OKLAHOMA
AGRICULTURAL AND MECHANICAL COLLEGE
AGRICULTURAL EXPERIMENT STATION
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BOLL WEEVIL
in
OKLAHOMA

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Boll Weevil In Oklahoma

Especially During the Years 1921 to 1925

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Introductory:

The Mexican Cotton Boll Weevil appears to have entered the cotton growing states of the United States from Mexico into Texas in 1891 or 1892, and Oklahoma near Caddo, from Texas in 1905. In the year 1843 it was identified by C. H. Boheman* as belonging to the genus Anthanomus, and named grandis by him. Its technical name, therefore, is *Anthanomus grandis*. Since it came into the United States from Mexico and fed on and developed in green squares and bolls of cotton, it has been referred to in the United States as the Mexican Cotton Boll Weevil.

The most complete of many American publications in reference to its life history, food habits, etc., is Bulletin No. 51, U. S. Bureau of Entomology, written in 1905 by Hunter and Hinds. Since the supply of practically all of the Oklahoma bulletins published on this subject has been exhausted, I will include such subject material from them as is desirable in this publication. Especially will I include a part of Circular No. 50, which relates to the weevil's life history and food habits.

Brief Life History of the Boll Weevil

The boll weevil can neither subsist nor develop on any plant grown in Oklahoma other than cotton.

It passes the winter in the full grown weevil stage. It can pass the winter in no other stage in this state.

It hibernates to some extent in cotton bolls. I have never found it hibernating in the cotton plants or on the cotton plants any place, neither have I known of others finding it in Oklahoma hibernating on or in any part of the plant, other than bolls, excepting in stored cottonseed and hulls.

About the time of the first killing frost, (see plate VIII) the adult weevils fly from the cotton fields seeking protection in piles of brush and leaves, and such similar places as will furnish shelter from superfluous moisture, and variable temperature.

All immature weevils are easily destroyed by the freezing of the bolls, consequently seasonal development is discontinued as soon as the cotton plants are severely singed with frost.

*Boheman, C. H. Genera et Species Curculionidum cum Synonymia hujus Famuliae ed. C. J. Schonherr. Vol V. pt. 2, pp. 232-233.

Some of the hibernating or overwintering weevils begin to appear each spring as soon as the planted cotton seed has germinated. The hibernating weevils do not all issue at the same time, but continue to come forth as late as the month of July. The early issuing weevils feed on the tender young leaves of the plants. Later in the season they feed almost entirely in the developing squares. The interior of the squares and bolls (the interior of green bolls late in the season) are practically the only parts of the cotton plant eaten by the weevils. This peculiar feeding habit renders the application of poison as for ordinary leaf eating insects, almost useless for controlling the boll weevil.

In the developing squares and young bolls the females deposit the eggs in punctures made by their beaks. A set of teeth is in the end of the beak. (See Fig. 1, b).

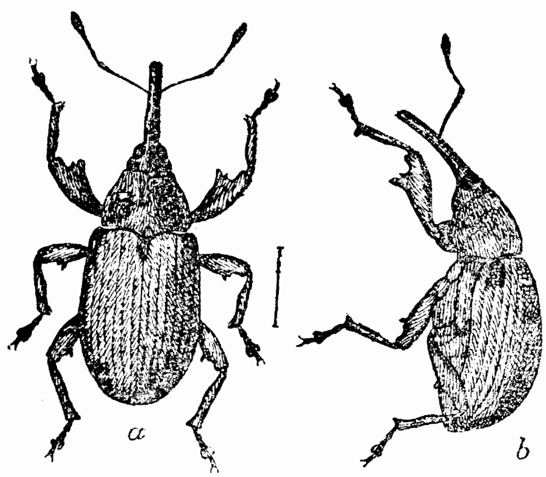

Fig. 1.—Cotton boll weevil: *a*, Beetle, from above; *b*, same, from side. About five times natural size.

The punctures made for the reception of the eggs are very similar to the punctures made in the squares by the weevils for food purposes. In addition to the location of these punctures the frequent presence of yellowish excreta is an added indication of infestation.

Rarely more than one egg is deposited in one square. When weevils become numerous and the squares become scarce, the females will lay eggs in the developing bolls. Often more than one egg is deposited in a single boll when the weevils are numerous and the squares are scarce. Under such conditions as many as a dozen eggs may be deposited in a single boll.

Each female, it is said, may deposit as many as one hundred and forty eggs. The eggs hatch within two or three days, except during cool weather when incubation is retarded.

The larva, grub or maggot as it may be called is footless and develops only in the square (see Figs. 2 and 3) or boll and ordinarially within a period of from seven to twelve days. Cold weather delays and warm weather hastens development.

The pupal or transitional stage (see Fig. 3)* of the larva to the adult takes place in the cavern of the square or boll made by the larva in obtaining its food. The pupal stage requires from three to five days. The total length of time, therefore, required for the hatching and development of a boll weevil is about two or three weeks.

Three to four generations and a portion of the fifth and sixth generations can develop in this state in one summer. The total progeny of one pair may amount to between four and five millions of boll weevils during a single season.

*Figures 1 to 3 inclusive, were taken from U. S. Department of Agri. Bulletin No. 1329.

Cotton squares are sufficiently developed in early advanced fields of the southeastern part of the state by the middle of June each year to become infested. (See schematic plan shown in Fig. 4 for the time of appearance and the development of various broods).*

Egg laying is begun at this time by some of the hibernation weevils. Young weevils of the first generation begin to appear July 1. Within one week later egg laying is begun by this, the first generation of the season. Meantime, however, the hibernating individuals have been continually issuing from winter quarters so that the hibernating weevils together with the first generation cause a very noticeable flaring of squares by the 10th of July. Some of the hibernation weevils probably survive until the appearance of the second generation which is approximately July 18th but they doubtless disappear before the appearance of the third generation which is bout the 4th of August. Temperature and rainfall have much to do with the increase or decrease of the weevil during the important square and boll production months of June, July and August. This is discussed under the topic "Atmospherical Effect."

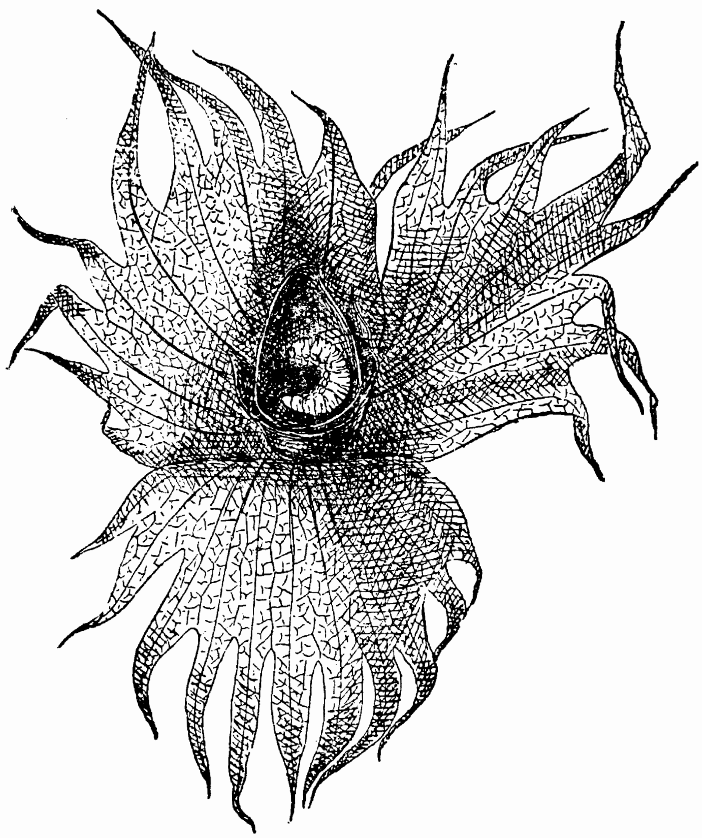

Fig. 2.—Cotton square showing larva of boll weevil in position. Natural size.

