LIFE SYSTEM OF STEGASTA BOSQUEELLA (CHAMBERS) ON PEANUTS IN OKLAHOMA

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CHAPTER I

INTRODUCTION

The rednecked peanutworm, Stegasta bosqueella (Chambers) is found in the United States wherever peanuts, Arachis hypogaea L. are grown and has been recorded as a severe pest in South America (Bondar, 1928). S. bosqueella has been a perennial insect pest of peanuts in Oklahoma (Wall and Berberet, 1979). This insect was not officially recorded in Oklahoma until 1957, although it undoubtedly was present before that time (Walton and Matlock, 1959). Many growers became concerned about this pest in 1957 when heavy infestations occurred in all peanut growing areas in the State. Larvae of S. bosqueella feed on several plant species but peanuts apparently are the preferred host (Bissell, 1941, Manley, 1961). The biology and description of life stages were presented by Manley (1961).

Larvae of S. bosqueella feed between adjacent leaflets and between the halves of unfolded leaflets within plant terminals. Heavy infestations of this insect over extended periods cause plant stunting and considerable defoliation (Wall and Berberet, 1979). Conflicting viewpoints regarding economic importance of the rednecked peanutworm are expressed in the literature. Arthur et al. (1959) reported that chemical control of this pest in Alabama produced a significant reduction in damage to foliage but did not result in significantly higher yields. Bissell (1941) stated that S. bosqueella did no appreciable

damage to peanuts in Georgia. However, Walton and Matlock (1959) obtained significantly higher peanut yields through use of chemical controls of this insect in Oklahoma. Manley (1961) while describing the biology of S. bosqueella, stated that infestations were at economic levels in Oklahoma from 1957 - 1960 but he did not define economic injury levels in terms of insect population density.

CHAPTER II

THERMAL REQUIREMENTS FOR DEVELOPMENT OF *S. BOSQUEELLA*

Introduction

Knowledge of temperature thresholds and developmental rates for life stages is essential for determination of lengths of successive generations and as an aid for predicting population fluctuations. The rate of insect development is determined by time and temperature above a threshold (Bernhardt and Shepard, 1978). A good estimator of developmental time which takes into account both time and temperature is based on accumulated degree days, which I have calculated for *S. bosqueella*. This study was conducted to enhance the capability for predicting occurrence of population increases and possible timing of chemical control measures.

Methods and Materials

Eggs, larvae, and pupae of *S. bosqueella* were reared in constant temperature cabinets to determine developmental thresholds and degree day accumulations necessary for completion of life stages. Ten replications were utilized for each life stage with at least 12 individuals held at each of 4 temperatures (12.8±1, 18.3±1, 23.9±1, and 29.4±1°C) for each replication. Humidity was maintained at 65±5% with a 12 hour

photoperiod for all studies.

Eggs were obtained by confining 3 pairs of newly emerged moths in clear plastic dishes (ca. 40 X 100 mm) covered with paper toweling which served as a substrate for egg deposition. Humidity was maintained by placement of a damp sponge covered with filter paper in each dish and moths were fed Gatoraid®. Eggs were counted on the paper toweling at the end of each 12 hour period using a stereomicroscope and replications were started in all 4 temperatures when sufficient egg numbers were available at the same time period. Virtually all eggs were laid during scotophase. Consequently, all egg replications were started as photophase commenced. Egg development was observed at 12 hour intervals and numbers hatching recorded.

To simulate field conditions as closely as possible, plant terminals were used in studies on larval development. Newly hatched larvae were placed in cut terminals which had been inserted into small containers of Hoagland's solution (Hoagland and Arnon, 1950). Parafilm® was utilized to seal stems in containers and prevent evaporation. Each container was then placed in a petri dish with a ring of Tanglefoot® applied around the edge to prevent escape of larvae when they left the terminal to pupate. Shortly before pupation S. bosqueella larvae discontinue feeding and become very active, descending the plant in search of an appropriate pupation site, which in the field is the upper 1-5 mm of soil around plants. Departure of larvae from terminals delineated the end of larval development. Developmental times for individual larval instars were not recorded because of the difficulty in observing larvae without injurying them once they have begun feeding within plant terminals.

The prepupal period was defined as the time when the larva discontinues feeding and descended the plant until the molt to the pupal instar was completed. Prepupae were obtained from larval studies. They were held in vials plugged with cotton at 23.9±1°C and checked at 6 hour intervals to accomplish our objective of determining degree day accumulation necessary for completion of the prepupal period. The threshold temperature calculated for larval development was utilized in these computations.

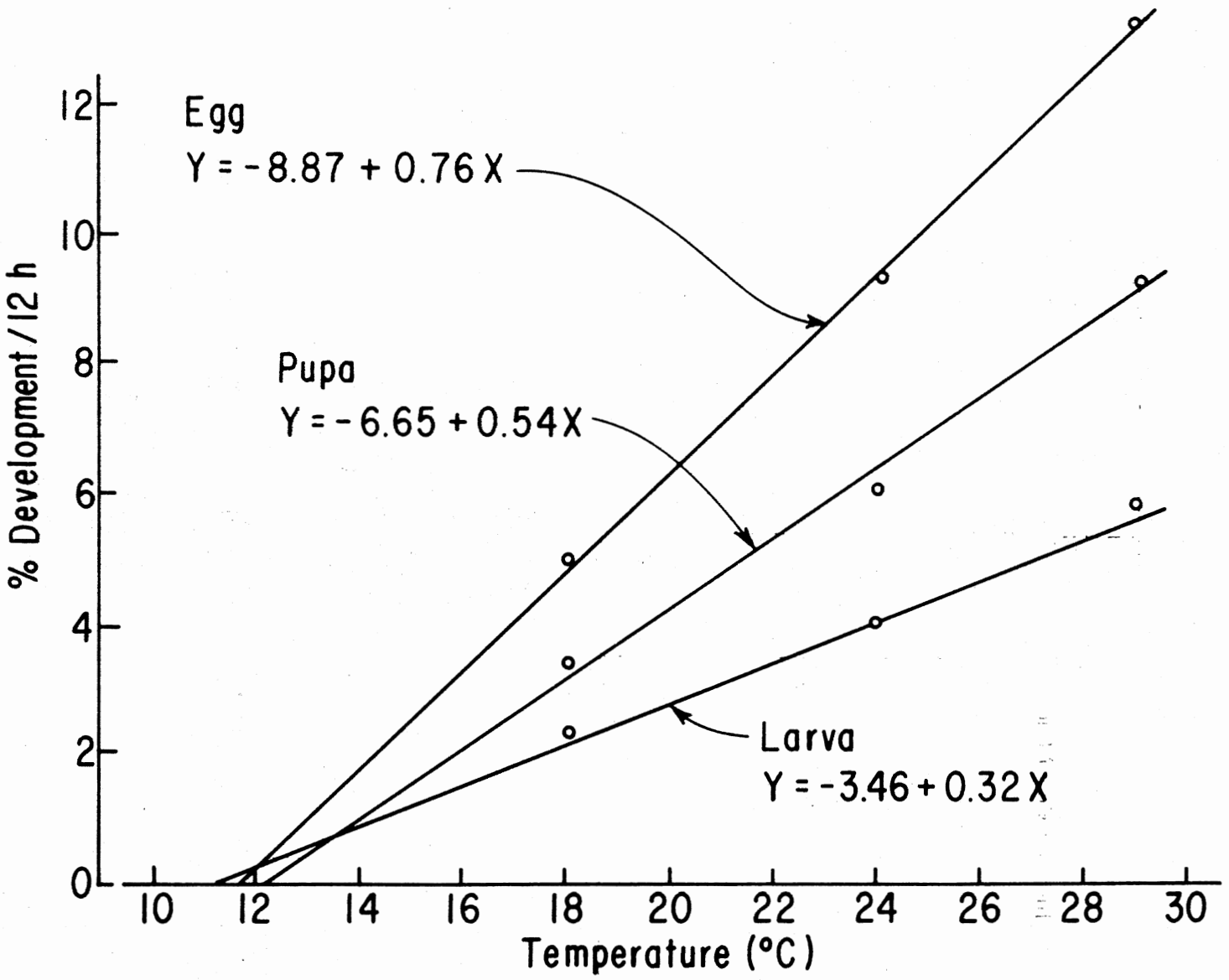
In order to obtain sufficient numbers of pupae of uniform age for developmental studies, large larvae were collected from plant terminals in the field and reared to pupation on artificial diet. When sufficient numbers of larvae (at least 48) pupated within a 12 hour period, they were used to establish replicates to determine requirements for pupal development. Pupae were incubated in 30 ml cups with cardboard lids and checked at 12 hour intervals to observe adult emergence.

In order to record adult longevity and oviposition rates, 25 groups each consisting of 3 pairs of newly emerged moths were reared at 23.9±1°C in chambers described previously in this paper. Adults utilized in these studies emerged from field collected pupae. Eggs deposited on paper toweling were counted at 48 hour intervals until all females had died.

Results and Discussion

The relationship between rate of development (percent/12 hours) and temperature is plotted in Figure 1 according to the regression equation computed for each life stage. The theoretical developmental threshold (°C) is shown by the X-intercept of the regression line for each stage.

Figure 1. Development of Immature Stages of S. bosqueella. % development/12 hr. = (1/(H/12))X100. Where: H = hours required to complete development.


Egg
Y = -8.87 + 0.76 X
Pupa
Y = -6.65 + 0.54X
Larva
Y = -3.46 + 0.32 X
% Development / 12 h
Temperature (°C)
0
2
4
6
8
10
12
10
12
14
16
18
20
22
24
26
28
30

Degree days required for development equals experimental temperature minus the threshold X the number of days at each constant temperature (Table I). No significant differences (P = 0.05) were found between degree day accumulations required for completion of life stages at 18.3±1, 23.9±1, and 29.4±1°C.

Although the theoretical threshold for embryogenesis in S. bosqueella was 11.7°C (Fig. 1), no hatching occurred in eggs incubated at 12.8±1°C. Color changes associated with normal embryonic development were detected at this temperature, however. Degree day requirements for hatching of eggs incubated at other experimental temperatures were quite similar and the mean was 66.5 C° days (Table I).

The threshold temperature for larval development was 11.0°C. Newly hatched larvae remained alive for 3-4 weeks at 12.8±1°C, but little feeding or development was observed. Apparently this temperature was too near the threshold to allow larval development to proceed efficiently. Thermal requirements for development at other temperatures varied from 154.9 to 157.0 C° days with a mean of 156.0 (Table I).

The prepupal period required an average of 25.1 C° days. A mean of 94.2 C° days was needed for the pupal stadium.

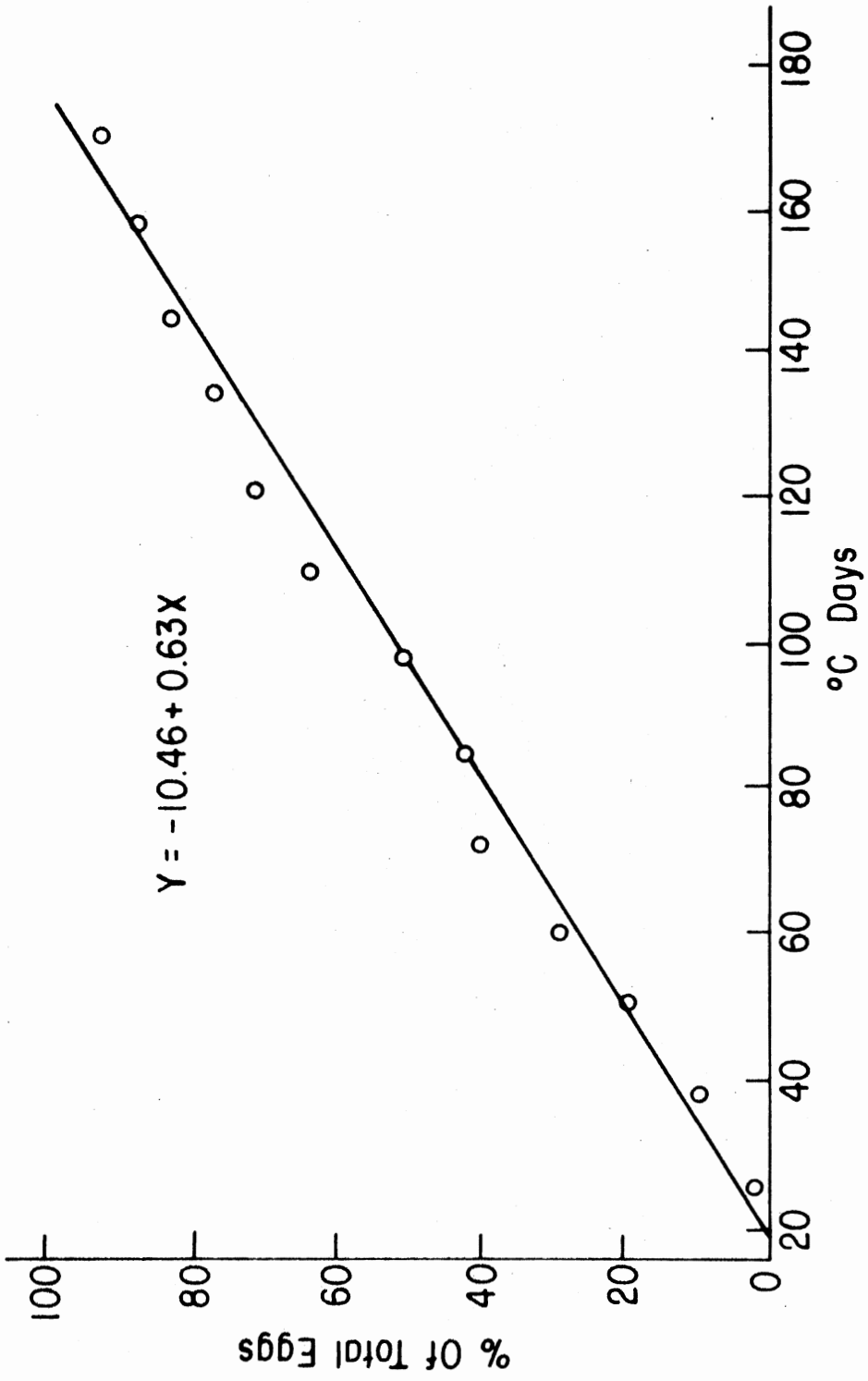
S. bosqueella laid an average of 16 eggs under laboratory conditions. Egg deposition progressed at a fairly constant rate for 12-14 days after adult emergence (Fig. 2). The mean number of eggs/female was produced during the initial 8 days of the adult stadium. Because a threshold for egg deposition was not determined, I utilized the figure for egg development (11.7°C) in calculating degree day accumulation for the ovipositional period. The total for the 8 days at 23.9±1°C required for mean egg production was 97.6 C° days.

