taper off and the test was terminated following collections the eighth week. Very few squares, but many small bolls, were present in the top of the plants. The bollworms seemed to restrict their damage to the young fruit that would not have sufficient time to mature. Two generations were present in 1970, as were in 1969, but they never occurred in numbers great enough to cause as much damage as in 1969. The second generation in 1970 resulted in more damaged squares in the treatments at the highest point but there was a sharp rise to the peak and a sharp decline after the peak resulting in an overall lesser level of damage.

All the treatments in 1970 attained higher damage levels at the peaks in September, the seventh date, than they did in August, the second date. Although the corn and peanut treatments had considerably higher numbers of damaged squares on the seventh date, there was no significant difference between treatments at the 0.05 level. It appears that the cotton was the major attractant for ovipositing moths since all treatments had similar levels of damage. The planting of the 5 alternate crops next to cotton did not show any difference from the check in 1970 (Table VI).

The lower incidence of square damage was the result of the overall smaller Heliothis population present in the area and an increase in the number of predators present over the previous year. The rates of damage seemed to occur at levels low enough for the plants to recover from the loss by producing more fruit. Mistric and Covington (1968) and Goodman (1957) stated that cotton plants seemed to have the ability to compensate for square removal. Yields are not as greatly affected as the time of maturity if bolls are protected. Square loss is usually overcome by increased square production, numbers of bolls set or weight of the set bolls.

Table VI contains the treatment means for 1969, 1970 and averages of both years. There was no significant difference between treatments at the 0.05 level when both years were analyzed together, indicating that no adjacent planting caused more squares to be damaged than another. Since the injury levels were so low in 1970 and the combined percent damaged squares were not different, it is thought a true indication of difference was not obtained. The same crops that showed significantly higher square damage in 1969 also had the highest rates of damage in 1970, with the exception of alfalfa, even though significance was not attained.

Averaged over both years it appeared that planting corn, alfalfa, sorghum and peanuts adjacent to cotton increased the percent damaged cotton squares. The first 3 crops are early season flowerers and the peanut is a mid-late season flowerer. All treatments acted in a similar manner each year. There was a significant difference at the 0.01 level between corresponding dates of the 2 years. In 1969 the dates of peak damage were 1 week later in every treatment. The peaks occurred on the third and eighth dates in 1969 and the second and seventh dates in 1970.

Boll Placement and Numbers--In 1969 there was no difference at the 0.05 level of significance between the total number of bolls/plant or their occurrence on either the top or bottom half of the plant (Table VII). This might indicate there is no correlation between the number of bolls reaching maturity in relation to the time of greatest damage or percent damaged squares. One might conclude since there was a significant difference found between treatment yields at the 0.01 level, there was a boll weight difference, although measurements were not taken. The density of plants ranged from 8.09 to 8.52/foot of row with no significant difference at the 0.05 level (Table VII).

In 1970 the weather conditions at the start of the season hampered the germination of the seeds and only half as many plants survived as compared to 1969. The range was from 3.46 to 4.26 plants/foot in 1970 but there was no significant difference between treatments at the 0.05 level. Those treatments with fewer plants produced from 0.28 to 0.41 more bolls in 1970. There was also a highly significant difference between the placement of bolls on the top and bottom halves of the plants in 1970 although there was no difference at the 0.05 level between treatments.

There were more bolls produced on the bottom of the plants in 1970 (Table VII). In 1969 the nonsignificant amount of about 0.085 more bolls on the tops increased to 0.54 more bolls produced on the bottoms of the plants. Although many factors in addition to insects affect boll set, this may partially be explained by the fairly small population of 1st generation larvae causing damage to fewer squares during the early part of the fruiting season and the ability of plants spaced farther apart to produce and hold more fruit. The smaller bollworm population did not cause as many squares to fall as did the previous year's population so more bolls matured on the bottom of the plants. The lesser numbers of bolls setting on the top of the plants was probably regulated to a great extent by physiological processes of the plant, larval damage, and lack of sufficient time for the bolls to mature.

Yields--Although no difference between treatments was observed in the number of bolls on each plant, there was a significant difference between treatments in the pounds of seed cotton harvested in 1969. The 4 treatments containing the smallest percentage of damaged squares had the fewest plants/foot of row and averaged more pounds of cotton than the 2 treatments which had the greatest percentage of damaged squares and the most plants/foot of row (Table VII). The size and weight of the individual bolls appears to be more important than the number of bolls that reach maturity. The low yield of the soybean treatment which had the next to the smallest percentage of damaged squares, largest number of bolls/plant and most plants/foot of row is unexplainable.

The planting of any crop in close association with cotton appeared to increase the population of Heliothis which resulted in greater square damage and a reduced yield in 1969. Alfalfa and corn, which both flower early in the season, were responsible for more square damage and lower yields than the other treatments.

In 1970 there was no significant difference in yields due to treatments. The fewer bollworms and their low levels of damage did not prevent plant compensation for the loss of damaged and naturally shed squares. The yields ranged from 168 pounds to 186 pounds. The check plot treatments yielded 176 pounds of seed cotton. Sorghum treated plots had the highest yield both years. Soybean and corn, the 2 lowest yielding treatments in 1969 were also the lowest in 1970.

When the data from both years were combined, a significant difference at the 0.01 level was evident between treatment yields. The corn treatment yield was significantly less than every other treatment (Table VIII). In 1969 the check treatment was significantly higher than all the others, but averaged over both years, it appears that the check and sorghum treatments performed equally well. The check and peanut treatment yields were not statistically different from each other but were different from the alfalfa and soybean treatments which were not different from each other.

There was an increase in yields from 1969 to 1970 in plots that received the corn, alfalfa and sorghum treatments. The other 3 treatments showed a decrease in yields from 1969 to 1970. This interaction of year by treatment indicates the treatment effects did not follow the same pattern from 1969 to 1970. It should be noted that the average yield for 1969 and 1970 were equal although there were nearly twice as many plants/foot in 1969 as there were in 1970. Since the square damage in 1969 was higher than 1970 it might appear that fewer plants resulted in less damage but this was not the result. The actual populations of larvae decreased from 1969 to 1970 in these plots as well as surrounding fields in the immediate area.

Conclusions

Since the check and sorghum treatments did not exhibit differences in percent damaged squares, location of bolls and total bolls on plants, or yield, it appears that planting sorghum in a strip cropping system with cotton could be advantageous. The possibility of encouraging and protecting predator populations as well as benefiting from the protection the thickly planted sturdy plants offer could aid the development of biological control of cotton insects. Visual observations and measurements on June 27, 1969, indicated that cotton plants between sorghum were from 0.1 to 0.6 inches taller than cotton in other treatments and the overall plant condition was better. The sorghum plants may protect the cotton from the prevailing south winds that blow almost constantly during the summer months. The grain and forage from the sorghum plants may be harvested and sold, providing additional income.

CHAPTER IV

EFFECTS OF *HELIOTHIS* SPP. AND STRIP CROPPING ON COTTON YIELDS AND LINT QUALITY IN OKLAHOMA

The effects of insects on fiber yield and quality have been reported in the past by a few workers. Many insects such as the boll weevil, aphids, spider mites, plant feeding bugs, pink bollworm, cotton leafworm, and cotton leaf perforator have been linked to lower lint yields and quality (Bishopp, 1956; Canerday and Arant, 1964; and Tugwell and Waddle, 1964). Lint quality is affected by boll punctures, presence of honeydew and stains, defoliation, and the reduction of plant vigor, especially in the period of high productivity.

Adkisson et al. (1964) reported reductions in yield due to the bollworm, *Heliothis zea* (Boddie) but concluded that the yield losses had little or no effect on the quality of lint and fiber.

In view of these findings research was conducted to determine the influence of strip planting cotton between 5 other crops known to be hosts of bollworms in Oklahoma. The *Heliothis* complex is comprised of the bollworm and the tobacco budworm, *Heliothis virescens* (Fabricius), during the latter part of the season.

Materials and Methods

During the 1969 and 1970 cotton growing seasons, tests were conducted on the Oklahoma State University Altus Irrigation Research Station at Altus, Oklahoma. Four rows each of corn, soybeans, alfalfa, peanuts, sorghum or no crop were planted along both sides of 8 rows of 'Delta Pine 16' cotton. Each plot contained 16 rows of 40 inch spacing and was 180 feet long. These plots were planted in a 6 x 6 Latin square design. Analysis of variance tables containing mean squares and significance levels of variables studied are in the appendix.