It is assumed also from the life history of the summer broods that the first generation will begin to decrease during August. Briefly summarizing the prevalence of particular broods during the cotton productive season, therefore, we find (see Fig. 4) that the hibernating brood and the first generation augmented by a partial second generation are prevalent during July.

The second generation augmented by a partial first, third and fourth brood is prevalent during August. These continue into September and are augmented by a partial fourth and perhaps fifth generation. The sixth generation begins about

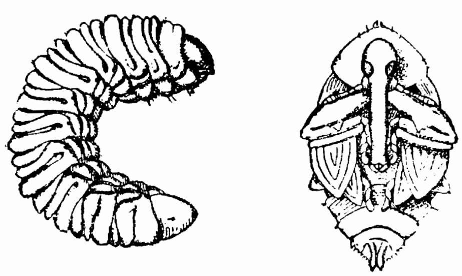

Fig. 3.—Cotton boll weevil: Larva at left, pupa at right. About five times natural size.

*Drawn by G. A. Bieberdorf of this department.

the first part of October and continues until the plants are killed. In some instances parts of the third, fourth, fifth and sixth broods continue to develop until the middle of December.

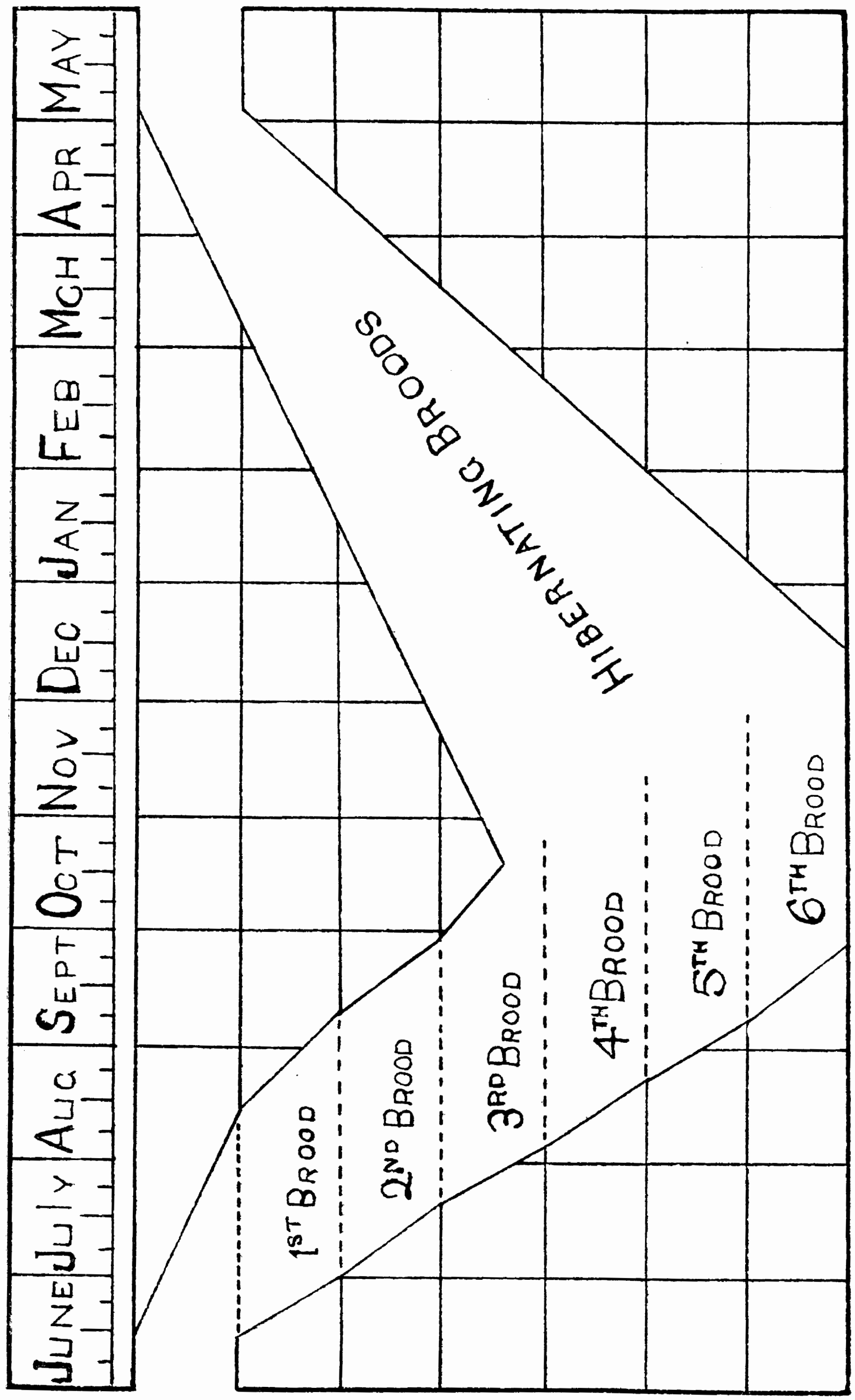

Fig. 4

GENERAL DESCRIPTION OF ADULT WEEVILS*

Color: Young weevils emerging from the squares or bolls are generally reddish or yellowish brown. As they become exposed to the weather and grow older they become dark gray brown, and finally in case of overwintering forms the color fades to a dark gray appearance. In some instances the color becomes dark brown on account of the removal or loss of the gray scale-like body covering. Small weevils are generally darker than large ones.

Size: The smaller forms (generally males) including the length of the proboscis may be as much as one-third of an inch in length. The width of the body varies from one-twenty-fifth to one-eighth of an inch respectively. It is found that there are about 1000 weevils in 44 cubic centimeters. Consequently there is a fraction more than 25028 in a quart and also a fraction more than 800908 in a bushel.

Weight: The average weight of a boll weevil is .227 grains,** as given by Hunter and Hinds, consequently from the weight and the number above given it is estimated that they weigh at the rate of about 26 pounds to the bushel. Many similar weevils are frequently mistaken for the real boll weevil. Anyone, however, having good eyesight and judgment can conclude whether specimens at hand are boll weevils or not by comparing them with the illustration as shown in figure 1, a and b. The reading of the life history herein given in addition to the description will also aid in this respect since weevils developing in other plants than cotton or other parts of cotton than the square or boll, are not cotton boll weevils.

The number of cotton plants grown on an acre of ground varies. The variance is caused by the different ideas of cotton growers and the nature and locality of the soil. In some localities where the soil is poor and the plants do not become large it seems advisable to grow more of them per acre than where the soil is rich and they naturally grow larger. The entomologist, however, must leave such problems as cotton spacing to the agronomist for consideration. For the present time an estimate of 7000 plants per acre will be used as a basis for estimating the number of boll weevils that may develop in a cotton field.

If a single pair of weevils can in a single season produce 4,000,000 as previously shown, then if an acre of cotton were sufficient for the purpose, it would be necessary for each of the 7000 cotton plants in an acre to furnish food and developmental conditions for more than 570 weevils.

At least one square would be required for the development of a single weevil. According to an estimate by Mr. Glen Briggs, of the Agronomy Department of the Oklahoma A. and M. College, an average cotton plant would, during an average year, produce about 150 squares. It is apparent that not more than half of these squares could develop weevils, since many of them would be punctured for food purposes, and thus destroyed so that weevils could not develop in them, consequently if every plant could develop 75 weevils, there could be developed only 525,000 weevils in an acre of cotton.

*For technical description, see Hunter and Hinds, p. 40, Bul. No. 51, U. S. Bureau of Entomology, or Dietz, T. A. E. S., Vol. XVIII, p. 205.
**Hunter and Hinds, p. 42, Bul. No. 51, U. S. Bureau of Entomology.

