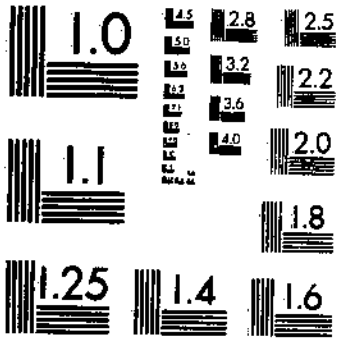
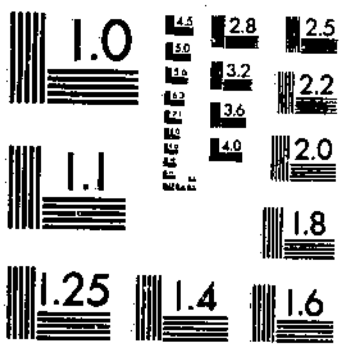
TB 486 (1935) USDA TECHNICAL BULLETINS UPDATA
COTTON BOLLWEEVIL SURVIVAL AND EMERGENCE IN HIBERNATION CAGES IN
GAINES, R.C. 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Technical Bulletin No. 486 — December 1935

UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D.C.

COTTON BOLLWEEVIL SURVIVAL AND EMERGENCE IN HIBERNATION CAGES IN LOUISIANA

By R. C. Gaines

Entomologist, Division of Cotton Insect Investigations, Bureau of Entomology and Plant Quarantine[1]

CONTENTS

INTRODUCTION

It is fortunate for the American cotton grower that the bollweevil (*Anthonomus grandis* Boh.) is of tropical origin. Its capacity for multiplication during the summer months is so great that cotton production becomes a race between the rate of increase of the weevil and the rapidity of development of the fruit on the cotton plant, and cotton production would be out of the question were it not for the fact that throughout most of the infested districts in the United States a high percentage of the fall population of weevils fails to survive the winter. Consequently, the number of surviving weevils becomes of paramount importance and all possible information on

[1] All hibernation tests from 1915–16 to Jan. 27, 1931, at Tallulah, La., were conducted under the direction of B. R. Coad, and since that time under the direction of the author. The field work was performed by G. L. Garrison, T. C. Barber, R. W. Howe, H. W. Lee, E. S. Tucker, M. T. Young, H. C. Young, R. W. Moreland, F. F. Bondy, T. P. Cassidy, and G. L. Smith, and a number of temporary assistants.

143975°—35——1

this critical period in the weevil's life should be obtained. This is especially important because survival is influenced by so many variable factors and also because of the ability of the species to adapt itself to adverse conditions. It will be necessary to extend observations over a long period in order to determine definitely whether the bollweevil may permanently change its habits as a result of repeatedly adapting itself to conditions in new environments.

Under normal conditions comparatively few factors dominate in the matter of survival but unusual circumstances may cause a factor ordinarily of minor importance to become of prime significance. Some of the best known survival factors may be designated as fall food supply, winter weather, type of shelter, and spring weather. Wet weather during October and November tends to insure a larger emergence of weevils the following spring, as this is favorable to late cotton growth, which, in turn, increases the available quantity of feeding and breeding material for weevils, thus enabling them to enter hibernation in better condition. The date of the first killing frost is also very important. A frost 1 or 2 weeks earlier than usual will greatly reduce the weevil survival, whereas a delaying of the first frost may increase it. Premature defoliation of cotton plants and destruction of the squares and young bolls by the cotton leaf worm (*Alabama argillacea* Hbn.) may affect the condition of weevils entering hibernation. The effect of altitude, latitude, available hibernation quarters, and many other local factors further complicate the problem and add to the difficulties of obtaining reliable and exact information on any one survival factor the significance of which is not open to question.

The importance of a study of bollweevil hibernation has been realized by investigators from the start, and various experiments along this line have been conducted in different localities. These have permitted some general conclusions to be drawn, but the subject is so complicated that the need of a broader series of experiments extending over a longer period has been obvious. Consequently, such a study was inaugurated at the Tallulah, La., field laboratory of the Bureau of Entomology in the fall of 1915 and was continued to 1931. This bulletin presents the results of the study from 1915–16 to 1930–31, with the exception of the winter of 1926–27, when the hibernation cages were destroyed by the overflow of the Mississippi River.

Experiments of the same nature were carried on at 17 cooperating laboratories, the results of which are discussed on page 26.

A study of the influence of the bollweevil on the cotton crop of any particular year must start with the conditions existing during the preceding fall. The factor for first consideration is the number of weevils entering hibernation and their condition at that time. Next in importance is the winter mortality, the result of which is generally expressed as "the percentage of survival." The time of emergence, the proportion of weevils that succeed in infesting cotton plants, and the effect of spring and summer weather on the rate of weevil multiplication must also be considered. It is therefore seen that the amount of weevil damage is the result of all these influencing factors, rather than any one of them. Each of these factors constitutes a separate subject for study, but in this bulletin the discussion is largely confined to only one phase of the problem, that of the factors influencing the percentage of survival. For this reason caution should be exercised in interpreting these results in terms of weevil injury. It is evident that spring population must depend on the percentage of survival of the number entering hibernation the previous fall. In the same way, the initial spring infestation depends on the proportion of these survivors that reach cotton plants and live long enough to produce progeny. The problem is further complicated by rehibernation. It is well known that some weevils in hibernation become active and stir around at times during the winter when there is a warm spell of weather. The number of active weevils increases as the warm weather of spring approaches, and continues to increase until the end of the emergence period. Any study of cage observations clearly shows that many weevils become active before growing cotton appears in the field. Some of these die before squares are available for breeding, but others survive. The above interrelated factors are mentioned at this time chiefly to show how easily incorrect interpretations might be placed upon the result of any one series of tests included in this bulletin.

The effect of low temperatures in killing weevils has been very carefully considered; however, the weevils are not actually exposed to the recorded air temperatures, and the present study is concerned with the resistance of the weevil and its ability to survive different atmospheric temperatures when protected by various types of hibernation shelter, as data of this type have the most practical significance.

PLAN OF EXPERIMENTS

The ideal plan for a study of bollweevil survival would be one in which it would be possible to count the weevils entering hibernation in nature in the fall and those emerging in the spring. This being obviously impossible, experimental conditions as nearly natural as possible were created. This involved the use of cages covered with screen wire; and, as far as possible, all methods were standardized and remained constant throughout the series. However, experience has shown that, even with precautions, it is not always possible to obtain natural conditions and, consequently, results obtained in cages cannot be accepted as valid for natural conditions without verification in the field. The principal merit of the cage tests lies in the fact that they are comparable with one another and with the results obtained by other investigators who used the same methods.

The cages utilized in these experiments were 4 feet square and 4 feet high, inside measurements, strongly constructed of wood, and covered with 16-mesh galvanized screen wire.

The ground on which each cage was placed was carefully leveled, smoothed, and lightly packed. The cage was placed upon the prepared site and securely nailed to stakes driven into the ground at each corner. In addition to this, one or more wires were placed across the top and securely fastened to stakes at some distance from the cage on each side. Several inches of soil was packed around the outside against the bottom of each cage. The hibernation material was placed in the cage, which was then ready to receive the weevils. A general view of the arrangement of these cages is shown in figure 1.

In all experiments the weevils, with the exception of those of series 13, were collected from the cotton fields in the vicinity of Tallulah immediately before being placed in the cages. Five hundred weevils were liberated in each cage, except in special studies. They were introduced into the cages in jars. The lids were removed and the jars left open in the cages for 24 hours, after which they were removed. The weevils unable to crawl from the jars were counted and discarded, and subtracting their number from 500 gave the number actually confined in each cage. In this way weaklings and those injured in handling were eliminated.

Since meteorological factors are of the utmost importance in their effect on weevil hibernation, special observations have been made to compare conditions within the cages with those in the open field. Various experiments conducted during several seasons have shown that the screen wire has a marked effect in either raising or lowering the temperature.[2]

FIGURE 1.—General view of hibernation cages.

A series of experiments conducted by Kimball[3] showed that "a plant in any part of the cage should receive on an average at least one-half the total solar and sky radiation, unless it is very close to the south side of the cage, and is considerably south of latitude 40° N." In another series of observations at Tallulah,[2] an anemometer was placed in a cage, and the reading therefrom, compared with that from one in the open air, showed that the air movement within the cage was decreased about 50 percent, a condition that would materially affect both evaporation and humidity. This fact has been verified by other tests which showed decreased evaporation and increased

[2] BARBER, T. C. TEMPERATURE STUDIES UNDER NORMAL AND VARYING CONDITIONS AT TALLULAH, LA., WINTER OF 1915–16. Manuscript reports, January 1917.

[3] KIMBALL, H. H. SHADING EFFECT OF WIRE INSECT CAGES. U. S. Monthly Weather Rev. 44: 501–506, illus. 1916.

humidity within the cages. It is thus seen that there is a wide difference between conditions within the cages and in the open field.

In connection with these cage tests meteorological records were made. Instruments were installed near the cages and such records as those of maximum and minimum temperatures, humidity, and precipitation were made. This bulletin, however, deals only with those phenomena found to influence the results.