Each plot was surrounded by a fallowed buffer area 25 feet in width (Fig. 1). All crops, with the exception of alfalfa, were planted at the end of May and allowed to reach maturity in the field. The alfalfa was drilled in early April 1969 and alternate rows were cut regularly during each growing season to produce renewed vegetative growth and periodic blooming. The cutting of the alternate rows prevented mass migrations of harmful and beneficial insects from the alfalfa that generally occur when the entire plots are cut (Schlinger and Dietrick, 1960).

Harmful and beneficial insect levels were determined at weekly intervals throughout the season. *Heliothis* was the primary pest encountered during both years of the study. Other harmful cotton insects present occurred at levels below those recommended for chemical control.

The middle 6 cotton rows were harvested twice by a 2-row mechanical harvester. Lint samples were collected at random from each plot. Fiber fineness was determined on a micronaire and is expressed as micrograms/inch. Fiber strength was determined on a stelometer and is expressed as the "o" inch gauge and "1/8" inch gauge which are direct readings from the instrument. Fiber length was determined on the digital fibrograph and is given as the 2.5% span length in inches.

The uniformity ratio was determined by (50% span length ÷ 2.5% span length) x 100.

Since no insecticides were applied on either the alternate crops or cotton, the populations of parasites, predators and harmful insects were allowed to become established and regulated by the association of the cotton and the respective alternate crop.

Results and Discussion

First Harvest--During the 2 year study there were no significant treatment differences at the 0.05 level observed in the number of Heliothis damaged squares although there was a difference in the pounds of lint/acre picked in the first harvest (Table IX). The corn treatment, which had the highest percent damaged squares produced less lint than the check and sorghum treatments but at the same time had significantly longer fibers at the 0.05 level than all the other treatments except the soybean. The values obtained in the uniformity ratio showed no significant differences but did indicate that uniformity was lacking in every treatment. Since mature fiber length is variable and uniformity is not expected, the higher the ratio of shorter to longer fibers is better.

Fiber from the peanut treatment, with about the average percent damaged squares and yield, fell in the average range for fineness. Every other treatment value fell within the coarse range although they were very close to being of average fineness.

Corn, soybean, and check treatment fibers were statistically stronger at the 0.05 level of significance than those from the sorghum treatment when tested at "o" inch gauge. There were no differences when tested at the "1/8" inch gauge.

Second Harvest--There were no treatment differences at the 0.05 level in either yield or lint characteristics averaged over both years of the second harvest. The fiber in all treatments again exhibited nonuniformity but none reached the level designated as coarse.

Conclusions

Generally, fineness, length, and strength of fibers are influenced primarily by heredity. Such factors as plant nutrients, soil moisture, disease, and environmental conditions, as well as harvesting and ginning practices, affect quality in some cases (Hoover, 1962). It appears that levels of Heliothis damage, although not significant at the 0.05 level, lowered the yields of lint of the first harvest but did not adversely affect lint characteristics. The corn treatment plots with the highest rate of damage produced fibers with the best length and strength qualities at "o" inch gauge. In the other tests, no differences in quality were indicated.

Since all the treatments were treated in an identical manner there were evidently underlying treatment effects resulting from planting alternate crops in close association with cotton. Further tests must be conducted to determine the causes of those treatment interactions with lint quality.

CHAPTER V

SUMMARY

Beneficial arthropods collected in greatest numbers from the cotton were lady beetles, primarily *Hippodamia* spp.; green lacewings, *Chrysopa* spp.; nabids, *Nabis* spp.; the flower bug, *Orius insidiosus* (Say); soft-winged flower beetles, *Collops* spp.; and several species of spiders. Those predators appeared to occur more frequently in the sorghum, peanut, and alfalfa treatments.

The destructive insects that occurred in sufficient numbers to warrant study were thrips, primarily *Frankliniella* spp.; cotton fleahopper, *Psallus seriatus* (Reuter); black fleahoppers, *Spanogonicus albofasciatus* (Reuter) and *Rhinacloa forticornis* (Reuter); and the *Heliothis* complex composed of the cotton bollworm, *Heliothis zea* (Boddie) and *Heliothis virescens* (Fabricius). Thrips and fleahopper populations did not reach recommended levels for chemical control and most likely did not damage the plant or its fruit to the point that yield or lint quality was reduced. Damaged resulting from *Heliothis*, although the populations were not exceedingly large, was severe enough to cause significant differences in treatment yields.

The sorghum and check treatments produced more pounds of seed cotton than the others. Yields decreased in the remaining treatments and the lowest producing treatment was corn. Although *Heliothis* apparently caused reductions in yield, it was not possible to correlate their damage to decreases noted in fiber strength. Further studies must be conducted to determine the causes of the fiber weakening in some treatments.

It appears that planting cotton and other crops in close association does have an effect on the numbers of predators present in the immediate area. Since the sorghum treatment contained the highest levels of predators and highest yield, even though it had the next to highest percent damaged squares, it appears to be the crop with the greatest potential for future research.

More extensive studies, to measure effects of alternate crops on insect populations in cotton, might include increasing the size of the plots and varying the numbers of rows in the tests. Samples could be taken at various distances from the alternate crops to see if numbers of insects increase or decrease in cotton rows farther away from the alternate crop.

More accurate methods of sampling to determine the potential *Heliothis* population and its damage in relation to actual numbers of squares and bolls damaged might also be employed by checking terminals and making egg and larval counts.

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APPENDIX

TABLE I

AVERAGE NUMBERS OF PREDATORS COLLECTED FROM 360 FEET OF COTTON ROW IN EACH TREATMENT IN JULY AND AUGUST OF 1969 and 1970[a]

Predator and Year	Corn July	Corn Aug.	Soybean July	Soybean Aug.	Alfalfa July	Alfalfa Aug.	Peanut July	Peanut Aug.	Check July	Check Aug.	Sorghum July	Sorghum Aug.	Mean
Lady beetles													
1969	5.0	0.1	2.4	0.0	2.7	0.0	1.8	0.1	2.0	0.1	3.2	0.0	1.5
1970	11.8	0.7	10.4	1.1	13.8	0.3	14.6	1.0	15.8	1.1	20.9	1.0	7.7
Combined	8.4	0.4	6.4	0.5	8.2	0.2	8.2	0.5	8.9	0.6	12.0	0.5	4.6
Collops													
1969	2.1	0.4	1.9	0.3	2.2	0.5	1.2	0.3	1.4	0.6	1.8	0.7	1.1
1970	4.3	4.3	4.0	4.7	9.2	4.8	5.6	3.2	6.4	4.0	7.5	6.0	5.3
Combined	3.2	2.4	2.9	2.5	5.7	2.7	3.4	1.7	3.9	2.3	4.7	3.4	3.2
Lacewings													
1969	1.5	1.6	1.2	0.7	0.8	1.0	1.2	0.9	0.8	1.2	2.4	0.9	1.2
1970	1.1	4.9	1.0	3.7	0.7	4.9	0.8	3.7	1.0	3.3	1.2	7.0	2.8
Combined	1.3	3.3	1.1	2.2	0.8	2.9	1.0	2.3	0.9	2.3	1.8	3.9	2.0
Nabids													
1969	1.9	0.3	0.9	0.1	0.6	0.2	0.4	0.1	0.9	0.1	0.7	0.1	0.5
1970	2.8	2.1	3.4	1.7	3.5	1.6	3.8	2.2	4.7	1.2	5.6	2.8	3.0
Combined	2.4	1.2	2.1	0.9	2.1	0.9	2.1	1.1	2.8	0.7	3.2	1.4	1.7
Flower Bugs													
1970	0.3	0.7	0.3	1.5	0.5	1.6	0.5	2.2	0.7	1.5	0.2	1.4	1.0
Spiders													
1969	3.4	7.3	3.7	4.7	2.7	6.0	3.6	5.1	3.6	5.0	3.4	4.9	4.5
1970	9.4	8.3	8.1	9.0	10.9	11.2	14.3	11.1	12.5	10.8	9.0	11.7	10.5
Combined	6.4	7.8	5.9	6.9	6.9	8.6	8.9	8.1	8.0	7.9	6.2	8.3	7.5
Grand Mean	4.0	2.8	3.4	2.5	4.3	2.9	4.3	2.7	4.5	2.6	5.1	3.3	3.5
Months Combined	3.4		3.0		3.6		3.5		3.6		4.2		

[a]Statistical differences are not indicated due to the great variations in weekly data and the many zero values accumulated throughout the course of the study.