Therefore several acres of cotton (about eight) would be required for developing the progeny of a single pair. An estimation of eight acres is not large enough since many of the squares in process of growth during the development of the first and second generations of weevils, would be free from infestation on account of a lack of weevils and on the other hand many boll weevils of the third and fourth generations would not have enough squares in which to develop. It is apparent then, that at this rate, eight acres of cotton would be insufficient for feeding and developing the progeny of a single pair of boll weevils during one season.

From these estimates it is apparent that there is more potential damage lurking in the wake of a pair of overwintering boll weevils than the average person is aware of. On account of the dynamical characteristics of hibernating boll weevils, more stress should be placed upon fall cleanup campaigns. The latter is discussed at length, herein under "Methods of Control."

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ARTIFICIAL METHODS OF CONTROL

The following data contains the results of a three year's test representing the summers of '22, '23 and '24. The experiments were conducted at various localities in the southeastern part of the state, where the boll weevil was expected to be numerous enough to warrant satisfactory conclusions. The localities, the name of the owner or manager of the fields chosen, the nature, cost and results of each experiment, are all given in outline form in Plates I, II and III.*

Calcium arsenate dust was applied according to a definite method of procedure to parts of fields of cotton in different localities belonging to persons whose names are given. (See Plate I). A part of the same field, not poisoned in each instance was used as a check plot; this, although not dusted with poison, was otherwise cultivated in exactly the same manner so that after the cotton was picked from each carefully marked and measured tract and weighed separately, absolute conclusions could be made as to whether special treatment applied for controlling the boll weevil really either increased or decreased the yield.

On the left of this diagramatic outline is a scale of measurement representing pounds of cotton per acre. Adjacent and to the right of this for the year 1922 is designated the poisoned and unpoisoned cotton acres in the fields of Mr. A. L. Harris. It is shown that the poisoned tract produced 463 pounds of cotton and the unpoisoned tract produced 475 pounds of cotton per acre respectively. The same system for showing the yields in other fields is shown to the right through the years '22, '23 and '24; the field of Mr. W. F. Moore, of Antlers, being the last experiment. His poisoned cotton is shown to have yielded at the rate of 459 pounds per acre, and his unpoisoned tract or check plot to have yielded 478 pounds per acre.

The method of using calcium arsenate as a boll weevil control in these experiments was the same as is advised by the U. S. Department of Agricul-

*Biennial Report, O. A. E. S., 1922-24, p. 24.

A Three Year Experiment on Boll Weevil Control with Calcium Arsenate Dusted on Growing Cotton Showing a Scale of Yields in Pounds per Acre on Poisoned and Unpoisoned Prairie and Bottom Land With Growers' Names and Localities for Years as Follows:

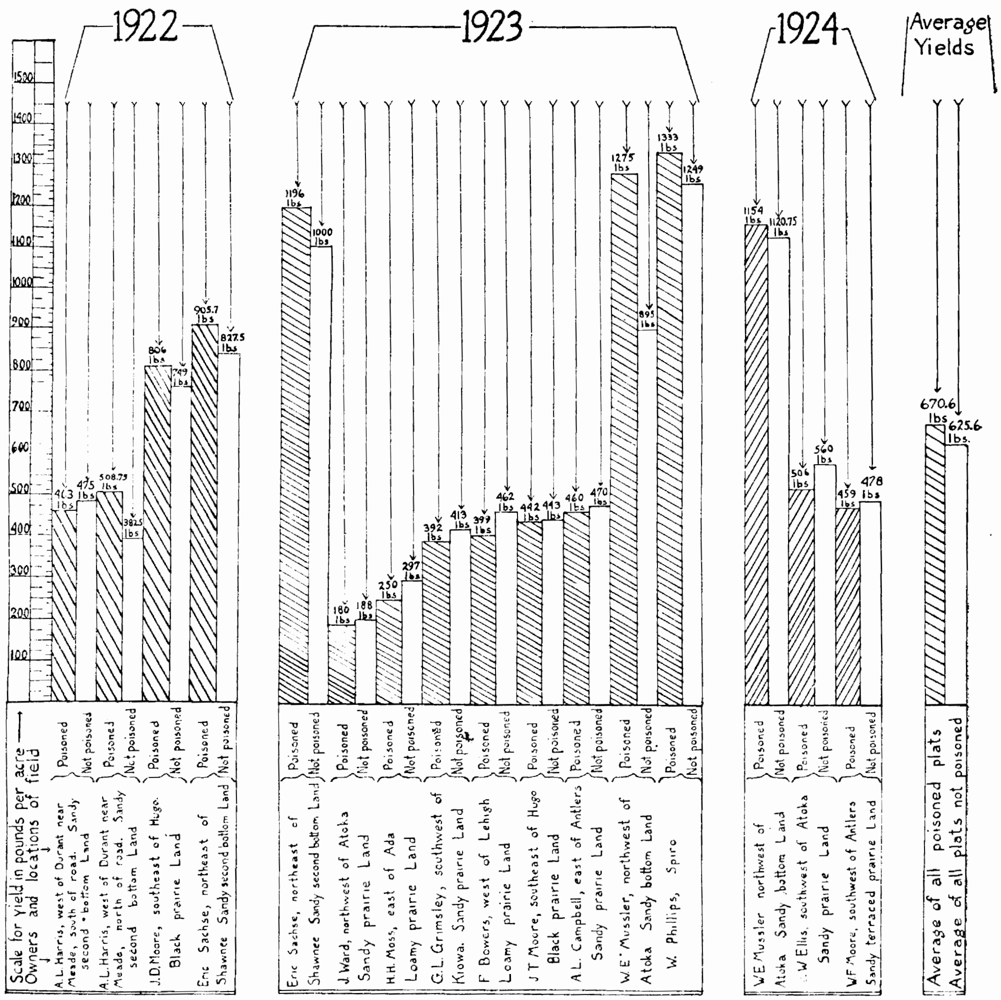

Plate I

ture, in Farmers' Bulletin Number 1329. The methods advised therein are such as have been used very successfully in the middle south where conditions are apparently quite different to those of Oklahoma. Atmospherical conditions such as the prevalence of dew and also wind make the application of calcium arsenate according to the rule, a very difficult procedure in Oklahoma.

For instance, poisoning must be begun when 10 to 15 per cent of the squares have been punctured; and 5 to 7 pounds per acre must be used at night while the air is calm and the plants are moist with dew, every four days until three applications have been made. In our work it was almost impossible to make the application as advised. We never used less than 7 pounds of calcium arsenate per acre, but generally used more. We could

