

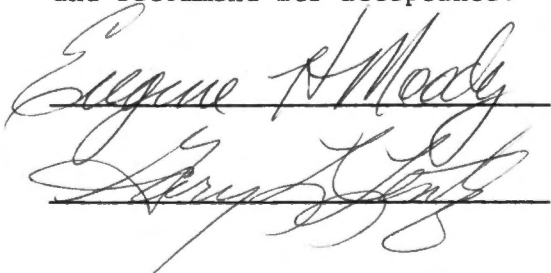
To the Graduate Council:

I am submitting herewith a thesis written by James Walton Mullins entitled "Boll Weevil (Anthonomus grandis: Curculionidae) and Bracon mellitor (Braconidae) Emergence from Cotton Squares." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Biology.



Charles D. Pless, Major Professor

We have read this thesis
and recommend its acceptance:



Accepted for the Council:



Vice Chancellor
Graduate Studies and Research

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BOLL WEEVIL (ANTHONOMUS GRANDIS: CURCULIONIDAE) AND
BRACON MELLITOR (BRACONIDAE) EMERGENCE
FROM COTTON SQUARES

A Thesis
Presented for the
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Degree
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James Walton Mullins

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ABSTRACT

First and second generation peak emergence periods of the boll weevil, Anthonomus grandis Boheman, occurred at two of the test fields. One field had a gradual build-up of weevils with no distinct peak periods of emergence. Although peak periods of emergence occurred, emergence occurring between these periods was sufficient to produce economically damaging numbers.

Weevils began to emerge 24-28 days after the initiation of squaring and 0-10 days after the appearance of the first blooms. First generation peaks occurred about one month after initiation of squaring. Second generation peaks occurred 50-55 days after initiation of squaring.

Air temperature and rainfall up to 15 days prior to emergence was only slightly correlated with the number of weevils emerging each day.

Percentages of fallen squares producing weevils were generally highest when the rate of square production was highest. Generally, 1/3 to 1/2 of the fallen squares collected yielded weevils during the first six weeks of squaring.

The largest number of the wasp, Bracon mellitor, was noted to emerge just prior to the major emergence of the second generation boll weevils.

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CHAPTER I

INTRODUCTION

The boll weevil, Anthonomus grandis Boheman, is the number one pest of cotton in the United States. It causes an annual loss of \$200 million or more due to yield reductions and an additional \$75 million for suppression cost. Approximately one third of all insecticides applied to crops in the United States are used to combat this pest (Cross, 1973). The boll weevil inhabits most of the cotton growing areas in the United States including West Tennessee.

To protect the cotton crop from insects at minimal costs, pest management programs must be designed such that the boll weevil can be reasonably suppressed with as few insecticide applications as possible. With a reduction of chemical applications, environmental contamination and establishment of secondary pests would become less significant problems. Reduction in the number of insecticide applications to attain adequate boll weevil suppression would require a knowledge of population dynamics, particularly the emergence pattern of the adult. With this knowledge, control programs could be coordinated with peak emergences of the adult weevils.

Little direct evidence has been presented by researchers to indicate if population increases, due to weevil emergence, occur by gradual, constant increases, or by sudden, sporadic increases. If large, sporadic increases in the field population occur due to weevil emergence, and if these peak periods of emergence could be determined

or predicted, control methods could be concentrated at these times. Therefore, the main objectives of this study were to determine boll weevil emergence patterns, under field conditions, and to determine the relationship between emergence and the initiation of squaring and blooming of cotton. Environmental effects (temperature and precipitation) on emergence were also considered.

As a result of the development of an adequate emergence cage and the acquisition of additional man power, the study was expanded in 1975 to include the determination of the percent of fallen squares from time to time during the season from which adult weevils emerge. Results of this study might prove helpful in predicting approximate numbers of weevils expected to emerge by observing the abundance of fallen squares.

Also recorded in 1975 was the number of emerging boll weevil parasites, Bracon mellitor, from the caged squares. This braconid wasp is the major natural enemy of the boll weevil in some areas. Usually its presence is noted only in abundance late in the cotton growing season, and the natural control afforded by this insect is minimal. Nevertheless, no study of this insect has been made in Tennessee regarding its emergence pattern and its relative seasonal abundance.

CHAPTER II

REVIEW OF LITERATURE

I. BOLL WEEVIL EMERGENCE FROM FALLEN SQUARES

Few studies of the patterns of boll weevil emergence from cotton squares or bolls have been made. Some researchers have suggested that the seasonal emergence pattern of the weevil is characterized by distinct peak periods of emergence. Direct, supportive evidence is lacking. In most cases, the evidence presented was only indirectly related to the actual emergence of the boll weevil in the field.

Fenton and Dunnam (1928) were two of the earliest investigators to recognize that weevil generations can occur in definite peaks. According to Grossman (1930), the first generation weevils normally emerge after the initiation of blooming. He proposed that many of the first eggs laid do not produce weevils because immature stages are killed by the sun prior to the time the cotton plant is large enough to provide sufficient protective shade. If rainy weather prevails early in the season, most of the early eggs will produce weevils. In this case, first generation weevils may emerge generally about the same time that blooming begins.

Calhoun (1930) reported that in order for emergence to occur before the first bloom weevils would have to develop from rather small squares at the time of oviposition. According to Calhoun, weevils normally do not develop in squares this small due to rapid dessication

once the squares are detached from the plant. Yet weevils may emerge three or four days after the first bloom. Some varieties of cotton have a long pre-bloom period which allows first generation weevils to emerge before the initiation of blooming, but ordinarily the numbers of weevils emerging prior to this time are small and do little damage.

According to Metcalf et al. (1962), boll weevil generations in a single season are not distinct because of the irregular emergence of adults from winter hibernation. However, Lincoln et al. (1963) report that the major boll weevil emergence from overwintering sites may occur early, or before the cotton plants begin to square. Early emergence would then result in distinct population peaks for overwintering, first and second generation weevils. Nevertheless, they recognized the possibility of late emergence from overwintering sites in relation to cotton fruiting which may result in a gradual population increase which lacked definite population peaks.

Walker (1962) observed in a Texas cotton field a major emergence of weevils within a few days, followed by an abrupt decline in numbers emerging. Walker and Hanna (1963), in later studies, found by observing fluctuations in the total population of weevils in Texas cotton fields that first generation weevils, in both treated and untreated fields, and second generation weevils, in untreated fields only, appeared to emerge in definite peaks. In most of those fields the greatest number of first generation weevils was observed 32 days after the first 1/3-grown squares had appeared. In one field the

major emergence of first generation weevils occurred only 20 days after the appearance of the first 1/3-grown squares. The early peak emergence was hypothesized to be due to an unusually early, rapid-fruited period in that particular field. Peak F_2 generation emergence occurred in most fields about the same time square production was at its maximum.

To study the population dynamics of the boll weevil, particularly the natural increase in weevil numbers from generation to generation, Walker and Niles (1971) allowed overwintering weevils to oviposit 17-19 days after the appearance of 1/3-grown squares in 1/22-acre plots. All weevils were then hand removed and an application of methyl parathion was made to insure complete removal of overwintered weevils from the plots. Any weevils found after that time were assumed to be first generation weevils. Weevil emergence was noted by observing the plants at one and two day intervals, counting and removing all weevils. Definite peak periods of the emergence of first generation weevils were observed in this study.