TABLE II

AVERAGE NUMBERS OF THRIPS COLLECTED FROM 20 COTTON PLANTS/PLOT IN EACH TREATMENT IN JUNE OF 1969 AND 1970[a]

Treatment and Year	1st Week	2nd Week	3rd Week	4th Week	Mean[b]
Corn					
1969	31.6	9.5	41.3	13.3	23.9
1970	26.3	21.8	9.5	15.1	18.2
Combined	29.0	15.6	25.4	14.2	21.1
Soybean					
1969	25.1	19.0	37.1	12.6	23.5
1970	21.8	28.5	7.3	15.3	18.2
Combined	23.5	23.7	22.2	14.0	20.8
Alfalfa					
1969	44.1	15.0	29.0	15.3	25.8
1970	23.1	22.6	6.3	9.3	15.3
Combined	33.6	18.8	17.6	12.3	20.6
Peanut					
1969	24.0	23.3	26.6	8.5	20.6
1970	26.5	14.8	9.1	8.0	14.6
Combined	25.2	19.0	17.9	8.2	17.6
Check					
1969	31.1	13.1	29.3	9.5	20.7
1970	19.6	22.8	7.3	15.6	16.3
Combined	25.4	18.0	18.3	12.5	18.5
Sorghum					
1969	29.5	16.0	47.1	11.0	25.9
1970	19.8	23.6	9.0	11.8	16.0
Combined	24.6	19.8	28.0	11.4	21.0
Grand Mean	26.9	19.2	21.6	12.1	20.0

[a]Statistical Comparisons were not made between the weekly treatment means.

[b]None of the differences between treatment means were significant at the 0.05 level of probability in 1969, 1970, or combined.

TABLE III

AVERAGE NUMBERS OF FLEAHOPPERS COLLECTED FROM 360 FEET OF COTTON ROW/PLOT IN EACH TREATMENT IN JULY AND AUGUST OF 1969 AND 1970[a]

Treatment and Year	July				August			Mean[b]
	Date 1	Date 2	Date 3	Date 4	Date 5	Date 6	Date 7	
Corn								
1969	7.83	4.50	12.00	2.16	1.83	0.50	0.00	4.11
1970	1.33	6.33	0.50	2.33	2.83	7.83	6.66	3.97
Combined	4.58	5.41	6.25	2.25	2.33	4.16	3.33	4.04
Soybean								
1969	2.83	2.83	11.16	1.50	0.83	0.50	0.00	2.80
1970	1.83	3.33	0.33	1.83	3.00	5.33	4.66	2.90
Combined	2.33	3.08	5.75	1.66	1.91	2.91	2.33	2.85
Alfalfa								
1969	1.83	3.33	11.33	1.16	0.66	0.16	0.00	2.64
1970	1.83	5.50	0.83	1.00	1.50	4.16	1.16	2.28
Combined	1.83	4.41	6.08	1.08	1.08	2.16	0.58	2.46
Peanut								
1969	1.33	3.16	12.83	0.66	1.66	0.50	0.00	2.88
1970	3.16	10.83	0.83	2.83	2.16	6.16	3.00	4.14
Combined	2.25	7.00	6.83	1.75	1.91	3.33	1.50	3.51
Check								
1969	1.00	2.16	9.16	1.00	1.00	1.00	0.00	2.19
1970	2.00	10.00	0.83	3.00	1.66	5.00	4.33	3.83
Combined	1.50	6.08	5.00	2.00	1.33	3.00	2.16	3.01
Sorghum								
1969	3.00	2.16	9.83	0.83	1.00	0.00	0.00	2.40
1970	2.16	3.33	0.50	0.83	1.33	5.50	2.33	2.28
Combined	2.58	2.75	5.16	0.83	1.16	2.75	1.16	2.34
Grand Mean	2.51	4.79	5.84	1.59	1.62	3.05	1.84	3.03

[a]Statistical comparisons were not made between the weekly treatment means.

[b]Significant differences by Duncan's multiple range test at the 0.05 level of probability are indicated for 1969 and both years combined on Table IV.

TABLE IV

AVERAGE NUMBERS OF DESTRUCTIVE AND USEFUL INSECTS, DAMAGED SQUARES, AND TREATMENT YIELDS IN 1969 AND 1970[a]

Variable and Year	Corn	Soybean	Alfalfa	Peanut	Check	Sorghum	Mean
Thrips							
1969	23.95	23.50	25.87	20.62	20.79	25.91	23.44
1970	18.20	18.25	15.37	14.62	16.37	16.08	16.48
Combined	21.08	20.88	20.62	17.62	18.58	21.00	19.96
Fleahoppers							
1969	4.11^{a}	2.80^{b}	2.64^{b}	2.88^{b}	2.19^{b}	2.40^{b}	2.84
1970	3.97	2.90	2.28	4.14	3.83	2.28	3.23
Combined	4.04^{a}	2.85^{b}	2.46^{b}	3.51^{ab}	3.01^{ab}	2.34^{b}	3.03
Damaged Squares							
1969	10.77^{a}	8.70^{b}	10.62^{a}	9.22^{ab}	8.41^{b}	9.58^{ab}	9.55
1970	6.16	5.04	5.08	6.25	5.16	5.58	5.54
Combined	8.47	6.87	7.85	7.74	6.79	7.58	7.55
Predators							
1969	2.36	1.59	1.67	1.47	1.12	1.81	1.67
1970	4.22	4.08	5.03	5.85	5.25	6.19	5.10
Combined	3.29	2.83	3.35	3.66	3.19	4.00	3.38
Lbs of Seed Cotton/Acre							
1969	1948^{a}	2130^{b}	2021^{a}	2214^{bc}	2299^{c}	2202^{bc}	2130
1970	2032	2081	2202	2142	2130	2251	2142
Combined	1994^{a}	2106^{b}	2112^{bc}	2178^{bcd}	2215^{cd}	2227^{d}	2136

[a]Means fillowed by the same letter are not significantly different by Duncan's multiple range test at the 0.05 level of probability. The contrasts between treatments were made within years for each variable except predators.

TABLE V

AVERAGE PERCENTAGES OF DAMAGED COTTON SQUARES FOR EACH TREATMENT IN JULY, AUGUST, AND SEPTEMBER OF 1969 AND 1970[a]

Month	Date	Year	Treatment: Corn	Soybean	Alfalfa	Peanut	Check	Sorghum	Combined
July	1	1969	3.83	2.66	1.66	3.66	2.16	3.50	2.91
		1970	6.83	7.66	5.00	6.16	9.16	6.00	6.80
August	2	1969	13.16	11.50	12.50	7.66	9.66	14.16	11.44
		1970	10.83	10.50	7.50	10.16	9.66	11.50	10.02
	3	1969	17.00[a]	10.83[c]	18.16[a]	10.66[bc]	9.16[c]	15.33[ab]	13.52
		1970	2.66	1.33	1.33	1.66	1.83	2.00	1.80
	4	1969	11.50[a]	7.66[bc]	8.16[b]	4.50[c]	5.33[bc]	5.66[bc]	7.13
		1970	1.66	0.33	1.50	1.00	1.33	0.66	1.08
	5	1969	8.16	5.83	8.33	9.50	5.66	6.66	7.44
		1970	0.33	0.50	1.00	0.33	0.33	0.83	0.55
September	6	1969	6.00	11.00	10.66	11.66	12.33	9.33	10.13
		1970	3.33	5.66	4.33	7.66	6.33	3.33	5.11
	7	1969	12.00	7.83	11.16	12.00	10.00	6.66	9.94
		1970	15.66	10.66	13.33	17.00	11.00	14.66	13.72
	8	1969	14.50	12.33	13.83	14.16	13.66	15.33	13.88
		1970	8.00	3.66	6.66	6.00	1.66	5.66	5.27

[a]Means followed by the same letter are not significantly different by Duncan's multiple range test at the 0.05 level of probability. The contrasts between treatments were made within dates.

TABLE VI

AVERAGE PERCENTAGES OF DAMAGED COTTON SQUARES FOR EACH TREATMENT IN 1969 AND 1970[a]

	Year		
	1969	1970	Mean
Corn	10.77[a]	6.16	8.46
Soybean	8.70[b]	5.04	6.87
Alfalfa	10.62[a]	5.08	7.85
Peanut	9.22[ab]	6.25	7.73
Check	8.41[b]	5.16	6.79
Sorghum	9.58[ab]	5.58	7.58
Combined	9.55	5.54	7.55

[a]Means followed by the same letter are not significantly different by Duncan's multiple range test at the 0.05 level of probability.