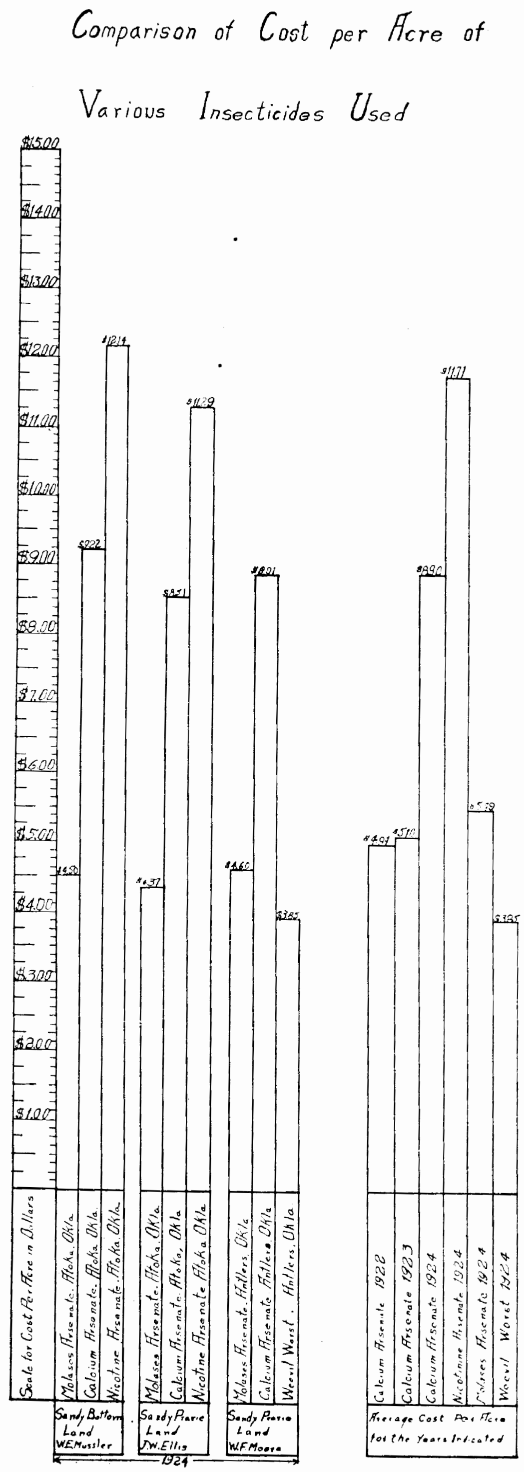

Plate II

find the proper percentage of infestation but in some cases the wind would blow all night and no dew would form for many nights.

Both hand guns and team drawn dusting machines were used. Since these experiments were not conducted on the Experiment Station farm, it might be that some persons may criticise the results. Such criticism might be just, nevertheless, it is contended that the experiments were conducted for the benefit of the cotton growers, and the work was superintended and carried on better than the average cotton grower could carry it on by following the printed directions. This being the case it is maintained that if the method was not profitable under the conditions of the experiments it certainly would not be profitable to the cotton grower were he to follow only abstract printed directions.

It should be noticed that there was not a regular increase in cotton yield in each instance arising from the use of poison. On the contrary in some instances the yield was less. For instance, the result in the yields of cotton in the field of Mr. J. W. Ellis for the year 1924, shows that the treated cotton yielded 506 pounds while the untreated plot yielded 560 pounds, a difference of 54 pounds in favor of the untreated acreage.

Finally and farthest to the right is given the average yield per acre of all the poisoned fields and the average yield per acre of the unpoisoned fields, as being 670.6 and 625.6 pounds respectively. The average gain by poisoning therefore, was 45 pounds per acre.

The cost of applying calcium arsenate is shown in Plate II. In the first or left hand column is shown a scale of cost per acre in dollars. The columns at the right of this show the various costs of other insecticides including calcium arsenate. In the right hand group of columns the cost of calcium arsenate is given for the years 1922, 1923 and 1924 as $4.91, $5.10 and $8.90 per acre respectively. The average cost for the three years was $6.30. The average in gain of cotton per acre in pounds of seed cotton was 45. The average price per pound for which the seed cotton sold was about 8 cents or $3.60. This represented a loss of $2.70 per acre.

Sweetened Mixture:

One of the principal sweetened mixtures used (during the year 1924) was molasses arsenate, consisting of one gallon of good table brand syrup, one gallon of water and one pound of calcium arsenate, thoroughly mixed and used fresh. It was splattered on the cotton plants by use of a mop made for the purpose. The mop consisted of a light wooden handle two feet long on which, at one end, was wrapped and tacked three or four thicknesses of cloth. This latter was then cut a few times lengthwise into a tasseled mop.

About one gallon of liquid was used per acre at each application. The amount used depended largely upon the stand and size of the cotton plants. More was used on large plants than on smaller ones. Three applications were made at intervals of about one week to ten days apart, the first application beginning after there was a 10 to 15 percent infestation.

Other Insecticides:

During the year 1924 experiments were conducted with Weevil Worst, a proprietary remedy, and nicotine arsenate. They were carried on according to a definite method of procedure to parts of the fields of cotton in different

Experiments with Three Insecticides Showing a Scale of Yields in Pounds per Acre on Poisoned and Unpoisoned Prairie and Bottom Land with Growers' Names and Localities:

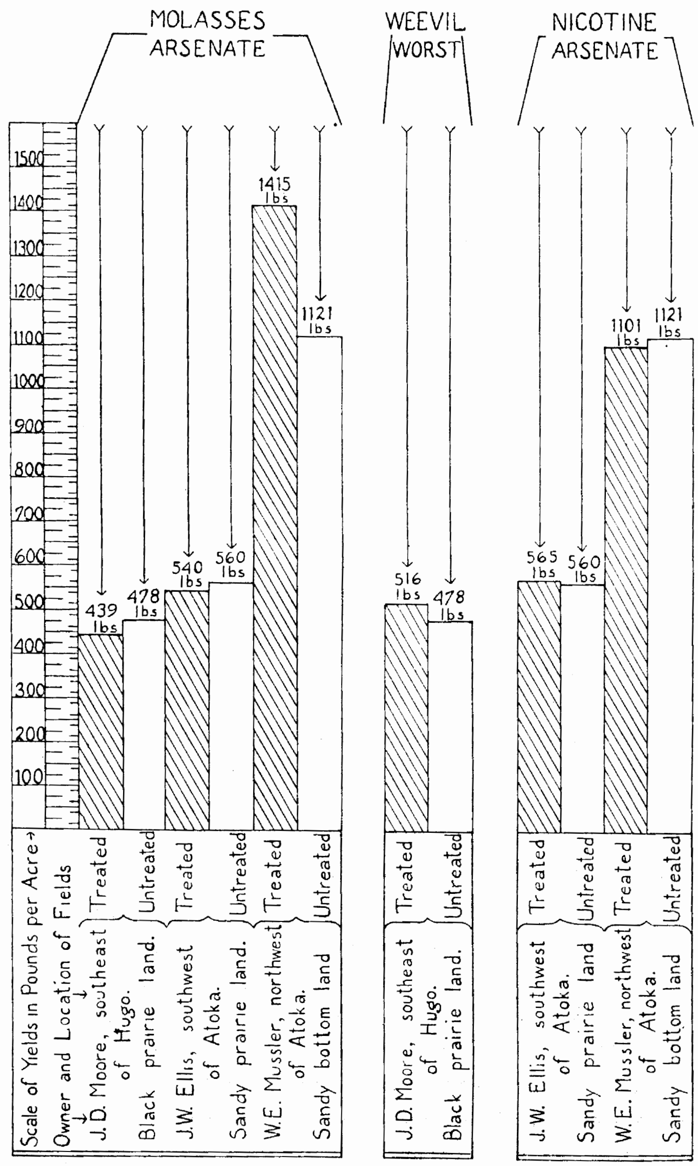

Plate III

localities belonging to persons whose names are shown in Plate III. A part of the same field not treated was otherwise cultivated in exactly the same manner, so that after the cotton was picked from each carefully marked and measured tract and weighed separately, absolute conclusions could be made as to whether special treatment applied for controlling the boll weevil really either increased or decreased the yield.

On the left of this diagramatic outline (Plate III) is a scale of measurement representing pounds of cotton, adjacent and to the right of this are the yields per acre for the treatments applied, also yields of the check plots per acre for comparison of results.

For instance, in the molasses arsenate treatments is given at the bottom and left of the chart the name of Mr. J. D. Moore, southeast of Hugo, whose field was on black prairie land. (Should be W. F. Moore, southwest of Antlers, on sandy soil). The treated plot made a yield of 439 pounds of seed cotton per acre and the untreated field made a yield of 478 pounds per acre. There was less cotton picked from the treated plot (540 lbs. per acre) than from the untreated plot (560 lbs. per acre) of Mr. J. W. Ellis' field. In the field of Mr. W. E. Mussler, however, the treated plot yielded 1415 pounds of seed cotton while the untreated plot yielded 1121 pounds per acre.