Using wing traps to measure weevil movement from field to field, Roach et al. (1971) observed two peak periods of capture which they postulated to represent the peak periods of emergence of the first and second generation weevils. Hopkins et al. (1971) proposed that major peak periods of weevil captures with flight screens coincided with the peak emergence of specific generations.

II. BRACON MELLITOR BIOLOGY AND SEASONAL ABUNDANCE

Bracon mellitor was first named and described by Thomas Say (1836). This braconid wasp is known to parasitize about 40 host species, primarily of the orders Lepidoptera and Coleoptera. This insect is distributed throughout the entire United States (Adams et al., 1969). Bracon mellitor, in some cotton growing areas, is the major natural enemy of the cotton boll weevil (E. T. Cherry, Ciba-Geigy Corp., Greensboro, North Carolina, Personal Communication).

The adult female is equipped with a long ovipositor which is able to pierce the outer layers of a weevil-infested square to locate and paralyze the boll weevil larva. Usually a single egg is deposited on the paralyzed larva. The egg hatches in one or two days and the parasitic larva feeds on the boll weevil larva. Two to three days later the larva spins a cocoon and about three to four days later develops into a pupa. It remains in the pupal stage for two to three days before it emerges from the square as an adult. The entire developmental period requires about 10 days (Fenton and Dunnam, 1929), and the entire life cycle ranges from two to three weeks (Miller and Crisfield, 1930; Folsom, 1936; Adams et al., 1969). Several generations can occur in one season.

Fenton and Dunnam (1929) reported that females will not oviposit in weevil-infested squares after they have fallen from the plant and are on the ground. Folsom (1936) contradictorally reported that females will oviposit in squares both on the plant and on the ground.

Generally this insect is present in cotton fields throughout the cotton growing season, but only in relative abundance with the boll weevil. Miller and Crisfield (1930) found populations of Bracon mellitor continuously from June until September in Georgia cotton fields. Adams et al. (1969) found that natural incidence of Bracon mellitor varied in Mississippi from field to field and month to month, and that parasitism ranged from 0-25% of weevil-infested squares. The possibility of mass releases for periodic control of the boll weevil has been recognized, but natural control of the weevil by these parasites is probably insignificant.

CHAPTER III

BOLL WEEVIL LIFE HISTORY

The boll weevil overwinters as a diapausing adult in the ground litter of wooded areas near previously infested cotton fields. Overwintered weevils emerge during late spring and early summer. Davis et al. (1967) found that, in Texas, 96% of the overwintered weevils emerged and entered cotton fields by June 15. Once in the field, the weevils begin feeding on the terminal portions of the young cotton plant.

When the plants begin to fruit the adult feeds on the floral buds (squares). The adult female, having mated, normally deposits her eggs among the anthers of the bud through the flask shaped feeding puncture made by her long, slender proboscis. The female usually deposits only one egg per square and plugs the oviposition puncture with frass. When squares become scarce the weevil feeds and oviposits in bolls, but squares are preferred.

Eggs hatch in two to four days and the larvae begin feeding. Five to nine days after an egg has been deposited in a square, the square abscises from the plant and falls to the ground. The larva continues its development inside the fallen square, molting two to three times, until it pupates and emerges from the square as an adult (Hunder and Pierce, 1912).

The emerging weevil escapes from a square or boll by cutting with its mandibles an escape hole about the size of its body. Just

after emergence, the weevil is comparatively soft and has an orange tinge which makes it readily distinguishable from older adults. After a day or two of feeding, the weevil's cuticle begins to harden and turn dark brown (Hunter and Hinds, 1905).

The entire developmental period from egg to adult varies according to existing temperatures (Fye et al., 1969), but normally requires from 2-1/2 to 3-1/2 weeks. Several generations can occur during one season.

During the end of the summer and early fall some adult weevils begin to accumulate reserves of body fat and enter a state of facultative diapause. At the onset of diapause, weevils leave the field and fly to a suitable winter shelter where they remain dormant until the following spring or summer (Metcalf et al., 1962).

CHAPTER IV

MATERIALS AND METHODS

Boll weevil emergence studies were conducted during 1974 and 1975 in cotton fields on the West Tennessee Experiment Station and on the Ames Plantation near Grand Junction, Tennessee. Each field was planted with Hancock variety cotton except the Jackson field in 1975 and where DPL 25 (Delta and Pine Land) variety was planted. All fields were located less than 1/10 mile from other cotton fields.

Planting dates and field size were as follows:

Ames 1974	May 1	140' x 500' (0.80 acre)
WTES 1974	May 17	100' x 500' (1.50 acre)
Ames 1975	May 13	65' x 300' (0.43 acre)
WTES 1975	May 2	100' x 450' (0.98 acre)

Natural populations of weevils were allowed to infest each field. The dates for initiation of squaring and blooming in each field were recorded. The number of squares per acre and infestation levels (percent damaged squares) were recorded periodically until the infestation level reached almost 100%. Infestation levels were determined by inspecting 50 squares picked randomly throughout each field for boll weevil oviposition and feeding damage. The number of squares per acre was determined by examining two 25-foot sections of cotton row randomly selected in each field.

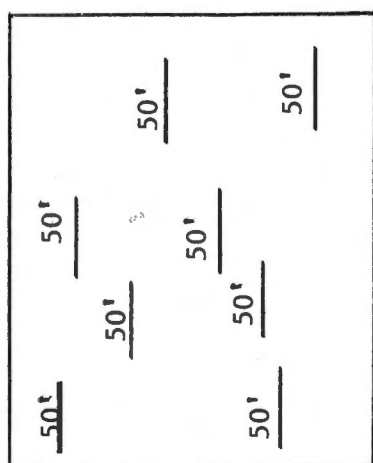
After squares began to fall from the plants, all fallen squares lying between two rows in designated sample areas for each plot were

collected two times per week and placed immediately into emergence cages specified for each day's collection. Consequently, every square that fell during the season in these sample areas was removed and put into an emergence cage. In 1975 all squares collected were counted. To insure adequate representation for each field, two criteria were used in selecting sample areas: uniformity of stand, and field size and shape. The number, size and total length of sample areas (Figure 1) for each field were:

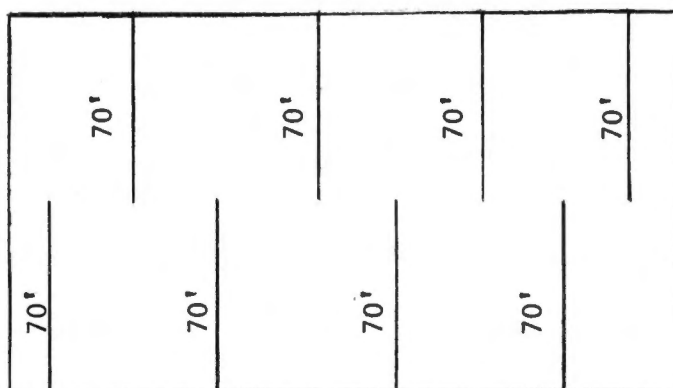
Ames 1974	Eight 50 ft. sections	(400 row ft. total)
WTES 1974	Eight 70 ft. sections	(560 row ft. total)
Ames 1975	Two 250 ft. sections	(500 row ft. total)
WTES 1975	Five 100 ft. sections	(500 row ft. total)

Initially, fallen squares collected from the sample area were placed into a 3 x 3 x 5-ft. tent-like, cloth screen cage (Figure 2) supported by four 3-ft stakes. Squares were placed into the cage through a zipper opening. The base of the cage was flared so that soil could be placed around the bottom anchoring it to the ground. The cages were placed between two rows of cotton to insure that the squares placed in the cages remained in nearly natural field conditions. Weevils which emerged from the squares inside the cages were collected, counted, and released back into the field.

