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HIBERNATION OF THE BOLL WEEVIL

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With the approach of cool weather in the fall the boll weevil instinctively seeks sheltered situations in which to pass the winter or hibernate. The insect does not enter a period of true hibernation but remains more or less active during warm spells in the winter and may leave the selected shelter, only to reenter it when temperatures decrease and become hazardous. Those individuals that pass the winter successfully constitute the only source from which infestations may develop in the crop the following spring. Knowledge of the winter survival of the weevil is therefore of practical value in anticipating the development of injurious infestations.

Among the factors influencing the extent of weevil mortality during the winter, minimum temperatures are most important. From 6 to 19 per cent of the overwintering weevil population survived when minimum temperatures did not fall below 25 degrees F. On the other hand, during seasons when minimum temperatures ranged from 17 to 0 degrees F., less than 2 per cent of the weevils survived. The average survival of the boll weevil in hibernation cages at College Station for 18 seasons (fall of 1925 to spring of 1942) was 6.04 per cent. The mortality among the weevils caged prior to October 15 was nearly three times greater than that recorded for installations made at subsequent dates. This illustrates the importance of early destruction of the weevil's food supply.

Emergence of the weevil from hibernation begins when average mean temperatures reach 55 to 60 degrees F. After emergence is definitely under way, rainfall has an important influence on the rate at which the surviving weevils leave shelter. Frequent well distributed showers followed by warm sunshine are favorable conditions for a maximum rate of emergence. During the 18-year period at least 50 per cent of the surviving weevils emerged by May 15; but emergence may not be completed until the middle of July. The heaviest emergence takes place during the latter half of May.

The percentage of weevil survival has no direct relation to the extent of injury that may be produced during the season. Prevailing climatic conditions are a limiting factor in this respect. A very light weevil survival followed by favorable weather conditions may increase rapidly and produce widespread injury to the crop, as was experienced in 1935. On the other hand, prolonged hot, dry weather may effectively check the activities of a heavy weevil survival as was recorded in 1931. Since future weather conditions remain an unknown factor, the development of injurious weevil infestations cannot be anticipated very far in advance of their actual occurrence.

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HIBERNATION OF THE BOLL WEEVIL

by

H. J. REINHARD

With the advent of decreasing temperatures in the fall, boll weevils begin to seek sheltered situations in which to pass the cold or winter period. The movement of the insect into winter quarters is a rather gradual process and usually extends from early fall to the time of frost or when the cotton plants are generally killed in the field. In seeking protection the weevils may select any shelter available in the cotton field or they may move to fence rows grown up in grass or weeds, hay stacks, barns, gin houses, or any other similar situations which may be available. In timbered or wooded sections of the State many weevils find and utilize the favorable shelter afforded by Spanish moss, leaves, and other materials. It has, in fact, been repeatedly demonstrated by examinations made during the winter season that Spanish moss when available is one of the most common shelters selected by the boll weevil for protection from cold weather.

The cold season, during which an insect remains inactive and does not feed, is called the hibernation period. Strictly speaking, there is no period of true hibernation in the boll weevil's seasonal history. It remains more or less active and during warm spells in the winter may leave its shelter entirely only to reenter it when temperatures again decrease and become hazardous. During unusually mild seasons weevils may continue to feed and reproduce during the winter months as long as green cotton squares and bolls remain available. This, however, is not a common occurrence in most sections of the State. Frosts ordinarily kill all cotton, which is practically the only food on which the insect can survive and reproduce.

The so-called hibernation period of the boll weevil or that season during which the insect is without food or means of multiplication is of particular importance to cotton growers, because at this time the weevil is perhaps most vulnerable to attack by clean-up measures. Obviously the weevils are producing no damage after the crop has been harvested but it should be remembered that those weevils which successfully pass the winter constitute the only source of infestation to the new crop the following spring. Any material reduction of the number of overwintering weevils, whether due to natural factors or to proper clean-up measures applied, results in a corresponding decrease in the potential source for early damage to the new or subsequent crop. It is not always the case that a heavy winter survival of weevils is followed by severe injury or that a light survival indicates prospects for little or no damage to cotton. The prevailing climatic conditions, especially during the early part of the growing season, seemingly determine in a

very large measure the extent of damage that is produced by the weevil population that survives the winter. In the past, cotton growers perhaps have over emphasized the importance of the percentage of winter survival of the weevil as an indication of future infestations of the current crop. The extent to which the weevil may be expected to injure any crop cannot be predicted with accuracy very far in advance of actual occurrence. The rate of weevil increase is directly influenced, either favorably or unfavorably, by prevailing weather conditions as the season advances. In other words, that portion of the weevil population which survives the winter successfully constitutes the source from which all subsequent weevil injury develops; knowledge of it is therefore essential to growers in anticipating the development of injurious infestations as influenced by climatic conditions.

Studies on boll weevil hibernation have been conducted by the Texas Agricultural Experiment Station at College Station since the fall of 1923 and the results are presented in this Bulletin.

METHOD OF CONDUCTING HIBERNATION STUDIES

Since the immature stages of the boll weevil are ordinarily destroyed by cold weather during the fall or winter all observations on the hibernation of this insect are confined to the weevil or mature insect.

To determine the percentage of winter survival boll weevils were collected in lots of 500 each and installed in cages under open field conditions with Spanish moss provided as shelter material. The collections and installations of weevils were made at weekly intervals beginning the first week in October and continued until the occurrence of the first frost. In nature the majority of weevils seemingly move to shelter during the time indicated and the individuals installed in the hibernation cages are assumed to represent a fairly close approximation of the natural overwintering population. All the weevils were collected from green cotton in local fields and placed in the cages without food on the date of collection.