Weevil Worst:

This proprietary mixture was used in only one field, that of a sandy field of Mr. W. F. Moore, southwest of Antlers (not that of Mr. J. D. Moore, southeast of Hugo) as shown in the Plate III. The treated plot showed a yield of 516 pounds per acre and the untreated plot a yield of 478 pounds per acre---a difference of 38 pounds of seed cotton per acre in favor of the treated plot.

Nicotine Arsenate:

This formulation was made up of nicotine which is a contact control, and calcium arsenate which is an arsenical control. The latter is protective to some insects, especially plant lice which suck sap from the plants, and do not eat them. It often happens that cotton which has been dusted with calcium arsenate becomes so badly infested with the cotton louse that it fails to fruit regardless of boll weevil conditions. It follows, therefore, that a perfect control of the boll weevil by use of calcium arsenate might not be obvious in the yield on account of a super infestation of plant lice.

In this experiment a 2½% strength (2½ pints of nicotine sulfate to 50 pounds of calcium arsenate) was used. Three treatments of from seven to fourteen pounds of the treated calcium arsenate was used per acre. Very little difference in yield per acre resulted as shown either on the sandy prairie land of Mr. J. W. Ellis, southwest of Atoka, or on the sandy bottom land of Mr. W. E. Mussler, northwest of Atoka. On the former the treated plot yielded 565 pounds, the untreated 560 pounds, a difference of 5 pounds in favor of the treated; and on the latter the treated yielded 1101 and the untreated 1121 pounds, or a difference of 20 pounds in favor of the untreated cotton per acre.

Cost and Profit or Loss of the More Important Treatments Used:

In the first or left hand column of Plate II is shown a scale for cost per acre in dollars. In the columns to the right are shown the cost per acre of each material used, the year it was used and the name and locality of the owner. At the extreme right the average cost per acre of each material used for each year that it was used is shown. For instance, the average cost of calcium arsenate per acre for the years 1922, 1923 and 1924 was $4.91, $5.10 and $8.90 respectively. The average cost per acre for the year 1924 for nicotine arsenate, molasses arsenate, and weevil worst, was $11.71, $5.49 and $3.85, respectively.

Comparative increased yield in pounds of seed cotton per acre, the average price for which this sold (8 cents per pound), the average cost of the various treatments and the loss or gain per acre are all as follows:

	Pounds Seed Cotton	Sold For	Cost of Treatment	Loss (—), Gain (+)
Calcium Arsenate	45.	3.60	6.30	— 2.70
Molasses Arsenate	235.	18.80	5.49	+ 13.31
Nicotine Arsenate	15.	1.20	1.71	— 10.51
Weevil Worst	38.	3.04	3.85	— .81

It appears, therefore, that of all the experiments which were conclusive (there were many which were not continued for various reasons) the only one which gave a profit was the molasses arsenate mixture.

Many more experiments were started each spring than are here reported. Unless an experiment was carried through the season and final results from the standpoint of cotton yield obtained, it was discarded. Consequently the investigations were much more extensive than are herein recorded.

Hills Mixture:

In experiments on "Hills Mixture" plots from which the most valuable data was expected, there appeared an infestation of web worms (*Loxostege similalis*). They damaged the cotton so severely that it could not be used for comparison. They were not attracted on account of the "Hills Mixture" but entered the plot from an adjoining alfalfa field after the latter had been mowed. This was on the farm of Mr. H. A. Goff, about 18 miles northeast of Oklahoma City. In another instance where this mixture was used every seventh day instead of every tenth as advised by the manufacturer, it apbetter to select the fields farthest from cotton gins, woods and overgrown with underbrush and thickly littered leaves and grass. Fields planted in cotton near such places are nearly always more seriously infested by hibernating weevils than other more distant fields.

boll weevils. The following are recorded* (see note) as being the most important species and are given in rank of importance, as follows: cliff swallow, barn swallow, orchard oriole, Baltimore oriole, kingbird, purple martin, and meadowlark.

cover may exist as hibernation quarters should be destroyed, preferably after

*U. S. Dept. of Agriculture, Biological Survey Bul. No. 29, page 30, 1907.

peared to give a profit of 46 cents per acre. Artificial soil fertilization of a part of the plot was thought, however, to have been responsible for the increased yield.

The Florida Plan:

Only one of several experiments with the Florida Plan was concluded. This was on the farm of Mr. Goodson, near McAlester. The results gave a loss of $1.09 per acre. Briefly, the Florida plan consists of the stripping of all squares from young plants and following this operation with a poison application in order to kill all of the adult weevils before they can have an opportunity of reproducing.

"During 1923, an experiment was conducted jointly by the Agronomy and Entomology departments for further study of boll weevil control. This work consisted of topping, mowing, and removing squares in different plots to see the effect this would have upon boll weevil control.

The cotton that had the tops mowed off rather low gave a yield of 237 pounds per acre, while that which had the squares removed during July produced 481.4 pounds of cotton per acre and the cotton that was topped, gave a yield of 543.9 pounds, while the plots that were not treated gave a yield of 693.21. However, there was very little weevil present and it was not possible to tell how this might have affected the total yields had there been a large number of weevils in the field. As there was no weevil present in 1924, this work was not continued the following year."*

It is apparent from the above experiment that the lack of and early growth of squares means a loss of yield. In the particular experiment pertaining to the removal of all the first few squares produced by the plants, which was July, the loss was 62.5 pounds per acre. In southern latitudes a loss might not be effected by denuding the young plants of their first borne squares, but our seasons are so short in Oklahoma that a delayed early growth means a decreased yield whether the boll weevil is present or not.

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WEEVIL DISSEMINATION

As previously stated, the weevil first appeared in Oklahoma during the summer of 1905. The northern boundary line of its infestation for that year and for all subsequent years to 1924 inclusive is designated on the map in Plate IV. This data has been obtained and arranged annually by the U. S. Bureau of Entomology in cooperation with weevil infested states. Without this data it would be exceedingly difficult, in fact impossible, to compare the effects of natural weather conditions one year with another on the relative abundance of the weevil.

The weevil disseminates mostly in the adult stage. It is apparent that the air currents aid largely in carrying the weevil while in flight. Ordinarily local infestation is brought about by simple flights from one field or one part of a field to another. This local infestation may be in any direction from a central focus of infestation notwithstanding the fact that a study of the map (Plate IV) might cause one to believe that infestation is always north-

*U. S. Dept. of Agriculture Biological Survey Bul. No. 29, p. 30, 1907.

westward. When an infestation overlaps it may not be any more conspicuous than where it does not overlap and consequently may not become serious until several overlappings occur. It may then become serious not on account of the overlapping alone but also on account of locally developing infestations.

On account of peculiar weevil developmental conditions in the fall of the year, the following year's infestation may commence severely in some localities and very mildly in others. This may be due to the fact that isolated fields of cotton in some localities not killed by frost remained in evcellent condition for attracting adult weevils and developing young ones for many weeks, while the main fields were devoid of weevils on account of the plants being killed by frost. Again during other falls the cotton plants may be uniformly destroyed by frost. Under such conditions the following year's infestation is likely to be more generally uniform.

During the late summer (August and September) there occurs a sort of a false swarming fever among the weevils which causes them to seek new and more distant localities than earlier in the season. The winds doubtless aid greatly in this dissemination. It is apparent that some weevils have in this migratory flight exceeded the boundary line of cotton in some instances, especially in the northeastern part of the state.

Although the wind is an important factor in boll weevil dissemination it is only one of many. Automobiles are common factors. Instances are known where weevils have been carried in them as long as two days and a night. Especially has this happened during cool weather. This length of time would permit weevils to be taken long distances. The same conditions would doubtless hold true with weevils in connection with railroad trains. Facts are, the first infestation in Oklahoma was found near a railroad extending out of the boll weevil infested area of Texas. A similar occurrence was with an isolated infestation near Wichita Falls, Texas, far from any known infestation at the time.