At the outset the tests were arranged in numbered series in such a way that each series afforded a study of one experimental variable. The general procedure was to prepare the cage with the necessary hibernation material and release the weevils at the desired time. Daily records were made of all weevils observed on the top and sides of the cages until activity ceased. The cages were then left undisturbed until March 1, at which time daily observations and removal of emerged weevils were begun.

One important variable was the kind of material provided for hibernation shelter, but for check purposes and in all tests of other factors Spanish-moss (*Tillandsia usneoides* L.) was used as the shelter. In all cases the quantity of hibernation material was uniform and remained so throughout the tests.

The detailed yearly records are omitted because of the space that would be required to present them properly. These records include the dates of cage installations during each fall; weevils found active from the time the cages were installed until all weevils had entered hibernation; daily emergence records for each cage from March 1 until emergence was completed; summary of weevil emergence in each cage and in each series; and temperature, humidity, and rainfall records from the time cages were installed until emergence was completed the following year.

Series 5, 8, and 14 are not discussed in this bulletin as the tests in these cases were for another purpose and not connected with the investigations here considered; and the records for series 2, 3, 7, 10, and 11 were so fragmentary that no definite conclusions could be gleaned from them; they are, however, included in the general summary tables 10, 11, and 13.

SCOPE AND RESULTS OF THE TESTS

RELATION BETWEEN DATE OF INSTALLATION AND WEEVIL SURVIVAL

Series 1 was conducted through 15 seasons, from 1915–16 to 1930–31, to determine the relation between date of weevil installation and survival. Spanish-moss suspended on wires stretched diagonally across near the top of the cage and cotton stalks stripped of fruit and leaves were provided for hibernation shelter in each cage, as illustrated in figure 2, *A*.

The cages were installed at weekly intervals each year, usually starting in the first or second week of September and continuing as long as sufficient weevils were available, the latest being on December 3. Most of the weevils, however, were in cages installed during the period from September 8 to November 11. The earliest cages of this series simulated the effect of an early frost or the early destruction of cotton plants, either of which, by depriving the weevils of food before any great number of them are in condition to survive the winter, would subject the weevils in the fields to conditions similar to those of the cages. The condensed data from these tests are given in table 1.

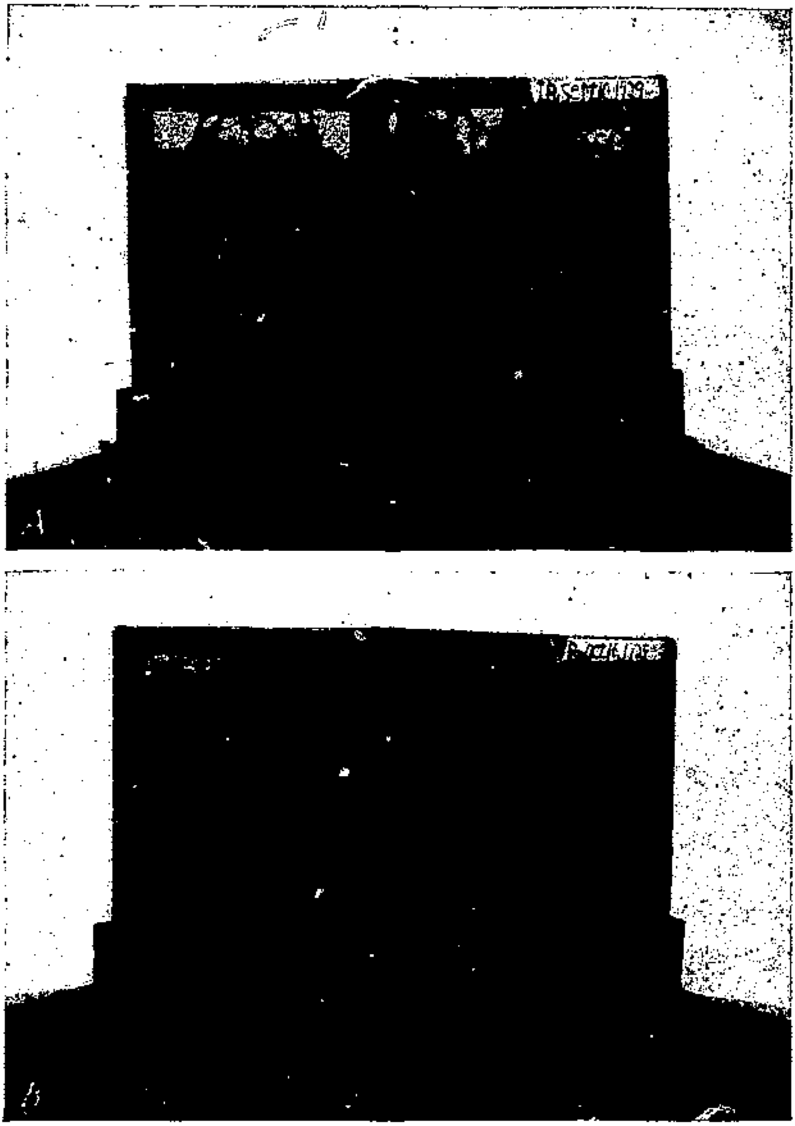


FIGURE 2.—Typical hibernation cages: *A*, Cage in series 1 with Spanish-moss and cotton stalks for shelter; *B*, cage in series 4 with oat straw for shelter.

TABLE 1.—*Relation of date of installation to weevil survival, Tallulah, La., 1915–16 to 1930–31*

[Summary of series 1, Spanish-moss, and cotton stalks for shelter]

Date of installation	Weevils installed	Emergence		Date of installation	Weevils installed	Emergence	
	Number	*Number*	*Percent*		*Number*	*Number*	*Percent*
Sept. 1–7	5,880	0	0.00	Oct. 27–Nov. 4	10,886	318	2.92
Sept. 8–14	8,344	8	.10	Nov. 5–11	6,902	178	2.58
Sept. 15–21	8,103	56	.69	Nov. 12–18	2,954	78	2.64
Sept. 22–28	10,323	77	.75	Nov. 19–25	2,880	17	.59
Sept. 29–Oct. 5	9,663	188	1.95	Nov. 26–Dec. 3	2,659	29	1.09
Oct. 6–12	10,560	107	1.01				
Oct. 13–19	9,322	107	1.15	Total [1]	98,858	1,428	1.44
Oct. 20–26	10,382	265	2.55				

[1] In tables 1 to 10, inclusive, and in table 16, the "total" at the bottom of a "percent" column constitutes a weighted average.

The high average survival of 2.92 percent was in cages installed during the 7 days ending November 4, though there is comparatively little difference in results for the 4 weeks extending from October 20 to November 18. Evidently this period, on the average, was the most favorable time for weevils to enter hibernation. Naturally the lowest survival was in the September installations. The fact that during the different years 12 cages, containing a total of 5,880 weevils, were installed during the first 7 days of September without a single individual surviving is particularly interesting.

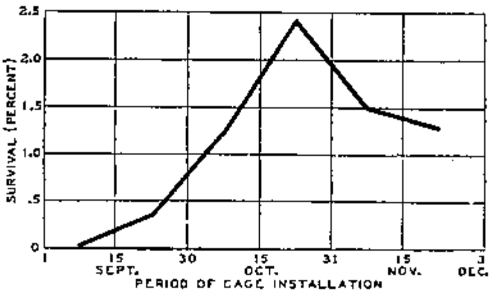


FIGURE 3.—Relation of date of cage installation to bollweevil survival, Tallulah, La., 1915–16 to 1930–31.

To throw further light on this subject, another summary has been prepared, the data of which are presented in table 2 and illustrated graphically in figure 3. In this summary all cages have been included, regardless of other conditions, and are classified solely on the date of installation. This brings in a much wider variety of conditions and greatly increases the number of records involved, thus permitting more representative averages. In this summary the cages have been grouped by approximately 15-day periods. The highest survival occurred in cages installed during the latter half of October and the next highest during the first half of November. It is during these 4 weeks that the first killing frosts, which may cause weevils to enter hibernation under natural conditions, usually occur in this locality. A fairly high survival is also noted in cages installed after November 15. The low survival with early installations is further emphasized in this summary, which shows quite clearly that to derive any benefit from fall stalk destruction in the average year at Tallulah, it would be necessary to clean the fields earlier than October 15, and that the maximum benefit could be expected only where stalks were destroyed in September.

TABLE 2.—*Relation of date of installation to weevil survival, Tallulah, La., 1915–16 to 1930–31*

[Summary of all cages and all shelters]

Date of installation	Weevils installed	Emergence		Date of installation	Weevils installed	Emergence	
	Number	*Number*	*Percent*		*Number*	*Number*	*Percent*
Sept. 1–15	61,460	11	0.02	Nov. 1–15	60,659	915	1.51
Sept. 16–30	73,779	261	.35	Nov. 16–Dec. 3	9,444	123	1.30
Oct. 1–15	125,325	1,531	1.22				
Oct. 16–31	99,607	2,405	2.41	Total	430,304	5,246	1.22

SURVIVAL OF UNFED WEEVILS

Series 2 of the tests was started in 1915–16 and repeated in 1916–17 to test the hibernating ability of weevils that had been deprived of all food since emergence as adults. The weevils used were reared in the laboratory from infested squares collected in the field and were released in the cages without having had opportunity to feed. In the cage used as a check, field-collected weevils were released. Spanish-moss suspended in the cages afforded the hibernation shelter. This was one of the series of tests that afforded no definite results.