The type of cage used in these studies (Figure 1) is a wood frame construction of 2 x 2 inch material and measures 4 x 4 x 4 feet. The sides and top are covered with 16-mesh wire screen. One side of the cage is provided with a door which is closely fitted to prevent the escape of any confined weevils. A few inches from the top in the cage Spanish moss is suspended from two diagonal wires as shelter for the weevils. This material was selected in these studies, since, as already pointed out, the weevil commonly chooses it in nature as a protective shelter against cold. The bottom of the cage is also covered with about a three-inch layer of the same material. The total amount of moss used in each cage ranges from 20 to 30 pounds and occupies in large part the space within the cage at the time the weevils are installed.

After the insects were installed in the fall the cages were left undisturbed until the following spring. It should be mentioned that in most

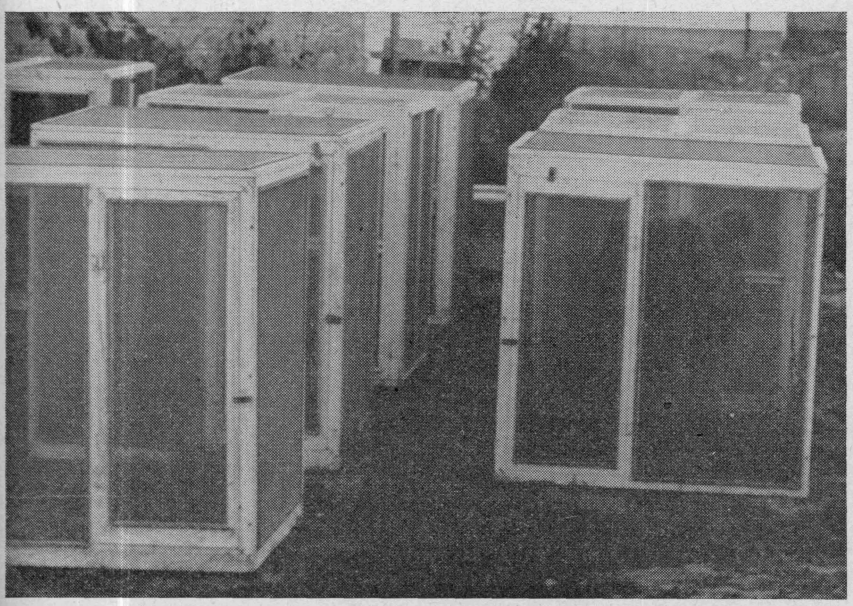

Figure 1. Type of cage used in the boll weevil hibernation studies.

cases the hibernation cages were situated under open field conditions, that is, fully exposed to sunshine, winds, and rains. Beginning March 1 during the period 1925 to 1935, inclusive, all active weevils were removed daily from each cage as they emerged from shelter. From 1936 to 1942, inclusive, removal of active weevils was delayed until one week after cotton first appeared in local fields; the first date when emergence was recorded each season usually occurred between April 1 and 15. All records were made daily at 1:00 P. M. and continued until the emergence was completed. Throughout the period of these studies climatological data were recorded for the purpose of noting the effect of these factors on winter survival and emergence from hibernation in the spring.

All the weevils used were taken at random from green cotton throughout the time of normal entrance into hibernation. They may be considered to represent an average cross-section of the hibernating weevil population in nature during any year included in these studies at College Station. Under natural conditions it appears quite likely that a smaller percentage of the weevils actually seek shelter prior to October 16 than is the case with the individuals which were confined in these cage tests. Many of the weevils installed early in the fall remained active and starved before temperatures low enough to induce hiberation occurred; whereas in nature weevils have free access to food until forced to seek winter shelter by the proper combination of factors. For these reasons the data presented herein may be considered conservative

with respect to the extent of winter survival of the insect under natural or field conditions.

DURATION OF HIBERNATION PERIOD

Entrance of the weevil into hibernation apparently begins at no regular or specific time in the fall. It is likely influenced to some extent by certain physiological changes within the insect as well as by the direct effect of climatic factors. It has been shown that some individuals may seek winter quarters and begin hiberation as early as September when green cotton squares and bolls may still be available for food in the field. The extent to which this occurs is seemingly limited and usually the majority of weevils do not cease to feed and multiply until about the time frosts occur. Throughout the period covered in these studies the weevils which were caged subsequent to October 15, survived in greatest numbers, indicating that this is the most favorable time for beginning entrance into winter shelter. To secure data on weevils hibernating prior to this time the cage installations for observation on winter survival were begun during the first week of October, which, it is assumed, is early enough to include the first definite movement of the insect from the field to winter quarters.

It has been pointed out that the weevil is more or less active during the warmer spells throughout the winter. Those overwintering individuals in the least protected situations are likely the first ones to be influenced by warm weather and leave their shelter, while others with more adequate protection may remain wholly inactive from the time of entrance into hibernation in the fall until the following June. In other words, the duration of the hibernation period cannot be limited by any very definite dates. At College Station the weevils normally become active in numbers after March 1 and for this reason removal of the active individuals from the hiberation cages was begun on that date during the early part of this study. During seasons when the insect has survived the winter in large numbers all individuals may not leave their winter quarters within the cages until some time during the early part of July and perhaps even later under field conditions. Apparently, the growing season may be well advanced before all surviving weevils have emerged from winter shelter and resumed normal activities.

The average period of boll weevil hibernation may be considered to extend from November to May, inclusive, a period of about seven months. The extremes of the period may possibly range from four to nine months.

CLIMATIC CONDITIONS DURING HIBERNATION PERIOD

Weather conditions, among other factors, during the hibernation period of the weevil have a direct influence on the percentage of survival. Assuming that the protection supplied in the hibernation cages approximates the type of shelter selected by weevils under natural conditions, it may be stated that mild winters with a minimum temperature

not lower than 25 degrees F., are followed by at least an average emergence, but when the temperature falls below 15 degrees F., the survival is much less than average, depending on the severity of the cold weather. The winter seasons during the period covered by these studies include contrasting years with respect to both minimum temperatures and rainfall. For example, a minimum temperature of 0 degrees F. was recorded in 1930, while the following year was exceptionally mild with barely freezing temperatures prevailing at any time during the winter. Rainfall during the hibernation period of the weevil is also subject to considerable variation, ranging from about 6 to 24 inches. An analysis of the weevil survival data recorded in these cage experiments shows no close correlation between the amount of rainfall and the successful overwintering of the weevil, but there is apparently a very direct relation between the percentage of survival and minimum temperature.