Other methods of dissemination than by natural flight are numerous but are much less important except those permitting the weevil to be carried from one cotton raising locality to another. Many are transported, especially during late fall, in loads of cotton picked and hauled from infested fields to other localities.

It will be noted on the map, Plate IV, that there is a great deal of variation in infestation from one year to another. This is caused by weather conditions. Although the temperature and rainfall is known for the period of time represented by the map, it is rather defficult to ascribe the exact cause in each instance for a greater or lesser infestation. That part of the subject is discussed further on under the heading of "Atmospherical Effect on Weevil Abundance."

The boll weevil was originally a tropical or warm country insect. It has adapted itself nicely, however, to the climate of cotton belt states, southeast of Oklahoma. It has to date apparently been unable to entirely adapt itself to our Oklahoma winter conditions, except in Zone 1, in the southeastern part of the state (Plate V).

It can pass safely through mild winters considerably north and west of this zone. During severe winters, however, it is not only controlled to a marked extent in the latter zone but is practically eliminated elsewhere in the state.

This natural climatic control should be augmented a great deal more in the future than it has been in the past by the fall renovation of gins, seed, and hull houses, and by the destruction or proper care of natural accumulations of vegetation used by weevils for winter protection.

In Zone 1 will probably always lie the annual source of weevils for reinfesting adjacent territory which in turn respectively exposes the remainder of the cotton territory of the state to infestation. It must be undersood that the boundary of Zone 1 is not absolute and that its northern and western edge does not exist as definitely as portrayed by the line on the map (Plate V). If this zone were uniformly level with a uniform drainage and plant growth, a definitely fixed maximum and minimum temperature and an equal rainfall, the boundary line might be definite, but that part of the country is so uneven and diversified in moisture and air drainage and also vegetation, that the real weevil boundary line is probably much more like that of a very crooked river and much more variable in location. The same is likewise true of the boundary lines for Zones 2 and 3.

Annual Infestation and Flight of Weevil in Oklahoma:

Unfortunately we do not have complete data showing the annual boundary line of the overwintering weevil (spring boundary line) from the time of its entrance into Oklahoma. Inspections have generally been made in the late fall in order to obtain the outermost limits of its summer or fall dissemination northward. It is apparent that such a boundary line (fall boundary line) would be inaccurate as a spring boundary line on account of the winter weevil mortality. In other words, favorable summer weather allows the weevil to increase and advance readily from a central focus of infestation while winter weather not only prevents it from increasing and also from advancing but inclement weather is fatal to many. Consequently a northern or spring boundary line can only be obtained by a special spring inspection of growing cotton.

Early Planting:

Much has been said in general relative to early planting of cotton. Seasons and localities vary so much, however, that no definite date can be established. Spring frost data for the years 1906 to 1924 inclusive is shown in Plate VIII.

It is apparent, however, that it is time to plant cotton whenever all danger of frost is past and the ground has begun to warm up so that seed will germinate quickly. It is better to delay a few days and be sure of rapid and vigorous germination and growth than to risk extremely early planting.

A quick or early maturing variety is infinitely more important than extremely early planting.

Agronomists appear to be unanimous in the idea of having a well prepared, clean, firm seed bed, in which cotton is to be planted shallow, so that on account of existing moisture near the surface the seed can soon germinate and develop a good stand of cotton. Every day that a young plant is delayed or retarded in growth means more probability of loss from the effect of the boll weevil. On the other hand advancement during the first part of the season means an early crop. The latter permits of an early fall clean up, which is very important and discussed at length further on under the topic "Fall Destruction of Green Cotton Stalks."

In order to be impressed with the significance of reasonably early planting one should turn to the introductory chapter of this publication and study the facts relative to the reproductive capacity of the weevil and note that in the fore part of the season there can be no more squares than weevils, while in the latter part of the season there may be more weevils than squares.

It is advisable, therefore, to take advantage of conditions and advance the growth of the cotton as much as possible during the time of early square development while there is a natural weevil scarcity.

In cases where a choice of fields is to be exercised in the planting of cotton from the standpoint of probable boll weevil infestation, it is generally better to select the fields farthest from cotton gins, woods and overgrown with underbrush and thickly littered with leaves and grass. Fields planted in cotton near such places are nearly always more seriously infested by hybernating weevils than other more distant fields.

Gathering Infested Squares:

When the early and much prized squares begin to flare, turn pale and drop to the ground, the average owner feels like taking issue with the boll weevil. Too often he goes far beyond the bounds of good judgment in his zeal to counteract the evil results of the weevil by purchasing most anything which may be recommended that he has never tried before.

If he feels like indulging in the gathering of the infested squares he may do so to a better advantage than by spending time in combating the weevil in any other manner, perhaps, than by cultivation.

In cases where the early punctured squares can be gathered without neglecting other work that may be known to be more important, it is quite advisable to gather them. This can be profitably continued for about a month during the beginning of the season, i. e., up until the latter part of July. Contrary to ordinary practices these gathered squares should not be destroyed. The parasites of the boll weevil develop on it in its immature stage, consequently the destruction of the infested squares in such a way as to kill the young boll weevils will also kill any parasites that may be developing on them.

In order to protect and breed the parasites into the adult stage it is advisable to place the infested squares in special cages. Boll weevils can not pass through ordinary screen wire but the parasites are so small that they can easily pass through.

It is, therefore, advisable to use screen cages for controlling the weevil in gathered squares. An ordinary box with a screen on one side, in which to enclose them, will serve fairly well.

If infested squares are placed in such cages and properly cared for, the parasites will develop to the adult stage. Likewise the boll weevils, but they will be unable to escape from the cage. The parasites being smaller can crawl out and proceed to lay eggs in the field infested squares where they will continue to multiply and aid in the control of the weevil.

The collected squares should not be allowed to heat or dry out rapidly. The cage should be placed in the shade preferably and on a support above the ground, where the squares can be in a condition similar to that in the shade of the cotton plants.

The most numerous parasite prevalent in Oklahoma is the species known as *Microbracon mellitor* Say. This is a brownish colored wasp-like insect about the size of an ordinary mosquito. From a standpoint of activity, however, it has more of a sneaking disposition and can easily worm itself through a texture that is formidable to an ordinary mosquito.

Mechanical Devices:

Other mechanical devices than the cages for the gathered squares are not advised in Oklahoma for boll weevil control. There are too many objectionable features to weevil and square gathering machines to make them profitable to the cotton grower. The implements used for the early fall destruction of cotton stalks, cultural purposes, preventing weed growth, and for developing and retaining a good soil mulch without injury to the cotton plant are the superior mechanical devices for controlling the boll weevil with a view of obtaining the maximum profit from cotton culture. (Suggestion: Read this paragraph again).

Birds as a Weevil Control:

In the present day of needed conservation of wild life, nearly every kind of bird may be favored as a boll weevil killer. Nearly all birds are certainly very beneficial as insect destroyers. Very few, however, feed heavily upon boll weevils. The following are recorded* as being themost important species and are given in rank of importance, as follows: cliff swallow, barn swallow, orchard oriole, Baltimore oriole, kingbird, purple martin, and meadowlark.

Early Fall Destruction of Green Cotton Stalks:

The advantage gained from the early fall destruction of cotton stalks is of great and far reaching importance from the standpoint of boll weevil control. It has been shown that the percentage of overwintering weevils is very low. From none in some localities to 6.8% in others. (See topic on "Hibernation").

Now it is apparent that time and energy could be well spent in reducing this percentage since the methods to be employed control other bugs and also otherwise advance the conditions of crop yield.