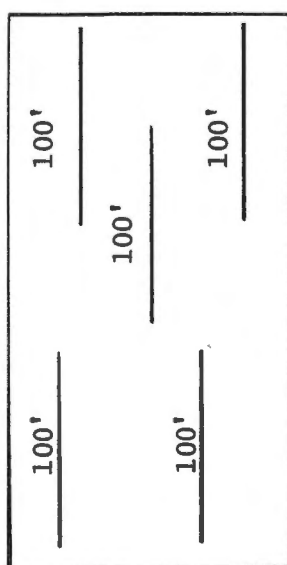
Because weevil collection from these cages became very tedious and time consuming, another form of emergence cage was designed to make weevil collection easier. A conical emergence cage (Figure 3) was constructed from fine gauge galvanized screen wire. The cage



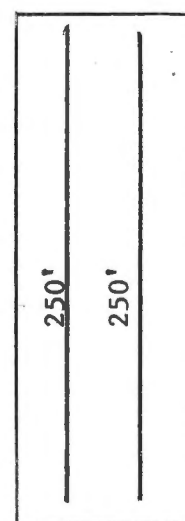
Jackson 1974



Ames 1974



Jackson 1975



Ames 1975

Figure 1. Unscaled representation of the shape of each test field and general location of respective sample areas.



Figure 2. Cloth screen cage used initially to trap emerging adult boll weevils from cotton squares.



Figure 3. The conical boll weevil emergence cage situated between two rows of cotton plants.

stood two feet high and had an open base approximately two feet in diameter covering about three square feet of soil surface. A 1/4-inch opening was left at the top of the cone to allow emerged weevils to crawl up the cone and out the small opening into a small plastic snap-top trapping box. The trapping box was prepared by drilling a 3/4-inch radius circular opening in the bottom of a two inch square plastic box. The box was fitted over the top 1-1/2-inch part of the cone and secured to it by melting the plastic around the hole to the screen with an acetylene torch. This type of emergence cage is very similar to the one designed by Polles and Payne (1972) used to capture adult pecan weevils as they emerged from the soil. Because the adult boll weevil exhibits a negative geotropic response, all emerged weevils were expected to crawl to the apex of the cone, out the 1/4-inch opening and into the trapping box. The conical emergence cage concentrated all weevils in a small area such that they were easily counted (Figure 4). The base of the cone was flared and anchored to the ground by placing soil around the base. As with the initial emergence cages, the conical cages were placed between two rows of cotton.

Weevil emergence from each cage was recorded daily except at the Ames field in 1974 where the weevils were counted on Monday, Wednesday, and Friday of every week. Squares were collected from the sample areas until the middle of September. Weevil emergence data were collected until all surviving weevils had apparently emerged from the squares.



Figure 4. Trapping box and method of weevil collection.

An unexpected advantage of the conical emergence cage was that the cage also trapped the emerging boll weevil parasite, Bracon mellitor. Consequently, in 1975, these braconid parasites emerging from each cage were counted daily. The number of Bracon mellitor was recorded and the wasps were released back into the field.

CHAPTER V

RESULTS AND DISCUSSION

I. BOLL WEEVIL EMERGENCE PATTERNS

Boll weevil emergence at Ames in 1974 (Figure 5) and Jackson in 1975 (Figure 6) exhibited distinct peaks most likely representing the major emergence of the first and second generations respectively. In the Ames field in 1975, the number of weevils each day increased gradually up to a point, and the emergence pattern showed no distinct peaks. In the Jackson field in 1974, emergence began significantly later than in the other test fields and greater numbers of weevils were observed to emerge comparatively late with respect to emergence in the other three fields. The complete emergence pattern in this field was not observed.

In 1974, the cotton at Jackson was not planted until nearly a week later than the recommended planting dates for Tennessee. Because of the delayed planting date and an unusually cool month of June (monthly average temperature was 5°F < normal monthly average), the cotton plants experienced a rather later period of fruiting (Figure 7). The rate of early season square production was quite slow and did not significantly increase until the third week in July. As a result of this rather late period of fruiting, emergence of new generations of weevils occurred comparatively later than in the other test fields. Unfortunately, as a result of a heavy rain on August 6, water collected in the alleyways where the emergence

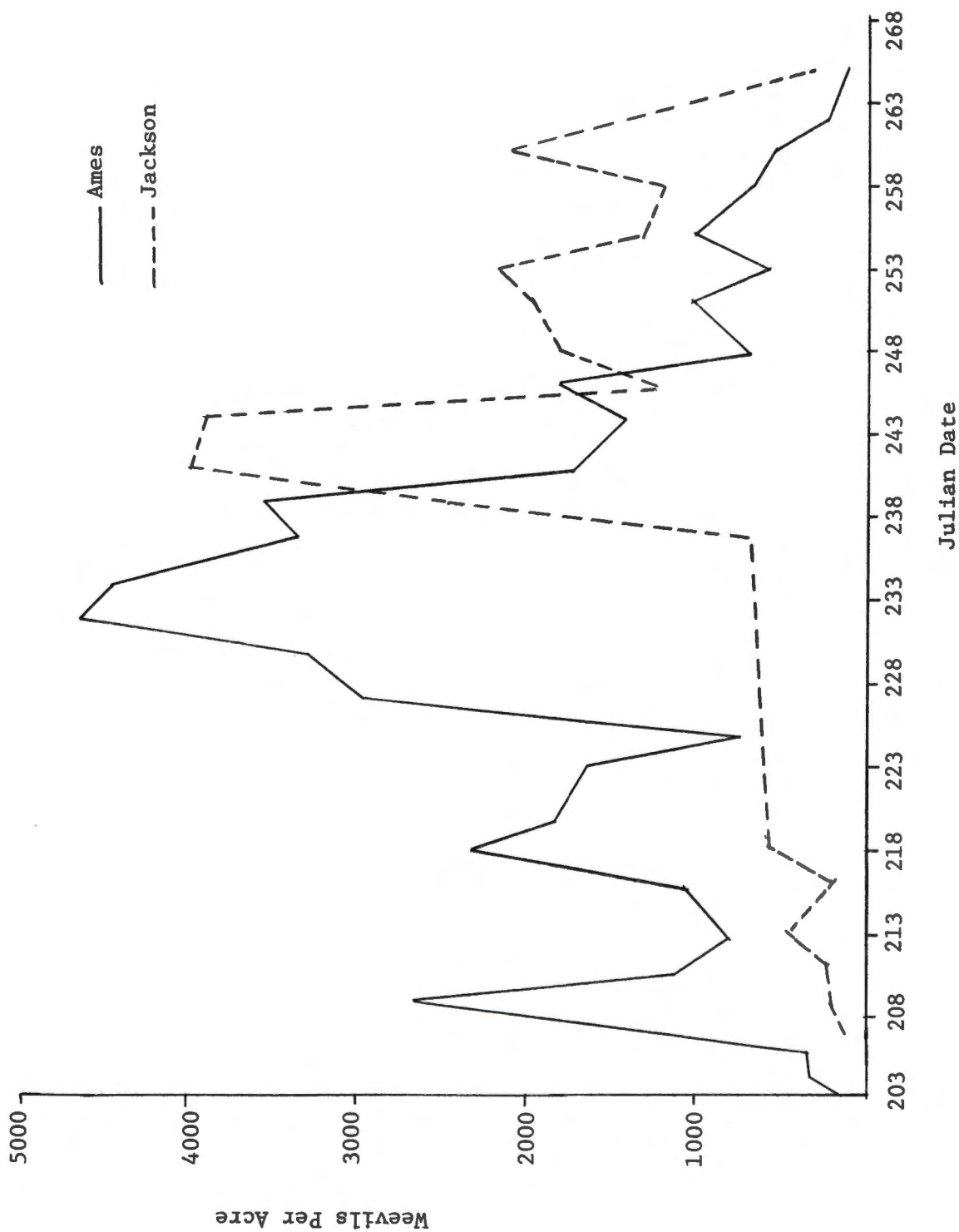


Figure 5. Average daily boll weevil emergence in 1974 derived from two or three day capture periods.