Effect of Minimum Temperatures on Weevil Survival

As determined by cage studies during the seasons 1925 to 1942, inclusive, the extent of weevil survival ranged from less than 1 to more than 19 per cent. In this connection it should be pointed out that even under most favorable conditions more than 80 per cent of all the confined weevils succumbed during the winter season. Obviously, not all this mortality is the direct result of unfavorable climatological factors. Many of the weevils which hibernate are apparently old or worn out individuals which die naturally, regardless of prevailing weather conditions. In the random collection of weevils made for cage installation, it may be assumed that the proportion of the individuals which were vigorous enough to withstand the rigors of a dormant season approximated that existing in natural or field populations.

Among the factors influencing the extent of weevil mortality during the winter, minimum temperatures seem most important. This relationship is graphically illustrated in Figure 2. It will be noted that generally 10 to 19 per cent of the caged hibernating weevils survived in 1931, 1934, 1937 and 1941 when the minimum temperatures for these years did not fall below 26 degrees F. On the other hand, in 1928, 1930, 1933, 1935, 1936, and 1940 with minimum temperatures of 17 to 0 degrees F. prevailing, less than 2 per cent of the individuals passed the winter successfully. The data further indicate that during winters with minimum temperatures not falling below 25 to 20 degrees F. a survival of about 4 to 7 per cent may be expected. Temperatures below these limits resulted in a sub-average percentage of survival among the caged weevils.

RELATION OF SHELTER TO WEEVIL SURVIVAL

The kind of shelter available to the weevil for protection during the dormant season is also an important factor that influences the extent to which the insect may survive the winter successfully. Obviously, those

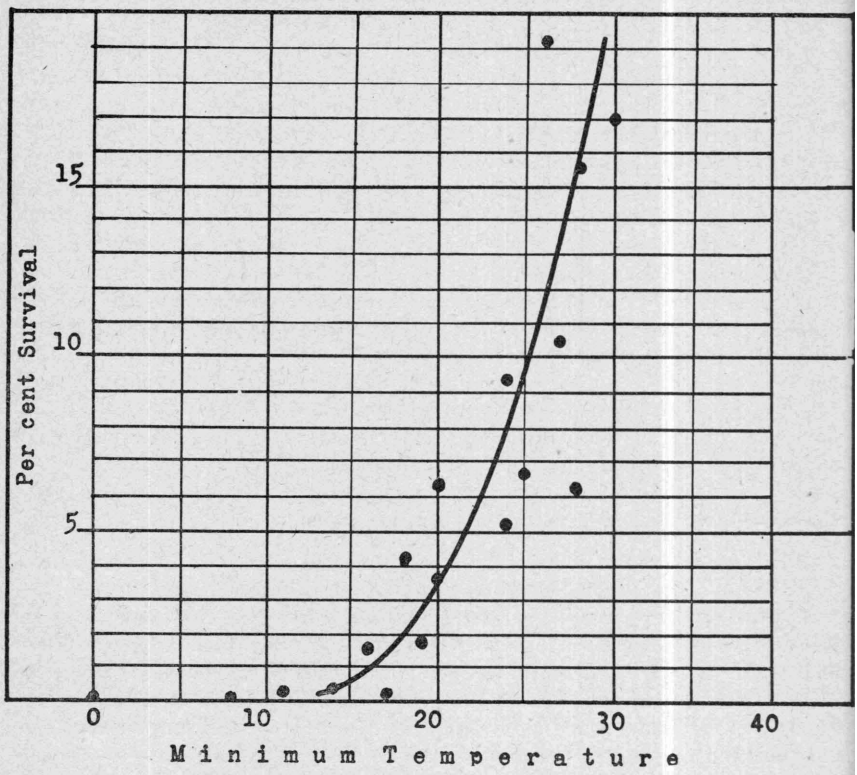

Figure 2. Percentage of boll weevil survival with relation to minimum temperatures.

individuals which find the most suitable shelter in the field will be least affected by minimum temperatures. For example, in wooded regions of the State the weevil finds more favorable shelter and survives the winter in greater numbers than in those sections where such type of shelter is not available. The relative differences in weevil survival as determined by hibernation cages situated in the woods and open fields are discussed in the following paragraphs.

Survival in Woods Shelter

During the three fall seasons, 1923 to 1925, boll weevils were installed in hibernation cages situated in woods shelter to determine the rate of winter survival under these apparently favorable conditions. Prior to the installation of any weevils the bottom of each cage was covered with 12 to 18 inches of dry leaves or Johnson grass for protection of the overwintering insects. The dates of installation ranged from October 2 to December 1. The mininmum temperatures recorded

Table 1. Survival of weevils in cages situated in woods shelter

Date of installations	Shelter material	No. weevils installed	No. weevils emerged	Per cent survival
Oct. 2—Dec. 1, 1923	Leaves	4570	1213	26.54
Nov. 29—Dec. 1, 1924	Leaves	618	57	9.22
Oct. 3, 1925	Johnson grass	500	0	0.00
Total		5680	1270	
Average				11.92

during the dormant seasons, 1923-24, 1924-25, and 1925-26 were 19, 18 and 20 degrees F., respectively. A summary of the data secured on the percentage of survival of the weevil in these tests is presented in Table 1. It will be noted that early fall installations, from which few weevils normally survive, were included in the tests. However, the average survival totaled nearly 12 per cent of the 5,680 weevils confined for observation. This average rate of winter survival is approximately two times greater than that recorded in cages situated in the open field.