SURVIVAL OF UNMATED FEMALES

Series 3 was undertaken in order to investigate the ability of unfertilized females to survive the winter. The series included cages containing reared female weevils that had had no opportunity to mate after reaching maturity, and, for comparison, other cages containing field-collected individuals. Spanish-moss was provided as a shelter. This series was conducted for only one winter, that of 1915–16 , and, as with series 2, offered no conclusive results.

COMPARISON OF VARIOUS SHELTER MATERIALS

OAT STRAW AS SHELTER

Series 4 was conducted for 15 seasons, from 1915–16 to 1930–31, to study weevil hibernation in oat straw and to compare this shelter material with Spanish-moss. Two cages, one with each material. were installed on the same day at biweekly intervals during the fall of each year. A cage with oat straw is shown in figure 2, *B*, and a check cage with Spanish-moss, such as was used with all the tests, is shown in figure 4, *A*.

The results of this test are given in table 3. In the final average there was only a slight difference between the protection afforded by oat straw and that afforded by Spanish-moss, the survival in the Spanish-moss being 1.60 percent and in the oat straw 1.24 percent.

TABLE 3.—*Comparison of Spanish-moss and oat straw as bollweevil shelter, Tallulah, La., 1915–16 to 1930–31*

[Summary of series 4]

Date of installation	Spanish-moss shelter			Oat-straw shelter		
	Weevils installed	Emergence		Weevils installed	Emergence	
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
Sept. 14–19	5,213	10	0.19	5,461	3	0.05
Sept. 25–Oct. 6	6,783	52	.77	6,668	11	.16
Oct. 11–18	6,315	133	2.11	6,176	85	1.38
Oct. 25–Nov. 6	6,811	206	3.02	6,677	210	3.15
Total	25,122	401	1.60	24,982	309	1.24

TREE STUMP AS SHELTER

A comparison of Spanish-moss and a tree stump as weevil shelters was afforded in the tests of series 6, conducted during 1915–16, 1916–17, and 1918–19. Field observations have called attention to the danger of stumps as weevil shelter because they are usually surrounded with masses of weeds and grass that are allowed to remain over the winter. The preceding test with oat straw, a somewhat similar material, showed the place of the material as an aid to successful hibernation.

The purpose of this series was to study the possibilities of the bare stump as a protection for hibernating weevils. On each date of installation a cage was placed over a stump cleared of grass and weeds, and 500 weevils were introduced, while the same number were released in a check cage containing Spanish-moss. From table 4 it is seen that while more than twice as many weevils emerged from the moss as from the stump, the survival in the stump cages was still high enough to be of importance.

TABLE 4.—*Comparison of Spanish-moss and stump as bollweevil shelter, Tallulah, La., 1915–16, 1916–17, and 1918–19*

[Summary of series 6]

Date of installation	Spanish-moss shelter			Stump shelter		
	Weevils installed	Emergence		Weevils installed	Emergence	
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
Oct. 20	500	1	0.20	500	1	0.20
Oct. 28	500	5	1.00	500	0	.00
Nov. 2	----	----	----	500	10	2.00
Nov. 3	500	22	4.40	----	----	----
Total	1,500	28	1.87	1,500	11	.73

Under such circumstances the practice of piling weeds or grass around field stumps in the winter and burning them is certainly to be recommended, not only as a means of getting rid of the stumps and trash, but also as a weevil-control measure.

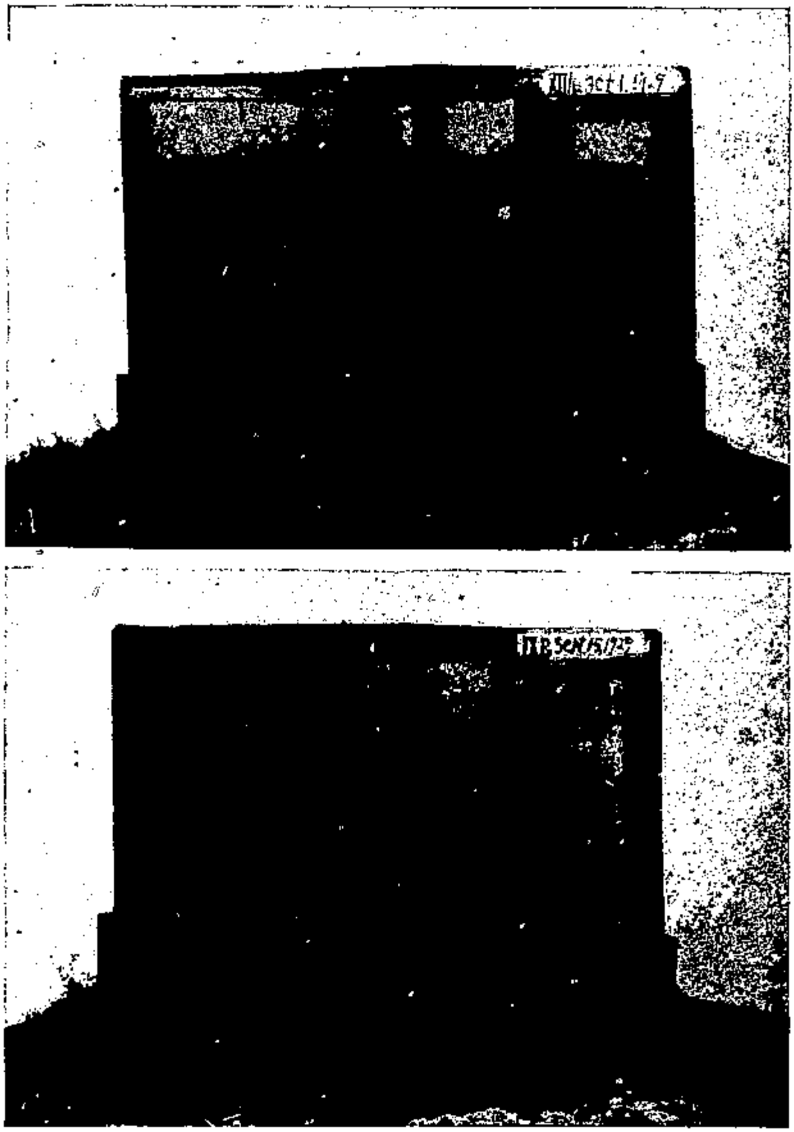


FIGURE 4.—Hibernation cages: *A*, Typical check cage with Spanish-moss for shelter; *B*, a cage in series 9 with cornstalks for shelter.

CORNSTALKS AND COTTON STALKS AS SHELTERS

A comparison of weevil survival in shelters of cornstalks, cotton stalks, and Spanish-moss was provided in series 9, which was carried on for 14 seasons beginning with 1916–17. Three cages, each containing one of these materials, were installed at regular biweekly intervals throughout the fall of each year. The test cages were partly filled with cornstalks (fig. 4, *B*), or cotton stalks from which the foliage and fruit had been removed (fig. 5, *A*). The Spanish-moss cages were prepared in the usual manner of the check cages. Table 5 shows that the cornstalks proved to be the superior shelter, with the moss ranking second and the cotton stalks third.

TABLE 5.—*Comparison of Spanish-moss, cornstalks, and cotton stalks as bollweevil shelter, Tallulah, La., 1916–17 to 1930–31*

[Summary of series 9]

Date of installation	Spanish-moss			Cornstalks			Cotton stalks		
	Weevils installed	Emergence		Weevils installed	Emergence		Weevils installed	Emergence	
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*
Sept. 2–9							1,000	0	0.00
Sept. 12–21	5,270	10	0.19	5,198	8	0.15	5,709	3	.05
Sept. 24–Oct. 2	6,795	40	.59	6,696	48	.72	7,194	13	.18
Oct. 6–19	6,234	93	1.49	6,189	96	1.55	6,786	55	.81
Oct. 22–Nov. 6	6,341	165	2.60	5,728	323	5.64	7,299	138	1.89
Nov. 13							500	5	1.00
Nov. 22							500	2	.40
Total	24,640	308	1.25	23,811	475	1.99	28,968	216	[1] .77

[1] This average is based only on the 4 periods that were covered by the averages obtained with Spanish-moss and cornstalk shelters. Including all 7 periods, the average is 0.75.

MIXTURE OF CORNSTALKS, STRAW, AND SPANISH-MOSS AS SHELTER

Series 11 was conducted for only two winters, 1916–17 and 1918–19. A mixture of oat straw, Spanish-moss, and cornstalks was compared with Spanish-moss alone as a hibernation shelter for the cotton bollweevil. There was no emergence from the stalk-straw-moss cages, but as emergence was generally low in those two seasons the results cannot be considered conclusive.

HIBERNATION ON BARE GROUND

One cage with Spanish-moss and one with no shelter whatever were installed at biweekly intervals during the fall of 12 years (1918 to 1930), 500 weevils being used in each cage. The results are summarized in table 6, where it is shown that 1.83 percent of the weevils survived in the check cages with moss, whereas only 0.09 percent survived in the cages with no shelter. Even this percentage of survival on the bare ground is rather surprising.