TABLE VII

AVERAGE PERCENTAGES OF DAMAGED SQUARES, NUMBER AND PLACEMENT OF BOLLS, PLANT DENSITY, AND POUNDS OF SEED COTTON FOR EACH TREATMENT IN 1969 AND 1970[a]

Year and Treatment	Percent Damaged Squares	Number and Location of Bolls/Plant			Plants/ Foot of Row	Pounds of Seed Cotton
		Top	Bottom	Sum		
1969						
Corn	10.77[a]	2.19	1.73	3.92	8.52	161[a]
Soybean	8.70[b]	2.27	2.11	4.38	8.22	176[a]
Alfalfa	10.62[a]	2.19	1.87	4.07	8.44	167[a]
Peanut	9.22[ab]	1.91	2.10	4.01	8.11	183[b]
Check	8.41[b]	2.26	1.89	4.16	8.09	190[c]
Sorghum	9.58[ab]	2.15	2.18	4.34	8.09	182[b]
Combined	9.55	2.16	1.98	4.14	8.24	177
1970						
Corn	6.16	2.19	4.49	6.68	3.46	168
Soybean	5.04	1.94	4.18	6.12	4.26	172
Alfalfa	5.08	1.91	4.87	6.78	3.56	182
Peanut	6.25	1.75	4.74	6.49	4.03	177
Check	5.16	2.08	3.99	6.07	3.86	176
Sorghum	5.58	2.15	3.92	6.07	3.60	186
Combined	5.54	2.01	4.36	6.37	3.80	177

[a]Means followed by the same letter are not significantly different by Duncan's multiple range test at the 0.05 level of probability.

TABLE VIII

AVERAGE PERCENTAGES OF DAMAGED SQUARES, NUMBER AND PLACEMENT OF BOLLS, PLANT DENSITY, AND POUNDS OF SEED COTTON FOR EACH TREATMENT AVERAGED OVER 1969 AND 1970[a]

Treatment	Percent Damaged Squares	Number and Location of Bolls/Plant			Plants/ Foot of Row	Pounds of Seed Cotton
		Top	Bottom	Sum		
Corn	8.46	2.19	3.11	5.30	5.99	165[a]
Soybean	6.87	2.11	3.14	5.25	6.24	174[b]
Alfalfa	7.85	2.05	3.37	5.43	6.00	175[b]
Peanut	7.73	1.83	3.42	5.25	6.07	180[c]
Check	6.79	2.17	2.94	5.12	5.97	183[cd]
Sorghum	7.58	2.17	3.05	5.22	5.84	184[d]
Combined	7.55	2.09	3.19	5.26	6.01	177

[a]Means followed by the same letter are not significantly different by Duncan's multiple range test at the 0.05 level of probability.

TABLE IX

AVERAGE PERCENTAGES OF DAMAGED SQUARES, POUNDS OF LINT PER ACRE, AND LINT QUALITY FROM THE FIRST AND SECOND HARVEST FOR EACH TREATMENT AVERAGED OVER 1969 AND 1970[a]

Harvest	Treatment	Percent Damaged Squares[b]	Pounds of Lint/Acre	Fibrograph 2.5% Span Length (inches)	Fibrograph Uniformity Ratio	Micronaire ug/inch	Stelometer "o" inch gauge	Stelometer "1/8" inch gauge
First	Corn	8.46	431[c]	1.127[a]	45.517	5.000	3.998[ab]	2.003
	Soybean	6.87	468[bc]	1.114[ab]	45.942	4.867	4.064[a]	1.978
	Alfalfa	7.85	481[abc]	1.105[bc]	45.292	4.950	3.965[abc]	2.001
	Peanut	7.73	482[abc]	1.107[bc]	45.567	4.992	3.953[bc]	2.008
	Check	6.79	492[ab]	1.101[bc]	45.750	4.917	4.002[ab]	1.998
	Sorghum	7.58	515[a]	1.094[c]	45.642	5.058	3.885[c]	1.963
Second	Corn	8.46	199	1.064	45.175	4.763	3.949	1.986
	Soybean	6.87	196	1.069	44.950	4.655	4.012	1.973
	Alfalfa	7.85	187	1.066	45.016	4.753	3.920	1.975
	Peanut	7.73	188	1.079	45.192	4.766	3.909	1.982
	Check	6.79	204	1.063	44.658	4.729	3.967	1.996
	Sorghum	7.58	191	1.072	44.642	4.826	3.884	1.950

[a]Means followed by the same letter are not significantly different by Duncan's multiple range test at the 0.05 level of probability. The contrasts between treatments were made within variables for each harvest.

[b]The seasonal average of percent damaged squares applied to both the first and second harvests.

TABLE X

ANALYSIS OF VARIANCES FOR THRIPS IN 1969, 1970, AND COMBINED

Source	df	Mean Squares 1969	1970	Combined
Col.[a]	5	100.8	389.6	175.8
Rows	5	303.8	318.5	262.3
Treat.[b]	5	130.9	52.6	105.3
Error A	20	117.1	67.6	110.2
Dates	3	4622.3**	1937.1**	2709.1**
Col. x Dates	15	292.4	98.3	223.1
Rows x Dates	15	377.6	90.8	226.1
Treat. X Dates	15	250.7*	65.1	146.8
Error B	60	136.9	57.1	102.6
Years	1			3486.1**
Col. x Years	5			314.6
Rows x Years	5			360.0
Treat. x Years	5			78.2
Error C	20			74.5
Years x Dates	3			3850.4**
Col. x Years x Dates	15			167.5
Rows x Years x Dates	15			242.3
Treat. x Years x Dates	15			169.0**
Error D	60			62.9

[a]Columns

[b]Treatments

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

TABLE XI

ANALYSIS OF VARIANCES FOR FLEAHOPPERS IN 1969, 1970, AND COMBINED

Source	df	Mean Squares 1969	1970	Combined
Col.[a]	5	7.4	24.1	6.4
Rows	5	12.1	17.7	11.8
Treat.[b]	5	19.2*	30.6	35.1*
Error A	20	6.9	12.7	12.2
Dates	6	520.6**	169.2**	200.8**
Col. x Dates	30	3.4	13.7	11.1
Rows x Dates	30	11.8	18.9	15.6
Treat. x Dates	30	6.3	12.4	7.0
Error B	120	6.0	10.5	8.2
Years	1			19.8
Col. x Years	5			25.1
Rows x Years	5			18.0
Treat. x Years	5			14.8
Error C	20			7.9
Years x Dates	6			489.0**
Col. x Years x Dates	30			6.0
Rows x Years x Dates	30			15.1
Treat. x Years x Dates	30			11.8
Error D	120			8.2

[a]Columns

[b]Treatments

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

TABLE XII

ANALYSIS OF VARIANCES FOR TOTAL POUNDS OF SEED COTTON FROM THE FIRST, SECOND, AND THIRD HARVESTS IN 1969, 1970, AND COMBINED

Source	df	Mean Squares		
		1969	1970	Combined
Col.[a]	5	94.0	1107.7	657.5
Row	5	120.4	139.9	115.5
Treat.[b]	5	230.8**	85.7	206.0**
Error A	20	16.2	42.4	32.7
Har.[c]	2	69378.2**	53001.8**	116321.9**
Col. x Har.	10	862.8	260.3	288.5
Row x Har.	10	158.3	149.2	107.7
Treat. x Har.	10	63.5	161.0**	161.2*
Error B	40	73.1	49.6	64.8
Years	1			0.8
Col. x Years	5			544.3
Row x Years	5			144.8
Treat. x Years	5			110.5**
Error C	20			25.9
Years x Har.	2			6058.1**
Col. x Years x Har.	10			834.6
Row x Years x Har.	10			199.9
Treat. x Years x Har.	10			63.4
Error D	40			60.2

[a]Column

[b]Treatment

[c]Harvest

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

TABLE XIII

ANALYSIS OF VARIANCES FOR NUMBER AND LOCATION OF BOLLS ON PLANTS IN 1969, 1970, AND COMBINED

Source	df	Mean Squares 1969	1970	Combined
Col.[a]	5	106.5	1629.3	865.7
Row	5	228.2	610.4	347.7
Treat.[b]	5	32.6	97.5	20.0
Error A	20	46.8	196.3	103.5
Loc.[c]	1	196.7	32300.3**	13728.0**
Col. x Loc.	5	16.5	336.1	152.2
Row x Loc.	5	265.6	716.3	412.9
Treat. x Loc.	5	60.5	261.5	184.4
Error B	20	118.7	259.1	261.0
Years	1			14480.1**
Col. x Years	5			870.1
Row x Years	5			490.9
Treat. x Years	5			110.1
Error C	20			139.6
Years x Loc.	1			18769.0**
Col. x Years x Loc.	5			200.4
Row x Years x Loc.	5			569.1
Treat. x Years x Loc.	5			137.5
Error D	20			116.8