TABLE I

MEAN NUMBER OF DAYS AND DEGREE DAYS FOR DEVELOPMENT OF *S. BOSQUEELLA*

Temperature (°C)	Eggs		Larvae		Pupae	
	days	degree days	days	degree days	days	degree days
12.8	-	-	-	-	-	-
18.3	10.2	67.6	21.5	154.9	15.2	92.7
23.9	5.3	65.2	14.1	156.0	8.3	97.3
29.4	3.8	66.7	8.6	157.0	5.4	92.5
Mean		66.5		156.0		94.2

Figure 2. Egg Deposition by Laboratory Reared *S. bosqueella* (r = 0.99)


Y = -10.46 + 0.63X
% Of Total Eggs
°C Days
0
20
40
60
80
100
120
140
160
180

I computed a total generation time for S. bosqueella of approximately 440 C° days. I utilized this figure to segregate generations for life table studies (Chapter III). In Oklahoma, temperature conditions during the peanut growing season permit completion of ca. 3 generations of S. bosqueella.

During late July and early August, when peanuts are most sensitive to defoliation (Wall and Berberet, 1979), larval population densities may increase quite rapidly. During this period, up to 20 C° days may be accumulated/calendar day, and the life cycle of S. bosqueella may be completed in as little as 23 days.

CHAPTER III

ABBREVIATED LIFE TABLES OF *S. BOSQUEELLA*

Introduction

Life tables are an important asset for insect pest management programs which involve systematic recording of causitive agents and extent of mortality in relation to the age distribution of a population. The predictive aspect of a life table is especially valuable in forecasting potentially serious infestations and determining when controls may be necessary. Abbreviated life table studies are those where all mortality factors for all life stages of the insect cannot be observed or quantified (Sears, 1975). This study was initiated to develop a better understanding of the population dynamics of *S. bosqueella* in Oklahoma.

The impact of parasitism on *S. bosqueella* populations is an important aspect of life table studies. Manley (1961) recovered 4 parasitic species from this pest but made no reference to their impact on host population densities in field situations. Wall and Berberet (1975) recovered 9 parasitic species from *S. bosqueella* and stated that parasitism averaged over 20% from 1972 - 1974 in Oklahoma.

Methods and Materials

S. bosqueella populations were studied during 1975-76 in 2 dryland fields with light, sandy soil located in Marshall County, Oklahoma.

These fields were selected because of their known history both for S. bosqueella infestations and lack of insecticide application by peanut producers. Spanish peanuts ('Spanhoma' variety) were planted on 0.9 m row spacing with a preplant application of Balan herbicide. The fields were culitvated once before pegging began as an additional aid in weed control. Dithane M-45® and Terraclor® were applied as needed to control fungal diseases. No insecticides were applied to the study areas. In 1975 the fields were separated by ca. 100 m of pasture. Field 1 was ca. 3 ha and field 2, ca. 12 ha in size. Both were surrounded on 3 sides by trees and grassland and on the fourth by a roadway or farmyard. The second field location was changed in 1976 as the cooperating producer rotated crops and planted his peanuts in another field. The second location utilized that year was surrounded by roadway, pasture, nursery stock, and peanuts. A weather station was placed at the research area in order to record temperature, humidity, rainfall, and moisture conditions.

Samples of larvae, pupae, and adults were taken at 4 day intervals. Eggs were not sampled because of the difficulty in finding them under field conditions. When deposited, eggs are easily overlooked because of their very small size (0.3 X 0.2 mm) and inconspicuous coloration (Manley, 1961). They are deposited singly almost anywhere on the plant and do not adhere well, making them easily dislodged when sampling is a attempted.

Larvae were sampled by examining peanut terminals. Five hundred terminals were collected randomly over the entire sampling area from each field per sampling date and refrigerated until examination in the laboratory was completed. Terminals were checked until at least 100

larvae were found or the entire 500 had been examined, whichever occurred first. The larval stage was divided into 2 periods. Small larvae were those less than 6 mm (ca. 1/4 inch) in length while large larvae exceeded 6 mm. The grouping of small larvae roughly corresponded to first-third instars and large, to fourth and fifth instars and prepupae. Field collected larvae were reared in the laboratory at 22±3°C and observed at 2 day intervals to record mortality or adult emergence and collect parasties for identification. Larvae were reared individually in 17 X 63 mm (2-dram) plastic vials containing ca. 5 ml of modified Vanderzant-Adkisson medium (Vanderzant et al., 1961) and plugged with cotton.

I observed that cocoons of the rednecked peanutworm were found almost exclusively beneath plants in the upper 1-5 mm of soil. Thus, I could assume that most were collected by sampling soil to a depth of ca. 25 mm. Soil was taken from a distance of 15 cm outward from each side of rows with a metal scoop 3 dm wide for each sample. These were sifted through a screen to separate cocoons from the soil. Fifty samples were taken at regular intervals over each field except when pupal numbers were very low (less than 1/sample), when 100 samples were taken to obtain more accurate estimates of population density. Cocoons were held in the laboratory in 10 ml plastic cups with cardboard lids at 22±3°C to await emergence of moths or parasites. After ca. 30 days cocoons were dissected to record empty cocoons and pupae that had died before emergence in order to get an accurate count of the pupae collected on that sampling date.

Adults were sampled by use of a drop trap ca. 60 X 45 X 45 cm. After the trap was placed over a row, moths were captured with an

aspirator after they were driven from foliage beneath the trap. The trap was constructed of nylon screen with an elastic sleeve for entry without loss of adults and a clear plexiglas top for easy viewing. Fifty samples (30 m of row) were taken at regular intervals in an X pattern over each field per sampling date. Adults were collected and sexes determined to obtain the sex ratio.

Parasites recovered from S. bosqueella were curated and identified by use of reference collections and by various taxonomists of the U.S. National Museum. Specimens of all parasites recovered were deposited in the K. C. Emerson Museum at Oklahoma State University.

Abbreviated life tables of S. bosqueella were constructed using density estimates of the various life stages obtained from sampling field populations of this insect. A raw estimate of each life stage/ha was calculated for each sampling date. Larval numbers were estimated as follows: number of larvae collected X (number of terminals per ha ÷ number of terminals checked). Plant terminal densities were recorded each week by counting the number of terminals on at least 100 plants randomly selected throughout the sampling area. The plant density/ha was established in each field at the beginning of the season. Pupal and adult numbers were estimated by calculating: number collected X (number of row m per ha ÷ row m sampled). The total number of a given life stage/generation could not be calculated by simple summation of raw numbers/ha for each sampling date because of variations in daily temperatures and differing developmental rates for the various life stages of the insect. In order to estimate the actual number of each life stage/ha for a generation I developed the general formula:

$$A = N \times I/T$$

where: A = the number attributed to a given stage for the sampling interval

N = the number/ha of a given life stage collected on a given sampling date

I = the sampling interval (expressed as accumulated degree days since last sampling)

T = the time required (in degree days) for that life stage to develop to the next life stage

This formula was utilized to compute numbers for each life stage during each sampling interval. It takes into account not only number of various stages collected per ha on each date for that generation but also time required for those stages to complete development (varies with environmental temperatures) and the sampling interval. The formula also produces standardized numbers which are in the desired units e.g. large larvae/ha, adults/ha, etc., and can be directly compared with standardized numbers from other generations. Use of this formula produced the same results as more involved procedures e.g. Southwood and Jepson's (1962) graphical method or Birley's (1977) without as much possibility for cumulative error. Summation of the calculated A's from each sampling date in a generation gave estimates of the total numbers of each stage that occurred for that generation. These estimates approximated the total population at the median age of that stage assuming a constant mortality rate. The developmental times used in these calculations were those shown in Chapter II.

The standardized numbers obtained for each life stage/generation (as used in the life tables) were analyzed using key factor analysis. The density dependence of the mortality factor to that of the host was

shown by plotting the log of the host density vs. the k factor (Varley and Gradwell, 1960). The slope of the line (b) represents the ability of the mortality factor (k) to compensate for changes in host density.

Results and Discussion

The temporal distributions of life stages of S. bosqueella are shown in Figures 3-6. Three generations occurred each year using the recruitment time of 440 degree days/generation (as calculated in Chapter II). Life tables were constructed for each field in 1975 and 1976 (Tables II-V). Laboratory studies indicated that moths lay an average of 16 eggs/female, however, field data indicated that each must lay at least 100 eggs. The large variation in total eggs/female indicated that moths did not oviposit normally in captivity. Therefore, a reliable basis for estimating egg numbers per generation was not established.

Moths generally appeared soon after the peanuts emerged in June and began egg laying. Observations in the laboratory and field collections indicated a sex ratio of ca. 1:1. Larval numbers during the first generation were not as large as those of the second, which had the highest population density. Numbers declined somewhat during the third generation.

The 3 generations of S. bosqueella produced large numbers of larvae with decreasing survival in each successive generation (Table II). In field 2 (Table III) results were very similar to those in field 1 although total numbers were somewhat smaller. In 1976 no third generation adults were collected before peanuts were dug. Therefore, I was unable to calculate a generation total. Population densities in 1976 were somewhat lower in field 1 than in 1975 and again survival decreased

Figure 3. Temporal Distribution of S. bosqueella on Peanuts in Oklahoma, Field No. 1, 1975

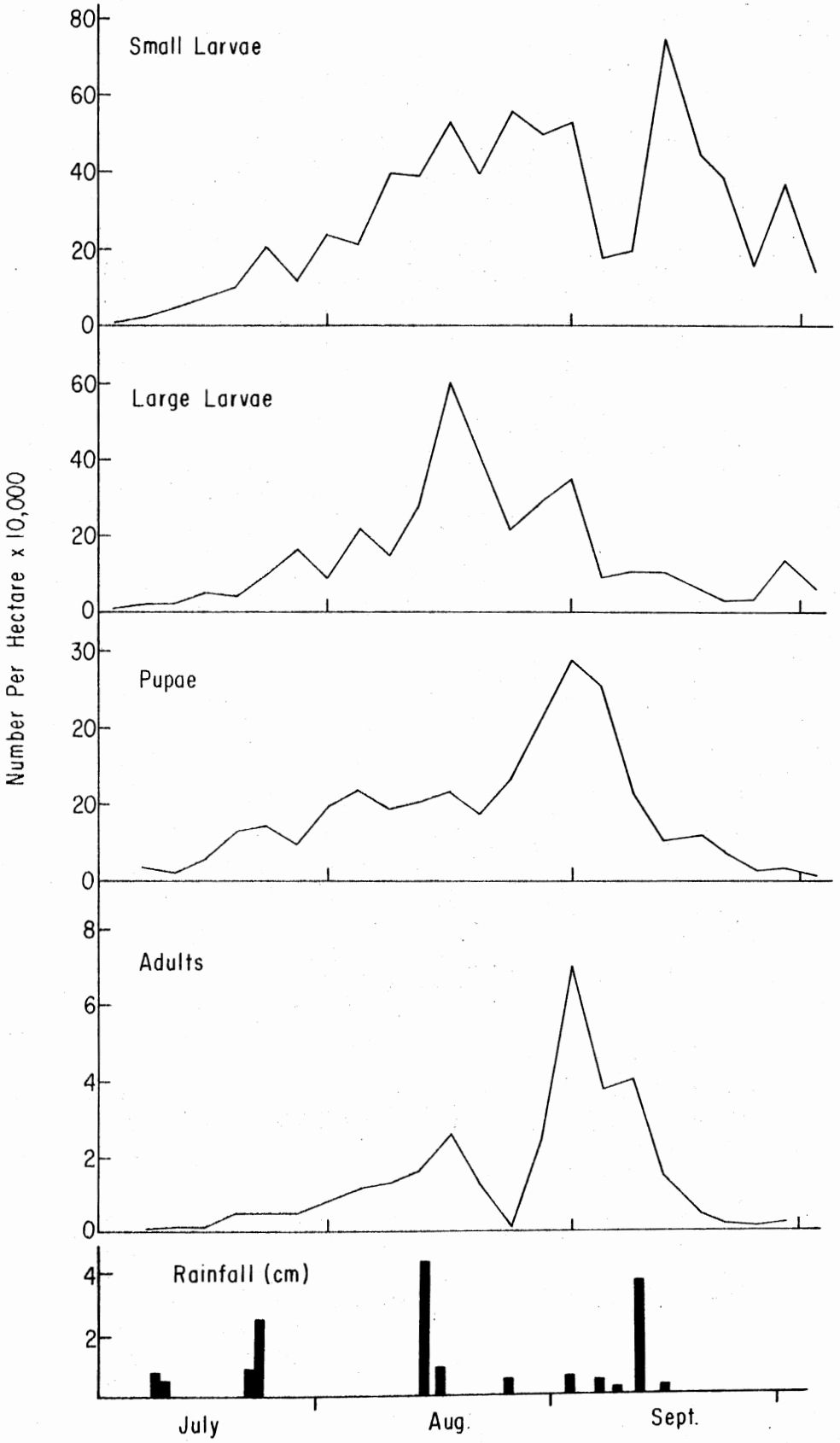

Small Larvae
Large Larvae
Pupae
Adults
Rainfall (cm)
Number Per Hectare x 10,000
July
Aug.
Sept.