FIGURE 5.—Hibernation cages: *A*, A cage in series 9 with cotton stalks for shelter; *B*, a cage in series 16 containing sawmill debris consisting of chips and pieces of board and bark.

TABLE 6.—*Comparison of bollweevil survival in Spanish-moss and on bare ground, Tallulah, La., 1918–19 to 1930–31*

[Summary of series 15]

Date of installation	Spanish-moss			Bare ground		
	Weevils installed	Emergence		Weevils installed	Emergence	
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
Sept. 14–19	5,021	18	0.36	5,224	1	0.02
Sept. 29–Oct. 2	5,263	87	1.65	5,120	1	.02
Oct. 13–18	5,299	112	2.11	5,373	9	.17
Oct. 25–Nov. 6	6,369	184	2.89	6,338	8	.13
Total	21,952	401	1.83	22,055	19	.09

SAWMILL DEBRIS AS SHELTER

Over a period of 11 winters, from 1919–20 to 1930–31 (except 1926–27), series 16 was conducted to compare the protection afforded by sawmill debris such as chips and pieces of board and bark with Spanish-moss. The cages (fig. 5, *B*) were installed at biweekly intervals from September 14 to November 6, as shown in table 7, with an average survival in the debris cages of 1.36 percent as compared with a survival of 1.74 percent in the cages with Spanish-moss.

TABLE 7.—*Comparison of Spanish-moss and sawmill debris as bollweevil shelter, Tallulah, La., 1919–20 to 1930–31*

[Summary of series 16]

Date of installation	Spanish-moss			Boards, chips, etc.		
	Weevils installed	Emergence		Weevils installed	Emergence	
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
Sept. 14–19	5,154	18	0.35	5,122	0	0.00
Sept. 29–Oct. 2	5,314	67	1.26	5,244	28	.53
Oct. 13–18	4,848	67	1.38	4,885	88	1.80
Oct. 29–Nov. 6	5,319	207	3.89	5,283	163	3.09
Total	20,635	359	1.74	20,534	279	1.36

EFFECT OF COVERING CAGES

Series 12 was conducted for 13 seasons, beginning with 1917–18, to study the effect of roofing the cages with boards and covering the sides of some of these with boards and of others with canvas (fig. 6, *A*). Spanish-moss was used as the hibernation material. Three cages, 1 altogether open as a check cage, 1 covered on the sides and top with boards, and 1 roofed with boards and having canvas sides, were installed every 2 weeks during the fall of each year.

The cages sided with boards were entirely rainproof, but a little moisture could enter the cages enclosed with canvas. The series was designed to furnish conditions as similar as possible to those that would be found by weevils passing the winter within or under

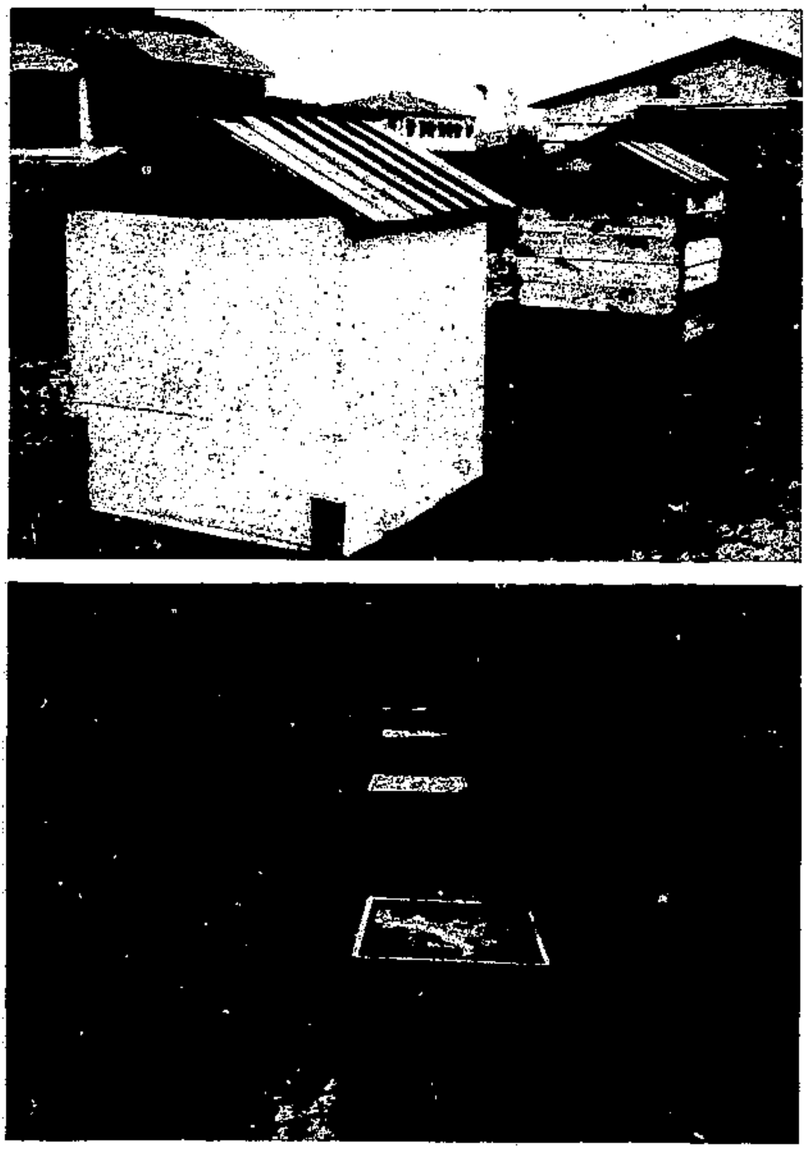


FIGURE 6.—Hibernation cages: *A*, covered cages used in series 12 showing a cage with canvas sides and one with board sides; *B*, cages protected by standing timber, series 18, containing Spanish-moss and cotton stalks for shelter.

buildings, sheds, gins, etc., where, in addition to some protection from cold, the insects would also escape the effects of rainfall. Table 8 shows that the emergence from the uncovered cages was roughly three times that from the covered ones, with no significant differences between the survival in the two types of covered cages.

TABLE 8.—*Bollweevil survival in Spanish-moss shelter as affected by covering of cage, Tallulah, La., 1917–18 to 1930–31*

[Summary of series 12]

Date of installation	Uncovered wire cage			Cage roofed and sided with boards			Cage roofed with boards and sided with canvas		
	Weevils installed	Emergence		Weevils installed	Emergence		Weevils installed	Emergence	
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*
Sept. 14–19	5,159	13	0.25	5,246	3	0.06	5,192	1	0.02
Sept. 29–Oct. 6	5,726	38	.66	5,878	5	.09	5,871	22	.37
Oct. 13–20	5,326	76	1.43	5,294	23	.43	5,228	27	.52
Oct. 23–Nov. 6	5,812	175	3.01	5,900	82	1.39	5,752	44	.76
Total	22,023	302	1.37	22,318	113	.51	22,043	94	.43

EFFECT OF STANDING TIMBER

Series 18 was conducted for 5 seasons between 1925–26 and 1930–31 in order to study the protection afforded by standing timber to the hibernating cotton bollweevils. Throughout the fall, cages containing Spanish-moss and cotton stalks were installed at weekly intervals. These cages were in every respect like those of series 1, with which they are compared, except that they were located in woodland, as shown in figure 6, *B*. Table 9 shows that the average survival in the cages in the woods was 0.57 percent as compared with that of 0.88 percent in the cages of series 1 in the open field for the same years.

TABLE 9.—*Comparison of bollweevil survival in cages in woods and in open field (Spanish-moss plus cotton stalks as shelter), Tallulah, La., 1925–26 to 1930–31*

[Summary of series 18]

Date of installation	Cages in woods			Cages in open field			Difference [1]
	Weevils installed	Emergence		Weevils installed	Emergence		
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Percent*
Sept. 1–7	2,479	1	0.04	3,453	0	0.00	−0.04
Sept. 8–14	2,465	0	.00	3,452	2	.06	+.06
Sept. 15–21	2,467	2	.08	3,407	6	.18	+.10
Sept. 22–28	2,461	5	.20	3,472	25	.72	+.52
Sept. 29–Oct. 5	2,462	6	.24	3,381	21	.62	+.38
Oct. 6–12	2,415	18	.75	3,385	23	.68	−.07
Oct. 13–19	2,438	16	.66	3,423	51	1.49	+.83
Oct. 20–26	2,447	29	1.19	3,450	53	1.54	+.35
Oct. 27–Nov. 4	2,952	45	1.52	4,458	59	1.32	−.20
Nov. 5–11	2,399	18	.75	3,424	67	1.96	+1.21
Nov. 12–18	960	16	1.67	977	36	3.68	+2.01
Nov. 19–25	970	3	.31	1,500	2	.13	−.18
Nov. 26–Dec. 3	949	0	.00	1,833	2	.11	+.11
Total	27,864	159	.57	39,615	347	.88	+.31

[1] Plus (+) denotes increased emergence in cages in open field, and minus (−) decreased emergence in those cages.