[a]Column

[b]Treatment

[c]Location

**Significant at the 0.01 level of probability.

TABLE XIV

ANALYSIS OF VARIANCES FOR PERCENT BOLLWORM DAMAGED SQUARES IN 1969, 1970, AND COMBINED

Source	df	Mean Squares 1969	1970	Combined
Col.[a]	5	9.1	56.4	35.7
Rows	5	103.8	17.1	72.4
Treat.[b]	5	45.5*	14.3	38.5
Error A	20	15.5	9.9	14.9
Dates	7	478.2**	759.0**	661.5**
Col. x Dates	35	23.3	34.3	20.5
Rows x Dates	35	16.7	25.4	16.3
Treat. x Dates	35	28.8**	14.5	28.0
Error B	140	14.1	11.6	12.8
Years	1			2012.0**
Col. x Years	5			29.8
Rows x Years	5			48.5
Treat. x Years	5			21.4
Error C	20			10.5
Years x Dates	7			575.8**
Col. x Years x Dates	35			37.1
Rows x Years x Dates	35			25.9
Treat. x Years x Dates	35			15.3
Error D	140			12.8

[a]Columns

[b]Treatments

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

TABLE XV

ANALYSIS OF VARIANCES FOR PERCENT BOLLWORM DAMAGED SQUARES AND POUNDS OF SEED COTTON FROM THE FIRST AND SECOND HARVESTS IN 1969, 1970, AND COMBINED[a]

			Mean Squares					
			Numbers of Bollworm Damaged Squares[a]			Pounds of Seed Cotton/Harvest		
Year	Source	df	Date 3	Date 4	Date 6	First	Second	Combined
1969	Col.[b]	5	22.1	8.4	27.0	1268.0	498.8	309.6
	Rows	5	26.9	9.1	15.2	307.4	62.4	519.6
	Treat.[c]	5	85.6**	39.3**	30.3	293.6	23.3	430.0**
	Error A	20	17.3	7.3	13.0	128.1	15.2	103.5
1970	Col.	5	3.7	0.5	10.7	1128.3	271.0	2499.5
	Rows	5	5.0	1.5	2.7	398.9	26.8	586.2
	Treat.	5	1.5	1.6	18.3	280.3*	25.8*	240.8
	Error B	20	1.8	0.8	8.9	89.2	8.1	110.6
Com-bined	Col.	5	20.8	4.3	10.1	319.5	709.2	1138.2
	Rows	5	15.8	5.8	13.7	284.3	20.1	348.0
	Treat.	5	46.8**	24.0**	42.6**	431.5*	25.5*	438.2*
	Error C	20	11.1	4.0	8.7	128.1	7.1	113.7
	Years	1	2473.4**	660.1**	455.0**	284.0	4512.5**	7060.7**
	Col. x Years	5	5.0	4.6	27.6	2076.8	60.6	1670.9
	Rows x Years	5	16.1	4.8	4.2	422.1	69.2	757.8
	Treat. x Years	5	40.3**	16.9**	6.0	142.3	23.6	232.6
	Error D	20	8.0	4.1	13.2	89.2	16.1	100.5

[a]Dates not included did not show significant differences at the 0.05 level of probability.

[b]Columns

[c]Treatments

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

TABLE XVI

ANALYSIS OF VARIANCES FOR POUNDS OF LINT PICKED AND LINT QUALITY FROM THE FIRST AND SECOND HARVESTS IN 1969, 1970, AND COMBINED

			Mean Squares				
			Pounds of Lint/Harvest			Lint Quality[a]	
Year	Source	df	First	Second	Combined Lint/Acre	2.5% Span Length Harvests Combined	"o" inch gauge First Harvest
1969	Col.[b]	5	164.4	84.3	6285.0	0.00040	0.03180
	Row	5	31.4	7.1	7926.0	0.00010	0.01580
	Treat.[c]	5	45.5	1.5	8026.4*	0.00200**	0.02360
	Error A	20	22.9	2.5	2851.3	0.00032	0.00901
1970	Col.	5	173.7	50.6	60092.7	0.00050	0.01240
	Row	5	88.1	5.5	18790.9	0.00060	0.00570
	Treat.	5	40.7	3.6	4581.0	0.00030	0.03690**
	Error B	20	19.1	1.4	3515.5	0.00036	0.01033
Com-bined	Col.	5	48.2	127.8	31829.4	0.00020	0.02840
	Row	5	43.8	2.3	7595.1	0.00020	0.00460
	Treat.	5	70.7*	3.7	9499.3*	0.00150*	0.04280*
	Error C	20	22.1	1.2	3084.0	0.00042	0.01220
	Years	1	24.5	393.3**	89923.9**	0.06000**	0.41860**
	Col. x Years	5	289.8	7.1	34548.2	0.00060	0.01580
	Row x Years	5	75.7	10.4	19121.7	0.00050	0.01700
	Treat. x Years	5	15.5	1.4	3108.2	0.00080*	0.01770
	Error D	20	19.9	2.7	3282.8	0.00027	0.00700

[a]Fiber characteristics not included did not show significant treatment differences at the 0.05 level of probability.

[b]Column

[c]Treatment

*Significant at the 0.05 level of probability.

**Significant at the 0.05 level of probability.

EAST

NORTH

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
	Column Row Treatment	Column Row Treatment	Column Row Treatment	Column Row Treatment	Column Row Treatment	Column Row Treatment
Row 1	1 1 1	2 1 2	3 1 3	4 1 4	5 1 5	6 1 6
Row 2	1 2 5	2 2 6	3 2 4	4 2 1	5 2 2	6 2 3
Row 3	1 3 2	2 3 1	3 3 5	4 3 3	5 3 6	6 3 4
Row 4	1 4 3	2 4 4	3 4 6	4 4 2	5 4 1	6 4 5
Row 5	1 5 4	2 5 5	3 5 2	4 5 6	5 5 3	6 5 1
Row 6	1 6 6	2 6 3	3 6 1	4 6 5	5 6 4	6 6 2

SOUTH

WEST

Treatment Number

1 - Corn

2 - Soybean

3 - Alfalfa

4 - Peanut

5 - Check

6 - Sorghum

Figure 1. Test Plot Diagram.

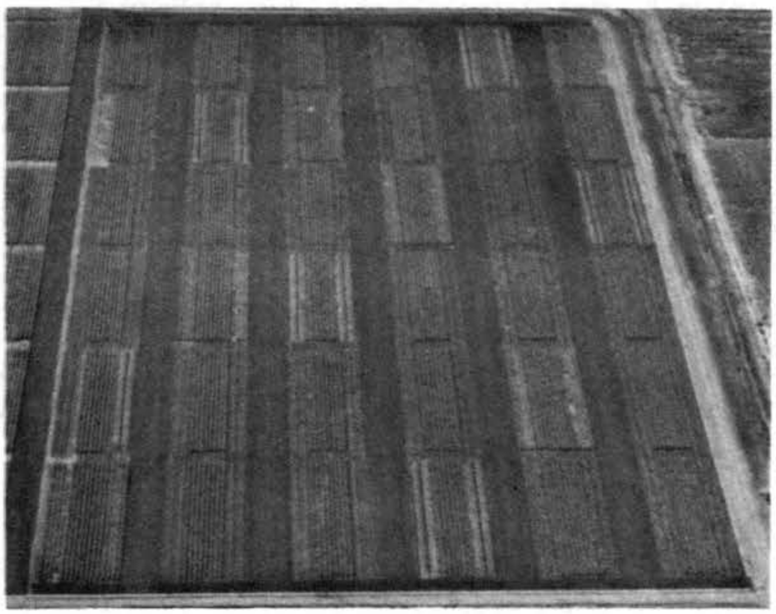

Figure 2. Aerial Photograph of Test Plots.