Survival in Open Field

Most of the important cotton producing counties of Texas are located in sections where woods shelter is not generally available for protection during the hiberation period of the weevil. For this reason most of the hibernation cages were placed under open field conditions to approximate as nearly as possible the type of shelter available to the weevil throughout the prairie or untimbered sections of the State. During these studies a total of 75,625 field-collected boll weevils were confined in separate hibernation cages in lots averaging about 500 each for observation on the winter mortality of the insect. The dates of installation ranged from September 29 to December 4. The materials supplied the confined weevils for protection during the winter season included dry weeds, Johnson grass, and Spanish moss in amounts of 20 to 30 pounds per cage. A summary of the data accumulated on the survival of the weevil is presented in Table 2. It will be noted that the extent of survival ranged from less than 1 to more than 19 per cent. These variations, as has already been shown, are closely associated with the minimum temperatures to which the confined weevils were exposed. The weevil survival under open field conditions as determined by local cage tests during eighteen seasons, averaged 6.04 per cent. In this connection it should be pointed out that under favorable conditions large numbers of weevils enter hibernation so that the seemingly small average percentage of survival recorded in the cage tests may prove quite significant when considered in terms of the number of weevils which become active at about the time when cotton is beginning to come up.

Table 2. Survival of weevils in cages situated under open field conditions

Date of installations	Shelter material	No. weevils installed	No. weevils emerged	Per cent survival
Dec. 2-4, 1924	Grass and weeds	711	29	4.08
Oct. 20—Nov. 13, 1925	Johnson grass	930	35	3.76
Oct. 1—Nov. 20, 1926	Johnson grass, Spanish moss	3984	210	5.27
Oct. 1—Dec. 3, 1927	Johnson grass, Spanish moss	4500	19	.42
Oct. 13—Nov. 25, 1928	Johnson grass, Spanish moss	4500	284	6.31
Oct. 3—Nov. 16, 1929	Spanish moss	3500	1	.03
Oct. 3—Nov. 14, 1930	Spanish moss	5000	850	17.00
Oct. 2—Nov. 25, 1931	Spanish moss	5000	469	9.38
Oct. 7—Nov. 11, 1932	Spanish moss	4000	11	.27
Oct. 7—Nov. 25, 1933	Spanish moss	4500	705	15.67
Sept. 29—Nov. 24, 1934	Spanish moss	4500	14	.31
Oct. 12—Nov. 23, 1935	Spanish moss	5000	82	1.64
Oct. 3—Nov. 7, 1936	Spanish moss	4500	472	10.49
Oct. 2—Nov. 13, 1937	Spanish moss	5000	336	6.72
Oct. 1—Nov. 12, 1938	Spanish moss	5000	311	6.22
Oct. 7—Nov. 18, 1939	Spanish moss	5000	2	.04
Oct. 5—Nov. 14, 1940	Spanish moss	5000	961	19.22
Oct. 4—Nov. 15, 1941	Spanish moss	5000	91	1.82
Total		75,625	4,882	
Average				6.04

RELATION OF FOOD SUPPLY TO THE RATE OF SURVIVAL

Since entrance of the weevil into winter quarters under field conditions may extend over a period of two or three months, it is of interest to consider the relation between the time of removal of the food supply to the rate of survival.

In the field most of the individuals normally seek shelter during October and November. The data recorded on survival with respect to the time when the weevils are installed in cages are summarized in Table 3. Compared with later installations, the weevils confined in the hibernation cages prior to October 15 survived in smallest numbers. In fact, only 2.8 per cent of these individuals passed the winter successfully. Obviously, most of the weevils caged this early in the season starved before temperatures were low enough to induce entrance into hibernation. The survival among the weevils placed in cages during the latter half of October was about three times greater than that recorded from

Table 3. Survival of weevils in cages with relation to the time of removal from Food

Year of Emergence	Survival of weevils when installed during biweekly periods indicated							
	Oct. 1–15		Oct. 16–31		Nov. 1–15		Nov. 16–30	
	Number weevils installed	Number weevils survived	Number weevils installed	Number weevils survived	Number weevils installed	Number weevils survived	Number weevils installed	Number weevils survived
1925	---	---	---	---	---	---	618	57
1926	500	0	510	7	420	28	---	---
1927	1,000	10	1,484	98	1,000	80	500	22
1928	1,500	4	1,000	3	1,000	4	500	6
1929	500	3	2,000	119	1,000	86	1,000	76
1930	1,000	0	1,000	1	1,000	0	500	0
1931	1,000	76	2,500	489	1,500	285	---	---
1932	1,000	23	2,000	144	1,500	239	500	63
1933	1,000	2	2,000	9	1,000	0	---	---
1934	1,000	106	1,500	293	1,000	101	1,000	205
1935	1,000	4	1,000	2	1,000	2	1,000	6
1936	500	2	1,500	21	2,500	50	500	9
1937	1,000	50	3,000	328	500	94	---	---
1938	1,000	31	2,500	224	1,500	81	---	---
1939	2,000	11	2,000	90	1,000	210	---	---
1940	1,000	0	2,000	1	1,500	1	500	0
1941	1,000	151	3,000	664	1,000	146	---	---
1942	1,000	4	2,000	27	2,000	60	---	---
Total	17,000	477	30,994	2,520	20,420	1,467	6,618	444
Per cent survival	2.81		8.13		7.18		6.71	

installations made during the first half of the month. This point is quite significant with respect to effective clean-up practices in the fall. If cotton stalks are destroyed generally before October 15 a very large part of the weevil population succumbs to starvation. The remaining individuals apparently enter winter shelter in such weakened condition that few have sufficient vitality to withstand the minimum winter temperatures. To reemphasize the relation between destruction of cotton in the fall and survival of weevils it may be stated that whenever the food of the insect is removed or destroyed prior to October 15 only 28 out of every 1000 weevils may be expected to enter shelter with sufficient vitality to live through the winter season. But when their food was not removed until the latter half of October, 81 out of each 1000 overwintering individuals emerged the following spring. The additional feeding period from October 16 to 31 is vitally important to the weevil for successful hibernation. It will be noted that no significant increase in the rate of winter survival ensued for each two weeks feeding period that the weevils were allowed after November 1. These observations indicate that the critical pre-hibernation period of the weevil occurs locally in October, and whenever green cotton squares and bolls remain available for food throughout this month the insect survives the hazards of the dormant season in maximum numbers.