GENERAL COMPARISON OF ALL HIBERNATION MATERIALS

The comparisons given show the results of the special tests with each kind of shelter, and, in order to afford a more general comparison, additional summaries have been prepared which include all cages classified by shelter materials regardless of other conditions. In table 10 is presented a summary of the percentage of survival in different materials, while the rate of emergence is given in table 11 to show any effect these materials may have on the time when the weevils leave hibernation. From table 10 it is seen that cornstalks gave the highest average survival of any type of shelter, with Spanish-moss ranking second, and that the lowest survival was recorded in the cages with bare ground. The fact that no weevils emerged in series 11 is not considered significant, as that series was conducted for only 2 years, and weevil survival in those years was low.

TABLE 10.—*General summary of boll weevil survival in all cages classified by hibernation shelter, Tallulah, La., 1915–16 to 1930–31*

Nature of shelter and series	Weevils installed	Emergence	
	Number	*Number*	*Percent*
Cornstalks (series 9)	23,811	475	1.99
Spanish-moss (series, 2, 3, 4, 6, 7, 9, 10, 11, 12, 13, 15, 16, 17)	129,026	2,143	1.66
Spanish-moss, plus cotton stalks (series 1)	98,858	1,428	1.44
Sawmill debris (series 16)	20,534	279	1.36
Oat straw (series 4)	24,982	309	1.24
Cotton stalks (series 9)	28,988	216	.75
Stump (series 6)	1,500	11	.73
Spanish-moss, plus cotton stalks (in woods, series 15)	27,864	159	.57
Spanish-moss, and cage covered with boards (series 12)	22,318	113	.51
Spanish-moss, and cage covered with canvas (series 12)	22,043	94	.43
Bare ground (series 15)	22,055	19	.09
Spanish-moss, oat straw, and cornstalks (series 11)	8,385	0	.00
Total	430,364	5,246	1.22

TABLE 11.—*Summary of rate of weevil emergence*[1] *from various shelters used in hibernation cages, Tallulah, La., 1915–16 to 1930–31*

Nature of shelter	Weevils installed	Cumulative emergence by months: March		March and April		March, April, and May		March, April, May, and June		March, April, May, June, and July	
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Stump	1,500	5	45.5	10	90.9	11	100.0				
Cotton stalks	28,988	55	25.5	129	59.7	211	97.7	216	100.0		
Oat straw	24,982	100	32.4	188	60.8	300	97.1	309	100.0		
Sawmill debris	20,534	113	40.5	190	68.1	263	94.3	279	100.0		
Spanish-moss and cage covered with canvas	22,043	27	28.7	60	63.8	88	93.6	94	100.0		
Bare ground	22,055	7	36.8	14	73.7	17	89.5	19	100.0		
Cornstalks	23,811	55	11.6	182	38.3	421	88.6	475	100.0		
Spanish-moss, plus cotton stalks	98,858	166	11.6	453	31.7	1,037	72.6	1,426	99.9	1,428	100.0
Spanish-moss	129,026	247	11.5	673	31.4	1,562	72.9	2,133	99.5	2,143	100.0
Spanish-moss and cage covered with boards	22,318	32	28.3	68	60.2	96	85.0	112	99.1	113	100.0
Spanish-moss, plus cotton stalks (in woods)	27,864	18	11.3	58	36.5	101	63.5	156	98.1	159	100.0

[1] Expressed as the percentage of the number that emerged as shown in table 10: not, therefore, comparable with the percentages of emergence given in preceding tables.

EFFECT OF SIZE OF CAGE

Series 7 was carried on for only one season, the winter of 1915–16, for the purpose of determining the effect on weevil survival of increasing the size of the cage to 8 feet long by 5 feet wide and 6 feet high as compared with the standard cage 4 by 4 by 4 feet. No conclusive difference could be detected.

EFFECT OF VARIOUS NUMBERS OF WEEVILS PER CAGE

Series 17 was begun in 1923–24 and conducted for 7 years to determine the effect of the number of weevils in a cage on the survival. In the regular tests the standard number of 500 weevils was used mainly because previous investigators had generally used that number, and it was highly desirable to follow their methods as far as possible so that results could be compared. It was felt, however, that this number might be excessive for the type of cage in use, and the overcrowding might prevent some of the weevils from receiving the best shelter and thus result in an increased mortality.

Consequently in series 17, populations of approximately 25, 50, 100, 250, 350, and 500 weevils were used; a complete series being started on October 10 and 20 of each year. Spanish-moss was furnished for shelter. Table 12 shows that the highest survivals occurred in the cages with approximately 50, 100, and 250 weevils per cage.

TABLE 12.—*Survival of bollweevils as affected by varying the numbers per cage (Spanish-moss used as weevil shelter), Tallulah, La., 1923–24 to 1930–31*

[Summary of series 17]

Date of installation	Weevils installed per cage (approximate)	Total weevils installed	Emergence	
	Number	*Number*	*Number*	*Percent*
Oct. 10 and 20	25	334	3	0.90
	50	671	14	2.09
	100	1,347	26	1.93
	250	3,321	66	1.99
	350	4,829	66	1.37
	500	6,884	103	1.50

COMPARISON OF WEEVILS FROM DIFFERENT SOURCES

Series 13 was conducted during the seasons of 1916–17 and 1917–18 for the purpose of ascertaining whether weevils from various localities differed in their resistance to winter weather. It had been suggested that weevils native to a more southerly district might be less resistant to winter conditions than those occurring in a more northerly district. Consequently, two additional localities were selected; one at Opelousas, La., about 125 miles south of Tallulah, and the other at Scott, Miss., about 100 miles north of Tallulah. Field-collected weevils were gathered at each of these points and also at Tallulah. Cage installations were made at each point with weevils from all three lots. At each point the complete series enabled a comparison to be made between native weevils and those from the other two points.

The results for the most part were somewhat erratic, and about the only consistent one was the fact that native weevils proved to be more resistant than those that had undergone shipment, regardless of the source. Consequently, it was apparent that the hardships of transportation overshadowed any other differences that might have existed.

GENERAL SUMMARY OF SURVIVAL AND EMERGENCE

All cage tests have been brought together by years in table 13 to show average percentage of survival, rate of emergence, and emergence period. From this table it is seen that a total of 430,364 weevils were installed in all cages under various conditions during all years. Of these 5,246 or 1.22 percent, emerged. Of the total number of weevils surviving, 15.7 percent emerged in March, 22.9 percent in April, 39.7 percent in May, 21.4 percent in June, and 0.3 percent in July. In other words, emergence was 38.6 percent complete at the end of April, 78.3 percent complete at the end of May, and 99.7 percent complete at the end of June. The average cumulative bollweevil emergence is shown graphically in figure 7. The emergence period for the various years ranged from 47 to 127 days, with a weighted average of 117 days. The extremely short periods were during the years of very low survival. During 3 of the 15 years emergence was recorded on March 1 and was recorded during March in 14 of the 15 years. The date of completion of emergence ranged from April 27 to July 7. Emergence extended into June, however, in all of the years except 3; and since only 11 weevils emerged during those 3 years, this number is too small to be significant. Extension of the period of emergence into June is therefore probably of general occurrence. Emergence extended into July in only 4 years.

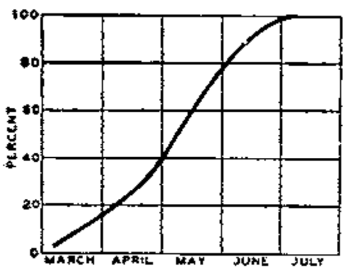


FIGURE 7.—Cumulative frequency curve: percentage of bollweevil emergence classified according to time of emergence.

Table 13.—*General summary of weevil emergence by months and periods of emergence, Tallulah, La., 1915–16 to 1930–31*

Year	Weevils installed	Period of emergence		Number of weevils and percent of total emergence by months										Total emergence		Period of emergence
		First date	Last date	March		April		May		June		July				
	Number			*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Days*
1915–16	13,100	Mar. 10	June 23	116	14.4	127	15.8	479	59.6	82	10.2	0	0.0	804	6.14	106
1916–17	21,669	Mar. 15	June 6	18	50.0	9	25.0	3	8.3	6	16.7	0	.0	36	.17	84
1917–18	9,500	Mar. 21	May 22	2	40.0	1	20.0	2	40.0	0	.0	0	.0	5	.05	63
1918–19	19,945	Apr. 2	June 10	0	.0	11	17.7	44	71.0	7	11.3	0	.0	62	.31	70
1919–20	27,341	Mar. 30	June 21	9	6.8	64	48.5	57	43.2	2	1.5	0	.0	132	.48	84
1920–21	26,286	Mar. 1	June 6	165	45.6	85	23.5	108	29.8	4	1.1	0	.0	362	1.38	98
1921–22	28,536	Mar. 14	July 7	173	14.4	264	21.9	466	38.7	298	24.8	2	.2	1,203	4.22	116
1922–23	34,375	Mar. 3	July 5	58	10.6	139	25.4	189	34.5	158	28.8	4	.7	548	1.59	125
1923–24	30,648	Mar. 4	June 14	3	8.6	14	40.0	14	40.0	4	11.4	0	.0	35	.11	103
1924–25	33,565	Mar. 12	Apr. 27	2	50.0	2	50.0	0	.0	0	.0	0	.0	4	.01	47
1925–26	40,376	Mar. 1	June 8	7	31.8	11	50.0	3	13.6	1	4.6	0	.0	22	.05	100
1927–28	46,384	Mar. 12	June 11	4	36.4	2	18.2	2	18.2	3	27.2	0	.0	11	.02	92
1928–29	33,999	Mar. 2	July 6	92	34.8	59	22.4	88	33.3	24	9.1	1	.4	264	.78	127
1929–30	31,786	Mar. 1	May 22	1	50.0	0	.0	1	50.0	0	.0	0	.0	2	.01	83
1930–31	32,854	Mar. 3	July 7	175	10.0	412	23.5	626	35.6	534	30.4	9	.5	1,756	5.34	127
Summary of all years	430,364	Mar. 1	July 7	825	15.7	1,200	22.9	2,082	39.7	1,123	21.4	16	.3	5,246	1.22	[1] 117

[1] Weighted average.