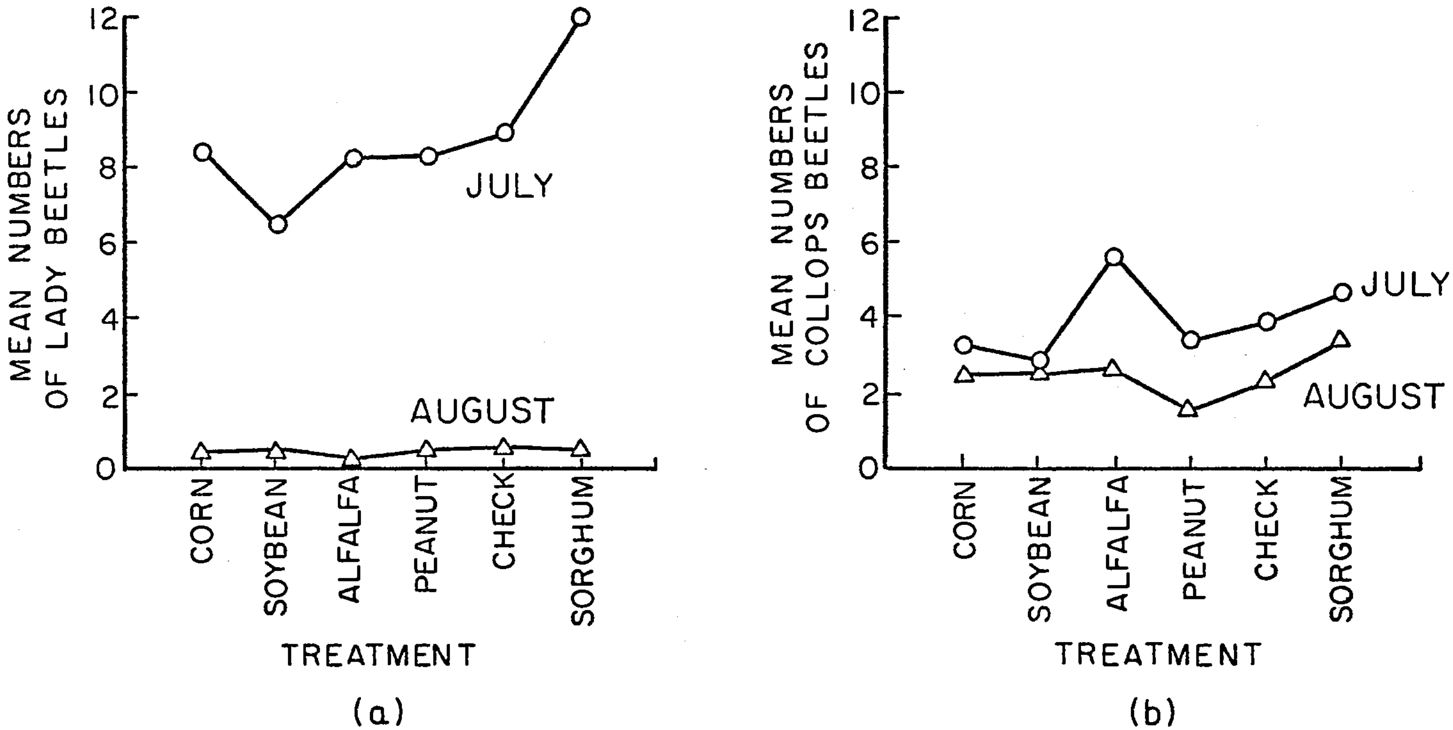

Figure 3. Mean Numbers of Lady Beetles and Collops Beetles Collected from 360 Feet of Cotton Row in Each Treatment in July and August of 1969 and 1970.

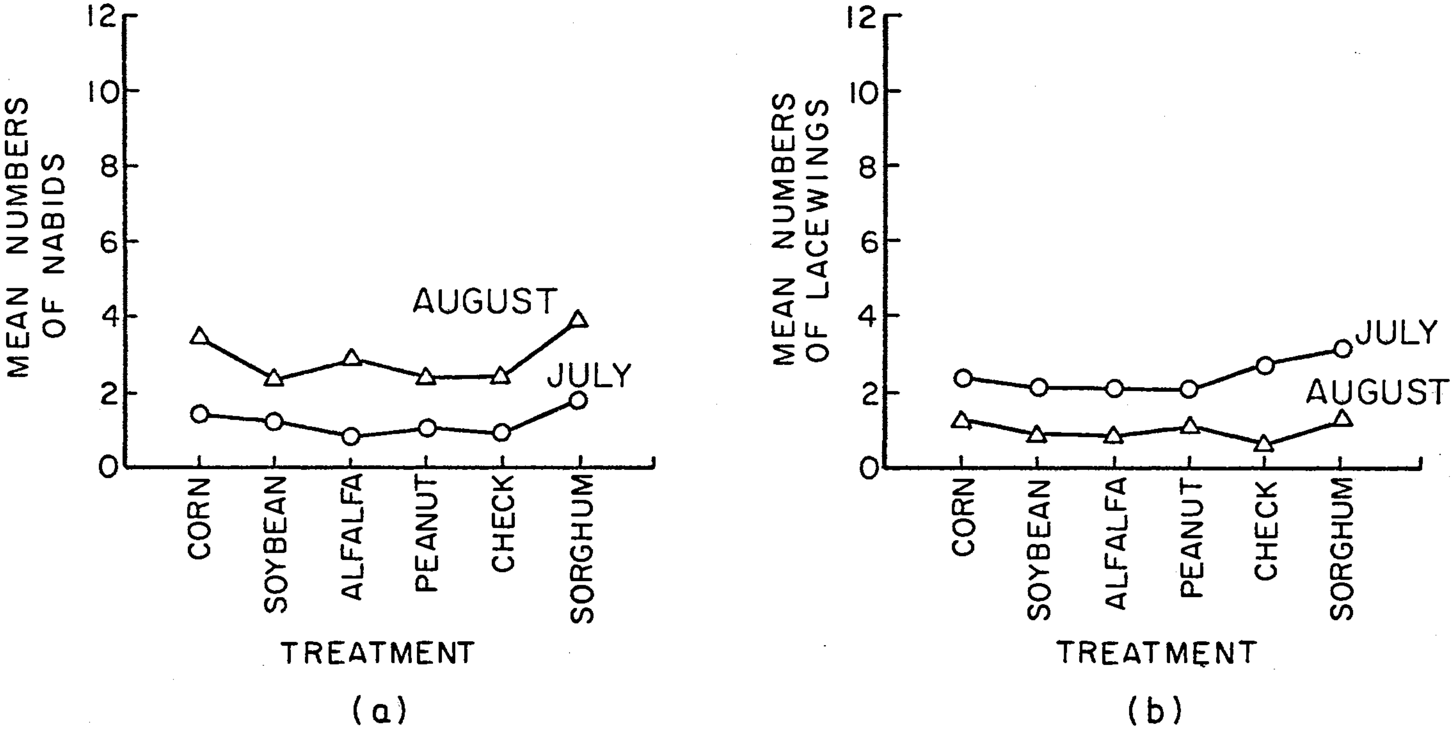

Figure 4. Mean Numbers of Lacewings and Nabids Collected from 360 Feet of Cotton Row in Each Treatment in July and August of 1969 and 1970.

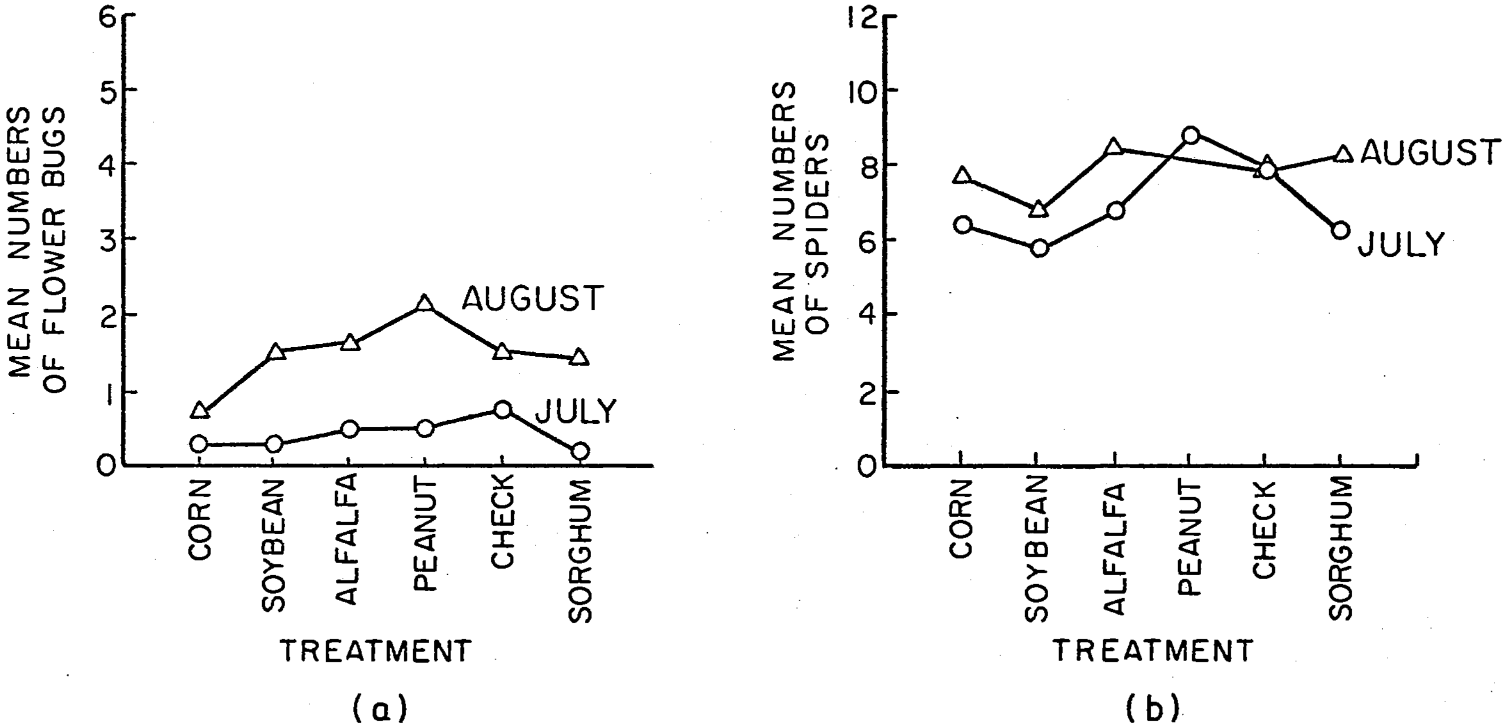

Figure 5. Mean Numbers of Flower Bugs and Spiders Collected from 360 Feet of Cotton Row in Each Treatment in July and August of 1969 and 1970.