EMERGENCE FROM HIBERNATION

The basic data on the number of weevils installed in hibernation cages and the number which emerged therein at bi-weekly intervals from March to July during the seasons, 1925 to 1942, inclusive, are presented in Table 4. It will be noted that the emergence from hibernation or winter shelter is usually protracted and rather irregular from year to year. It is not affected by the presence of food and seemingly depends largely upon prevailing weather conditions, particularly temperature and rainfall.

Table 4. Installations of weevils and the number that emerged in hibernation cages at bi-weekly periods from 1925 to 1942, inclusive

Year	Total number weevils installed	Number of weevils emerged during periods indicated								Total number weevils emerged
		March 1–15	March 16–31	April 1–15	April 16–30	May 1–15	May 16–31	June 1–15	June 16–30	
1925	711	4	12	11	2	--	--	--	--	29
1926	930	14	21	--	--	--	--	--	--	35
1927	3984	61	30	57	9	16	32	5	--	210
1928	4500	13	2	2	2	--	--	--	--	19
1929	4500	5	21	41	29	70	91	24	3	284
1930	3500	--	--	--	1	--	--	--	--	1
1931	5000	42	64	75	127	152	162	192	36	850
1932	5000	13	96	129	83	25	94	29	--	469
1933	4000	2	1	4	2	1	--	1	--	11
1934	4500	19	22	81	96	189	244	54	--	705
1935	4500	3	1	2	--	1	7	--	--	14
1936	5000	--	4	13	7	10	30	18	--	82
1937	4500	--	--	--	179	128	150	15	--	472
1938	5000	--	--	36	91	72	100	34	3	336
1939	5000	--	--	67	92	82	48	22	--	311
1940	5000	--	--	1	1	--	--	--	--	2
1941	5000	--	--	--	182	159	311	236	52	961*
1942	5000	--	--	13	9	30	19	16	4	91

*21 of these weevils emerged July 1–15.
1936–1942, inclusive, emergence was recorded beginning one week after cotton first came up in local fields.

Climatological Factors Affecting Emergence

Temperature: Among the factors affecting emergence of the weevil from hibernation, temperature is seemingly the most important. Little, if any, activity occurs among the dormant weevils when temperatures range below 45 degrees F. Apparently, there is no very definite tendency toward emergence from hibernation until average mean temperatures reach 55 to 60 degrees F. These conditions are normally approximated in March. As the prevailing mean temperatures rise to 70 degrees F. or above, the weevils leave winter shelter in increased numbers. Those individuals in the least protected situations are seemingly the first to react to the occurrence of effective temperatures, while others with more adequate protection respond more slowly. In fact, some of the caged weevils did not emerge until after average mean temperatures of 75 to 80 degrees F. had prevailed for four or five weeks.

It already has been noted that when the winter is relatively mild and the minimum temperature does not fall below 26 degrees F., usually

10 to 19 per cent of the weevils survive. It is interesting to compare the percentages of survival following these mild winters, when the minimum temperatures were similar, and to note the effect of the frequency in the occurrence of high mean temperatures during March.

Table 5. Relation of high mean temperatures in March to percentage of weevil survival

Year of Emergence	Min. temp. previous winter	No. days in March when mean temp. was above 75° F.	Percentage survival
1937	27°	6	10.49
1941	26°	3	19.22
1938	25°	24	6.72
1939	28°	16	6.22

When mean temperatures reach 75 degrees F., activity among the overwintering weevils is affected and the frequency with which such mean temperatures occur indicates wasted energy and vitality at a time when food of the insect is not available. Excessive activity during March is probably the reason for the relatively lower emergence during the years 1938 and 1939.

Rainfall: After emergence of the weevil from hibernating quarters is definitely under way, rainfall has an important influence on the rate at which the surviving individuals leave shelter. During protracted dry spells in April and May, even though effective temperatures prevail, emergence decreases and may cease entirely until the occurrence of rain. Frequent well distributed light showers throughout the emergence period are most favorable for the maximum rate of emergence. An increase in the number of weevils leaving the Spanish moss shelter within the cages was especially noticeable when light rains were followed by warm sunshine. The duration of the effectiveness of limited rainfall, especially during warm weather, is apparent for only a short period and emergence ceases when moisture conditions fall below a certain minimum requirement for the resumption of activity by the overwintering weevils.

Time and Rate of Emergence

Knowledge of the time and rate at which any overwintering population of weevils leaves shelter to resume normal activities is of practical value with respect to the status of field infestation during the early part of the growing season. The results of a comparison of the time and rate of weevil emergence are shown in Table 6 when the records were begun March 1 and in Table 7 when the records were delayed until a week after cotton first appeared in local fields. These records are based on a study of the emergence from installations made in hibernation cages from 1925 to 1942, inclusive. It will be noted that there appears

Table 6. Per cent of weevil emergence in hibernation cages at bi-weekly intervals from 1925 to 1935, inclusive

Year	Per cent emergence during periods indicated							
	Mar. 1–15	Mar. 16–31	Apr. 1–15	Apr. 16–30	May 1–15	May 16–31	June 1–15	June 16–30
1925	.56	1.69	1.55	.28	---	---	---	---
1926	1.50	2.26	---	---	---	---	---	---
1927	1.53	.75	1.43	.23	.40	.80	.13	---
1928	.29	.04	.04	.04	---	---	---	---
1929	.11	.47	.91	.64	1.56	2.02	.53	.07
1930	---	---	---	.03	---	---	---	---
1931	.84	1.28	1.50	2.54	3.04	3.24	3.84	.72
1932	.26	1.92	2.58	1.66	.50	1.88	.58	---
1933	.05	.02	.10	.05	.02	---	.02	---
1934	.42	.49	1.80	2.14	4.20	5.42	1.20	---
1935	.07	.02	.04	---	.02	.16	---	---
Average	.51	.81	.91	.69	.89	1.23	.57	.07
Per cent of total emergence	8.98	14.26	16.02	12.15	15.67	21.65	10.04	1.23

to be no regularity from season to season with respect to the time over which emergence extends or to the rate at which it occurs. Except in 1930, the weevils generally became active and began to leave winter quarters during March. In five of the eighteen seasons they continued to emerge until the latter part of June and in 1941 until the middle of July. A majority of the surviving weevils in the cages resumed activity during April and May when temperatures and rainfall during these months approached the normal. In local sections of the State this period of maximum weevil emergence extends from the time when the new crop is up generally until the plants have begun to produce squares.