From the foregoing it is seen that the experimental procedures were standardized, except for certain variables which may be grouped in the following nine classifications: Varying dates of installation; weevils that had been fed versus unfed weevils; fertilized females versus unfertilized ones; comparisons of various shelter materials; different sizes of cage; covered cages versus uncovered ones; weevils from different localities; varying numbers of weevils per cage; and open-field location versus timber. Of these the dates of installation and various shelter materials were the most important variables and received the most attention.

RELATION BETWEEN WINTER WEATHER AND PERCENTAGE OF SURVIVAL

The relation between winter weather and percentage of survival, as shown in table 14, is evident; however, in analyzing the results of these tests every effort has been made to isolate those factors which showed the closest correlation with survival. All meteorological observations available have been summarized and compared with the figures representing survival. For the sake of brevity, a discussion of fruitless efforts is not included, but it may be mentioned that no correlations were found between the records of survival and those of maximum temperature, mean temperature, humidity, or rainfall; and it was not until minimum temperatures alone were considered that significant correlations were encountered.

TABLE 14.—*Relation between minimum temperatures and percentage of weevil survival, Tallulah, La., 1915–16 to 1930–31*

Year	Days temperature September to March fell below—						Minimum temperature	Weevil survival
	32° F.	30° F.	24° F.	22° F.	20° F.	18° F.		
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	° *F.*	*Percent*
1929–30	44	33	15	13	11	9	1.8	0.01
1924–25	40	37	15	8	4	2	15	.01
1927–28	43	34	15	10	10	6	11	.02
1925–26	47	31	11	6	3	2	13	.05
1917–18	60	51	28	21	14	10	1	.05
1923–24	51	34	8	7	5	3	10.5	.11
1916–17	45	33	19	11	5	4	16	.17
1918–19	45	30	13	9	4	4	9	.31
1919–20	39	29	12	5	2	0	18	.48
1928–29	43	34	15	12	7	3	16	.78
1920–21	35	24	6	3	1	1	10	1.38
1922–23	26	23	7	3	0	0	20	1.59
1921–22	30	10	3	0	0	0	22.5	4.22
1930–31	37	28	6	1	0	0	20	5.34
1915–16	32	21	9	4	0	0	20	6.14

The coefficients of correlation between the number of times the temperature fell below a certain number of degrees Fahrenheit and the percentage of weevil survival are given in table 15. It will be noted that all coefficients, except one, between these two variables are significant, and that the greatest correlation, which was -0.64 ± 0.10, was shown between the number of times the temperature fell below 32° and 30° F. and the percentage of weevil survival. Correlation is also shown between the minimum temperature for the winter and survival, the coefficient being $+0.63 \pm 0.10$. To determine what particular minimum temperatures cause the highest mortality of weevils in hibernation, coefficients of correlation were computed between the number of times a given temperature prevailed and the percentage of weevil survival. These are also given in table 15. It will be noted that only 2 of these coefficients are significant, namely, the number of times the temperature ranged from 18° to 20°, and from 1° to 17°. In other words, the results indicate that the occurrence of temperatures of 20°, or lower, are accompanied by the lowest survival. Winter minimum temperatures taken by themselves seem to explain only in part the winter mortality of weevils. Undoubtedly, all such factors as the temperatures preceding low temperatures, the duration of extremely cold spells, the rate of change in temperature, the frequency of temperature changes, whether or not rain precedes low temperatures, and the presence of sleet or snow, have an influence on weevil mortality.

TABLE 15.—*Percentage of bollweevil survival correlated with winter temperatures at Tallulah, La., 1915–16 to 1930–31*

Percentage of weevil survival correlated with—			
Days temperature fell below the following degrees:		Days temperature fell to the following degrees:	
° *F.*	*Correlation coefficient*	° *F.*	*Correlation coefficient*
36	−0.33±0.16	35, 34, and 33	+0.24±0.16
32	−.01± .10	32, 31, and 30	−.06± .17
30	−.64± .10	29, 28, and 27	−.39± .15
24	−.57± .12	26, 25, and 24	+.10± .17
22	−.62± .11	23, 22, and 21	−.06± .17
20	−.62± .11	20, 19, and 18	−.57± .12
18	−.57± .12	17 to 1	−.57± .12
Minimum temperature for winter	+.63± .10		

INFLUENCE OF TEMPERATURE ON WEEVIL EMERGENCE

Before discussing the influence of temperature on weevil emergence at Tallulah, it will probably be well to review the findings of a few other investigators.

Hunter and Hinds [4] state:

Emergence depends largely, as has already been shown, upon the mean average temperature prevailing. The presence of food does not seem to affect it. In the season of 1903 for one month preceding the emergence of weevils at Victoria [Texas] the mean average temperature was 65.4° F. For the first two weeks of April it averaged 68.4° F. Weevils left their winter quarters from the middle to the last of April. While the mean average temperature for May was nearly 3° lower than the temperature prevailing at the time of emergence, weevils remained actively at work in the fields. In the fall also weevils remained at work at a lower temperature than that which seems to be necessary to draw them from their winter quarters. The reason for this fact is not apparent, but it is certain that once having left hibernation weevils will remain active at considerably lower temperatures.

According to Hunter and Pierce: [5]

The number of weevils emerging under 57° F. is very small indeed. From that point the emergence increases with the increase in temperature until a

[4] HUNTER, W. D., and HINDS, W. E. THE MEXICAN COTTON BOLL WEEVIL. U. S. Dept. Agr., Bur. Ent. Bull. 51, 181 pp., illus. 1905. (See pp. 106–107.)
[5] HUNTER, W. D., and PIERCE, W. D. THE MEXICAN COTTON-BOLL WEEVIL: A SUMMARY OF THE INVESTIGATIONS OF THIS INSECT UP TO DECEMBER 31, 1911. U. S. Dept. Agr., Bur. Ent. Bull. 114, 188 pp., illus. 1912. (62d Cong., 2d sess., Sen. Doc. 305.) (See p. 108.)

majority of the weevils have emerged. Most weevils have been found to leave their winter quarters during a temperature averaging between 64° and 78° F. At Keatchie 75 per cent and at Dallas 96 per cent of the total emergence took place between these limits. At Dallas the largest emergence occurred between temperatures of 64° and 68° F., while at Keatchie the largest emergence occurred between 74° and 78° F.

Hinds and Yothers [6] state:

The more complete records now at hand indicate that emergence may take place whenever the mean average temperature exceeds 55° F. It is certain that weevils may be active at a temperature considerably lower than this, but the records do not indicate that there is a general emergence from hibernation at a lower temperature.

Weevil emergence at Tallulah began between March 1 and 15 in 12 of the 15 years covered by this study; on March 21 in 1 year; on March 30 in 1 year; and on April 2 in 1 year. On the days that the first weevils emerged the maximum temperature ranged from 55° to 84° F., the average being 73.8°; however, the maximum was less than 72° in only 3 years. On the day preceding the first weevil emergence of the year the maximum temperature ranged from 44° to 84°, with an average of 71°. The maximum was less than 70° in only 4 of these years.

In 8 of the years the mean temperature was from 60° to 69.5° F. on the day the first weevils emerged, and in each case this date had been preceded by days with mean temperatures of 60° or higher. In the remaining 7 years the mean temperature was from 43.5° to 59.5° on the day the first weevils emerged, but during 5 of these years the mean temperature was 60° or above on 1 or more days prior to emergence. These records indicate that few weevils emerge from hibernation in cages when the maximum temperatures are below 70° and mean temperatures below 60°, which temperatures are usually reached in the vicinity of Tallulah during the last few days of February or the first few days of March.

After weevils begin to emerge there is a definite positive correlation between emergence and both maximum and mean temperatures until the peak of emergence is reached, which is usually during May. After the peak is reached no further correlation exists between these factors.