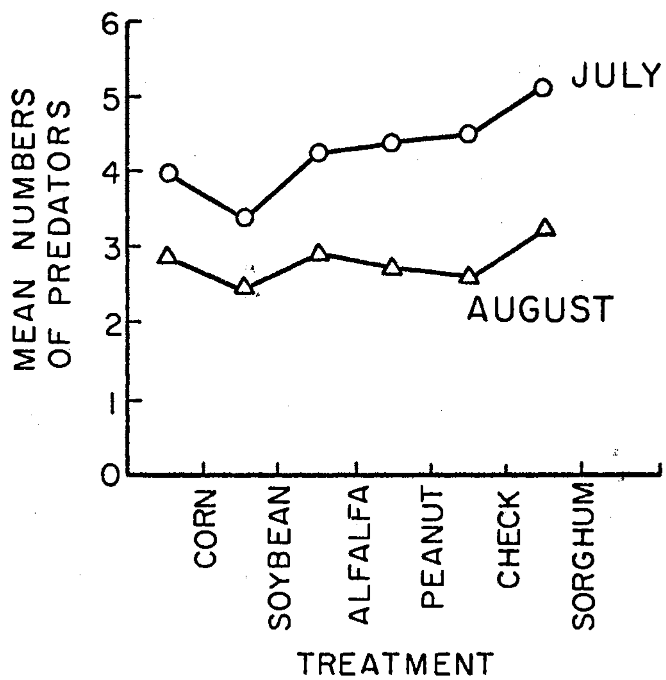

Figure 6. Mean Numbers of All Predators Collected from 360 Feet of Cotton Row in Each Treatment in July and August of 1969 and 1970.

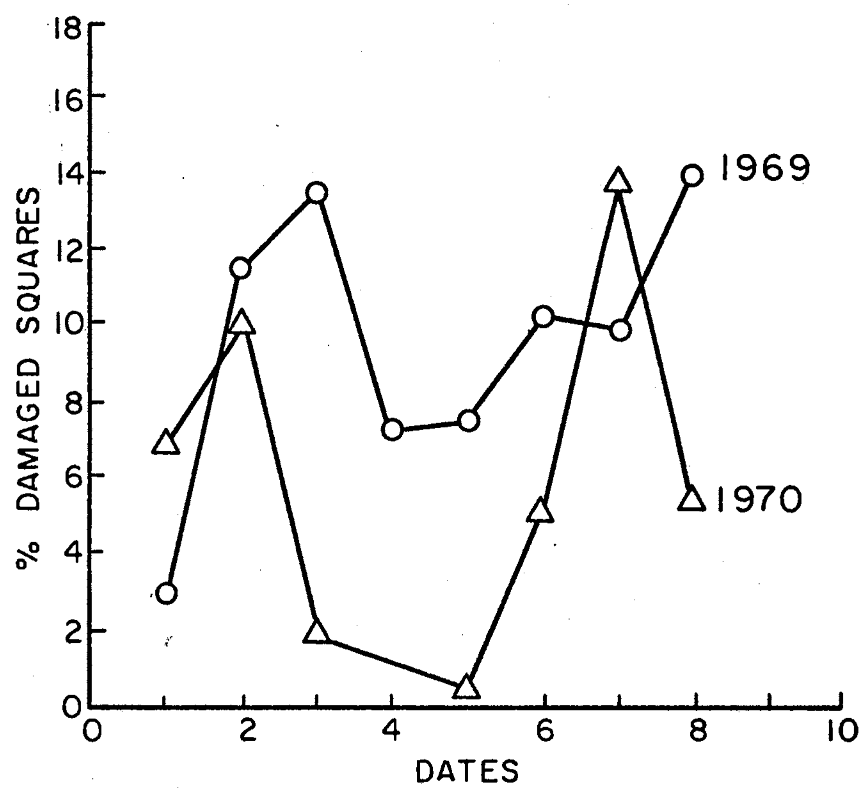

Figure 7. Mean Percentages of Damaged Cotton Squares from All Treatments for Each Date in 1969 and 1970.

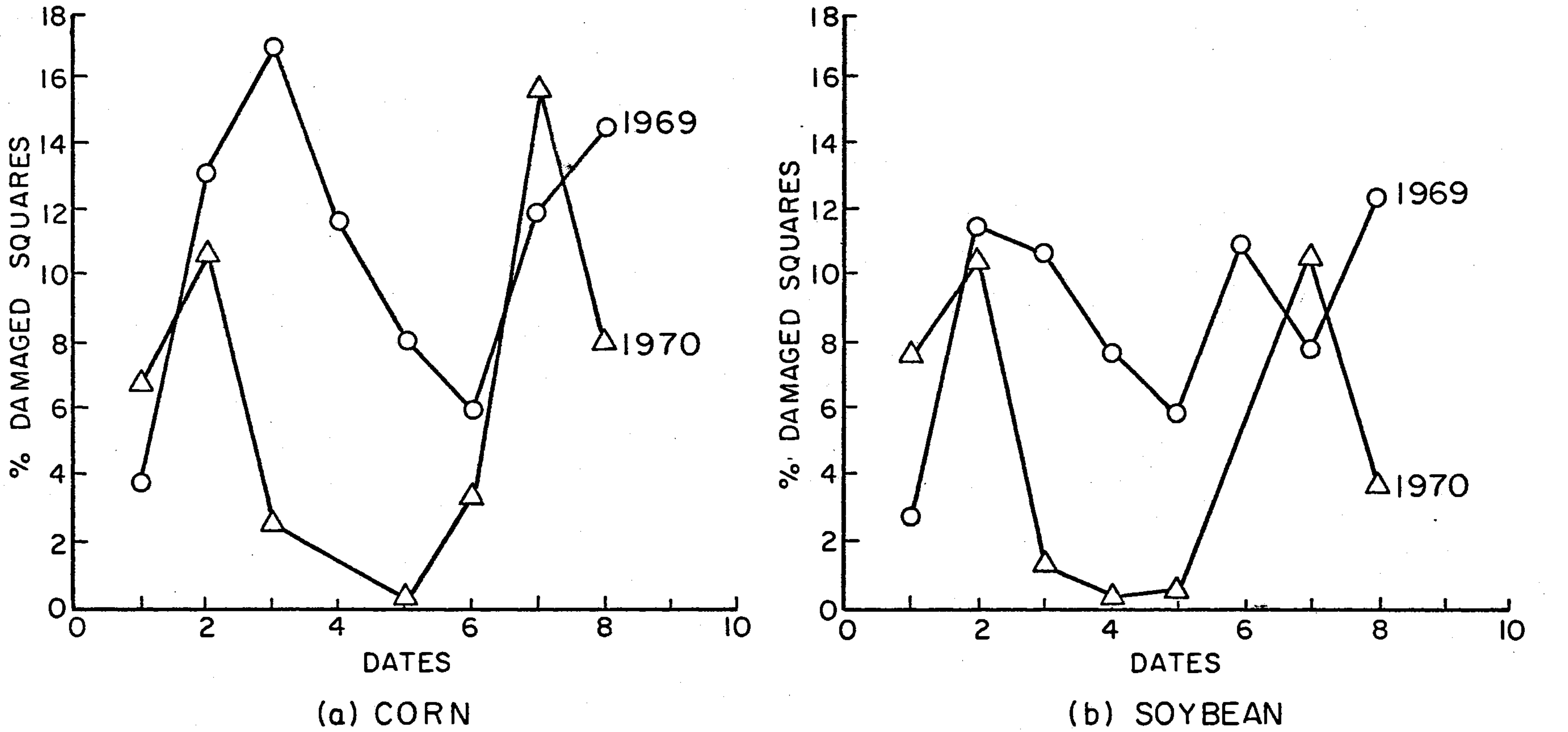

Figure 8. Mean Percentages of Damaged Cotton Squares from the Corn and Soybean Treatments for Each Date in 1969 and 1970.

