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THE FIRST AND LAST ESSENTIAL STEP IN COM- BATING THE BOLL WEEVIL¹

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The Problem of Weevil Control

Statement of the Problem.—During the past fifteen years the Mexican cotton boll weevil has spread throughout Texas, northward to about the middle of Oklahoma and southeastward from that region through southern Arkansas nearly to the Mississippi River, then southward through Louisiana, covering practically the entire western portion of the state and even spreading across the river into a few of the southwestern counties of Mississippi. Nothing seems likely to permanently check its eastward movement throughout the other cotton-growing states. It now infests practically one half of the cotton-growing area and is doing damage which can hardly be estimated at less than \$25,000,000 a year.

To the entomologist the practical problem is that of reducing the injury within the infested area to the smallest possible amount and to restrict the spread of the pest so far as it may be within human power to do so by the enforcement of quarantine regulations to prevent its being carried long distances into uninfested territory by commercial agencies.

Brief Survey of the Results of Investigational Work on Control

Factors in Natural Control.—These factors are, by their very nature, inconstant and unreliable, although they may often be of prime importance and are apparently of generally increasing value. The uncertainty of climatic factors which are sometimes of greater im-

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portance than any others need only be mentioned as an illustration of this class. The general difficulty is that we cannot tell what their effect may be until it becomes too late to take proper advantage of the conditions which they produce.

Natural enemies, both predaceous and parasitic, may also be valuable allies in the fight and every advantage possible should be taken of them, but it is simply folly for the cotton planter to sit idly by trusting nature to do all of the control work for him. However, it is certain that we would have a much more hopeless task in attempting control without the help of these natural factors and we may well study object lessons of the strongest kind, which nature frequently gives us as practical effects which man may himself, in some measure, reproduce.

Methods of Direct and Indirect Combat.—Naturally, through their general applicability to similar problems, the first recourse of the entomologist and of the planter as well is to insecticides. It is sufficient to say that "hosts" of these, both promising and otherwise, have been carefully tested and invariably found practically useless in fighting the weevil. The most promising and also widely tested of them all is Paris Green dusted on the young plants at intervals beginning before squares form, but its use has proven so constantly disappointing when applied that it has been practically abandoned by entomologists and by most planters.

The real reason for failure with Paris Green applies with equal force to all other arsenicals and to contact insecticides as well. Owing to the practical impossibility of applying it to those partially protected places where the weevils normally feed, only from one third to one half, on the average, of the adult weevils on the plants at the time of the treatment can be killed. The very long period of emergence from hibernation makes the number of weevils on the plants at one time but a very small fraction of the entire number which may survive and attack the crop. This renders frequent treatments necessary and their effectiveness is only partial at best. The immature stages cannot be reached by any insecticide, as they are surrounded constantly by several layers of vegetable tissue, and to penetrate that would require a power in the insecticide that would be fatal to the plant. Repeated applications of dry Paris Green (and of other insecticides as well) will often do more damage to the crop through its harmful effect upon the growth of the plant than would the weevils if allowed to do their worst.

No method of applying any efficient fumigant has been found applicable to a field crop like cotton. Small-scale experiments with the leading fumigants have indicated that none of them could be de-

pended upon to kill the immature stages even if they would kill the adults.

Trap rows are rendered impracticable by many considerations, but especially by the period of emergence from hibernation extending far beyond the time of any practicable delay in the planting of the main crop.

Among the multitude of machines devised, most have been designed for collecting and destroying the adults, or both adults and the infested fruit. Although some of them have been built at great expense and with the best of mechanical skill, none has yet proven superior to the practical difficulties encountered in field operation. It may be said fairly that there is not now on the market a practicable machine for combating the weevil. It is possible that the most promising device of this nature is one originated by the writer during the latter part of the season of 1907, which is now being patented by the Department of Agriculture. But this machine has not yet been tested upon a sufficiently large scale to justify its commendation for general use. However, it belongs rather to the methods of cultural control, since it combines the action of drawing the fallen, infested forms to the centers of the paths where the weevil stages will be mostly destroyed by the action of the direct sunshine, with the coincident cultivation of the crop.

The constant failures experienced in applying any direct method of attack have made it necessary that primary reliance for the control of the weevil should be placed upon indirect methods of cultural control which have as constantly given more encouraging results. It is now more than ten years since Dr. L. O. Howard first suggested the importance of cultural methods in fighting this insect. Ever since that time in all of the extensive work which has been carried on by the agents of the Bureau of Entomology, particular attention has been given to this phase of the problem. The general recommendations worked out by the agents of the Bureau have been frequently repeated in various publications and are now widely known. They have also been demonstrated in a practical way through the Demonstration Farm work carried on by the Bureau of Plant Industry. There is evident a large increase in the proportion of the most progressive planters who have adopted part, if not all, of these recommendations. There can be no adequate measurement of the value of the results of this work already obtained and it is equally certain that the possible good results are only beginning to be realized.