Table 7. Per cent of weevil emergence in hibernation cages at bi-weekly intervals from 1936 to 1942, inclusive

Year	Per cent emergence during periods indicated							
	Mar. 16–31	Apr. 1–16	Apr. 16–30	May 1–15	May 16–31	June 1–16	June 16–30	July 1–15
1936	.08	.26	.14	.20	.60	.36	---	---
1937	---	---	3.98	2.84	3.34	.33	---	---
1938	---	.72	1.82	1.44	2.00	.68	.06	---
1939	---	1.34	1.84	1.64	.96	.44	---	---
1940	---	.02	.02	---	---	---	---	---
1941	---	---	3.64	3.18	6.22	4.72	1.04	.42
1942	---	.26	.18	.60	.38	.32	.08	---
Average	.01	.37	1.66	1.41	1.93	.98	.17	.06
Per cent of total emergence	.15	5.61	25.19	21.40	29.29	14.87	2.58	.91

Some of the weevils that emerge from hibernation prior to April undoubtedly succumb, since food or green cotton plants are not generally available at that time. Also some reenter hibernation with the occur-

rence of lower tempartures and apparently find better shelter than was previously occupied and may be less affected by warm weather.

The return of weevils to hibernation shelter is indicated by the similar averages of total emergence recorded as shown in Tables 8 and 9. Some of the weevils that resumed activity in March and were not removed from the cages reentered hibernation shelter. This is indicated

Table 8. Accumulative per cent of weevil emergence in hibernation cages by bi-weekly periods and the accumulative per cent of total emergence from 1925 to 1935, inclusive

Year	Accumulative per cent of emergence prior to dates indicated						
	April 1	April 16	May 1	May 16	June 1	June 15	July 1
1925	2.25	3.80	4.08	4.08	4.08	4.08	4.08
1926	3.76	3.76	3.76	3.76	3.76	3.76	3.76
1927	2.28	3.71	3.94	4.34	5.14	5.27	5.27
1928	.33	.38	.42	.42	.42	.42	.42
1929	.58	1.49	2.13	3.69	5.71	6.24	6.31
1930	---	---	.03	.03	.03	.03	.03
1931	2.12	3.62	6.16	9.20	12.44	16.28	17.00
1932	2.18	4.76	6.42	6.92	8.80	9.38	9.38
1933	.07	.17	.22	.25	.25	.27	.27
1934	.91	2.71	4.84	9.04	14.47	15.67	15.67
1935	.09	.13	.13	.16	.31	.31	.31
Average	1.32	2.23	2.92	3.81	5.04	5.61	5.68
Accumulative per cent total emergence	23.23	39.26	51.41	67.08	88.73	98.77	100.00

by an emergence of 30 per cent during April of the years 1936 to 1942. Practically the same proportion, 28 per cent, emerged for the period 1925 to 1935. If all emerged weevils had remained active the former proportion probably would have been much larger. Weevils that resume activity after cotton is up, but before the plants have begun to pro-

Table 9. Accumulative per cent of weevil emergence in hibernation cages by bi-weekly periods and the accumulative per cent of total emergence from 1936 to 1942, inclusive

Year	Accumulative per cent of emergence prior to dates indicated							
	April 1	April 16	May 1	May 16	June 1	June 15	July 1	July 15
1936	.08	.34	.48	.68	1.28	1.64	1.64	---
1937	0	0	3.98	6.82	10.16	10.49	10.49	---
1938	0	.72	2.54	3.98	5.98	6.66	6.72	---
1939	0	1.34	3.18	4.82	5.78	6.22	6.22	---
1940	0	.02	.04	.04	.04	.04	.04	---
1941	0	0	3.64	6.82	13.04	17.76	18.80	19.22
1942	0	.26	.44	1.04	1.42	1.74	1.82	---
Average	.01	.38	2.04	3.46	5.38	6.36	6.53	6.59
Accumulative per cent total emergence	.15	5.92	30.96	52.50	81.64	96.51	99.09	100.00

duce squares, are commonly able to subsist on the tender foliage until fruits are set.

Throughout central Texas cotton is not normally up to a stand in the field prior to April 16, and as a rule the plants are not fruiting freely until the latter part of May. With these points in mind, it is of interest to consider the available information in terms of the emergence completed at specific dates during April, May, and June. The data presented in Tables 8 and 9 picture the status of weevil emergence at biweekly intervals throughout the period indicated. The figures show no trend toward any regularity in the procedure of emergence. For example, all dormant weevils in the cages became active during March 1926 when the survival was light, but during seasons of heavy survival as in 1931 and 1934, activity was barely well under way by the end of March.

During the period 1925 to 1935, when weevils were removed as they became active during March, an average of nearly one-fourth of the population that overwintered successfully was taken out of the cages during the month. Similarly a little more than one-fourth was removed during April, and emergence for the two months totaled 51 per cent, Table 8. When removal of weevils was delayed until after cotton first appeared in the field 50 per cent of the total emergence was not completed until about the middle of May, Table 9. The greatest increase in the resumption of weevil activity, as indicated by the average accumulative percentage of emergence, occurs during the last two weeks of May or about the time when the plants are beginning to produce fruits abundantly.