Figure 4. Temporal Distribution of S. bosqueella on Peanuts in Oklahoma, Field No. 2, 1975

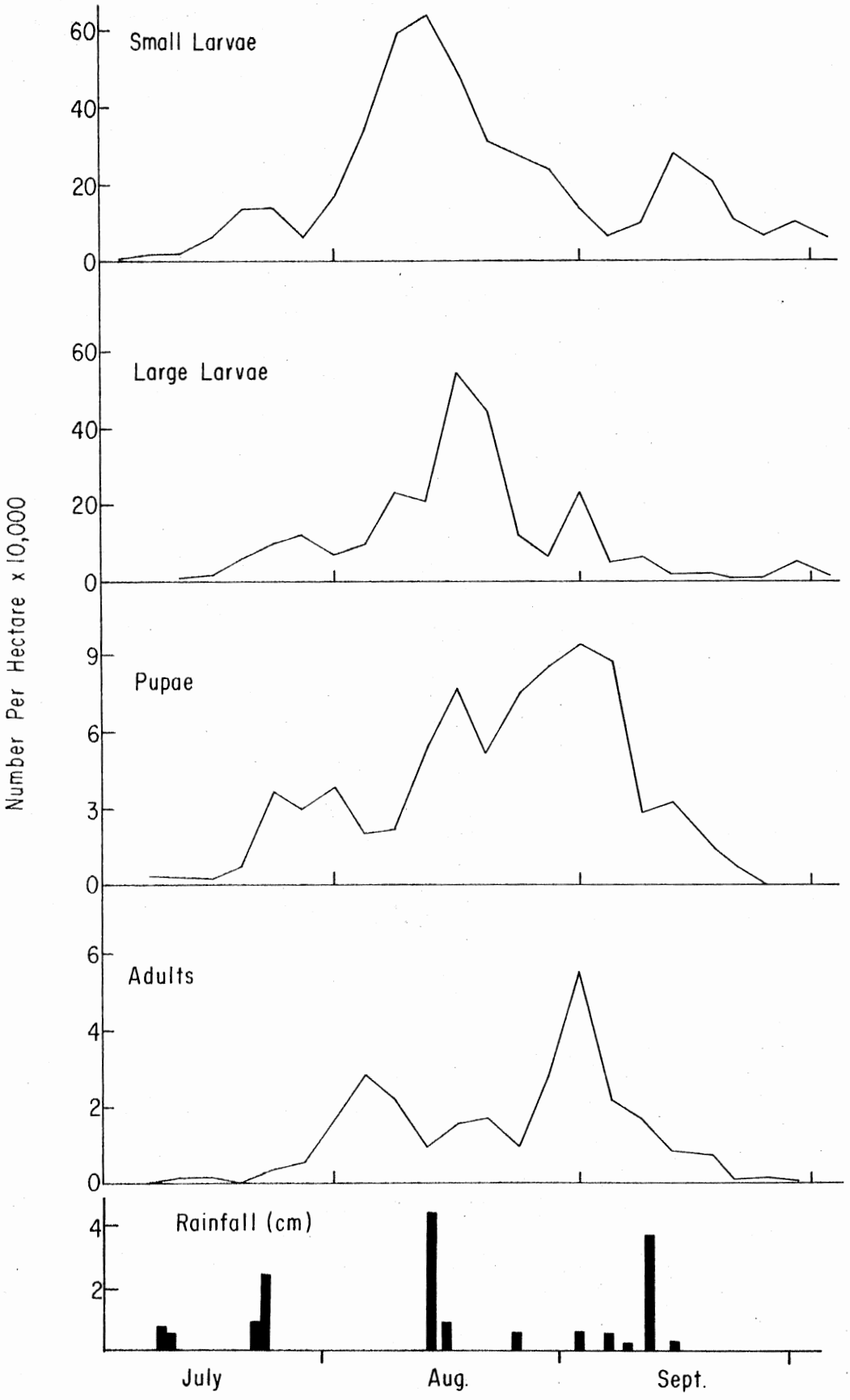

Small Larvae
Large Larvae
Pupae
Adults
Rainfall (cm)
Number Per Hectare x 10,000
July
Aug.
Sept.

Figure 5. Temporal Distribution of S. bosqueella on Peanuts in Oklahoma, Field No. 1, 1976

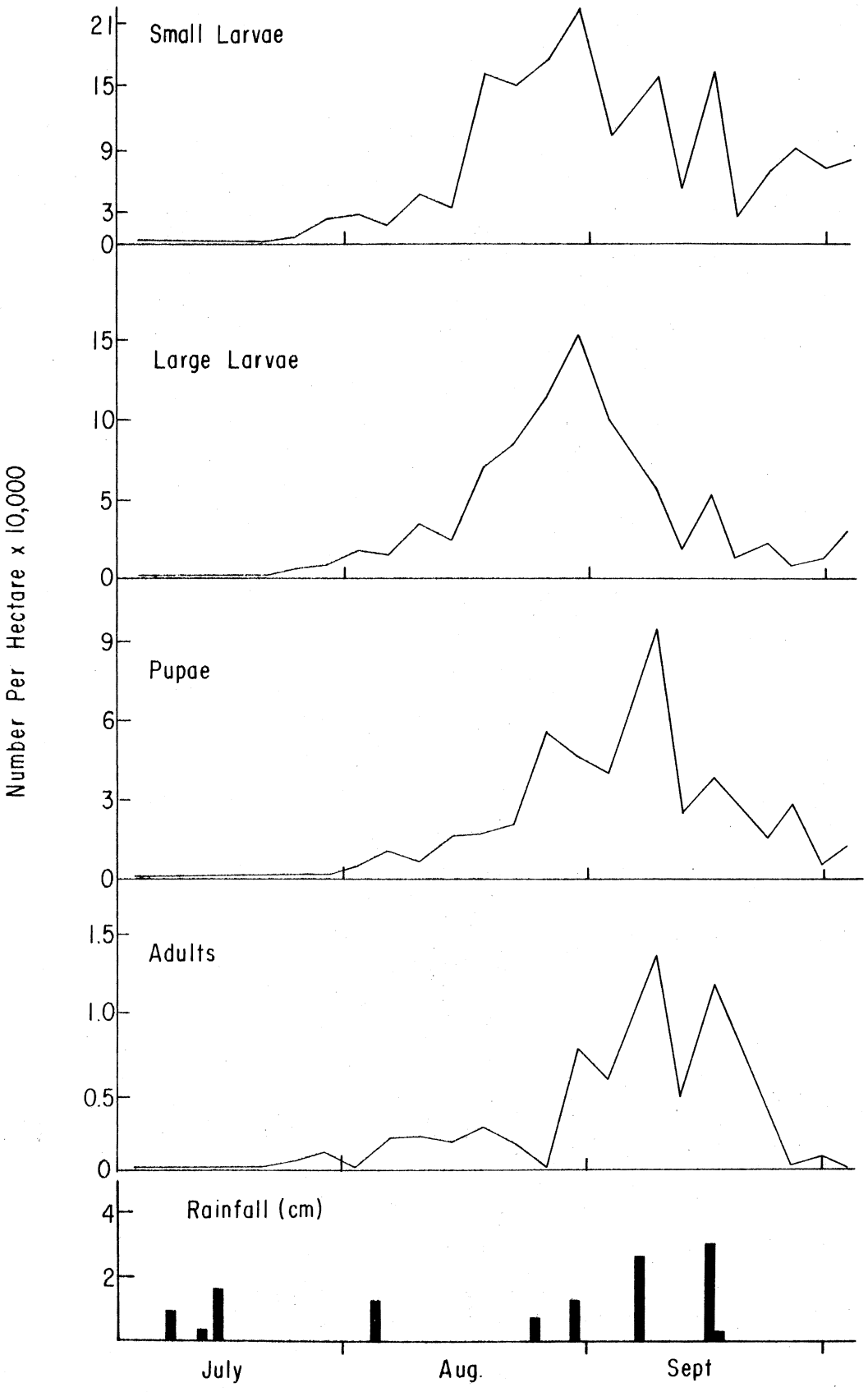

Small Larvae
21
15
9
3
0
Large Larvae
15
10
5
0
Pupae
9
6
3
0
Adults
1.5
1.0
0.5
0
Rainfall (cm)
4
2
July
Aug.
Sept
Number Per Hectare x 10,000

Figure 6. Temporal Distribution of S. bosqueella on Peanuts in Oklahoma, Field No. 2, 1976

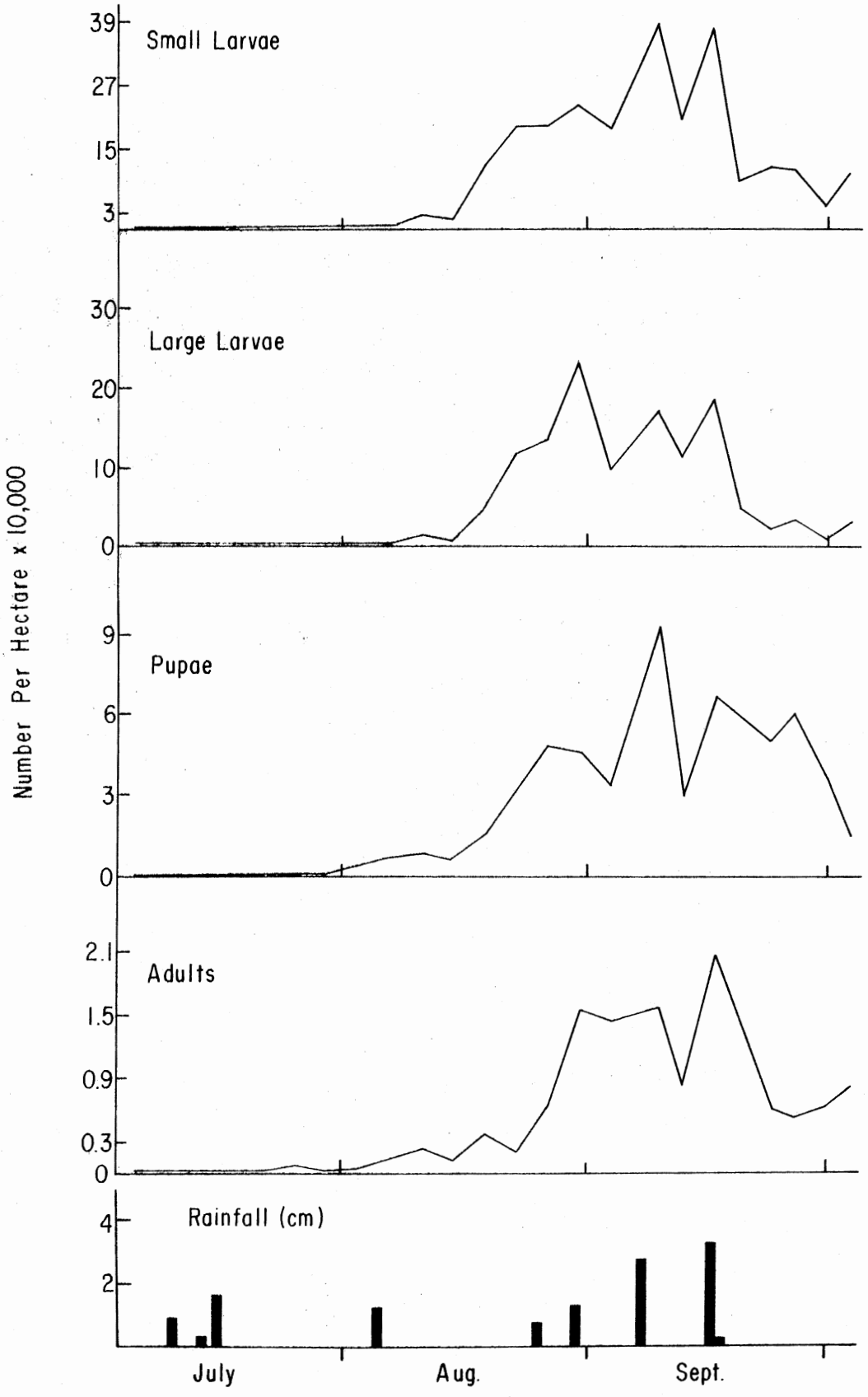

Number Per Hectare x 10,000
Small Larvae
39
27
15
3
Large Larvae
30
20
10
0
Pupae
9
6
3
0
Adults
2.1
1.5
0.9
0.3
0
Rainfall (cm)
4
2
July
Aug.
Sept.

TABLE II

ABBREVIATED LIFE TABLE FOR S. BOSQUEELLA ON PEANUTS IN OKLAHOMA, FIELD 1, 1975

x	1x	dxF	dx	100qx	Sx
		Generation 1			
Small larvae	1121016	parasitism	15867	1.42	
		disappearance	266429	23.77	
		total	282296	25.18	0.75
Large larvae	838720	parasitism	75268	8.97	
		disappearance	191386	22.82	
		total	266654	31.79	0.68
Pupae	572066	parasitism	169811	29.55	
		disappearance	311985	54.54	
		total	481796	84.22	0.16
Adults	90270				
Generation totals			1030746	91.95	0.08
		Generation 2			
Small larvae	3137730	parasitism	22084	0.70	
		disappearance	945761	30.14	
		total	967845	30.85	0.69
Large larvae	2169884	parasitism	583873	26.91	
		disappearance	392888	18.11	
		total	976761	45.01	0.55
Pupae	1193124	parasitism	417235	34.98	
		disappearance	569845	47.76	
		total	987080	82.73	0.17
Adults	206044				
Generation totals			2931686	93.43	0.07
		Generation 3			
Small larvae	4676144	parasitism	1676246	35.86	
		disappearance	1952343	41.75	
		total	3628589	77.61	0.22
Large larvae	1047555	parasitism	372509	35.58	
		disappearance	528413	50.47	
		total	900922	86.04	0.14
Pupae	146633	parasitism	123061	84.21	
		disappearance	20124	13.77	
		total	143185	97.98	0.02
Adults	3448				
Generation totals			4672696	99.93	0.001

TABLE III

ABBREVIATED LIFE TABLE FOR S. BOSQUEELLA ON PEANUTS IN OKLAHOMA, FIELD 2, 1975

x	lx	dxF	dx	100qx	Sx
		Generation 1			
Small larvae	1134834	parasitism	3993	0.35	
		disappearance	399651	35.22	
		total	403644	35.57	0.64
Large larvae	731190	parasitism	56330	7.70	
		disappearance	450920	61.67	
		total	507251	69.37	0.31
Pupae	223939	parasitism	50432	22.52	
		disappearance	58599	26.17	
		total	109030	48.69	0.51
Adults	114909				
Generation totals			1019925	89.87	0.10
		Generation 2			
Small larvae	2549320	parasitism	9672	0.38	
		disappearance	920109	36.09	
		total	929781	36.47	0.64
Large larvae	1619539	parasitism	332824	20.55	
		disappearance	788783	48.70	
		total	1121606	69.25	0.31
Pupae	497932	parasitism	106236	21.33	
		disappearance	240031	48.21	
		total	346266	69.54	0.30
Adults	151666				
Generation totals			2397653	94.05	0.06
		Generation 3			
Small larvae	2168330	parasitism	313653	14.46	
		disappearance	1473354	67.91	
		total	1787007	82.37	0.18
Large larvae	381323	parasitism	106233	27.86	
		disappearance	131398	34.46	
		total	237631	62.32	0.38
Pupae	143692	parasitism	113288	78.84	
		disappearance	24419	16.99	
		total	137707	95.83	0.04
Adults	5985				
Generation totals			2162345	99.72	0.003