In the best sense of the word, the methods advocated for the cultural control of the weevil constitute a "system." The various steps

are so interdependent that securing the full benefit from any one of them involves the adoption of many of the others. A careful consideration of each step, both as to its independent and interdependent effectiveness seems to justify the broad general assertion that the early fall destruction of its food-supply—cotton—may reasonably be called, as it has frequently been, “the most important step in the cultural system of controlling the weevil.” The exhaustive studies which have been made by the field agents of the Bureau on all phases of the life and seasonal histories and upon natural and artificial control of the weevil indicate that the few weeks which may intervene between the maturity of the bulk of the crop and the time that is most favorable for the weevils to enter hibernation constitutes the strategic period for largely reducing the number of weevils which may survive hibernation and attack the crop of the following season. The application of all other steps in the system recommended is designed primarily and ultimately to render this period as long as possible and to thereby increase the practical possibility of the general adoption of this step as the final and most important thing in the work of each season, and thus open the way for the most successful results with the culture of a cotton crop with the minimum of weevil injury during the following year.

The most convincing experiments showing definitely the possibilities of and urgent necessity for the adoption of this plan and also a large-scale field demonstration of the great, practical benefit obtainable in a community by its general adoption, have been accomplished during the past year. A full account of the experimental work is being published by the Bureau of Entomology under the title of “Hibernation of the Cotton Boll Weevil” by Mr. W. W. Yothers and the writer.

Having given but a very brief and partial view of the general problem which the presence of the boll weevil inevitably presents and of the general results of the investigation to secure feasible methods of control, the writer would add a brief summary of the data which support the conclusions stated as to the essential value of stalk destruction. For the sake of brevity much important work cannot be mentioned here. The extensive hibernation experiments of 1906-'07 will alone be considered, although mention may be made of the general results of other investigations when needed for comparisons.

Principal Data Indicating the Importance of Stalk Destruction

Hibernation Work of 1906-'07.—Some knowledge of the general plan and purpose of this work seems essential to a clear understanding

of its value and a correct interpretation of the results observed. Three localities, Dallas, Calvert and Victoria, Texas, were selected for experimental work, as these represented in a general way the northern, central and southern sections of the state, and considerable work of a similar nature had been done at each place which might serve as a check or for comparison. At each place was erected a cage 20 x 50 feet and 6½ feet high, covered with 14-mesh, galvanized wire screening and having cross-partitions so as to form ten sections, each having a ground area of 100 square feet. The three localities offered a considerable range in geographical and climatic conditions. It was planned to provide similar shelter conditions in corresponding sections and to enclose weevils in each section upon as nearly the same date in each locality as might be possible. The weevils used were collected in the immediate locality and from 1,000 to 4,000 were placed in each section, making a total of over 75,000 in the three cages. Observations were made at intervals, from the time weevils were placed in the cage until the beginning of the general emergence movement in the spring, and daily thereafter. Suitable and reliable data as to climatic conditions were secured by providing standard types of weather bureau instruments in a shelter erected beside the cage in each locality. Temperature, rainfall, humidity and other records were thus kept throughout the period covered by the experiments. In this way it was anticipated that data might be obtained bearing especially upon the following points:

1. The effect of the time of entrance into hibernation upon the survival of weevils. In the first experiments either entrance upon hibernation or starvation was forced by the destruction of the food supply. The geographical range would naturally increase the interval between the beginning of the experiment and the time when weevils would naturally enter hibernation at each locality.

2. The effect which the complete destruction of the food supply at varying dates might have upon the success of hibernation. For these experiments the shelter conditions were made as uniform and as favorable as it was possible to make them in the different localities. It was hoped by these tests to determine the minimum interval which must elapse between the destruction of food and the successful hibernation of the weevils.

3. To determine the effect of exceptionally favorable and unfavorable conditions of shelter upon the successful hibernation of weevils placed in the corresponding sections upon the same date in each locality. It was intended that the shelter conditions provided should be so exaggerated as to represent the extremes of conditions which might naturally occur in or around the fields.

4. To determine the effect which varying depths and classes of shelter might exert upon the success of hibernation and also upon the time of beginning and the range in the period of emergence from hibernation.

5. To test the power of adaptation to climatic variations by bringing weevils from widely separated localities and hibernating them for comparison with weevils collected at Dallas. In each section food and shelter conditions were to be similar.