RELATION BETWEEN PRECIPITATION AND WEEVIL EMERGENCE

During the 15 years under consideration, from the beginning to the end of weevil-emergence periods there was a total of 1,425 days, and on 715, or 50.2 percent of these days, 1 or more weevils emerged. A total of 5,246 weevils emerged in all cages, or an average of 3.68 weevils per day for the total of the emergence periods. Rainfall of 0.01 inch or more was recorded on 372 of the 1,425 days in the total emergence periods. A total of 1,330 weevils emerged on the days on which rain occurred, or an average of 3.58 weevils per day. On 189 days on which rain occurred no weevils emerged in any of the cages.

For an average of all years, 25.4 percent of the total surviving weevils emerged on days on which rain was recorded, 12.2 percent on

---

[6] HINDS, W. E., and YOTHERS, W. W. HIBERNATION OF THE MEXICAN COTTON BOLL WEEVIL. U. S. Dept. Agr., Bur. Ent. Bull. 77, 100 pp., illus. 1909. (See pp. 68–69.)

the first day following rain, 10 percent on the second day, 8.5 percent on the third day, 6.7 percent on the fourth day, 6.4 percent on the fifth day, 7.1 percent on the sixth day, 5.8 percent on the seventh day, and so on, with percentages decreasing to the twenty-seventh day. A total of 82.1 percent of the surviving weevils emerged on the days on which rain was recorded and within 7 days after rain occurred, and the remaining 17.9 percent emerged from the eighth to the twenty-seventh day, inclusive, after rain occurred. A total of 37.6 percent emerged on days of rain and on the first day following.

In cases of several days of consecutive rainfall the weevils emerging on such days were recorded as emerging on a day of rainfall even though the same date could have been considered as a day following rain or 2 or 3 days after a rain.

EFFECT OF DELAY IN REMOVAL OF WEEVILS FROM CAGES

At the suggestion of C. L. Marlatt, at that time chief of the Bureau of Entomology, a special series of tests was started in 1928–29 and continued in the seasons of 1929–30 and 1930–31, to determine the effect on weevil survival of delaying the removal of weevils from cages until the cotton plants in the field were sufficiently large to furnish food for weevils. The removal of weevils from the cages was delayed until May 9 in 1929 and until May 4 in 1930 and in 1931. It will be noted in table 16 that an average survival of 2.62 percent was recorded in the cages where weevils were removed on and after March 1 and that an average survival of 2.06 percent was recorded in the cages where the removal of weevils was delayed until early in May. The average survival in the cages where the removal of weevils was delayed until early in May was 78.6 percent of that recorded in the cages where weevils were removed on and after March 1.

TABLE 16.—*Weevil survival in cages where emergence records were started on Mar. 1 and on May 4 and 9, Tallulah, La., from 1928–29 to 1930–31*

Year	Cages	Nature of shelter	Date emergence records started	Weevils installed	Emergence		Difference in percentages
	Number			*Number*	*Number*	*Percent*	
1928–29	12	Spanish-moss plus cotton stalks.	Mar. 1	5,894	38	0.64	0.44
	12	do	May 9	5,901	12	.20	
	8	Spanish-moss	Mar. 1	3,948	23	.58	.15
	8	do	May 9	3,923	17	.43	
1929–30	10	Spanish-moss plus cotton stalks.	Mar. 1	4,946	0	.00	0
	10	do	May 4	4,922	0	.00	
	8	Spanish-moss	Mar. 1	3,880	0	.00	0
	8	do	May 4	3,857	0	.00	
1930–31	11	Spanish-moss plus cotton stalks.	Mar. 1	5,320	301	5.66	1.42
	11	do	May 4	5,330	226	4.24	
	8	Spanish-moss	Mar. 1	3,887	369	9.49	1.42
	8	do	May 4	3,939	318	8.07	
Total			Mar. 1	27,875	731	2.62	.56±0.17
			May 4 and 9	27,872	573	2.06	

SUMMARY OF FALL AND SPRING EXAMINATIONS OF SPANISH-MOSS, PERCENTAGES OF SURVIVAL IN HIBERNATION CAGES, EXAMINATIONS OF COTTON PLANTS IN MAY AND JUNE, AND PERCENTAGE OF INCREASED YIELD IN EXPERIMENTAL PLOTS

Table 17 presents records made in the vicinity of Tallulah for the winters from 1915–16 to 1930–31 which show the importance of hibernation-cage records and further show the relation of such records to certain other variables. The most important of these records are presented in figures 8 and 9. Figure 8 shows the minimum temperature for the winter, bollweevil survival (live weevils per ton) in Spanish-moss under natural conditions, and weevil survival in hibernation cages. The two survival curves have practically the same trends. The graph also shows the high degree of correlation existing between weevil survival and minimum temperatures. It is also interesting to note (table 17) that during this period the mini-

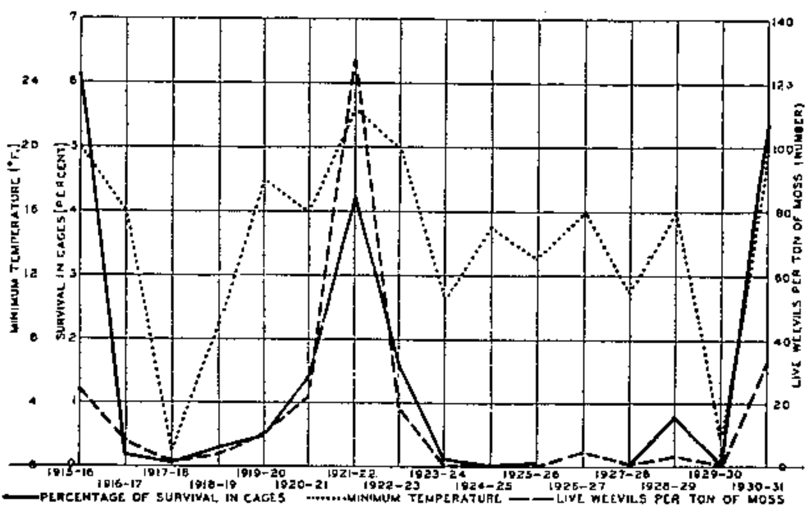


FIGURE 8.—Minimum temperature for the winter, number of live bollweevils per ton of Spanish-moss (spring examination), and bollweevil survival in hibernation cages, Tallulah, La., 1915–16 to 1930–31.

mum temperature was 20° F. during the winters of 1915–16, 1922–23, and 1930–31; 22.5° during the winter of 1921–22; and lower than 20° during the 11 remaining winters for which survival records of weevils in hibernation cages are available. The average survival for the 4 years that the minimum temperature was 20° or higher was 3.96 percent, as compared with an average survival of 0.29 percent during the remaining 11 years when the minimum temperature fell below 20°.

There is also positive correlation between the minimum temperature of the preceding winter and the percentage of increased yield in experimental plots (table 17) where bollweevils were controlled with calcium arsenate. The coefficient of correlation between these two variables is $+0.44 \pm 0.16$. Kincer [7] showed that there is a definite

[7] KINCER, J. B. WEATHER AND COTTON BOLL WEEVIL. U. S. Monthly Weather Rev. 56: 301–304, illus. 1928.

correlation between the lowest temperature during the preceding winter and the reported bollweevil damage. The correlation coefficients by States are as follows: Texas +0.71, Oklahoma +0.61, Arkansas +0.71, Louisiana +0.63, Mississippi +0.74, Alabama +0.37, and Georgia +0.63.

TABLE 17.—*Summary of fall and spring Spanish-moss examinations, percentage of bollweevil survival in hibernation cages, cotton-plant examinations during May and June, and percentage of increased yield in experimental plots, Tallulah, La., 1915–16 to 1930–31*

Season	Weevils entering hibernation (live weevils per ton of Spanish-moss)	Minimum temperature for winter	Survival in Spanish-moss (live weevils per ton)	Survival in hibernation cages	Cotton-plant examinations in field, May and June (average plants per weevil)	Total precipitation, June to August	Increased yield in calcium arsenate treated plots
	Number	*°F.*	*Number*	*Percent*	*Number*	*Inches*	*Percent*
1915–16	------	20.0	24.0	6.44	52	10.00	------
1916–17	------	10.0	8.0	.17	5,056	10.27	------
1917–18	------	1.0	1.7	.05	354	6.20	------
1918–19	------	9.0	4.0	.31	245	15.30	------
1919–20	------	18.0	9.5	.48	223	12.51	32.8
1920–21	------	16.0	22.0	1.38	139	12.62	44.6
1921–22	------	22.5	127.0	4.22	135	21.32	83.9
1922–23	------	20.0	10.0	1.59	258	9.42	20.7
1923–24	------	10.5	.5	.11	1,788	2.11	1.1
1924–25	------	15.0	.0	.01	5,690	0.38	11.7
1925–26	280	13.0	.0	.05	558	10.51	69.3
1926–27	242	16.0	4.0	------	------	14.58	33.0
1927–28	21	11.0	1.0	.02	2,016	18.06	41.2
1928–29	240	16.0	3.8	.78	600	6.68	11.7
1929–30	189	1.8	.2	.01	1,511	2.38	9.3
1930–31	40	20.0	33.0	5.34	2,685	13.04	31.8

Figure 9 shows weevil survival in hibernation cages, total precipitation during June, July, and August, and percentage of increased yield in experimental plots where weevils were controlled with calcium arsenate.