TABLE IV

ABBREVIATED LIFE TABLE FOR S. BOSQUEELLA ON PEANUTS IN OKLAHOMA, FIELD 1, 1976

x	lx	dxF	dx	100qx	Sx
		Generation 1			
Small larvae	194447	parasitism	-	-	
		disappearance	23327	12.00	
		total	23327	12.00	0.88
Large larvae	171120	parasitism	6929	4.05	
		disappearance	70652	41.29	
		total	77581	45.34	0.55
Pupae	93539	parasitism	18671	19.96	
		disappearance	56555	60.46	
		total	75226	80.42	0.20
Adults	18313				
Generation totals			176134	90.58	0.09
		Generation 2			
Small larvae	1142319	parasitism	6373	0.55	
		disappearance	542888	47.53	
		total	549261	48.08	0.52
Large larvae	593058	parasitism	5943	1.00	
		disappearance	261062	44.02	
		total	267005	45.02	0.55
Pupae	326053	parasitism	55606	17.05	
		disappearance	230633	70.73	
		total	286239	87.79	0.12
Adults	39814				
Generation totals			1102505	96.51	0.03
		Generation 3			
Small larvae	863110	parasitism	127504	14.77	
		disappearance	531803	61.61	
		total	659307	76.39	0.24
Large larvae	203803	parasitism	34607	16.98	
		disappearance	80845	39.67	
		total	115453	56.65	0.43
Pupae	88350	parasitism	69286	78.43	0.22

TABLE V

ABBREVIATED LIFE TABLE FOR S. BOSQUEELLA ON PEANUTS IN OKLAHOMA, FIELD 2, 1976

x	lx	dxF	dx	100qx	Sx
		Generation 1			
Small larvae	74554	total	-	-	-
Large larvae	75118	total	-	-	-
Pupae	85437	parasitism	5844	6.84	
		disappearance	46930	54.93	
		total	52774	61.77	0.38
Adults	32712				
Generation totals			52774	61.77	0.38
		Generation 2			
Small larvae	1760102	parasitism	74186	4.21	
		disappearance	576247	32.74	
		total	650433	36.95	0.63
Large larvae	1109669	parasitism	6701	0.60	
		disappearance	676997	61.01	
		total	683699	61.61	0.38
Pupae	425970	parasitism	75451	17.72	
		disappearance	264887	62.18	
		total	340338	79.90	0.20
Adults	85632				
Generation totals			1674470	95.13	0.05
		Generation 3			
Small larvae	1130364	parasitism	141295	12.50	
		disappearance	673767	59.61	
		total	815062	72.11	0.28
Large larvae	315302	parasitism	42124	13.36	
		disappearance	54334	17.23	
		total	96458	30.59	0.69
Pupae	218844	parasitism	124870	57.06	0.43

throughout the season (Table IV). In field 2 generation 1 began slowly during 1976 and it appeared that there was very little larval mortality (Table V). This field had fewer parasites as only 4 species were recovered. Survival was generally greater in field 2 than in field 1 in 1976. The combined life table (Table VI) indicates the large populations that occurred in the second and third generations. However, more than twice as many larvae completed development in the second generation as compared to the third because of the higher mortality of small larvae in the third generation.

The third generation was not completed when peanuts were dug however, life table data were included to indicate population trends. The numbers of each life stage in the third generation of the life tables were estimates calculated by extrapolation of data. These extrapolated data were included only in Tables II-VI.

Disappearance included a number of factors which could not be quantified. These factors included such things as predation, disease, and weather related mortality. Predation was seldom observed in the field however, spiders in the genus Xysticus were common and were occasionally observed capturing moths in our sampling traps. Predation of larvae was not observed probably because of their secretive habits. Reduction in S. bosqueella populations due to predation and parasitism of eggs was not determined and might have resulted in some population reductions.

Rain may also have had an influence on egg mortality due to the dislodging of eggs which do not adhere well to the plants (Manley, 1961). Much of the mortality included in disappearance appeared to be related to rainfall. It was often noted that immediately after a rain

TABLE VI

COMBINED ABBREVIATED LIFE TABLES FOR *S. BOSQUEELLA* ON PEANUTS IN OKLAHOMA, 1975 & 1976

x	lx	dxF	dx	100qx	Sx
		Generation 1			
Small larvae	2535734	parasitism	19860	0.78	
		disappearance	689407	27.19	
		total	709267	27.97	0.72
Large larvae	1826467	parasitism	138527	7.58	
		disappearance	712958	39.03	
		total	851485	46.62	0.53
Pupae	974982	parasitism	244758	25.10	
		disappearance	474069	48.62	
		total	718827	73.73	0.26
Adults	256155				
Generation totals			2279579	89.90	0.10
		Generation 2			
Small larvae	8589471	parasitism	112315	1.31	
		disappearance	2985005	34.75	
		total	3097320	36.06	0.64
Large larvae	5492150	parasitism	929341	16.92	
		disappearance	2119730	38.60	
		total	3049071	55.52	0.44
Pupae	2443079	parasitism	654528	26.79	
		disappearance	1305396	53.43	
		total	1959924	80.22	0.20
Adults	483156				
Generation totals			8106315	94.38	0.06
		Generation 3			
Small larvae	8837948	parasitism	2258698	25.56	
		disappearance	4631267	52.40	
		total	6889965	77.96	0.22
Large larvae	1947983	parasitism	555474	28.52	
		disappearance	794990	40.81	
		total	1350463	69.33	0.31
Pupae	597520	parasitism	430505	72.05	0.28

adult moths were stuck to leaves or sand by the moisture. Excessive moisture also caused difficulty in adult emergence from cocoons. A decrease in the numbers per ha for all instars of S. bosqueella was observed in most cases following rainfall of ca. 1 cm or greater (Fig. 3-6). The reasons for rainfall related mortality were not determined. There was no evidence that pathogens affected S. bosqueella populations during this study.

Parasites recovered from S. bosqueella and their relative abundance in 1975 and 1976 are shown in Table VI. All parasites were in the order Hymenoptera. The majority of parasitism was caused by Orgilus modicus Mues. Other important parasites included Invreia spp. and Chelonus (Microchelonus) sp. all of which were found by Wall and Berberet (1975). Invreia spp. however, were observed much more commonly in these studies than indicated by Wall and Berberet in 1975. Hyperparasitism by Perilampus fulvicornis Ash. was of minor importance in reducing rates of parasitism.

The number of parasitic species recovered decreased from 12 in 1975 to 7 in 1976. Table VII indicates the percentage of total parasitism caused by the various species in relation to the stage of S. bosqueella parasitized. After the data were analyzed and life tables constructed, it was discovered that the parasitic species listed as Invreia spp. also included some specimens in the genus Haltichella. Thus, Invreia spp. as reported in this thesis, includes a combination of both genera.

It was apparent from observation of field collected S. bosqueella reared on medium that most parasitic species emerged from mature larvae or prepupae. Of the species I collected, Invreia spp. have been reported as pupal parasites (Berberet et al., 1979). However, all direct host

TABLE VII

PARASITES RECOVERED FROM *S. BOSQUEELLA* AND PERCENT OF TOTAL PARASITISM, 1975 & 1976

Parasite species	Small larvae	Large larvae	Prepupae & Pupae	Total
Apanteles epinotiae [a]	-	0.04	-	0.04
Apanteles spp. [a]	0.07	-	0.25	0.32
Chelonus texanus [a]	-	-	0.04	0.04
Chelonus (Microchelonus) sp.	2.36	0.07	3.78	6.21
Diadegma compressum [a]	0.04	0.25	0.51	0.80
Invreia spp. [b]	-	-	18.27	18.27
Macrocentrus ancylivorus	0.18	0.15	0.25	0.58
Microplitis croceipes	-	-	0.99	0.99
Orgilus modicus	12.02	10.68	43.66	66.36
Pristomerous spinator [a]	0.22	0.22	1.20	1.64
Spilochalris sanguinivantris [a]	-	-	0.04	0.04
Unidentified hymenoptera	0.65	0.58	3.49	4.72
Total	15.54	11.99	72.48	

[a] collected in 1975 only

[b] includes *Haltichella* sp.

mortality due to parasitism recorded in Table VII and the life tables was assigned to the pupal stage because of difficulty in identifying stages in field collected cocoons. In sampling for cocoons it was impossible to determine whether they contained parasites or prepupae and pupae of S. bosqueella and we found it impractical to open cocoons because of the large numbers involved and risk of injury to insects within. Thus, parasites which actually emerged from prepupae within cocoons were not distinguished from those that emerged from pupae. The reported rates of larval parasitism were reduced somewhat due to assignment of prepupal parasite emergence to the pupal stage.

Foliar damage by S. bosqueella ceases with the end of larval feeding and so assignment of all parasitism to the pupal stage was of little economic importance. It should be remembered however, that I am not suggesting that those parasites all emerge from the actual pupal stage of the host.

Larval mortality due to parasitism as reported in the tables was an indirectly observed factor. It was noted that in most instances there was a decrease in the observed parasitism from small larvae to large larvae collected in the field. Theoretically, parasitism should remain the same or increase the longer the host in exposed to parasites assuming no increase in host mortality before parasite emergence. Apparently larvae that were parasitized were more susceptible to mortality than unparasitized individuals as indicated by a consistent decrease in parasitism as larvae matured. It was not possible to assign this mortality to any given parasitic species by direct observation. The actual decreases in observed percent parasitism from 1 host stage to the next accounts for this mortality figure.

Tables VIII-XII show the mortality budgets for the 2 complete generations/year in each field. The No./ha column in these tables indicates the density of S. bosqueella before and after the various k factors. Log No./ha is the common logarithum of the No./ha. The k values were obtained by subtracting the log No./ha after the action of the k factor from the log No./ha before that mortality occurred. Comparing k values with K in these tables readily identifies the key factors responsible for mortality. Disappearance was the major factor responsible for mortality of S. bosqueella in all cases except for the large larvae of generation 2 in field 1, 1975 where parasitism surpassed disappearance.

Figures 7-12 graphically show the relationship of the mortality factor (k) to host density. Varley et al. (1974) stated that a positive slope indicates direct density dependence of the factor to the host population and is often equated with factors such as parasitism. A negative slope indicates inverse density dependence which is equated with non-specific predators. Density independence is shown by a slope of zero and is attributed to catastrophic mortality usually associated with weather or climatic conditions. The larger the variation of the k values from the mean the more variation or catastrophic the effect of k (Varley et al., 1974). Southwood (1966) stated that the degree of slope also indicates the relationship between mortality factor and host densities. The closer the slope is to 1 the greater the stabilizing effect of that mortality factor. A slope of 1 shows the factor completely compensates for any changes in host density. A slope of less than 1 indicates the factor undercompensates for changes in host density while a slope greater than 1 indicates overcompensation. Figure 7 shows that

TABLE VIII

PARTIAL MORTALITY TABLE FOR S. BOSQUEELLA,
FIELD 1, 1975

	No./hectare	Log No./hectare	k value
	Generation 1		
Small larvae	1121016	6.050	
Parasitism	1105149	6.043	0.007
Disappearance	838720	5.924	0.119
Large larvae			
Parasitism	763452	5.883	0.041
Disappearance	572006	5.757	0.126
Pupae			
Parasitism	402997	5.605	0.152
Disappearance	91011	4.959	0.646
			K = 1.091
	Generation 2		
Small larvae	3137730	6.497	
Parasitism	3115646	6.494	0.003
Disappearance	2169884	6.336	0.158
Large larvae			
Parasitism	1586011	6.200	0.136
Disappearance	1193124	6.077	0.123
Pupae			
Parasitism	775889	5.890	0.187
Disappearance	206044	5.314	0.576
			K = 1.183

TABLE IX

PARTIAL MORTALITY TABLE FOR *S. BOSQUEELLA*,
FIELD 2, 1975

	No./hectare	Log No./hectare	k value
	Generation 1		
Small larvae	1134834	6.055	
Parasitism	1130841	6.053	0.002
Disappearance	731190	5.864	0.189
Large larvae			
Parasitism	674860	5.829	0.035
Disappearance	223939	5.350	0.479
Pupae			
Parasitism	173508	5.239	0.111
Disappearance	114909	5.060	0.179
			K = 0.995
	Generation 2		
Small larvae	2549320	6.406	
Parasitism	2539648	6.405	0.001
Disappearance	1619539	6.209	0.196
Large larvae			
Parasitism	1286715	6.109	0.100
Disappearance	497932	5.697	0.412
Pupae			
Parasitism	391697	5.593	0.104
Disappearance	151666	5.181	0.412
			K = 1.225

TABLE X

PARTIAL MORTALITY TABLE FOR *S. BOSQUEELLA*, FIELD 1, 1976

	No./hectare	Log No./hectare	k value
	Generation 1		
Small larvae	194447	5.289	
Disappearance	171120	5.233	0.056
Large larvae			
Parasitism	164192	5.215	0.018
Disappearance	93539	4.971	0.244
Pupae			
Parasitism	74868	4.874	0.097
Disappearance	18313	4.263	0.611
			K = 1.026
	Generation 2		
Small larvae	1142319	6.058	
Parasitism	1135946	6.055	0.003
Disappearance	593058	5.773	0.282
Large larvae			
Parasitism	588005	5.769	0.004
Disappearance	326943	5.514	0.255
Pupae			
Parasitism	271379	5.434	0.080
Disappearance	40745	4.610	0.824
			K = 1.448

TABLE XI

PARTIAL MORTALITY TABLE FOR *S. BOSQUEELLA*, FIELD 2, 1976

	No./hectare	Log No./hectare	k value
	Generation 1		
Small larvae	74554	4.872	
Large larvae	75118	4.876	
Pupae	85437	4.932	
Parasitism	79593	4.901	0.031
Disappearance	32662	4.514	0.387
			K = 0.418
	Generation 2		
Small larvae	1760102	6.246	
Parasitism	1685916	6.227	0.019
Disappearance	1109669	6.045	0.182
Large larvae			
Parasitism	1102967	6.043	0.002
Disappearance	425970	5.629	0.414
Pupae			
Parasitism	350519	5.545	0.084
Disappearance	85632	4.933	0.612
			K = 1.313