6. To determine upon a large scale and in widely separated localities and under various conditions of shelter the proportion of weevils entering hibernation which might survive.

7. To determine the relation of climatic conditions to the emergence period in each locality.

8. To determine the longevity of hibernated weevils after emergence both with and without food.

In the following table are summarized the principal points relating to the installation of the experiments for this season:

Table I. Installation of hibernation experiments, 1906-1907

No. of Section.	Date of Starting Experiments, 1906.			Character of Shelter Supplied.	Conditions as to Food Supply.
	Dallas.	Calvert.	Victoria.		
1	Oct. 13	Oct. 13	Oct. 25	Leaves and grass 4-5 in. deep.	All cotton removed after two days.
4	Oct. 16	Oct. 19	Oct. 25	do.	Stalks cut and left.
2	Oct. 19	Nov. 26	Oct. 28	do.	Food removed after two days.
7	Oct. 25	Oct. 25	Nov. 6	Spanish moss hung around top of cage. Loose bark on ground.	Food present; cut and allowed to dry.
8	Oct. 31	Oct. 31	Nov. 10	Leaves and grass 4-5 in. deep.	Food removed after two days.
5	Nov. 6	Nov. 5	Nov. 14	do.	Cotton cut and allowed to remain and dry.
3	Nov. 12	Nov. 14	Nov. 21	Leaves and grass two inches deep.	do.
9	Nov. 12	Nov. 12	Nov. 21	Leaves and grass ten inches deep.	do.
6	Nov. 28	Nov. 25	Nov. 28	Ground absolutely bare.	No food supply.
10	Dec. 6 and 10	Dec. 3	Nov. 29	Three bushels, probably, infested bolls on surface of half of cage and 3 bushels buried under 2 inches dirt in other half.	do.

Having now followed the beginning of the experiments, it is in order to note the climatic conditions prevailing throughout them. Temperature records were the most abnormal and also the most significant and therefore only those are given in Table II.

Table II. Mean monthly temperatures and departures from normals at Dallas, Calvert and Victoria, Texas, November, 1906, to June, 1907, inclusive

Locality, Texas.	November.		December.		January, 1907.		February.	
	Monthly mean °F.	Departure °F.	Monthly mean °F.	Departure °F.	Monthly mean °F.	Departure °F.	Monthly mean °F.	Departure °F.
Dallas	54.3	-0.6	51.6	+3.8	53.4	+8.5	51.2	+6.6
Calvert	59.1	+0.1	56.8	+4.1	59.8	+9.6	54.8	+2.8
Victoria	62.9	-1.8	59.2	+1.4	63.4	+9.8	60.2	+6.2

Locality, Texas.	March.		April.		May.		June.	
	Monthly mean °F.	Departure °F.	Monthly mean °F.	Departure °F.	Monthly mean °F.	Departure °F.	Monthly mean °F.	Departure °F.
Dallas	66.7	+11.1	61.4	-4.2	65.8	-7.7	78.8	-1.9
Calvert	70.0	+9.2	62.2	-5.9	66.6	-7.3	76.6	-4.4
Victoria	72.4	+9.7	69.4	-3.3	73.0	-5.0	81.6	-0.6

The columns giving the departures from normals are particularly significant as showing the very unusually warm winter and early spring and the exceptionally cold period following. It was actually much warmer in March throughout Texas than during April and May. These facts account for the unusually large percentages of survival, the remarkably early beginning of emergence and the long duration of the emergence period. At no time during the winter was hibernation complete anywhere in Texas. Weevils were active both in the cages and in the fields. This has never happened before, except rarely in extreme southern Texas.

Next in order will be the consideration of the general results of the observations upon the survival of weevils.

Table III. Summary of Emergence records from hibernation experiments, 1906-1907

Locality, Texas.	No. of Weevils put in Cages.	No. of Weevils as basis for determining per cent. of Survival. ¹	No. Weevils Emerg.	Per cent. of Survival.
Dallas.....	32,439	30,864	3,464	11.22
Calvert.....	20,430	19,408	1,842	9.49
Victoria.....	23,645	22,463	3,026	13.47
Totals.....	76,514	72,735	8,332	11.45

It is probable that 11.5 is the largest percentage that has ever survived in Texas considering so large an area. In the experiments of

¹Basis for computing percentage of emergence is 5% less than the number placed in the cage to allow for the escape of some through the wire.

the preceding season at Keachie, La., and Dallas, Texas, among 35,900 weevils, the average survival was only 2.18 per cent. The emergence movement began on March 22 and continued until June 28, 1906. These are unquestionably closer to the normal facts regarding emergence than are the figures shown in 1907. We have thus in two seasons a range in percentage of survival of from 2 to 11 per cent and in emergence from February 15 to the end of June. These facts emphasize very strongly the importance of reducing the number of weevils entering hibernation.