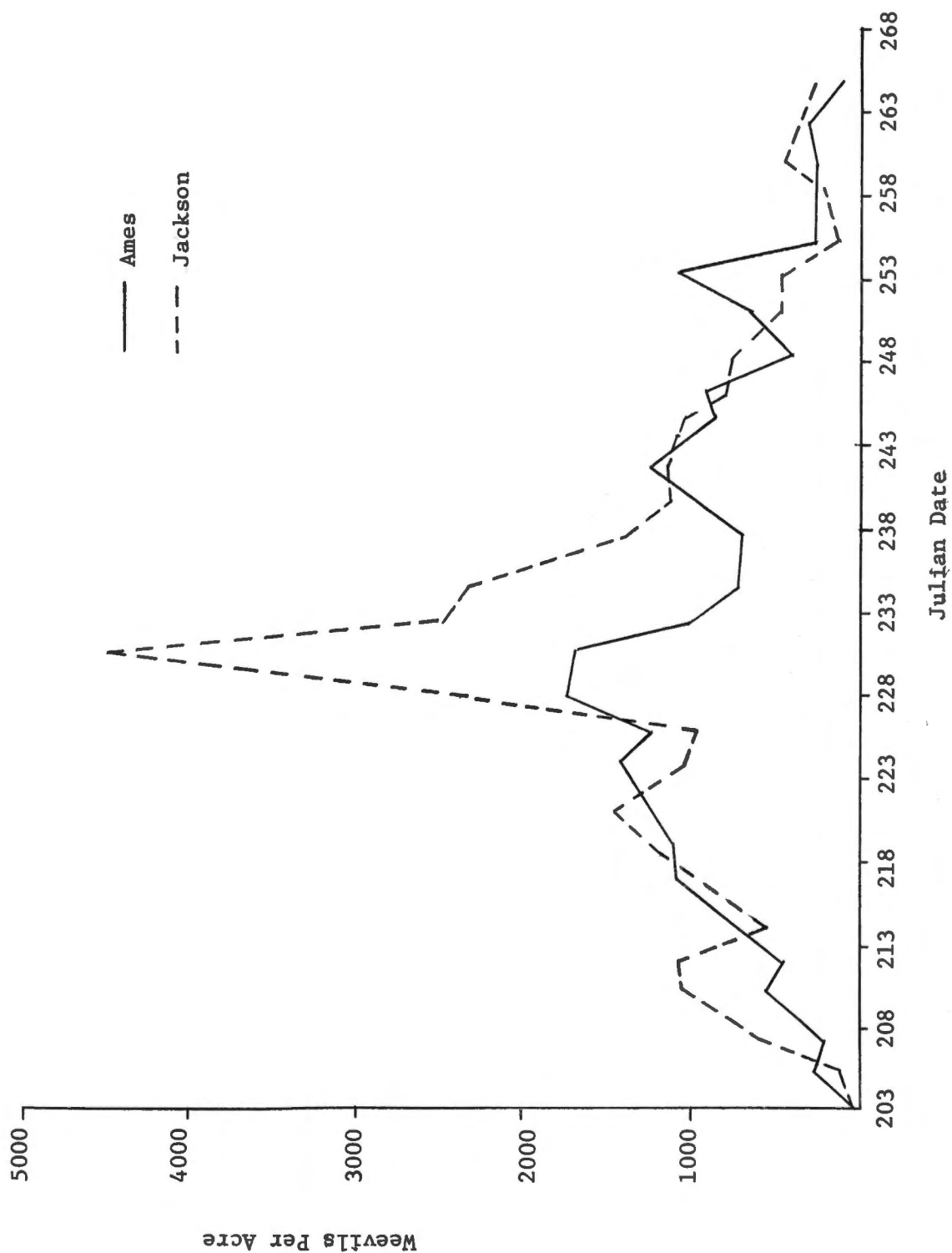


Figure 6. Average daily boll weevil emergence in 1975 derived from two or three day capture periods.