TABLE XII

TOTAL MORTALITY TABLE FOR S. BOSQUEELLA ON PEANUTS IN OKLAHOMA, 1975 & 1976

	No./hectare	Log No./hectare	k value
Small larvae	11114322	7.0459	
Parasitism	10982148	7.0407	0.0052
Disappearance	7307735	6.8638	0.1767
Large larvae			
Parasitism	6248658	6.7958	0.0680
Disappearance	3415970	6.5335	0.2623
Pupae			
Parasitism	2509654	6.3996	0.1339
Disappearance	730189	5.8634	0.5362
			K = 1.1823

Figure 7. Response of Disappearance to Changes in Small Larval Populations of *S. bosqueella*

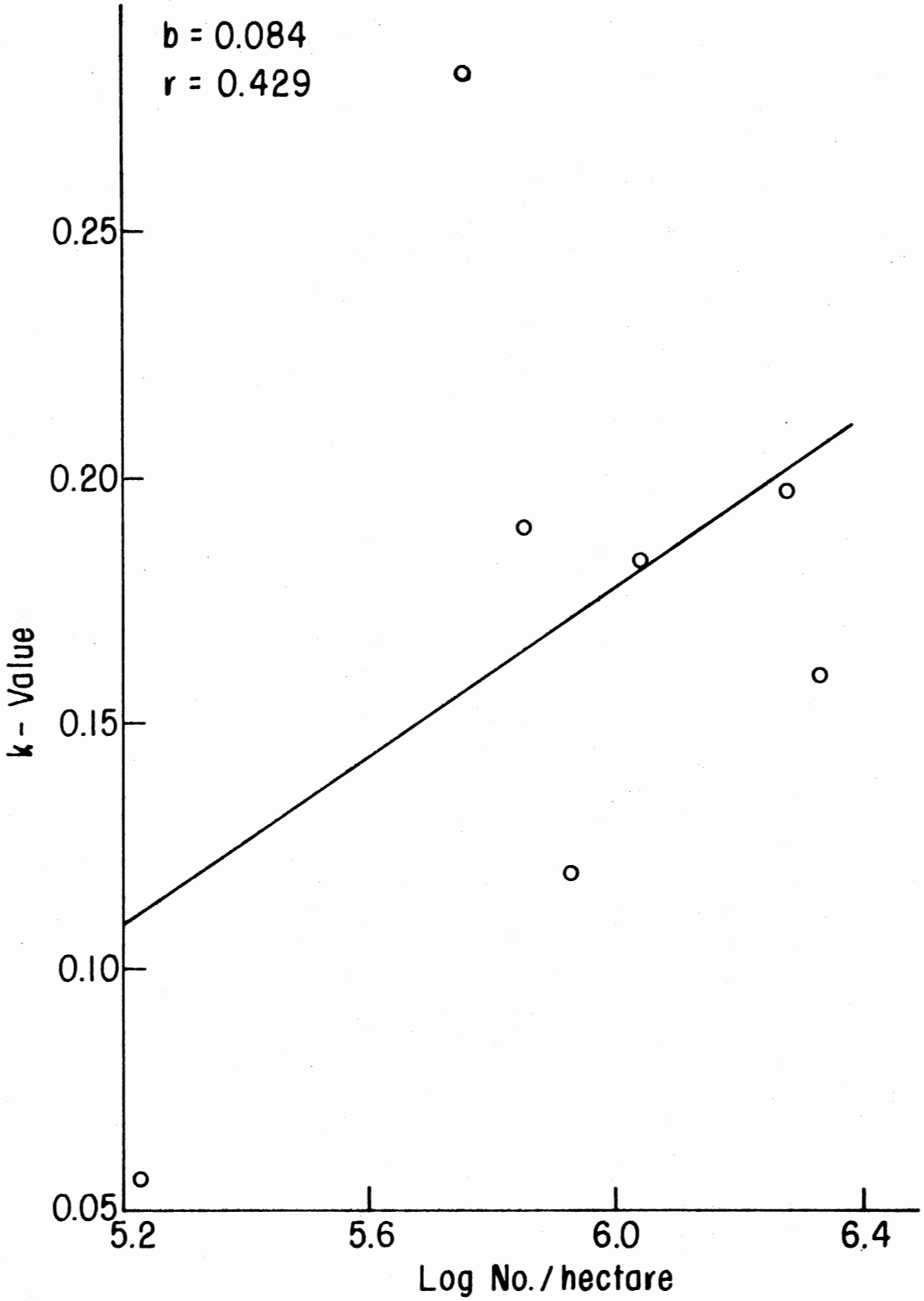

b = 0.084
r = 0.429
0.25
0.20
0.15
0.10
0.05
k - Value
5.2
5.6
6.0
6.4
Log No./hectare

Figure 8. Response of Disappearance to Changes in Large Larval Populations of *S. bosqueella*

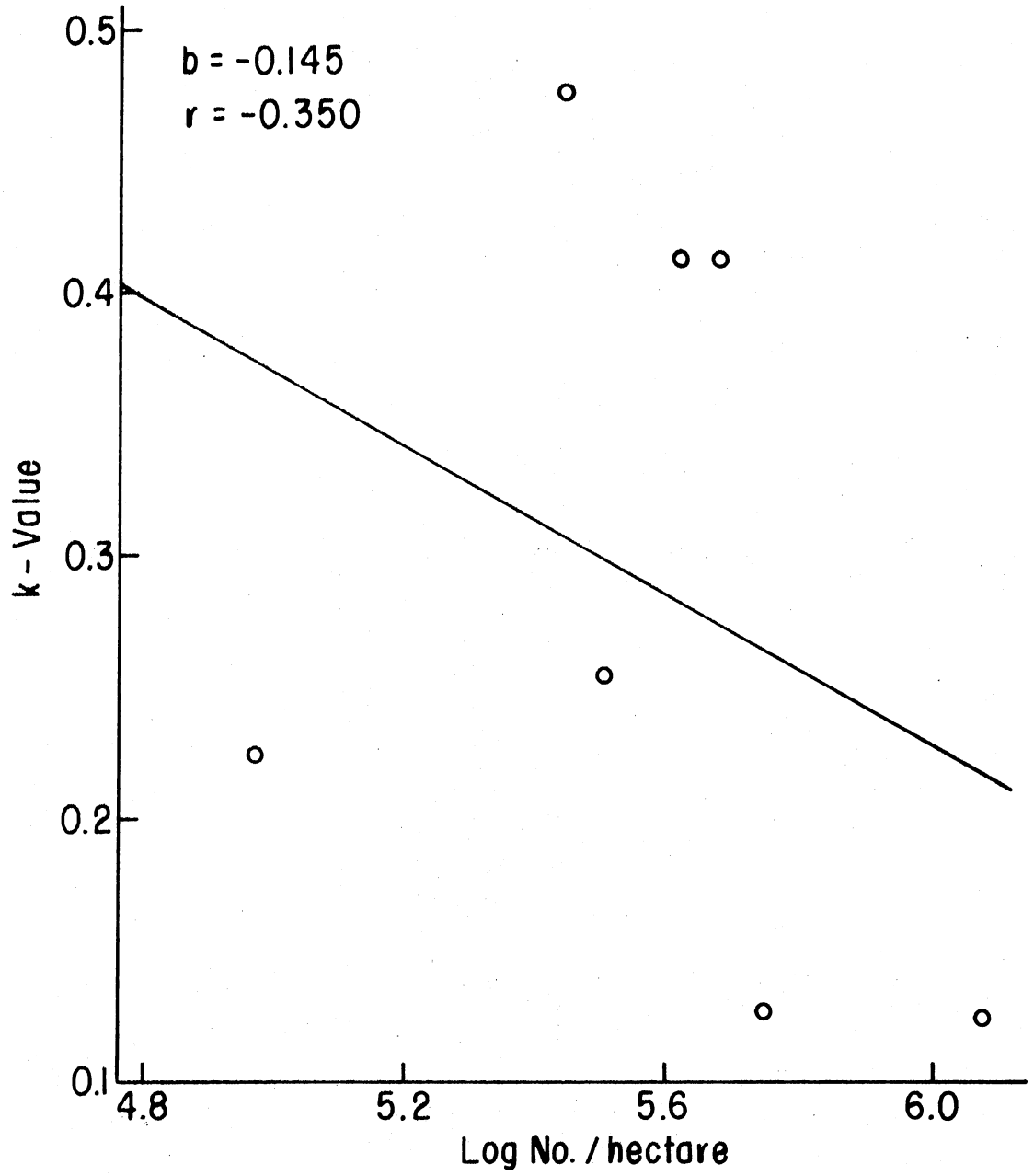

b = -0.145
r = -0.350
0.5
0.4
0.3
0.2
0.1
k - Value
4.8
5.2
5.6
6.0
Log No. / hectare

Figure 9. Response of Parasitism to Changes in Pupal Populations of S. bosqueella

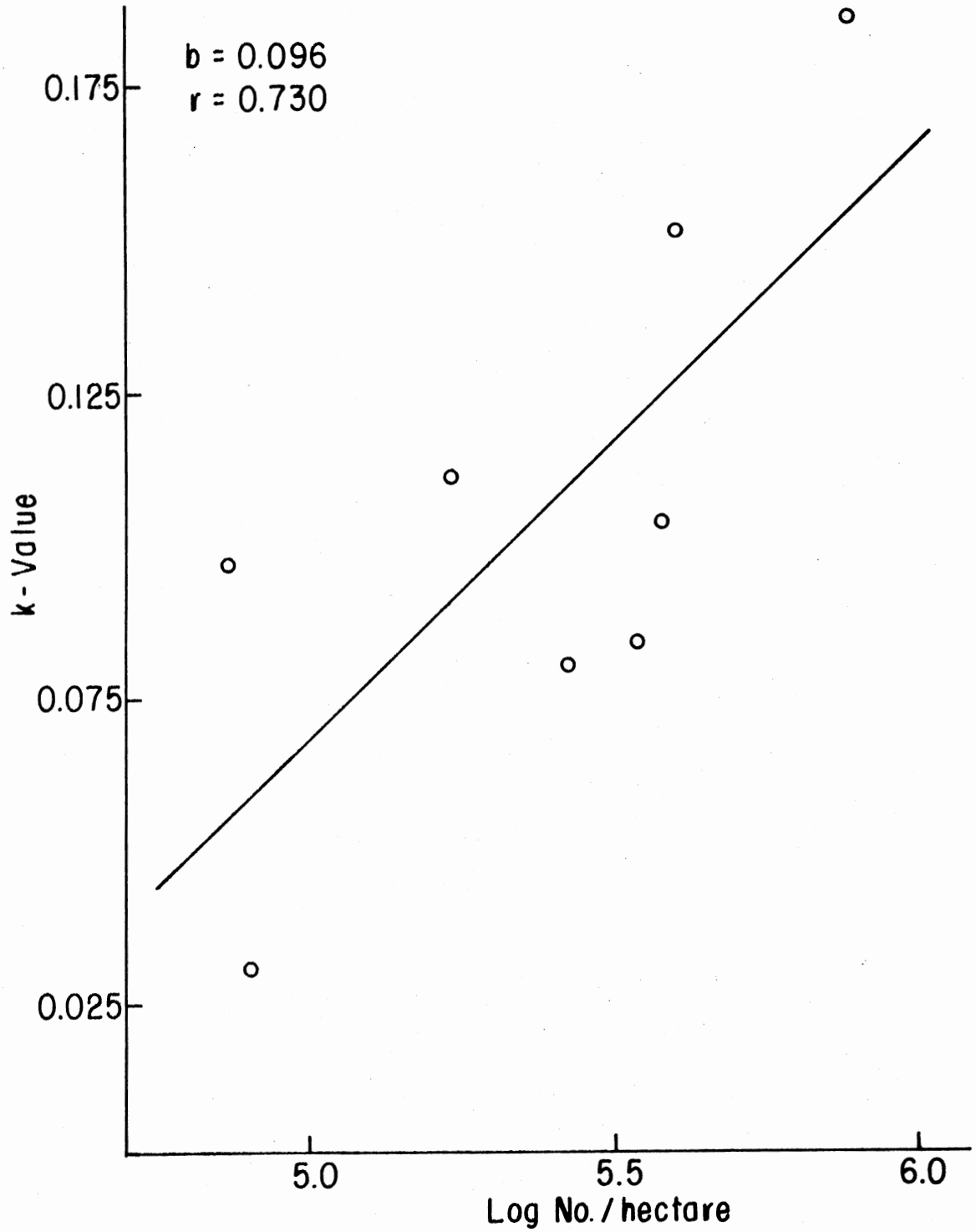

b = 0.096
r = 0.730
0.175
0.125
0.075
0.025
k - Value
5.0
5.5
6.0
Log No. / hectare

Figure 10. Response of Disappearance to Changes in Pupal Populations of *S. bosqueella*