In order to make the following facts represent general conditions and avoid the possibility of being misled in our conclusions by the variations which might reasonably occur in a single experiment, we shall present the data in groups of experiments and base our conclusions upon the average results shown by the totals and average percentages for each group. The chronological significance of the data may be most clearly shown by grouping the records for those localities at which experiments were started upon the same or approximate dates. The shelter and food conditions represented in each group are therefore fairly averaged and the time at which the experiments were started becomes the most significant factor in each group. The desired comparisons can be most briefly shown by tabular arrangement.

In Table IV it may be seen that averaging all localities at which weevils were started upon approximately the same date, there is a most striking increase in successful survival from the middle of October to the middle of November. In the interval of eleven days from October 14 to 25 the percentage of survival practically doubled. During the next ten days the percentage again doubled and a corresponding increase is observable between November 5 and 14. After that time hibernation might have been successful for practically the maximum possible proportion of weevils. The first freeze occurred on November 18. The facts shown may appear more emphatic if stated in another way. Under otherwise similar average conditions, the chances for survival for weevils in Texas in 1907 were: On October 15, one; October 25, two; November 5, four; November 15, six. These facts make it plainly evident that from October 15 to November 15 constitutes the *strategic period* for attack upon the boll weevil. The data and conclusions are here given that they may be studied carefully by those who are interested to do so.

Conclusions Drawn from Data Presented

Application of Conclusions.—The method of attack which has proven most effective consists of the successive steps constituting the

Table IV. Effect of time of entrance into hibernation, or isolation from food supply upon survival of weevils

Date, 1906	Locality, Texas.	Section Number.	No. Weevils Present.	No. Weevils Emerged.	Per cent. of Survival.	Rank of Group in Survival.	Remarks.
Oct. 13	Dallas	1	3,800	99	2.61		
Oct. 13	Calvert	1	2,375	75	3.15		
Oct. 18	Dallas	4	2,090	85	4.07		
Totals for group		3	8,265	259	3.14	8	
Oct. 19	Calvert	4	2,375	116	4.88		
Oct. 20	Dallas	2	3,610	226	6.26		
Totals for group		2	5,985	342	5.71	7	
Oct. 24	Dallas	7	3,325	231	6.95		
Oct. 25	Calvert	7	2,375	105	4.42		
Oct. 25	Victoria	1	2,375	201	8.46		
Oct. 25	Victoria	4	2,375	105	4.42		
Totals for group		4	10,440	642	6.15	5	
Oct. 28	Victoria	2	2,389	194	5.61		
Oct. 30	Dallas	8	2,850	250	8.85		
Oct. 31	Calvert	8	2,375	63	2.65		
Totals for group		3	7,614	447	5.87	6	
Nov. 5	Dallas	5	3,135	383	12.22		
Nov. 5	Calvert	5	2,375	45	1.89		
Nov. 6	Victoria	7	2,850	674	23.65		
Totals for group		3	8,360	1,102	13.18	4	
Nov. 10	Victoria	8	2,850	362	12.70		
Nov. 12	Dallas	3	3,040	448	14.74		
Nov. 13	Dallas	9	3,040	788	25.92		
Nov. 14	Calvert	9	2,375	438	18.44		
Nov. 14	Victoria	5	2,850	449	15.86		
Nov. 15	Dallas	11	2,565	804	31.34		
Totals for group		6	16,720	3,284	19.67	2	
Nov. 21	Dallas	12	1,570	65	4.14		Brownsville Weevils.
Nov. 21	Victoria	9	2,886	374	13.19		
Nov. 21	Victoria	3	2,850	558	20.63		
Totals for group		8	7,256	1,027	14.15	3	16.91 % without B. W.
Nov. 25	Calvert	6	1,425	359	25.19		
Nov. 26	Calvert	2	1,358	380	27.98		
Nov. 28	Dallas	6	975	46	4.72		(Absolutely bare ground.)
Nov. 28	Victoria	6	1,088	139	12.78		
Totals for group		3	4,816	924	19.07	1	(22 % without Dallas lot.)

Cultural System. Having secured an early maturing crop, it should be picked out as soon as open, the earlier the better. If not all gathered before October first in South Texas, every effort should be put forth to clean up the fields by that time and the few late opening bolls should not be allowed to delay the immediate destruction of the stalks in some thorough manner. In the southern part of the state where sprout cotton commonly occurs, great care should be taken to destroy enough of the roots to prevent any sprouting in the spring. Clean

the fields as thoroughly as possible, including the turn-rows and along ditches and fences and under timber fringes. This thorough treatment is even more essential in south than in north Texas, although in the latter portion of the state it seems advisable.