It may be safely assumed that the percentage of total weevil survival or emergence for the same periods under field conditions is greater than the figures indicated above, since these data are based on overwintering populations which contained a larger proportion of early entrants into hibernation than the corresponding populations overwintering in the field. Furthermore, many individuals in the field undoubtedly find more adequate shelter than that supplied in the cages and are therefore not so unfavorably affected by prevailing minimum temperatures.

Should weather conditions in the spring retard normal planting or the subsequent appearance of cotton, boll weevil emergence also would be delayed. However even under favorable weather conditions the weevils may remain in hibernation or if previously active may return to shelter with the occurrence of falling temperatures. These facts explain why it is not possible to effectively control boll weevils by delayed planting of the crop.

Peak of Emergence: At College Station the weevil becomes active in March when temperatures for the month approach the normal. This movement gains momentum during April but does not seem to attain its maximum until the proper combination of effective climatic conditions prevails. Cage records show that the peak of emergence or the time

during which the maximum number of weevils resume activity does not occur until the latter half of May. The significance of this point should be emphasized. In other words, the majority of weevils passing the winter successfully remain inactive or dormant until after the crop is well advanced and fruits are usually present in abundance. The peak of weevil emergence based on the yearly average percentage of the data recorded on caged weevils from 1936 to 1942, inclusive, is graphically

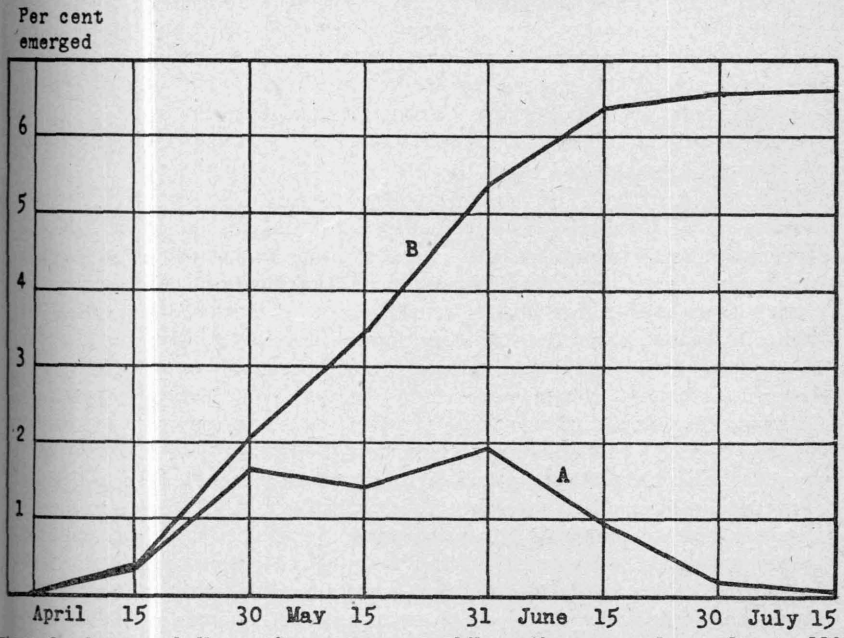

Figure 3. Average boll weevil emergence in hibernation cages from 1936 to 1942, inclusive. (A) Emergence at bi-weekly intervals; (B) Accumulative emergence at bi-weekly intervals.

illustrated in Figure 3. After the peak has been attained, the emergence declines rapidly and is usually complete in south-central Texas by the end of June.

Dispersal at Time of Emergence

After resuming activity and leaving winter quarters in the spring, the weevil apparently seeks the most available source of food. This explains the heavier infestations which usually occur early in the season in those portions of cotton fields nearest to wooded areas, fence rows, or other situations which provide favorable winter quarters for the insect. During seasons of heavy winter survival the weevil obviously spreads in all directions from the center of any large hibernating population. The maximum distance which the insect can cover to reach suitable food has not been determined.

After reaching cotton plants that have begun to produce squares overwintered weevils show but little tendency toward wider dissemination by means of flight. Field records made in this connection indicate that the average maximum distance covered by hibernated individuals during the first week of activity on freely fruiting cotton plants totaled less than 100 feet from the point of entrance into the field. As the supply of uninfested squares became limited in the localized areas the weevils gradually moved to fresh squares by crawling from plant to plant and by short intermittant flights. During the early part of the growing season when the supply of squares is still limited it appears quite likely that dispersal of hibernated weevils within such fields may proceed at a more rapid pace. At any rate the weevil upon entering a field of young cotton is diligent in its search for squares and seems able to locate the plants which produce the first fruit.

WEEVIL SURVIVAL IN RELATION TO EXTENT OF INJURY

Those weevils which pass through the dormant season successfully constitute the source from which injurious infestations may subsequently develop. It is likewise true that the extent to which any overwintering population of weevils may prove destructive by multiplication in the crop is directly influenced by climatic conditions which prevail during the early summer months.

In any consideration of weevil survival with relation to the extent of injury produced to the crop, as measured in terms of yield per acre, it must be remembered that other factors such as the deleterious effect of climatic conditions on the crop or reductions of full yields per acre due to other insects and plant diseases cannot be readily separated or accurately measured. However, it has been repeatedly shown that heavy boll weevil infestations during the greater part of the fruiting period of cotton plants are manifested by noticeable reductions in yields. Since a heavy emergence of overwintered weevils constitutes a potential source from which early and destructive infestations may develop, it is of interest to compare the crop yields secured during years of heavy and light weevil survival.