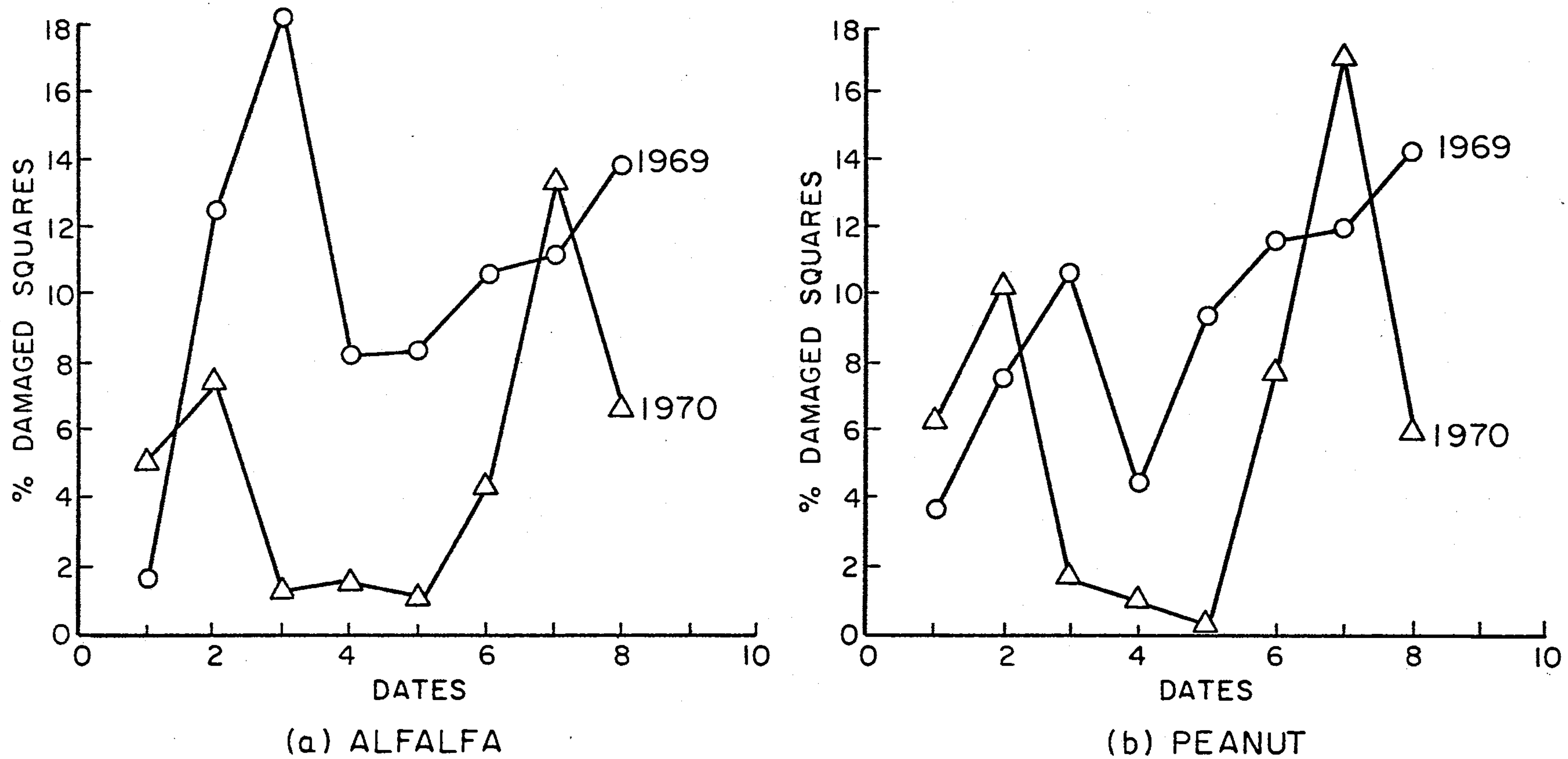

Figure 9. Mean Percentages of Damaged Cotton Squares from the Alfalfa and Peanut Treatments for Each Date in 1969 and 1970.

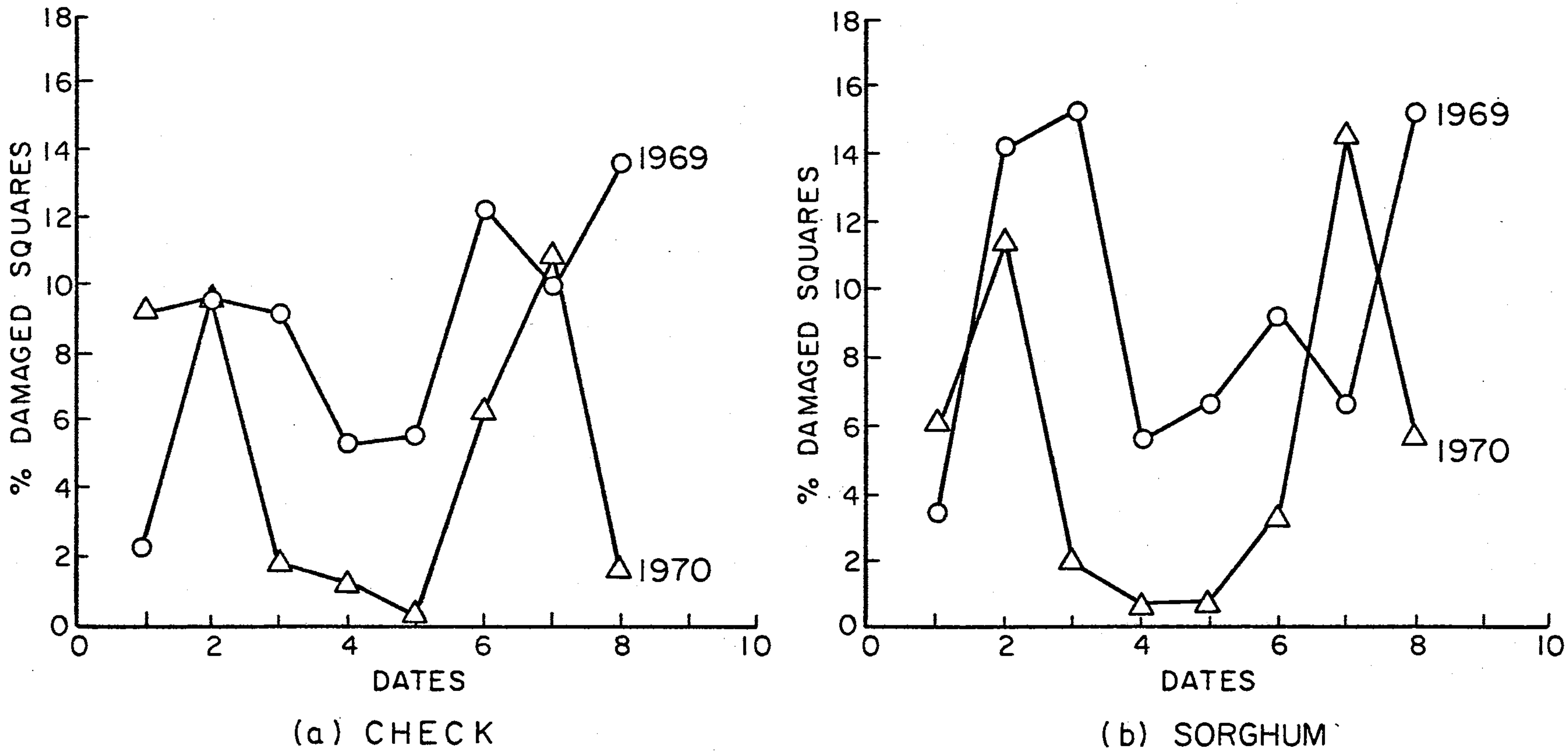

Figure 10. Mean Percentages of Damaged Cotton Squares from the Check and Sorghum Treatments for Each Date in 1969 and 1970.

VITA

Robert Ray Robinson

Candidate for the Degree of

Doctor of Philosophy

Thesis: EFFECTS OF STRIP CROPPING COTTON AND OTHER FIELD CROPS ON THE ABUNDANCE OF PREDATORY AND INJURIOUS INSECTS IN COTTON IN RELATION TO DAMAGE, YIELD, AND LINT QUALITY

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