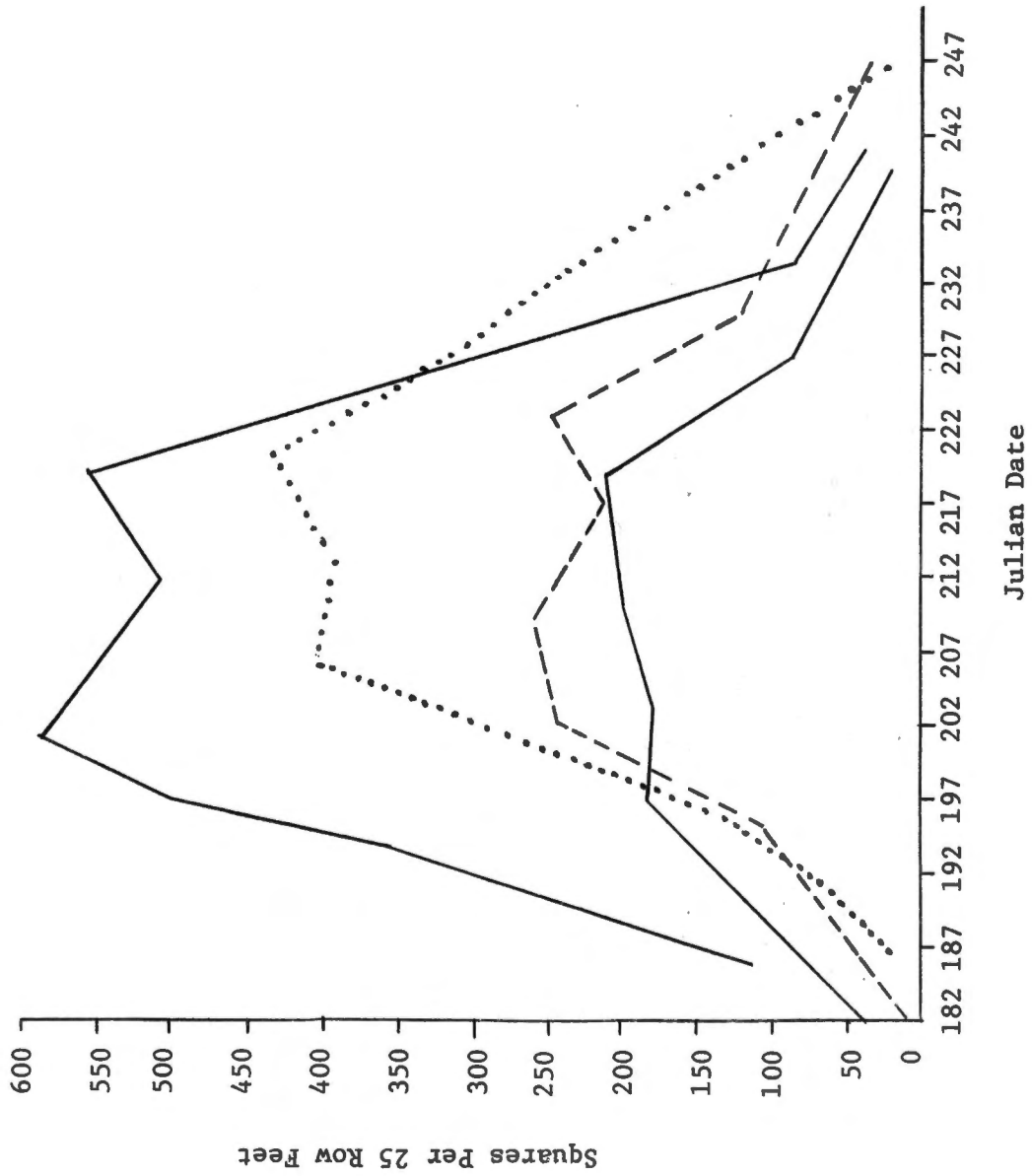


Figure 7. Square production in the four test fields.

cages were located and all immature weevils contained in the emergence cages were drowned; thus, the emergence pattern for the next 20 days could not be reliably determined. With respect to the other fields, weevils were noted to emerge in large numbers comparatively later in the season. This was probably due to the late and highly productive fruiting period.

Three well-defined peaks of emergence were observed at the Ames field in 1974 (Figure 5), the first occurring only six days after emergence began. This peak represents at least a three-fold increase of weevil numbers over the initial overwintering population (2500 overwintering weevils/acre). The second peak must represent a continuation of first generation emergence because insufficient time had passed since the initial first generation emergence to permit full development of F_1 progeny. This peak alone represents a greater than two-fold increase over the initial overwintering population. The third and largest peak was noted approximately 23 days after the first. This peak represents primarily second generation emergence with a continuation of emergence of some overwintered weevil progeny. The overall large number of weevils emerging in this field could be attributed to the unusually large initial overwintering population and the extended prolific square production period by the cotton plant (Figure 7), providing ample oviposition sites.

In 1975 at Jackson, two small first generation peaks and a well-defined second generation peak were observed (Figure 6). The initial first generation peak occurred only five days after emergence in that field began. Because the variance of number of weevils emerging per

day during the period between first two peaks is relatively small, it could be postulated that the differences in actual counts are due to experimental or sampling error; nevertheless, a rather distinct second generation emergence peak was noted approximately 21 days after the initial major emergence (first peak) of the first generation. During this period two to three times as many weevils were emerging per day than on any previous period.

The number of weevils emerging each day at the Ames field in 1975 (Figure 6) increased gradually up to a single peak, with no observable first generation peaks. Although square production was greater in this field than in the Jackson field in 1975, the unusually high infestation level of the bollworm (Heliothes zea) and the tobacco budworm (Heliothes virescens) in that field possibly may have limited the number of available squares for the boll weevil for oviposition. Many squares already containing weevil eggs were probably destroyed by the worms. As a result, fewer boll weevils were produced. Also early season square production was lower compared to the Ames field in 1974 and the Jackson field in 1975. In general, the more searching required for squares by the female weevil, the greater the reduction in egg deposition. Therefore, fewer early season squares necessitated longer searching periods for the female and as a result, fewer eggs were deposited.

Although emergence peaks did occur in two of the test fields, emergence occurring in the periods between these peaks was probably sufficient to produce economically damaging numbers of weevils. In

the three fields that the entire emergence pattern was observed, there were no five consecutive day-periods, between July 28 and September 1, when less than 3,000 weevils per acre emerged. The exact number of weevils that constitutes a threat to cotton yield in Tennessee is undetermined, yet Roach, et al. (1971), found in a study done in South Carolina that 80-90% of all developing cotton fruiting structures were continually destroyed when the population was 2,000 or more per acre. This population number prevented nearly all lint production by the cotton plants. Therefore, from the available evidence it would appear that once an economically damaging population is present, failure to comply with a regular insecticide program at four or five day intervals may result in yield loss.

Normally, the greatest threat to the potential yield of cotton plants is from the feeding and ovipositional activity of the first generation weevils (Walker and Niles, 1971) due to the fact that these weevils normally emerge during the critical period of fruiting. Especially in the more northern sections of the cotton growing areas, the bulk of the yield is dependent on the maturation of the squares set early in the season (Mistic and Covington, 1968). Because of the relatively short season, squares produced later would not have time to mature to open bolls; therefore, it is imperative that the squares produced in the first five or six weeks of square production are protected to insure a good yield. In order to protect these early squares, the emergence of large numbers of first generation weevils should not go unchecked (Grossman, 1930). Presently, in Tennessee,

weekly monitoring of infestation levels of boll weevils in cotton fields is recommended to determine when to initiate insecticide spraying programs. From the emergence patterns derived from the Ames field in 1974 and the Jackson field in 1975, it appears that large numbers of first generation weevils may emerge in a relatively short period of time causing the percent of damaged squares to surpass the economic damage level undetected. Hypothetically, a field could be scouted one day and a sub-economic damage level observed. Yet, a recent peak emergence of first generation weevils could have occurred, but because weevils normally do not feed or oviposit in squares for three or four days after emergence, little damage has been done. One week would pass before the next time the field would be scouted. During this week, the presently large numbers of first generation weevils could do considerable damage and quite possibly cause the infestation level to exceed the economic damage level.

Data from The University of Tennessee Extension cotton scouting reports, which listed weekly boll weevil infestation levels for several cotton fields in Madison County in 1975, showed that in one particular week (July 28-August 3) more than one-half of all the fields scouted showed economically significant increases in infestation levels of 10% or more over the previous week's infestation level (Table I). This particular week coincided precisely with the period of the initial first generation peak emergence occurring in the Jackson field in 1975 (Figure 6). Recognizing the problem of failure to detect significant numbers of first generation weevils

Table I. Weekly increases in infestation levels for several Madison County cotton fields in 1975.

Week Cotton Scouted	Total Number of Fields Scouted	Number of Fields Experiencing Increases in Infestation Levels Over Previous Week			
		Damage Level Difference			Total 10% or More **
		10-19%*	20-29%*	30% or more	
7/7-7/13	32	6	0	0	6
7/14-7/20	41	0	0	0	0
7/21-7/27	47	3	0	0	3
7/28-8/3	46	15	4	6	25
8/4-8/10	46	2	1	0	3
8/11-8/17	47	5	3	4	12
8/18-8/24	43	13	4	1	18
8/25-8/31	32	2	1	1	4

* Infestation levels are reported as the percent of boll weevil damaged squares. Therefore, the percent here does not indicate a percent of change, but rather the absolute difference in the percent of damaged squares from one week to the next.

** The 10% difference in damage levels was considered economically significant because the economic threshold for boll weevil damage to cotton squares in Tennessee has been established as 10%.

and making applications too late before a considerable amount of squares are punctured, it would seem advantageous to recommend monitoring infestation levels twice a week rather than once a week until the spraying program has been initiated.