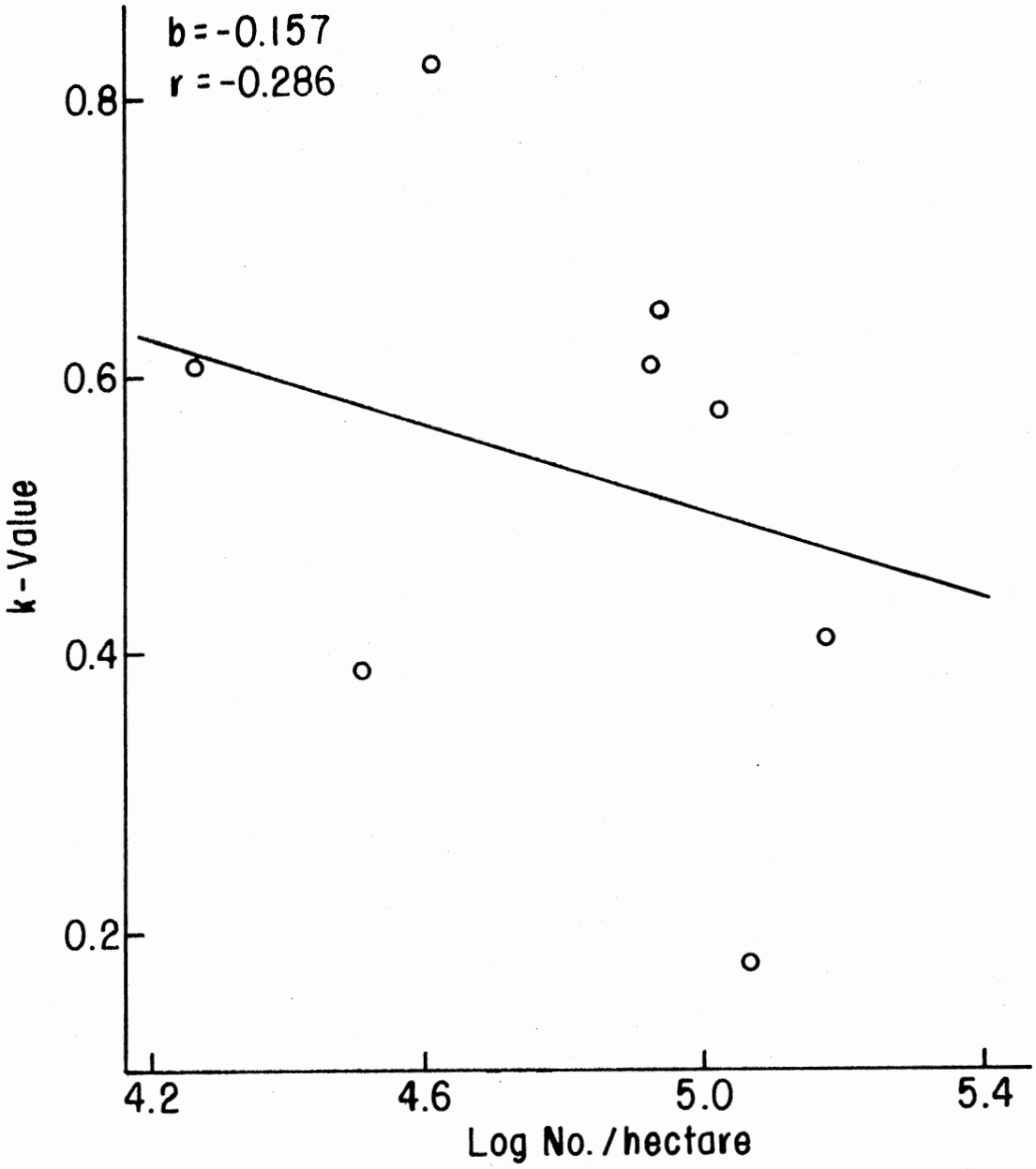

b = -0.157
r = -0.286
0.8
0.6
0.4
0.2
k - Value
4.2
4.6
5.0
5.4
Log No. / hectare

Figure 11. Response of Disappearance to Changes in Populations of S. bosqueella

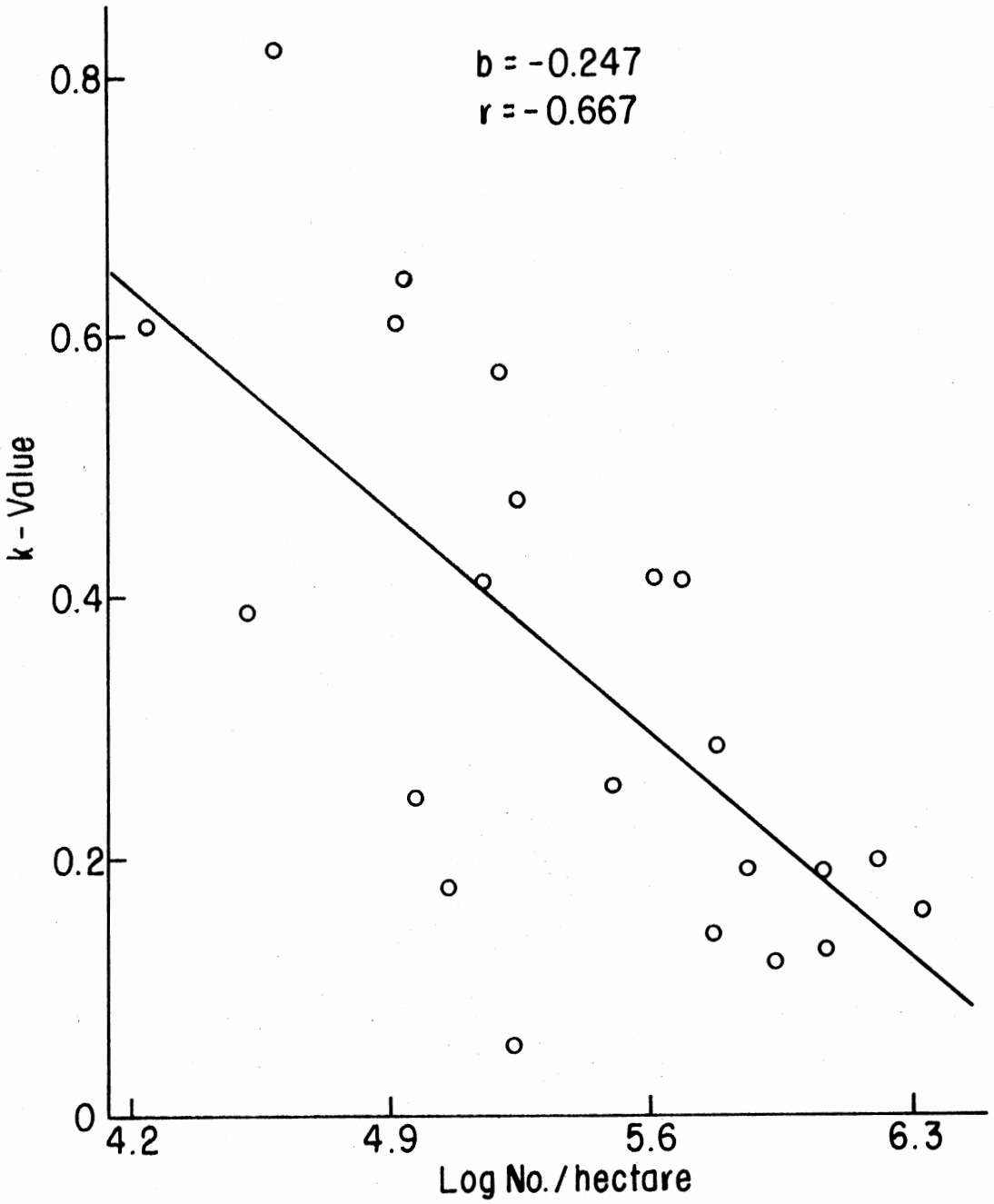
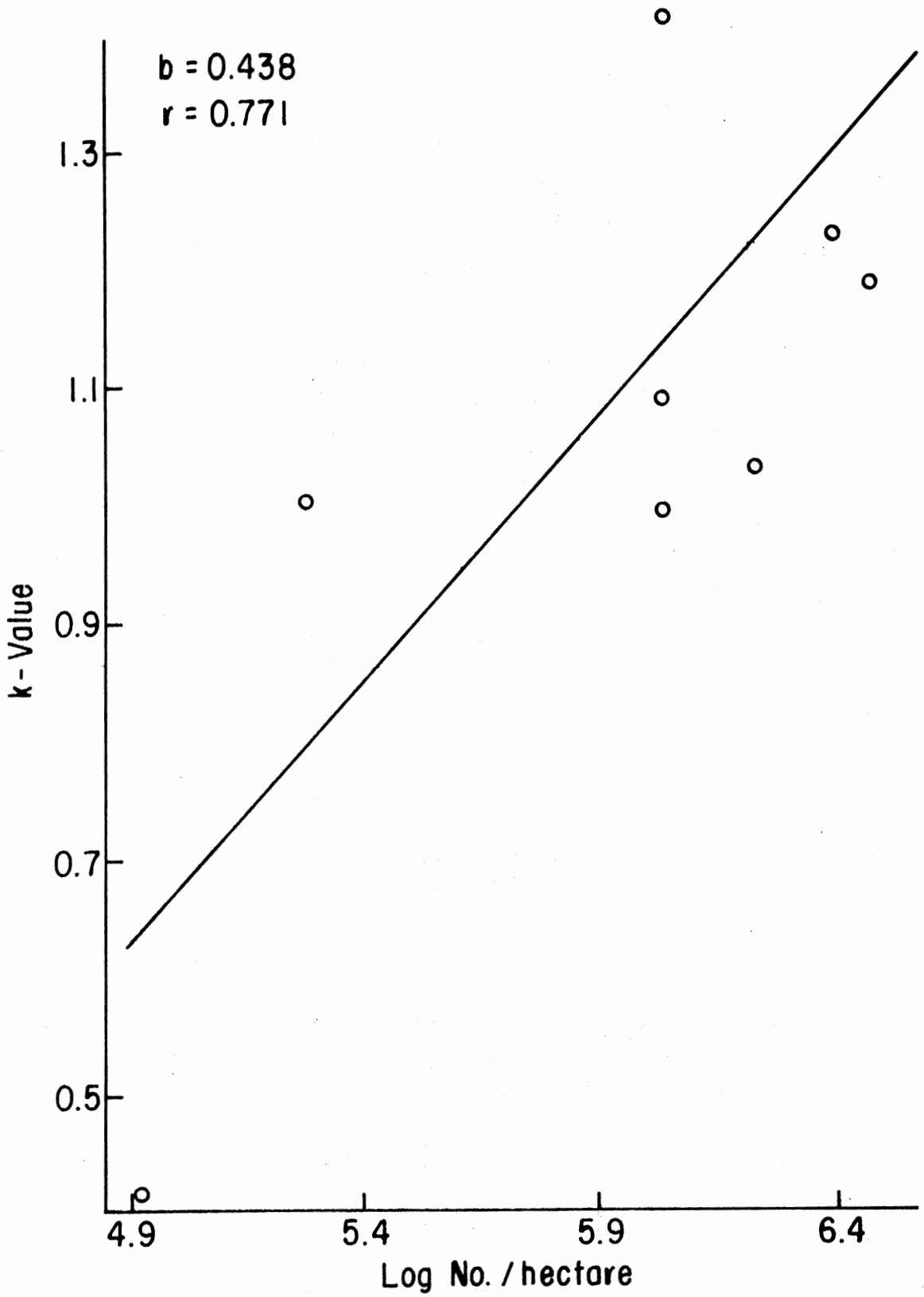
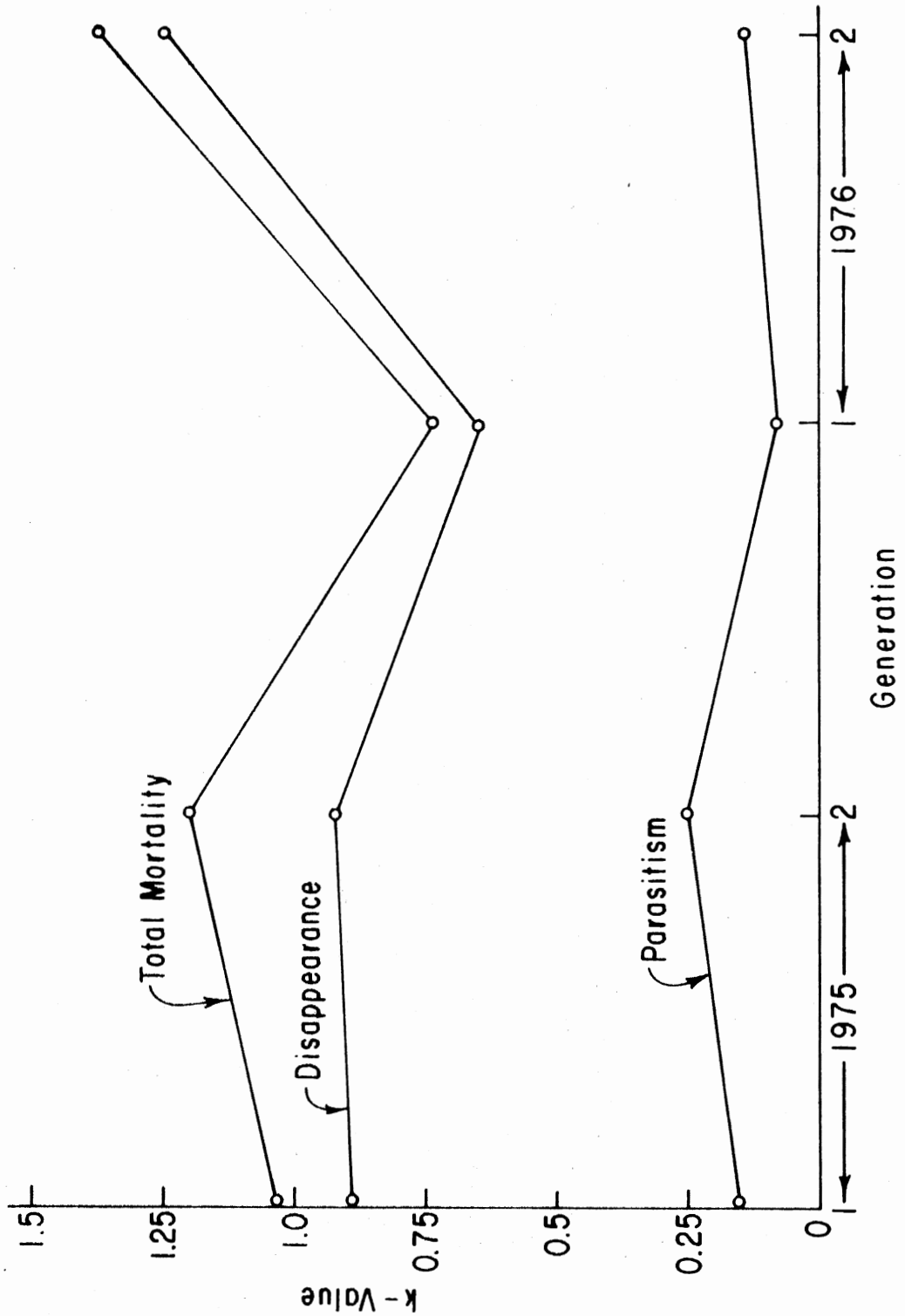

b = -0.247
r = -0.667
0.8
0.6
0.4
0.2
0
k - Value
4.2
4.9
5.6
6.3
Log No./hectare

Figure 12. Response of Total Mortality (K) to Changes in Populations of *S. bosqueella*


b = 0.438
r = 0.771
1.3
1.1
0.9
0.7
0.5
k - Value
4.9
5.4
5.9
6.4
Log No. / hectare

disappearance of small larvae was density dependent (b = 0.084) and that it greatly undercompensated for increases in larval density indicating that it may be a biological agent. Figure 8 indicates an inverse density dependence (b = -0.145) for disappearance of large larvae. Parasitism was density dependent (b = 0.096) but greatly undercompensated for changes in pupal populations (Fig. 9). Pupal disappearance (Fig. 10) indicated inverse density dependence (b = -0.157). Total disappearance (Fig. 11) was inversely density dependent of population numbers (b = -0.247). Total mortality (K) was directly density dependent but undercompensated (b = 0.467) for changes in host density suggesting that a major portion of the total mortality for S. bosqueella was produced by a biological agent such as parasitism (Fig. 12). Although disappearance produced the majority of mortality, its action was very similar to that of parasitism (Fig. 13). This indicated that much of the disappearance perhaps was due to undetected parasites or predators. This fact along with the density dependence of total mortality (Fig. 12) suggested that biological agents were responsible for the majority of S. bosqueella mortality.