As has been frequently pointed out, this early fall destruction prevents absolutely the further breeding of weevils and many of those partly developed in squares or bolls will not be able to mature. The late developed weevils are most liable to hibernate successfully. By destroying the most favorable shelter which the weevils that escape destruction could possibly find, the chances of their surviving the winter are greatly lessened. In a variety of ways, therefore, the actual number of weevils entering hibernation becomes very greatly reduced and the chances of the successful hibernation of those entering are correspondingly decreased. The number of weevils ready to attack the crop the following spring would, with these practices, be but a small fraction of what might otherwise be present.

The Demonstration.—That these conclusions are correct and practicable has been proven by actual field application on a large scale. At Olivia, Texas, in the fall of 1906, about twenty planters on adjoining farms were persuaded to enter into agreement to do this work by Mr. J. D. Mitchell. All stalks were destroyed upon an area of about 40 acres between October 1 and 10. This area was well isolated from other cotton, but had been badly infested up to that time. A check area some six miles away across a bay received the usual treatment. No special treatment was given to the Olivia tract during 1907. In spite of the fact that the survival of weevils, as has been shown, was unprecedented during this intervening winter, they did not become numerous enough to do any considerable damage to the Olivia crop, while on the check area they were exceedingly injurious. Although the Olivia crop was grown on soil that was not as rich as that in the check, it yielded more than 1,000 lbs. of seed cotton per acre, whereas the check yielded but about 300 lbs. per acre. The difference in value of these two crops was fully \$20 per acre, or more than enough to pay for the land upon which the crop at Olivia was grown.

The Difficulties.—If there were no obstacles in the way of an easy adoption of these recommendations, it is not likely that the same necessity for them would exist. Any prospect for a late "top crop" of cotton is removed by the presence of the weevils. Every experience shows that the crop must be made early. The difficulty of getting sufficient labor is great in some sections. It is evident that there is necessity for the production of an efficient machine for cotton picking to meet this need. The actual destruction of stalks may be accom-

plished in any way possible so long as the desired results are obtained. The question is not one of method but of results. More particulars as to time and methods are given by Mr. W. D. Hunter in Circular 95 of the Bureau of Entomology. It is certain that the individual adopting the Cultural System may reap a large share of its benefits regardless of the lack of coöperation on the part of his neighbors, but it is desirable that a strong sentiment should be fostered which shall lead to united action over considerable areas. It is to be hoped that the practical difficulties presented by the tenant system may be overcome, so that every tenant will be led (or forced if need be) to consider that his season's work is not complete until he has added this step to the harvesting of the crop. This idea would be welcomed if there could be a general understanding by landowners and tenants of the fact that fields thus treated will produce better yields, as a rule. They would be better inducements to securing a good class of tenants, and such tenants having cleared their fields in the fall would be less likely to move.

The question here presented is a vital one for the weevil-infested area. It demands not merely acquiescence, but action. The accuracy of the facts presented cannot be questioned, but each man must decide for himself as to the correctness of the conclusions. To us it appears that this statement does abundantly justify the broad, general conclusion that "the DESTRUCTION OF STALKS BY SOME EFFECTIVE METHOD AND AS LONG AS MAY BE POSSIBLE BEFORE THE NORMAL TIME FOR WEEVILS TO ENTER HIBERNATION CONSTITUTES THE MOST EFFECTIVE METHOD NOW KNOWN OF REDUCING THE SEVERITY OF THE WEEVIL ATTACK UPON THE FOLLOWING CROP AND THAT IT THEREFORE DESERVES GENERAL RECOGNITION AND ADOPTION AS THE LAST STEP IN THE TREATMENT OF EACH SEASON'S CROP AND ESSENTIALLY THE FIRST STEP ALSO IN THE PRODUCTION OF A CROP WITH THE MINIMUM WEEVIL INJURY DURING THE FOLLOWING SEASON."

Grape Blossom Midge

Cecidomyia johnsoni Sling. This species, unknown as an adult, caused exceptional injuries at Fredonia, where it destroyed 60% to 75% of the blossoms on one acre of Moore's Early grape. The work of this species has been known for years, and the familiar galled blossoms were easily found throughout the entire Chautauqua region. The work above described is undoubtedly due to exceptional conditions and is probably explainable by the blossoms being in just the right stage of development at the time when a large number of the midges were flying. Repeated attempts to rear the adult have been unsuccessful, though it is probably referable to the genus *Cecidomyia*.

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