Once the population level of weevils that constitutes an economic threat to cotton yield is determined, the conical emergence cage may be used to determine when this population level is reached. Consequently, treatment decisions could be made based on actual numbers of weevils rather than the amount of damage already incurred.

II. RELATION OF EMERGENCE TO THE INITIATION OF SQUARING AND BLOOMING

First generation weevils began to emerge approximately 3-1/2 weeks after the initiation of squaring and about the same time or up to 10 days after the appearance of the first bloom (Table II). The first major first generation peak emergence periods in the fields, where peaks were observed (Ames, 1974; Jackson, 1975), occurred approximately one week after the weevils began emerging or about one month after the initiation of squaring. Because the initial rate of square production is low the first 10 days, intraspecific competition for available squares for oviposition caused the weevils to oviposit in squares too small to allow for proper development of the progeny. Those squares that did reach a suitable size were often repeatedly punctured and damaged to the extent that no weevils could develop in the squares. Therefore, few weevils emerged from squares punctured the first 10 days of squaring. As the rate of square

Table II. Temporal relation of boll weevil emergence to the initiation of squaring and blooming.

	JACKSON 1974		AMES 1974		JACKSON 1975		AMES 1975	
	Days After First: Square	First: Bloom	Days After First: Square	First: Bloom	Days After First: Square	First: Bloom	Days After First: Square	First: Bloom
First Emergence	24	7	24	10	28	1	26	1
Initial F ₂ Generation Emergence Peak	No Peak Observed	No Peak Observed	30	16	34	6	No Peak Observed	No Peak Observed
F ₂ Emergence Peak	No Peak Observed	No Peak Observed	53	39	55	27	50	25

production increased, more squares of suitable size became available to the overwintered weevils. Given about an 18-day early season developmental period (Lambert, 1975), first generation weevils should be expected to emerge in noticeably larger numbers 28 days after the appearance of the first square; thus, as the rate of daily square production increased, so did the resulting number of boll weevil progeny, following an 18-day lag. The rate of squaring was much more gradual in the Ames field in 1975 than in the Ames 1974 and Jackson 1975 fields. This could be the reason the daily number of weevils emerging increased gradually with no distinct first generation peaks.

The second generation peak periods of emergence occurred 50-55 days after the initiation of squaring. These second generation peaks are partly the result of the surviving overwintered weevils' continued oviposition, but are primarily the result of the increased ovipositional activity due to the sudden presence of large numbers of first generation weevils. Weevils emerging in late July or early August in Tennessee have a preoviposition period of about three days. Eggs deposited in squares during this time require about 21 days to develop into adults (Lambert, 1975). Therefore, a second generation peak, hypothetically, should occur about 24 days after the first generation peak. The first and second generation peaks of the Ames field in 1974 and the Jackson field in 1975 occurred 23 and 21 days apart, respectively.

III. EFFECT OF TEMPERATURE AND RAINFALL ON EMERGENCE

A time-series statistical analysis correlating daily maximum and minimum air temperatures and precipitation with the number of weevils emerging daily was conducted from the Ames and Jackson 1975 data (Tables III-V). Each day of emergence was correlated with the existing temperature and rainfall. In order to determine any lagging effect that temperature or rainfall had on emergence, temperature and precipitation up to 15 days prior to each day of emergence was correlated with the number of weevils emerging daily. If significant relationships do exist, predictive models could be made.

Precipitation and emergence were not significantly correlated (Table III). Although a slight correlation appears between emergence at Jackson and precipitation 14 and 15 days prior to the date of emergence, the correlation is so small it has no practical value for use in predictive models.

Correlation coefficients for temperature and emergence (Tables IV and V) were, for the most part, higher than the coefficients for precipitation and emergence. Nevertheless, these values were still too small to be of any practical value for predictive purposes. Because temperature was correlated with itself, i.e., temperatures on two successive days were normally about the same, and because the weevil count one day tended to be about the same as the weevil count the next day, the correlation coefficients for successive day lags were about the same.

Table III. Correlations between daily precipitation with 0-15 day lags and the number of weevils emerging per day.

Number of Day Lags	Cross Correlation	
	AMES, 1975	JACKSON, 1975
0	0.146	-0.096
1	-0.027	-0.147
2	0.090	-0.069
3	0.016	-0.034
4	0.001	-0.071
5	-0.036	-0.024
6	0.014	-0.063
7	-0.030	-0.075
8	0.064	-0.010
9	0.069	-0.004
10	-0.091	-0.083
11	0.069	-0.060
12	0.087	0.068
13	0.112	0.146
14	0.088	0.330
15	0.074	0.344

Table IV. Correlations between daily maximum air temperatures with 0-15 day lags and the number of weevils emerging per day.

Number of Day Lags	Cross Correlation	
	AMES, 1975	JACKSON, 1975
0	0.409	0.374
1	0.379	0.351
2	0.337	0.327
3	0.308	0.333
4	0.297	0.329
5	0.316	0.300
6	0.276	0.269
7	0.198	0.214
8	0.153	0.151
9	0.106	0.107
10	0.110	0.092
11	0.076	0.070
12	0.098	0.028
13	0.115	-0.025
14	0.061	-0.062
15	0.079	-0.072

Table V. Correlations between daily minimum air temperatures with 0-15 day lags and the number of weevils emerging per day.

Number of Day Lags	Cross Correlation	
	AMES, 1975	JACKSON, 1975
0	0.440	0.385
1	0.442	0.387
2	0.391	0.372
3	0.375	0.361
4	0.346	0.365
5	0.339	0.359
6	0.314	0.315
7	0.264	0.267
8	0.244	0.204
9	0.232	0.159
10	0.210	0.115
11	0.204	0.083
12	0.203	0.073
13	0.222	0.067
14	0.233	0.072
15	0.253	0.097

Temperature and rainfall undoubtedly affect the time and degree of emergence to an extent, but predictions regarding only temperature and rainfall would probably not be very useful. Predictive models would be reliable only if all other factors affecting emergence such as photoperiod, substrate availability, oviposition rates, physiology of the insect, and so forth, were considered.

IV. PERCENT OF FALLEN SQUARES PRODUCING WEEVILS

In both test fields the percent of squares producing weevils (Tables VI and VII) was quite variable, ranging from 2.68 to 64.67%. Cotton tends to fruit slowly the first 10 days or so of the squaring period and boll weevils are often forced to oviposit, often repeatedly, in squares too small for successful weevil development to occur. This, in part, is responsible for the low percentages derived early in the season.

Generally, much higher percentages were noted from mid-July to mid-August. During this period, percentages ranged from 22.51 to 64.67%. As the infestation level increased in July, so did the percentage of squares producing weevils. By mid-July ample oviposition sites were available to the weevils due to the increased rate of squaring. As the level of infestation rose, more squares that would have been shed as a result of stress other than boll weevil ovipositional damage were probably utilized by the weevil for oviposition. Once the field became saturated, with infestation levels of 95% or more, the percentage of squares producing weevils began to drop again.

Table VI. Percentage of fallen squares yielding adult boll weevils at Jackson in 1975.

Date Squares Collected	Number of Fallen Squares	Total Number of Emerged Weevils	Percentage of Squares Yielding Weevils
7/9	115	10	8.69
7/15	260	44	16.92
7/18	167	108	64.67
7/22	264	132	50.00
7/25	521	175	33.59
7/29	415	184	44.34
8/4	903	259	28.68
8/8	794	473	59.57
8/13	1385	442	31.91
8/15	--	170	--
8/19	971	199	20.49
8/22	708	74	10.45
8/26	1026	136	13.26
9/2	951	121	12.72
9/9	669	101	15.10

Average for squares collected in July: 36.37%.