The data recorded on weevil survival, rainfall, and cotton yields in Brazos County during the crop years 1928 to 1941, inclusive, are shown in Table 10. These data indicate no apparent correlation between the percentage of weevil survival and the average yield produced. When average yields of lint have exceeded 200 pounds per acre the percentage of survival has varied from .42 in 1928 to 10.49 in 1937. On the other hand in 1929 and 1936 when average yields were lowest or about 100 pounds per acre the survival was 6.32 and 1.64 per cent, respectively. In the four years with high yields the rainfall during the critical period of crop production (May-July) varied from 5.32 to 11.05 inches, while in the two years of low production the rainfall for May to July, inclusive, was more than 20 inches. It will be noted that extremes of local

Table 10. Average per cent of weevil survival and average yield of lint cotton per acre in Brazos County, 1928 to 1941, inclusive

Year	Per cent weevil survival	Rainfall in May, June, and July			Average yield lint per acre (pounds)
		Total (inches)	Departure from normal	Distribution (days)	
1928	.42	11.05	+ .68	18	218
1929	6.32	20.91	+10.54	26	99
1930	.03	12.90	+ 2.53	19	181
1931	17.00	4.80	— 5.64	17	196
1932	9.38	7.16	— 3.28	16	155
1933	.27	11.01	+ .57	15	196
1934	15.67	1.31	— 9.13	7	157
1935	.31	15.65	+ 5.21	32	181
1936	1.64	21.34	+10.71	26	107
1937	10.49	5.32	— 5.31	15	208
1938	6.72	10.14	— .49	26	242
1939	6.22	10.16	— .47	17	248
1940	.04	16.98	+ 6.35	24	175
1941	19.22	14.94	+ 4.31	33	143

weevil survival were recorded in 1930 and 1931 and again in 1940 and 1941. Yet the average yields for the years within each of these two groups did not vary greatly. However, a comparison of the climatic conditions that prevailed during May-July 1930 and 1931 shows the occurrence of a marked difference, especially with respect to the amount of rainfall. The few weevils that survived the minimum temperature of 0 degrees F. in 1930 encountered approximately normal temperatures in May, June, and July. The rainfall during this period totaled 12.9 inches (2.53 inches above normal) and was distributed over 19 days. Under these favorable climatic conditions the small number of overwintered weevils multiplied rapidly and produced general field infestations, which resulted in subsequent reductions from full yields per acre throughout the county. On the other hand, the mild temperatures which prevailed throughout the winter 1930-31 were exceptionally favorable to the dormant weevil population and large numbers emerged up to the following July. This emergence seemingly indicated prospects for severe damage to the crop. However, it did not develop. The activities of this large overwintered population of weevils were practically eliminated by prolonged spells of dry weather during May, June, and July. The rainfall during these months totaled only 4.80 inches, which was 5.64 inches below normal. The continuance of dry weather during the following August checked any general development of late weevil infestations and apparently losses in yields attributable to weevil injury were practically negligible throughout the season. Further observations which are of interest in this connection are presented in the following paragraph.

During the winter 1939–40, the weevil survival was one of the lightest on record. As determined by local cage experiments, only .04 per cent of the overwintering population passed the dormant period successfully. Nevertheless, general and destructive weevil infestations occurred throughout Brazos County that season. Rainfall in May, June, and July totaled 16.98 inches (6.35 inches above normal) and was dis-

tributed over 24 days. These and similar conditions which occurred in 1935 seemingly approached an optimum for the maximum rate of weevil multiplication. This evidence clearly illustrates that a light winter survival of weevils, if favored by optimum climatic conditions, may become an important limiting factor in the production of a crop. Knowledge of the percentage of weevil survival in the spring is useful in delimiting the potential source from which any subsequent injury to the crop may originate. This information, when considered in connection with the prevailing weather conditions during the early part of the growing season, constitutes the only reliable index by means of which future infestations may be anticipated. Unfortunately, weather conditions beyond a very limited period remain an unknown factor, and for this reason advanced forecasts with reference to boll weevil injury based on survival alone are generally uncertain.

SUMMARY

During the fall, boll weevils instinctively seek sheltered situations in which to pass the winter but the insects do not enter a period of true hibernation. They remain more or less active during warm spells in winter and may emerge from shelter until forced to reseek protection by the recurrence of lower temperatures. The average duration of the so-called weevil hibernation period, as determined by local cage studies, extends from November to May.

Under open field conditions, the average survival of the boll weevil at College Station for 18 seasons (fall of 1925 to spring of 1942) was 6.04 per cent. The maximum was 19.22 per cent in 1941 and the minimum .03 per cent in 1930. The survival of weevils in cages protected by woods shelter for three seasons (1923-25) averaged 11.92 per cent. Among the factors affecting survival of the weevil minimum temperatures are most important. Approximately 10 to 19 per cent of the confined weevils survived when minimum temperatures did not fall below 26 degrees F., but less than 1 per cent of the weevils passed the winter successfully when minimum temperatures reached 15 to 0 degrees F.

Winter survival among weevils placed in hibernation cages from October 1 to 15 and October 16 to 31 averaged 28 and 81 per thousand, respectively. The later installations of weevils made from November 1 to 15 and November 16 to 30 showed no significant increases in the rate of survival.

Activity of the weevil in hibernation begins when average mean temperatures reach 55 to 60 degrees F. Such temperatures may cause some of the weevils to become active and emerge but when cold weather occurs many of the weevils reenter hibernation and may find better protection against temperature changes and emerge later. This is one reason why delayed planting is not successful in avoiding boll weevil damage. After emergence is definitely under way, rainfall has an important influence on the rate at which surviving weevils leave shelter.

Frequent well distributed showers followed by warm sunshine are most favorable for a maximum rate of emergence.

The percentage of weevil survival has no direct relation to the extent of injury that may be produced during the season. The prevailing weather conditions are the limiting factor in this respect. Frequent showers during the early part of the growing season are favorable for weevil injury. Under such conditions a light weevil survival may be followed by widespread damage to the crop as was experienced in 1935 and 1940. On the other hand, prolonged hot, dry weather effectively checked the activities of the maximum weevil survival recorded in 1931. Since future weather conditions are an unknown factor, the development of injurious weevil infestations cannot be anticipated very far in advance of their actual occurrence.