The early fall destruction of cotton stalks by plowing them under permits the plants to decay and form humus to the advantage of the following year's crop. In case of fields where soil washes badly, wheat may be planted for pasture and a good soil binder established to aid in the prevention of erosion, although the buried cotton stalks act as an excellent soil binder and should be more serviceable for this purpose than when left standing.

*U. S. Dept. of Agriculture, Biological Survey Bul. No. 29, page 30, 1907.

Ground treated in this manner should be better adapted for hastening germination and advancing growth during the following spring than loose soil containing undecayed plant vegetation.

It is shown herein under the topic "Effect of Frost" that the annual propagation of the weevil from the standpoint of numbers is in its ascendacy during the early fall.

If this development can be prematurely culminated by early cotton plant destruction it is evident that the number entering hibernation later will be materially curtailed.

Now the destruction of cotton stalks after they have already been killed by frost or in any other manner amounts to little or nothing as a boll weevil control because it generally leaves the cotton fields very soon after the plants are dead. Consequently the best yielding, early maturing varieties should be used, so that the cotton may be picked early, in order that the plants can be destroyed while they are still green and as long before frost as possible, in order to prevent continuous weevil development.

It is a fact that all overgrown fields of brush and grass wherein sufficient cover may exist as hibernation quarters should be destroyed, preferably after frost, by burning them. The weevil hibernates in such places and not in ordinary cotton fields. The destruction of the green cotton stalks is advised for the prevention of its breeding and to bring about starvation before the weather is cold enough to induce hibernation. These facts should not be misinterpreted. If this method is carefully followed, the boll weevil as well as other injurious insects can at least be partially controlled and prevented from seriously infesting crops of the following year.

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ATMOSPHERICAL EFFECT ON WEEVIL ABUNDANCE

Primarily the prevalence of the boll weevil depends upon growing cotton. After becoming prevalent its abundance depends to a marked extent upon rainfall and temperature.

Rainfall:

Generally speaking, the weevil will develop to a much better advantage during a growing season in which the rainfall is above normal than it will when the rainfall is below normal.

Notice, for instance, on Plate IV that the northern fall weevil boundary line of 1914 was not nearly as extensive as is shown by its fall boundary line for 1915. The question arises: what caused such a boll weevil increase? Abnormal rainfall was apparently one cause for this. It should be understood, however, that rainfall above normal was not the only reason. (For summer rainfall, normal mean rainfall of the same, and total annual rainfall except for 1924 which was 29.05 inches, see Plate VI).* Another remarkable reverse condition arose during the summer of 1924, during which the rainfall was below normal. For relative weevil abundance, compare the fall weevil boundary line of 1924 with that of 1915. (See Plate IV). From these two

*All rainfall and temperature data in this bulletin was obtained from the U. S. Weather Bureau through the office of J. P. Slaughter, Meteorologist at Oklahoma City.

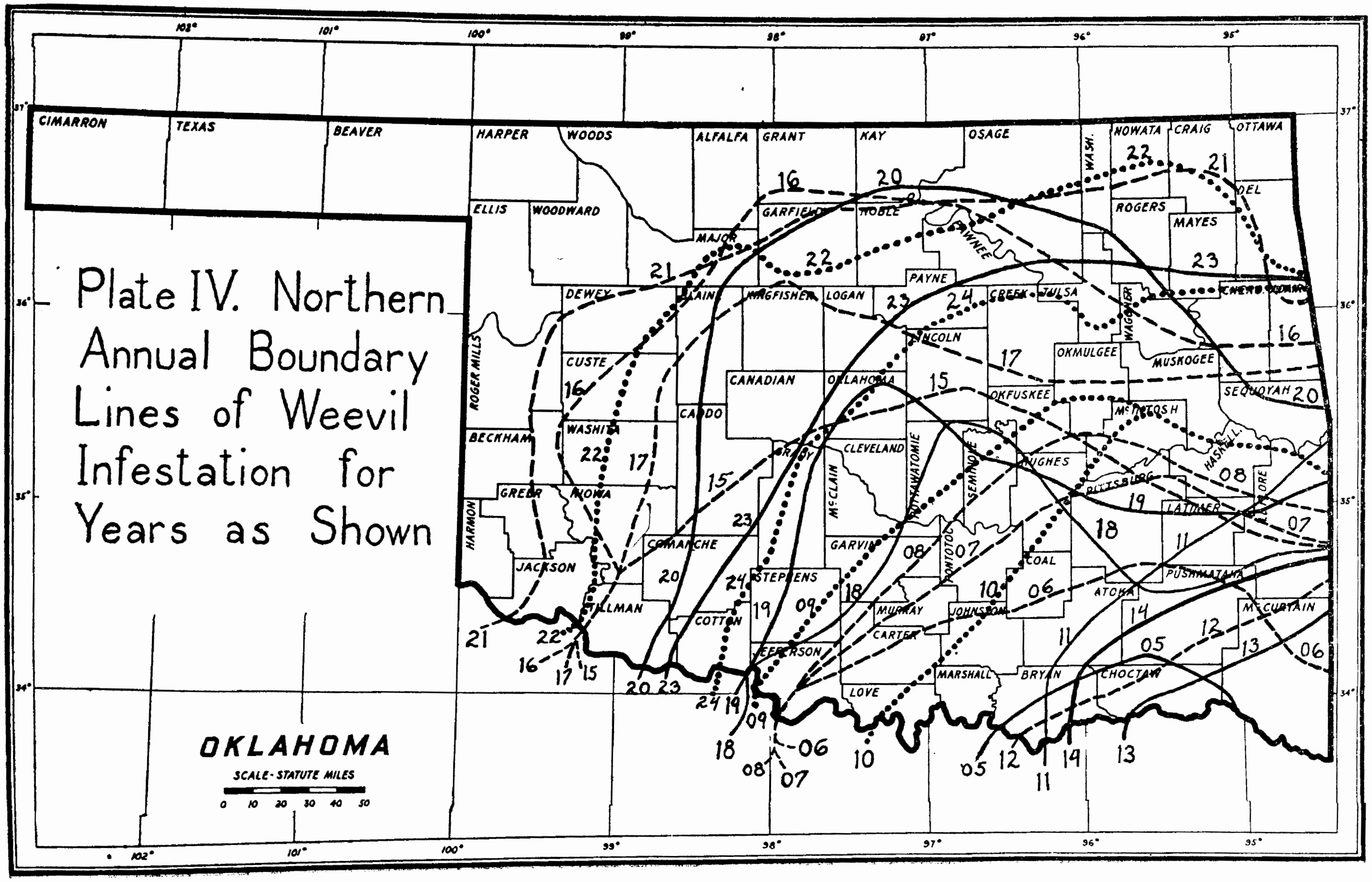

Plate IV. Northern Annual Boundary Lines of Weevil Infestation for Years as Shown