Average for squares collected in August: 31.63%.

Average for July and first two weeks of August (peak squaring period): 37.54%.

Average for remainder of season: 14.40%.

Table VII. Percentage of fallen squares yielding adult boll weevils at Ames in 1975.

Date Squares Collected	Number of Fallen Squares	Total Number of Emerged Weevils	Percentage of Squares Yielding Weevils
7/14	115	35	30.43
7/17	82	22	26.83
7/21	207	82	39.61
7/24	205	85	41.46
7/28	513	253	49.32
7/31	460	243	52.83
8/5	618	187	30.26
8/7	346	139	40.17
8/11	635	143	22.51
8/14	637	114	17.90
8/18	1463	181	12.37
8/21	951	87	9.15
8/25	1640	119	7.26
8/28	1073	96	8.95
8/31	1037	79	7.62
9/4	--	53	--
9/8	859	23	2.68

Average for squares collected in July: 40.09%.

Average for squares collected in August: 17.35%.

Average for July and first two weeks of August (peak squaring period): 35.13%.

Average for remainder of season: 8.00%.

This is partly because of the late-season tobacco budworm and bollworm damage to the squares, especially at Ames. Also, because of the large numbers of boll weevils present in the field, possible competition for squares may have forced many individuals to feed and oviposit repeatedly in single squares, thus damaging the squares to the point that larvae from eggs deposited in the squares could not completely develop.

An exact prediction of potential boll weevil numbers could never be possible by observing the abundance of fallen squares in a field because of the unusually large numbers of squares which may be shed due to adverse weather conditions, nutrient deficiencies, disease, or mechanical injury. Many squares will fall solely as a result of boll weevil feeding damage. Boll weevil mortality in the squares may be quite variable through the season and would thus affect the percent of squares yielding weevils; nevertheless, during the peak period of squaring (mid-July to mid-August) 1/3 to 1/2 of all fallen squares can produce weevils.

V. BRACON MELLITOR EMERGENCE PATTERN

The emergence patterns at both study sites (Figures 8 and 9) were very similar. Adults began to emerge in the cages about the first of August. Daily emerging numbers were rather low the first 2-1/2 week period emergence was observed, including several intermittent days when no emergence occurred at all.

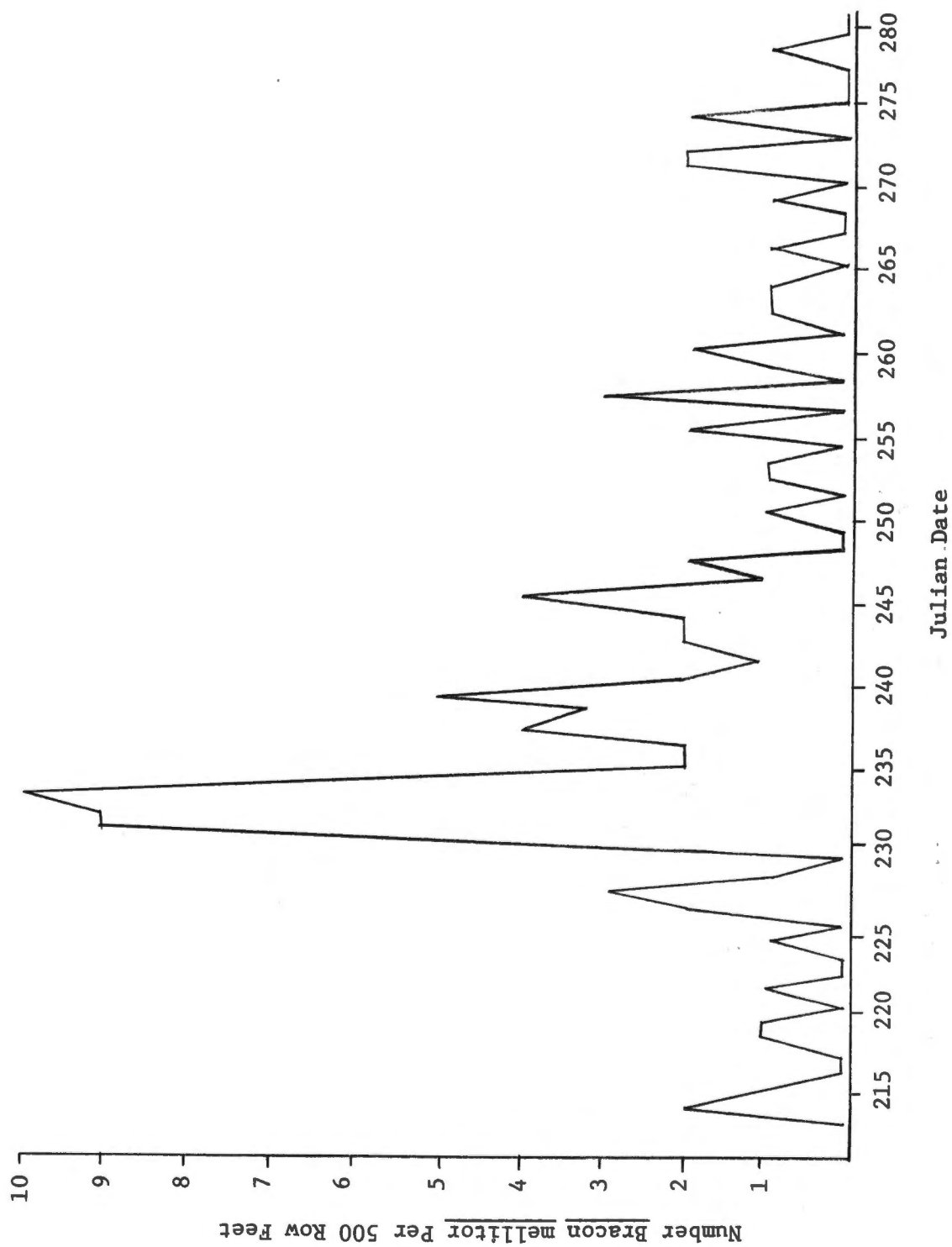


Figure 8. Daily emergence of Bracon mellitor in cotton field at Jackson in 1975.