Figure 13. Mortality Affecting S. bosqueella on Peanuts in Oklahoma


k - Value
1.5
1.25
1.0
0.75
0.5
0.25
0
Total Mortality
Disappearance
Parasitism
1975
2
1976
2
Generation

CHAPTER IV

PEANUT RESPONSE TO DAMAGE BY *S. BOSQUEELLA*

Introduction

Studies have shown that defoliation can cause a significant yield reduction in peanuts and other legumes by reducing numbers of pods and size of kernels (Enyi, 1975, Poston and Pedigo, 1976, Williams et al., 1976). The probabilities of economic losses due to foliar feeding damage by the rednecked peanutworm have not previously been investigated. Many peanut growers have expended time and funds making insecticide applications for control of this pest without sufficient knowledge of its damage potential. The objective of this research was determination of plant responses to the possibilities for yield reductions due to feeding of *S. bosqueella* in Spanish peanuts, so that control recommendations could be adjusted to minimize insecticide applications and producer costs.

Methods and Materials

Characterization of plant response in Spanish peanuts to foliar damage in developing leaflets was accomplished by mechanically removing tissue within terminals of 'Spanhoma' variety peanuts. Simulated *S. bosqueella* damage was produced by using punches 1.6, 2.4, 3.2, and 4.0 mm in diameter constructed on the tips of forceps to remove precise

amounts of tissue without damage to the remainder of leaflets. One to 3 holes were punched in each leaflet as it emerged from the terminal (before it had begun to unfold) to remove 1-10% of the tissue while avoiding damage to the midrib which is seldom fed upon. Leaflets were photographed immediately after punching using a 1 mm^2 grid background to measure the leaflet area and compute area removed. When mature, leaflets were again photographed against the grid background to compare total area vs. missing area by viewing photographic negatives under a stereomicroscope. Division of missing area by total area yielded percent reduction in both newly punched and mature leaflets. Leaflet response to damage (= leaflet compensation) was calculated by the equation:

$$\% \text{ compensation} = \frac{P1 - P2}{P1} \times 100$$

Where: P1 = percent leaf area removed at punching

P2 = percent leaf area reduction at maturity

Forty-two observations were utilized in forming the regression to show the relationship between size when punched vs. percent compensation.

To calculate the reduction in leaf area caused by actual feeding of S. bosqueella, larvae were confined singly within terminals on field grown 'Spanhoma' peanuts and allowed to feed until pupation. Cylindrical cloth cages (ca. 10 X 30 cm) were placed over terminals to protect larvae from predation and parasitism and eliminate the possibility of infestation by additional larvae. After larval development was completed, cages were removed to insure unrestricted leaf maturation. Terminals were protected from additional damage by weekly applications of carbaryl insecticide. Mature leaflets (damaged and undamaged) were

removed and measured using an electronic area meter (Lambda Instruments Corporation, Lincoln, NE.).

Midrib length was used as an index of leaflet area in comparisons between damaged and undamaged leaves because it was the best measurable characteristic present in both. S. bosqueella larvae frequently destroyed much of the tissue of leaflets but seldom fed on the midrib and it appeared to grow normally in spite of such tissue destruction. Mean values for mature leaflet areas vs. midrib lengths were determined for undamaged leaflets and utilized to predict areas when midrib lengths were known.

Midribs of leaflets from each infested terminal were measured and these lengths were used to predict total areas which would have been present had no damage occurred. The remaining area of damaged leaflets was compared with the predicted total area to compute reduction due to feeding by each larvae. Average reductions were utilized in determinations of percent defoliation caused by various levels of S. bosqueella infestation.

The overall peanut plant response to foliar damage was investigated by taking quantitative measurements of individual stems from undamaged plants and those which had been artificially damaged or damaged by red-necked peanutworm feeding. One hundred stems of each treatment were selected at random from mature plants (ca. 120 days old), cut off at ground level and brought into the laboratory where the number of pegs and pods, dry weight of kernels and leaves, and the internodal lengths were recorded. Artificial damage was produced by punching holes in immature leaflets on field grown peanuts as described previously. Leaflets damaged in this manner as they emerged from the terminal closely

resembled those damaged by S. bosqueella feeding. Artificial damage was inflicted on all new leaflets on each plant 30-90 days post plant. Plants were checked for new leaflets at 3 day intervals and treated weekly with carbaryl insecticide to prevent insect infestation. An attempt was made when producing the artificial damage to remove 50% or more of each leaflet area. Peanutworm damaged stems were obtained from natural infestations in the field. A stem was considered damaged if it showed any signs of peanutworm feeding damage. The amount of damage to each stem was not quantified. Undamaged stems were obtained from a field plot which was kept uninfested by weekly applications of carbaryl insecticide. Data were analyzed using Duncans multiple range test to identify differences between means.

Results and Discussion

Unlike many lepidopterous peanut pests that feed mainly on mature leaves, larvae of the rednecked peanutworm feed in the terminals of the plant between adjacent leaflets or between halves of folded leaflets. Larvae continue to retreat into the terminal as leaflets on which they are feeding begin to unfold. Though the actual amount of tissue consumed by each larva within a terminal is quite small, it may represent a substantial reduction in mature leaf area from that terminal.

The ability of leaflets to compensate for damage appears to be influenced by the physiology of leaf growth. Primary growth of leaves as they develop from meristematic tissue is due largely to cell division. As they mature, cell enlargement becomes the predominant factor in size increase and cell differentiation begins to produce the various leaf tissues (Meyer et al., 1973). Cell division may permit replacement of

some missing undifferentiated cells if damage occurs when leaflets are small. As leaflets mature, however, cell division decreases and expansion of cells is responsible for leaflet enlargement. Leaflets damaged in later stages of development apparently lose the ability to replace missing cells, and decreased compensation for damage results.

When a percentage of tissue was removed from very small leaflets, plant compensation resulted in some repair of damage and percent area reduction became less as leaflets matured (Table XIII, Fig. 14). In computing area removed at punching, it is important to remember that the area of each opening must be multiplied X 2 because the same injury is inflicted in each half of the folded leaflets. If 10% of the tissue was removed from a leaflet which was 100 mm^2 in size, area reduction at maturity equaled only 6.7% due to compensation (Table XIII, Fig. 15, I). Leaflets which were ca. 158 mm^2 in size at the time of injury were no longer able to compensate and percent area reduction persisted at the same level until maturity (Fig. 14). When damage was inflicted as leaflets emerged from terminals and began to unfold, percent area reduction increased as they matured and a negative value for percent compensation was computed (Table XIII, Fig. 14). A leaflet from which 10% of the tissue was removed when ca. 450 mm^2 in size, exhibited an area reduction of 26.4% at maturity (Fig. 15, II). Damage by S. bosqueella was not observed after leaflets began to unfold.

The consistent relationship between midrib length and leaflet area made it possible to predict total area of damaged leaflets (Fig. 16). Mature, undamaged 'Spanhoma' peanut leaves had a mean area of 3388 mm^2. Feeding by each peanutworm larva resulted in a mean leaf area reduction of 3993 mm^2 which is slightly over 1 leaf (1.18 leaves = 4.7 leaflets).

TABLE XIII

COMPENSATION FOR 10% TISSUE REMOVAL IN GROWING LEAFLETS OF 'SPANHOMA' PEANUTS

Size mm^2 [a]	Area removed mm^2 [b]	Area removed % [b]	Area reduction mm^2 [c]	Area reduction % [c]	Compensation %
50	5	10	34	4.0	60
100	10	10	57	6.7	33
150	15	10	81	9.5	5
250	25	10	128	15.1	-51
350	35	10	176	20.7	-107
450	45	10	224	26.4	-164

a/ Leaflet area when damage was inflicted

b/ Area removed when damage was inflicted

c/ Area reduction in mature leaflet

Figure 14. Regression for Leaflet Size at Punching vs. Percent Leaflet Compensation for Tissue Removed in 'Spanhoma' Peanuts ($r = -0.838$)

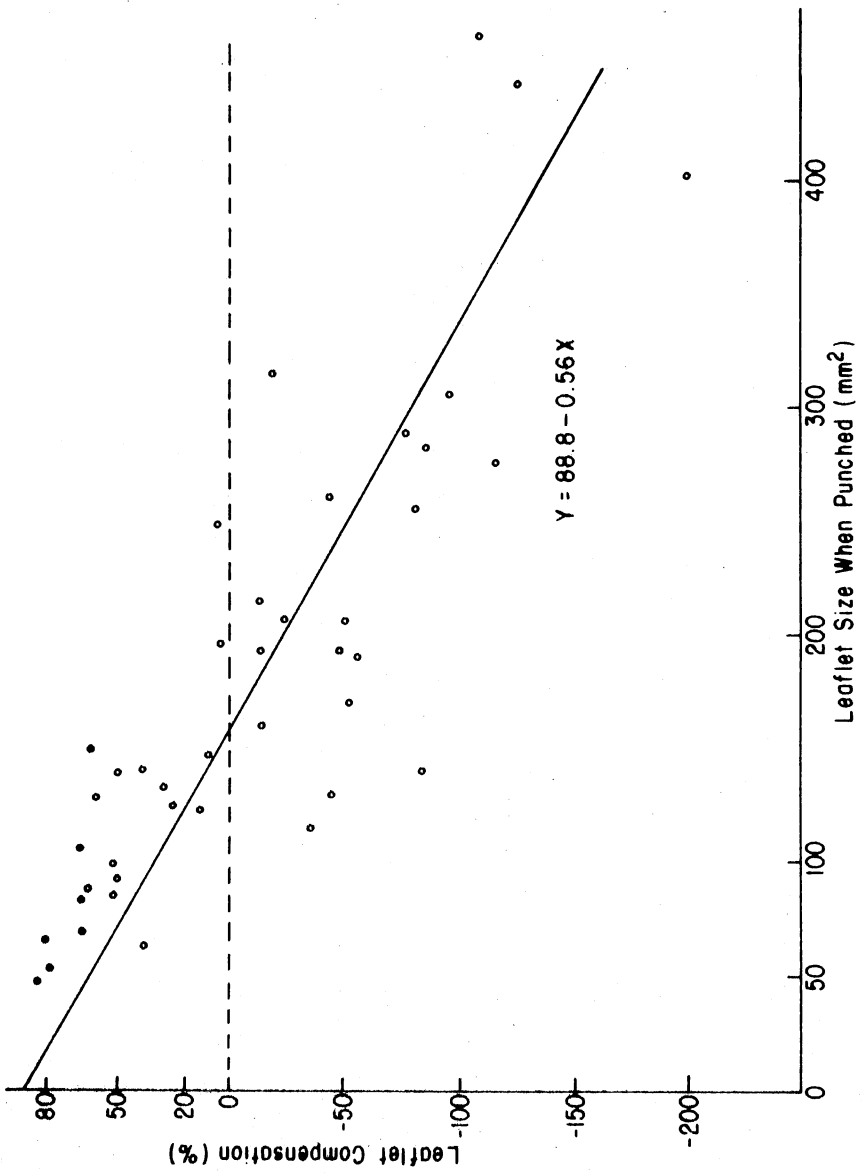

Leaflet Compensation (%)
80
50
20
0
-50
-100
-150
-200
0
50
100
200
300
400
Leaflet Size When Punched (mm²)
Y = 88.8 - 0.56 X

Figure 15. Area Reduction in Mature Leaflets of 'Spanhoma' Peanuts Relative to Size when Damage is Inflicted at 100 mm^2 (I; punch dia. = 2.4 mm) and 450 mm^2 (II; punch dia. = 4.0 mm) A, Leaflets Folded Within Terminal; D, Mature Leaf. Areas given are for individual leaflets.