The increased yields on dusted plots (as compared with untreated plots) reflect the degree of weevil infestation in the different seasons, since the increase in yield of treated over untreated plots was greater in the seasons of severe infestation. The curves of figure 9 show a marked correlation between increased yield and total precipitation for June, July, and August, except for the season of 1926, in which there was a heavy infestation of the cotton flea hopper, *Psallus seriatus* Reut., and in 1927, the year of the overflow.

This increased-yield curve (which indicates the weevil population) does not follow the survival curve so closely as it does the precipitation curve, showing that the final population depends more on the weather than on the initial infestation.

The correlation coefficient between the percentage of increased yield in the dusted plots and the total precipitation during June, July, and August was $+0.79 \pm 0.07$. Kincer[8] gives the correlation coefficients between rainfall in inches, concurrent year, and reported weevil damage by States as follows: Texas +0.54, Oklahoma +0.70,

[8] KINCER, J. B. See footnote 7.

Arkansas +0.49, Louisiana +0.78, Mississippi +0.69, Alabama +0.46, and Georgia +0.23. Rainfall for the following periods were used: Texas, June to August, inclusive; Oklahoma, Arkansas, and Louisiana, June and July combined; Alabama and Georgia, July and August combined; Mississippi, June to September, inclusive.

COMPARISON BETWEEN RESULTS AT TALLULAH, LA., AND AT COOPERATING STATIONS

During the last 7 years of this investigation valuable cooperation was extended by a number of workers at State experiment stations and other points of investigation and by the Bureau's laboratory at Florence, S. C.

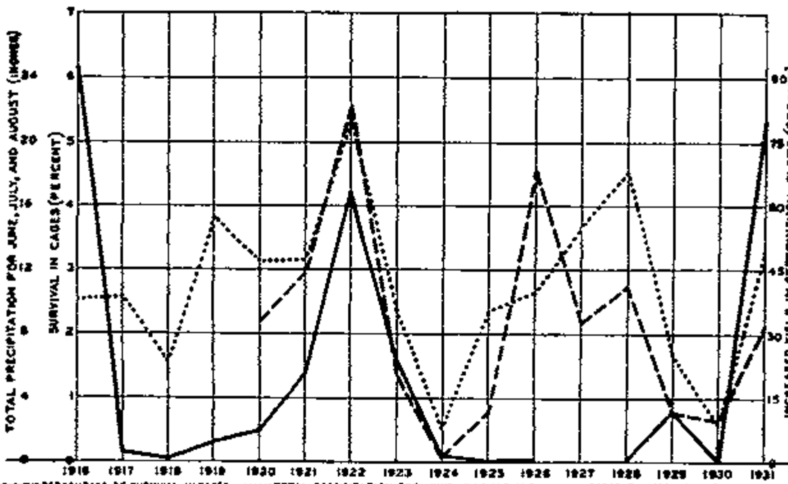


FIGURE 9.—Bollweevil survival in hibernation cages; total precipitation for June, July, and August; and percentage of increase in yield in experimental plots where boll-weevils were controlled with calcium arsenate, Tallulah, La., 1916–1931.

In a comparison of the results of the cage tests at Tallulah, with results obtained at the 17 cooperating stations from 1924–25 to 1930–31, as shown in table 18, it will be noted that the average survival in the cages at Tallulah, was consistently lower than the average survival at most of the cooperating stations. This may be in large part due to the fact that at Tallulah, 60.5 percent of the weevils were installed prior to October 16 (table 2), when many of them perished before they entered hibernation, whereas at the cooperating stations only 43.3 percent of the weevils were installed during the same period. At Tallulah, 30.9 percent of the weevils were installed in cages where the hibernation material provided showed average survivals of less than 1 percent over a long period (table 10), while at the cooperating stations, in many cases, more favorable shelters were used.

TABLE 18.—*Percentage of emergence in hibernation cages at cooperating laboratories, 1925–31*

Location of laboratory	Cooperator	1924–25		1925–26		1926–27		1927–28		1928–29		1929–30		1930–31	
		Weevils installed	Weevils emerged	Weevils installed	Weevils emerged	Weevils installed	Weevils emerged	Weevils installed	Weevils emerged	Weevils installed	Weevils emerged	Weevils installed	Weevils emerged	Weevils installed	Weevils emerged
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Aberdeen, N. C.	R. W. Leiby	1,072	0.93	2,000	0.85	2,425	3.26	2,500	0.68	2,500	21.36				
Auburn, Ala.	J. M. Robinson	1,750	15.71	1,500	.60	3,804	.29	7,008	.07	10,888	.20	2,420	0.00	191	0.00
Baton Rouge, La.	W. E. Hinds	7,326	6.61	13,295	6.13	816	.00	3,385	2.13	6,055	.56				
Clemson College, S. C.	C. O. Eddy	4,000	3.80	4,000	.25			7,500	1.21	5,600	.54	6,000	.95		
Cleveland, Miss.	G. I. Worthington							3,000	.07	2,850	.60	2,800	.00		
College Station, Tex.	F. L. Thomas	1,329	6.47	1,430	2.45	3,984	5.27	4,500	.42	5,570	7.74	3,500	.03	5,000	17.00
Experiment, Ga.	R. P. Bledsoe	2,781	1.62	8,373	.02	1,097	.00	6,000	.00	750	.00				
Fayetteville, Ark.	Dwight Isely					2,000	.30	2,000	.55						
Florence, S. C.		19,427	6.50	14,425	.80	15,462	8.49	18,500	1.54	22,000	14.27	22,000	4.82	20,000	5.99
Holly Springs, Miss.	T. F. McGehee	1,250	.08	1,350	.00	4,100	.02	5,000	.00	3,500	.29	1,200	.00		
Poplarville, Miss.	J. E. Lee			2,000	.10	2,500	.20	2,000	.10	2,000	.00				
Raymond, Miss.	O. M. Chance			2,000	.35	2,000	2.05	700	.71	1,000	9.90	2,000	.10		
Rocky Mount, N. C.	R. W. Leiby	2,177	.37	3,700	.11	4,300	1.67	4,000	1.40						
State College, Miss.	H. H. Kimball			1,130	.09	3,291	.91	4,100	.27	3,972	8.31	5,000	.02		
Stoneville, Miss.	D. W. Grimes			8,330	.00										
Tifton, Ga.	W. J. Davis			4,000	.08										
Yazoo City, Miss.	Chesley Hines							3,000	1.00	3,000	10.43	2,575	.00		
Tallulah, La.		33,565	.01	40,376	.05			46,380	.02	33,999	.78	31,786	.01	32,854	5.34

SUMMARY

This bulletin gives the results of a 15-year study of various factors influencing the survival in hibernation of the cotton bollweevil. The study was conducted by using a standard procedure and introducing one variable in each series of tests.

In a study of the effect of time of entering hibernation the highest survival was found among the weevils placed in cages between October 20 and November 18. There was no survival among weevils put into the cages prior to September 7.

The study of the survival in various materials provided in the cages for shelter revealed that the highest percentage of survival was in cornstalks, followed by Spanish-moss, Spanish-moss and cotton stalks, sawmill debris, and oat straw; with a number of other materials and combinations showing a much lower rating.

In a study of the effect of the number of weevils in a cage it was found that the highest percentage of survival in cages 4 by 4 by 4 feet was obtained when from 50 to 250 weevils were used.

Weevils transported from other points were less resistant to winter conditions than weevils collected locally.

In a study of the relation of winter weather conditions to weevil survival it was found that the only significant correlations were between minimum temperatures and survival. Coefficients of correlation between weevil survival and the number of times the temperature fell below 32°, 30°, 24°, 22°, 20°, and 18° F., respectively, were found to be significant, as were also those between weevil survival and the number of times the temperature ranged from 18° to 20° and from 1° to 17° F., and that between weevil survival and the minimum temperature for the winter. The weighted average weevil survival for the 4 years that the minimum temperature for the winter was 20° F. or higher was 3.96 percent, as compared with an average survival of 0.29 percent during the remaining 11 years when the minimum temperature fell below 20° F.

As a result of 15 years' observations at Tallulah, an average winter survival under all cage conditions of 1.22 percent was shown. In a special 3-year study, when the average survival was 2.62 percent in the cages from which the weevils were removed beginning March 1 (the customary procedure), a survival of 2.06 percent was indicated when the recording of the emergence was not begun until the early part of May.

Of the total number of weevils surviving, 15.7 percent emerged in March, 22.9 percent in April, 39.7 percent in May, 21.4 percent in June, and 0.3 percent in July. In other words, emergence was 38.6 percent complete at the end of April, 78.3 percent complete at the end of May, and 99.7 percent complete at the end of June. The emergence period for the different years ranged from 47 to 127 days, with a weighted average of 117 days. The extremely short periods of emergence were during the years of very low survival. Emergence extended into July in only 4 of the 15 years.

The final field population of weevils by the close of the growing season depends more upon the weather than upon the initial infestation.

The survival records obtained at Tallulah, La., were usually much lower than those obtained at 17 cooperating stations.

U. S. GOVERNMENT PRINTING OFFICE: 1935

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 5 cents

END