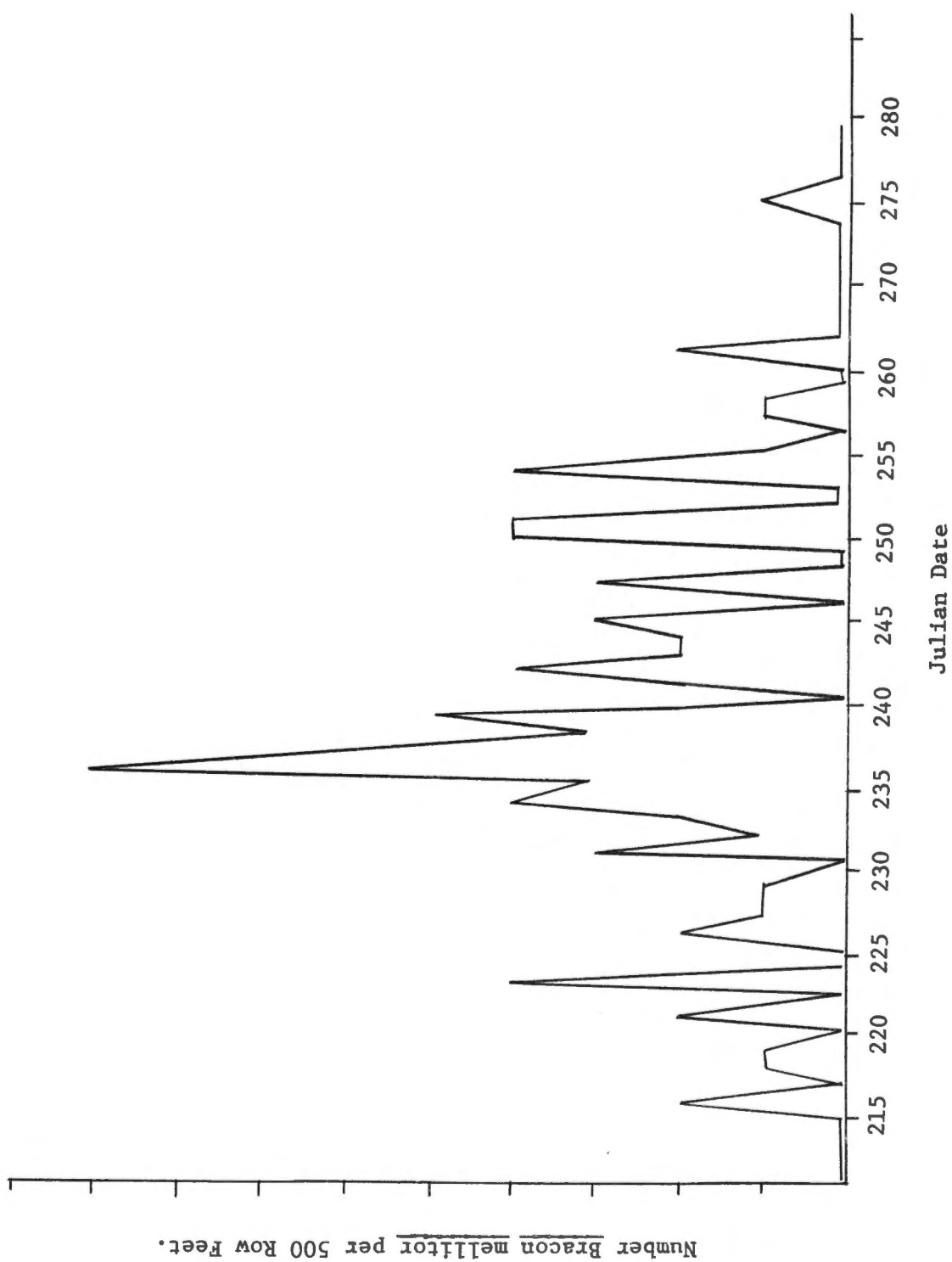


Figure 9. Daily emergence of Bracon mellitor in cotton field at Ames in 1975.

In both fields, significantly greater numbers of Bracon mellitor began emerging August 19 and continued to emerge in large numbers in the following two weeks. These peak periods of parasite emergence coincided precisely with the peak periods of second generation boll weevil emergence for each respective field. This association of peak periods of Brancon mellitor and second generation weevil emergence could be expected. As a result of the ovipositional activity of the overwintered and first generation weevils in the field, at least 50-70% of the squares on the plants contained weevil eggs by August 10 (Table VIII). Because of the abundance of weevil-infested squares, this peak emergence of Brancon mellitor was due to the greater ease with which the parent generation could find suitable oviposition sites. The decrease in numbers emerging the latter half of September could be attributed to the late-season reduction in the number of squares produced by the cotton, thus limiting the availability of squares infested with weevils that the parent generation could parasitize.

Two problems may be encountered using the conical boll weevil emergence cage for monitoring absolute numbers of emerged Brancon mellitor. Because these wasps vary markedly in size, smaller individuals may escape through the screen. This problem could be remedied by using a smaller mesh screen. Another potential problem arises from the possibility of excluding the female wasps from the fallen squares by placing them in the cage, and thus preventing any natural parasitism to occur while the squares were on the ground. Fenton and Dunnam (1929)

Table VIII. Square counts and boll weevil infestation levels
(percentage damaged squares) for four cotton fields in
West Tennessee.

JACKSON 1974			AMES 1974		
Date	Squares Per 25 Row Feet	Percentage Damaged Squares	Date	Squares Per 25 Row Feet	Percentage Damaged Squares
7/6	22	0	7/5	108	2
7/10	63	5	7/13	359	--
7/15	136	10	7/16	501	12
7/25	405	17	7/20	590	20
8/1	395	14	7/22	576	16
8/8	437	32	7/31	512	47
8/15	314	70	8/7	561	67
8/20	251	96	8/14	280	97
JACKSON 1975			AMES 1975		
Date	Squares Per 25 Row Feet	Percentage Damaged Squares	Date	Squares Per 25 Row Feet	Percentage Damaged Squares
7/1	38	0	6/30	9	0
7/7	93	78	7/7	67	50
7/15	188	--	7/14	106	--
7/22	183	--	7/21	246	--
7/29	200	80	7/28	261	70
8/8	214	92	8/5	214	86
8/15	90	98	8/11	249	92
8/22	58	90	8/18	131	94

report that the female Bracon mellitor does not oviposit in squares already on the ground. Folsom (1936) reports contradictorally that these wasps will oviposit in infested squares either on the plant or on the ground. Depending on the ovipositional preference of the species, exclusion of the fallen squares from wasps may or may not be a problem.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Emergence patterns of the boll weevil were studied in four fields in the West Tennessee cotton growing area. First and second generation peak emergence periods occurred at two of the fields. One field had a gradual buildup of weevils with no distinct peak periods of emergence. Although peak periods of emergence may occur, emergence occurring between these periods was sufficient to produce economically damaging numbers (assuming 3,000 weevils/acre constitute an economically damaging number). On the basis of this information, it would not appear to be advantageous for Tennessee cotton producers to deviate from the recommended regular season boll weevil control program of making four applications at five day intervals, once the infestation level reaches an economically damaging level. Because of the possibility of large numbers of weevils emerging in a short period of time, it would appear advantageous, once cotton begins to square, to monitor infestation levels two times per week rather than on a weekly basis until a spraying program was initiated.

Weevils began to emerge from cotton squares 24-28 days after the initiation of squaring or 0-10 days after the appearance of the first bloom. When initial first generation peaks were noted, they occurred about one month after the initiation of squaring. Second generation peaks occurred 50-55 days after the initiation of squaring.

Results of a time-series study correlating air temperature and rainfall conditions with the number of weevils emerging each day in the two fields in 1975 revealed no significant relationships. Temperature and rainfall up to 15 days prior to a particular day of emergence had very little measurable affect on the number of weevils emerging on that day. Consequently, predictive models based on temperature or rainfall alone could not be made.

In 1975 all fallen squares collected from the sample sites were counted in order to determine the percent of fallen squares that yield weevils during various periods in the season. Percentages were highest when square production was highest, and as the rate of square production decreased, the percentages also decreased. Generally, 1/3 to 1/2 of the squares collected during the peak period of square production (first six weeks) yielded weevils.

The utility of the conical emergence cage for trapping emerged Bracon mellitor from infested cotton squares was demonstrated. Emergence patterns of Bracon mellitor at Ames and Jackson were very similar. The largest number of wasps emerged just prior to the major emergence of the second generation of boll weevils.

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