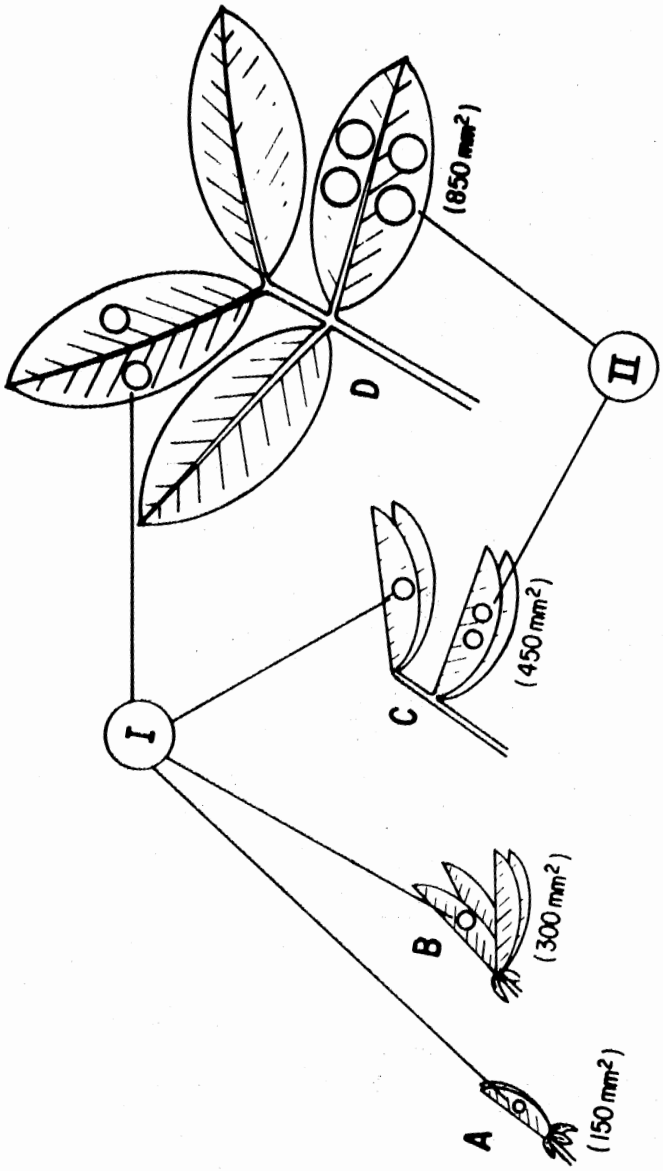
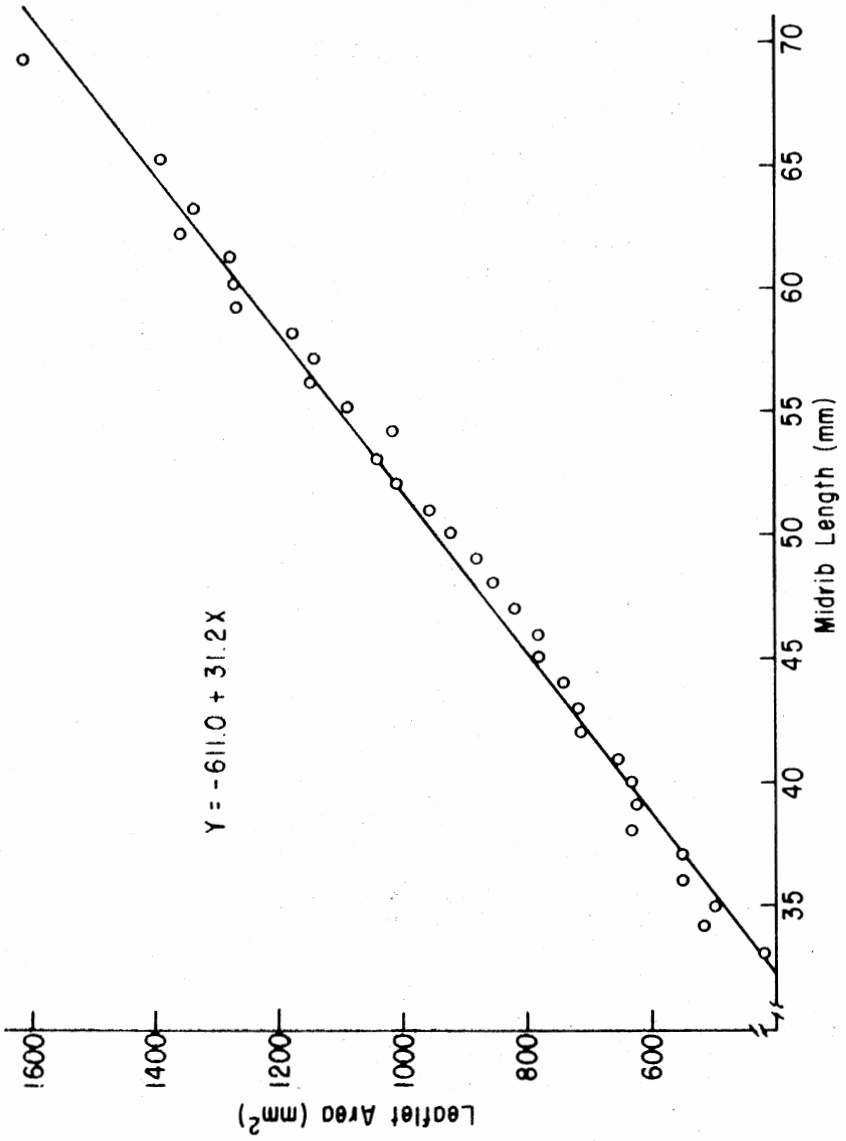

(850 mm²)
D
II
(450 mm²)
C
I
(300 mm²)
B
(150 mm²)
A

Figure 16. Regression for Leaflet Midrib Length vs. Leaflet Area (r = 0.99)


Leaflet Area (mm^2)
1600
1400
1200
1000
800
600
Y = -611.0 + 31.2X
35
40
45
50
55
60
65
70
Midrib Length (mm)

It was assumed in this study that leaf area reduction caused the same plant effects as defoliation. Thus, the terms are used interchangeably. Percent defoliation was estimated in Figure 17 for plants with varying numbers of leaves when larvae per plant was known. For example, if 10 larvae completed development on a plant with 80 leaves, approximately 15% reduction in leaf area would result.

Although Figure 17 presents the mean percent defoliation as an absolute figure, there may be considerable variation per larva, depending on the population size and size of leaflets being fed upon. As a population increased, young larvae began to feed in terminals just vacated by pupating larvae. When this happened young larvae found fewer unfolded leaflets emerging from terminals in which to feed and were forced to feed deep within the terminals. Resulting destruction of meristematic tissue reduced numbers of leaves from each and at times prevented growth entirely. In such cases the damage done per larva far exceeded 3993 mm^2. Figure 17 was constructed with data obtained from terminals that were damaged by only 1 larva and subsequently protected from additional larval damage. Thus, predicted percent defoliation tended to become progressively more conservative as the population levels increased.

The overall plant response to actual and artificial larval damage differed significantly (Table XIV). Although foliar damage produced by artificial means appeared very similar to that produced by larvae of the rednecked peanutworm, plant response to the 2 types of damage was not the same. Peanut plants which sustained heavy artificial damage showed a significant reduction in all characteristics measured except number of pegs and internodal length as compared to either larval damaged or

Figure 17. Percent Defoliation in Peanuts due to Infestation by *S. bosqueella*

NUMBER OF LEAVES / PLANT

S. BOSQUEELLA / PLANT

	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195
1	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	6	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
3	9	8	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
4	12	10	9	9	8	7	7	6	6	6	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	2	2
5	15	13	12	11	10	9	8	8	7	7	7	6	6	6	5	5	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3	3
6	18	16	14	13	12	11	10	9	9	8	8	7	7	7	6	6	6	6	5	5	5	5	5	5	4	4	4	4	4	4	4	4
7	21	18	16	15	14	13	12	11	10	10	9	9	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	5	5	4	4	4
8	24	21	19	17	16	14	13	13	12	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	6	6	5	5	5	5	5
9	27	24	21	19	18	16	15	14	13	12	12	11	11	10	10	9	9	8	8	8	8	7	7	7	7	6	6	6	6	6	6	5
10	29	26	24	21	20	18	17	16	15	14	13	12	12	11	11	10	10	9	9	9	8	8	8	8	7	7	7	7	7	6	6	6
11	32	29	26	24	22	20	19	17	16	15	14	14	13	12	12	11	11	10	10	10	9	9	9	8	8	8	8	7	7	7	7	7
12	35	31	28	26	24	22	20	19	18	17	16	15	14	13	13	12	12	11	11	10	10	10	9	9	9	9	8	8	8	8	7	7
13	38	34	31	28	26	24	22	20	19	18	17	16	15	15	14	13	13	12	12	11	11	11	10	10	10	9	9	9	9	8	8	8
14	41	37	33	30	27	25	24	22	21	19	18	17	16	16	15	14	14	13	13	12	12	11	11	11	10	10	10	9	9	9	9	8
15	44	39	35	32	29	27	25	24	22	21	20	19	18	17	16	15	15	14	14	13	13	12	12	11	11	11	10	10	10	10	9	9
16	47	42	38	34	31	29	27	25	24	22	21	20	19	18	17	16	16	15	14	14	13	13	13	12	12	11	11	11	10	10	10	10
17	50	44	40	36	33	31	29	27	25	24	22	21	20	19	18	17	17	16	15	15	14	14	13	13	13	12	12	11	11	11	11	10
18	53	47	42	39	35	33	30	28	26	25	24	22	21	20	19	18	18	17	16	16	15	15	14	14	13	13	12	12	12	11	11	11
19	56	50	45	41	37	34	32	30	28	26	25	24	22	21	20	19	19	18	17	17	16	15	15	14	14	14	13	13	12	12	12	11
20	59	52	47	43	39	36	34	31	29	28	26	25	24	22	21	20	20	19	18	17	17	16	16	15	15	14	14	13	13	13	12	12
21	62	55	49	45	41	38	35	33	31	29	27	26	25	24	22	22	21	20	19	18	18	17	16	16	15	15	15	14	14	13	13	13
22	65	58	52	47	43	40	37	35	32	30	29	27	26	25	24	23	22	21	19	19	19	18	17	17	16	16	15	15	14	14	14	13
23	68	60	54	49	45	42	39	36	34	32	30	29	27	26	25	24	23	22	20	20	19	19	18	17	17	16	16	15	15	15	14	14
24	71	63	57	51	47	43	40	38	35	33	31	30	28	27	26	25	24	23	21	21	20	19	19	18	18	17	17	16	16	15	15	14
25	74	65	59	55	51	47	43	39	37	35	33	31	29	28	27	26	25	24	23	22	21	20	20	19	18	18	17	17	16	16	15	15
26	77	68	61	56	51	47	44	41	38	36	34	32	31	29	28	27	26	24	23	23	22	21	20	20	19	19	18	17	17	17	16	16
27	80	71	64	58	53	49	45	42	40	37	35	33	32	32	29	28	26	25	24	24	23	22	21	21	20	19	19	18	18	17	17	16
28	83	73	66	60	55	51	47	44	41	39	37	35	33	31	30	29	27	26	24	24	23	23	22	21	21	20	19	19	18	18	17	17
29	85	76	68	62	57	53	49	46	43	40	38	36	34	33	31	30	28	27	26	25	24	24	23	22	21	21	20	20	19	18	18	18
30	88	79	71	69	59	54	50	47	44	42	39	37	35	34	32	31	29	28	27	26	25	24	24	23	22	21	21	20	20	19	19	18

TABLE XIV

MEAN PEANUT PLANT RESPONSES TO FOLIAR DAMAGE

	Undamaged	Artificially damaged	Peanutworm damaged
No. pegs/ internode	0.66[b]	0.61[ab]	0.41[a]
No. pods/ stem	3.03[b]	1.82[a]	2.70[b]
Total kernel wt./ stem (g)	1.69[b]	0.94[a]	1.49[b]
Total leaf wt./ stem (g)	1.79[b]	1.21[a]	1.89[b]
Internode length (mm)	33.41[a]	20.32[b]	10.54[c]

Means followed by the same letter are not significantly different at the 0.05 level.

undamaged plants.

Artificially damaged plants produced significantly less dry leaf weight than either larval damaged or undamaged plants. These plants appeared attenuated (thin stems and leaves). It appeared that the artificial damage was more severe in leaf tissue removal than actual larval feeding however, plant growth as indicated by internodal length was affected more by larval feeding than artificial damage. This difference in growth may have been due to larval feeding deep within the terminal (on meristematic tissue) which could have caused a direct reduction in cell numbers resulting in shorter stems. Another possible explanation might be that larvae of the rednecked peanutworm produced a plant auxin inhibitor which either reduced cell numbers or inhibited their elongation. Field observations verify that plants damaged by S. bosqueella often appeared stunted and tended to produce thick stems and leaves.

Peanutworm damaged plants produced significantly fewer pegs than did undamaged plants however, pod and nut production was not significantly affected. Artificially damaged plants did not produce as many pods as did the other 2 treatments although peg production was not significantly different from either. The reduction in nut production may have simply been due to the inability of the pegs to penetrate and remain in the soil because of the constant plant manipulation experienced in producing the artificial damage.

Summary

The actual amount of yield reduction resulting from defoliation depends on the extent of damage and the age of the plant (Williams et at., 1976). Peak S. bosqueella populations generally occur at ca. 50-

90 days post plant in Oklahoma. Smith[1] (personal communication) has conducted studies which show that Spanish peanuts are quite susceptible to yield reductions due to defoliation during this period of plant development. As little as 10% defoliation may cause reductions of several hundred kg/ha.

Low numbers of S. bosqueella often cause peanut leaves to become very ragged but it is somewhat doubtful that they can cause serious yield reductions due to defoliation alone except for the time when the plants are most susceptible (50-90 days post plant). It should also be pointed out that area reduction in mature leaves is cumulative for the plant so that feeding of multiple generations of S. bosqueella or damage by other foliage feeders increases the probabilities for significant economic losses in production. Furthermore, actual peanut yield reductions caused by larval feeding of S. bosqueella may involve more than those caused by simple defoliation. We found no feasible way to quantify losses due to complete destruction of meristematic tissue within plant terminals or those caused by larval feeding in leaf axils. Undoubtedly heavy feeding in leaf axils could reduce the number of pegs, resulting in decreased numbers of pods. As populations of this pest increase, the probability for economic loss increases, not only from the increased defoliation but from destruction of meristematic tissue in terminal buds and developing pegs in leaf axils.

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APPENDIX A

TOTAL PARASITES RECOVERED

Parasite species	1975 Field #1	1975 Field #2	1976 Field #1	1976 Field #2	Total
Apanteles epinotiae	1	-	-	-	1
Apanteles spp.	7	2	-	-	9
Chelonus texanus	1	-	-	-	1
Chelonus (Microchelonus) sp.	143	22	5	1	171
Diadegma compressum	19	3			22
Invreia spp. [a]	300	77	59	67	503
Macrocentrus ancylivorus	1	1	8	4	14
Microplitis croceipes	17	5	5	2	29
Orgilus modicus	1070	357	154	245	1826
Pristomerous spinator	38	7	-	-	45
Spilochalris sanguinivantris	-	1	-	-	1
Unidentified hymenoptera	88	25	10	6	129
Perilampus fulvicornis [b]	17	2	1	-	20
Total [c]	1685	500	241	325	2751

[a] includes Haltichella sp.

[b] a hyperparasite

[c] does not include P. fulvicornis

APPENDIX B

NUMBER OF PLANT TERMINALS

1975			1976		
	No. terminals/ plant			No. terminals/ plant	
Plant age (days post plant)	Field #1 [a]	Field #2 [b]	Plant age (days post plant)	Field #1 [c]	Field #2 [d]
35	4.7	5.0	27	3.2	3.4
43	4.2	5.1	35	2.9	5.1
51	8.0	5.6	43	4.1	5.7
59	10.1	9.8	51	4.1	6.7
67	10.7	12.3	59	4.1	6.6
75	9.7	10.8	67	4.1	6.2
83	11.8	11.7	75	4.2	6.9
91	11.6	10.3	83	4.6	6.8
			93	4.6	5.9
			100	4.6	6.1

[a] plant density = 9.8 plants/row meter

[b] plant density = 10.2 plants/row meter

[c] plant density = 17.7 plants/row meter

[d] plant density = 13.5 plants/row meter

VITA[2]

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