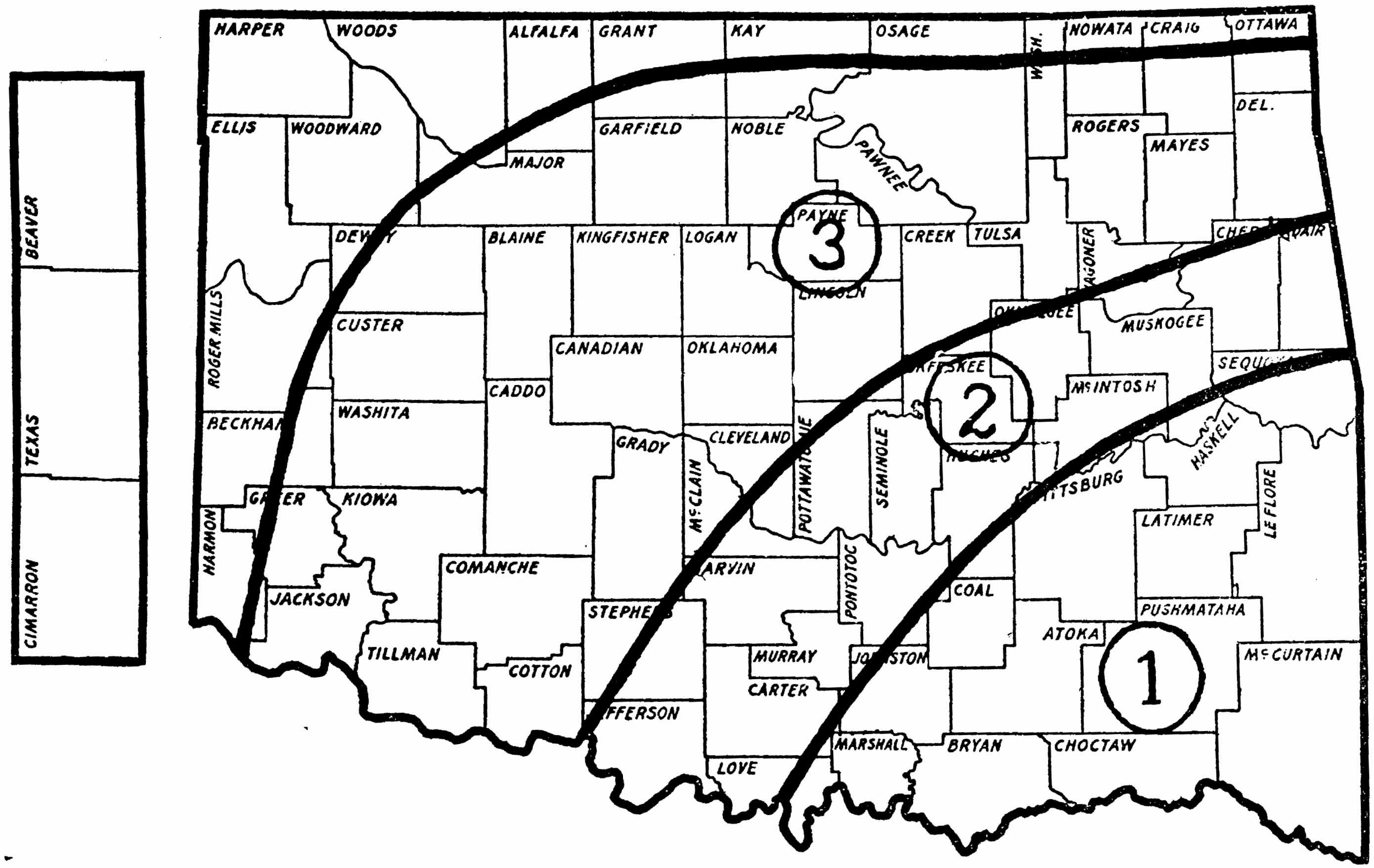

Plate V. Cotton Boll Weevil Zones

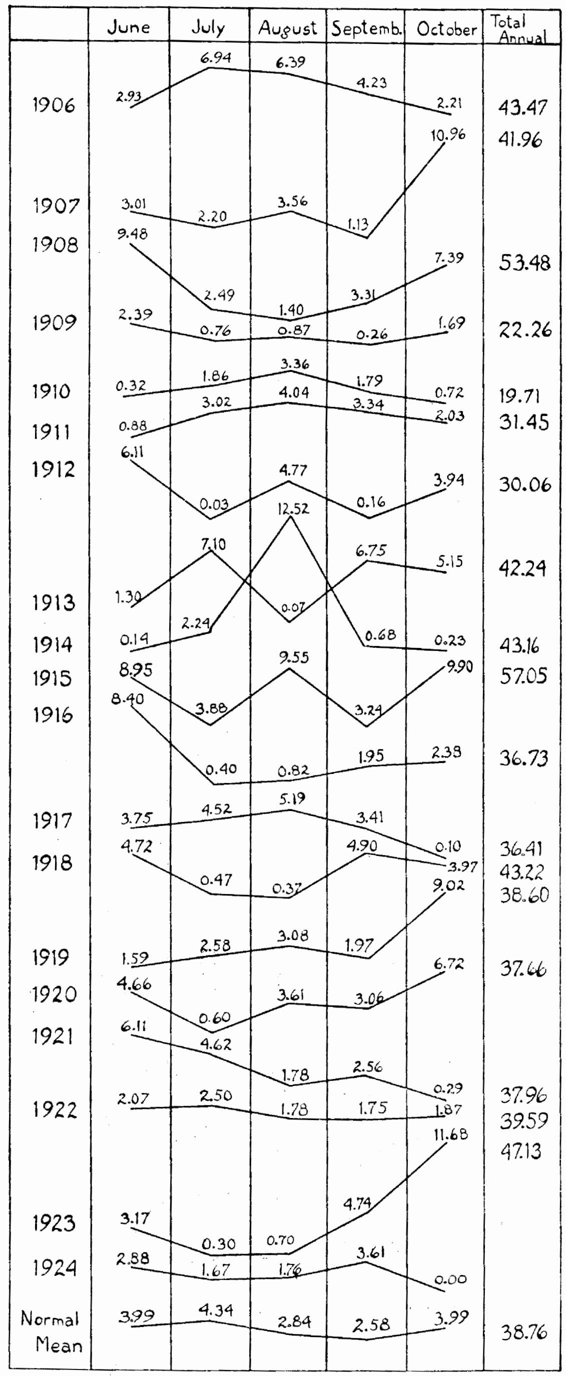

Plate VI. Rainfall of the Summer and Early Fall as Recorded Each Month at Durant, Oklahoma, for the Years 1906 to 1924 inclusive.

extreme conditions it appears evident that the summer rainfall is a remarkable governing factor in boll weevil development. There are, however, so many other factors entering into the problem, as previously inferred that the comparative abundance of weevils one year with another can not be ascribed alone to rainfall. Since the weevil is a tropical insect, some of the most important additional factors that should be considered are variations in temperature, and especially low or minimum temperature.

Temperature:

A summer with rainfall below normal is generally a hot one. While hot weather does not roast adult weevils, it certainly does dry out any exposed infested squares to such an extent as to prevent the immature weevils therein from developing. Consequently dry hot weather has a fatal effect on immature weevils. This condition was especially obvious during the summer of 1924. (For maximum temperatures 1906 to 1924 inclusive, also normal mean temperature, see Plate VII). A winter following such a summer as 1924, in which only a small number of weevils developed might be exceedingly mild, and an unusually large percentage of the small number of weevils entering hibernation might live through and issue during the following spring. Yet the spring infestation might not be nearly as severe as the overwintering percentage alone would indicate. For instance if one thousand weevils entered hibernation in a given area, and ten percent lived through the winter, there would be a survival of one hundred weevils in the given area.

If on the other hand the conditions of the summer had been such than an percentage of the large number entering hibernation had survived the following winter, the infestation would have been a great deal more severe than the overwintering percentage alone would have indicated. For instance, if one hundred thousand weevils had entered hibernation in a given area, and two per cent had lived through the winter there would have been a survival of two thousand weevils in a given area.

In other words, the nature of the winter and the percentage of overwintering weevils do not alone signify as to whether an infestation at the beginning of the year will be severe or not.

In order to estimate the severity and extent of a summer's infestation in advance, it is necessary to consider the extent of the previous year's infestation, fall development of weevils and the effect of winter temperature. The spring prevalence can be rather definitely established, but the severity of the summer infestation depends so much on summer rainfall and temperature that it can not easily be foretold.

The effect of winter temperature is frequently overestimated by the average person. The "ice man" may say that weevils cannot be frozen because he has seen them imprisoned for days in a block of ice, and after the ice was melted they crawled away! Now anyone ought to know that the weevils could not be subjected, under such conditions, to a temperature much below freezing, which is thirty-two degrees.

A glance at Plate VIII for the year 1918 will show that the temperature dropped to 6 degrees below zero during January. The average person might

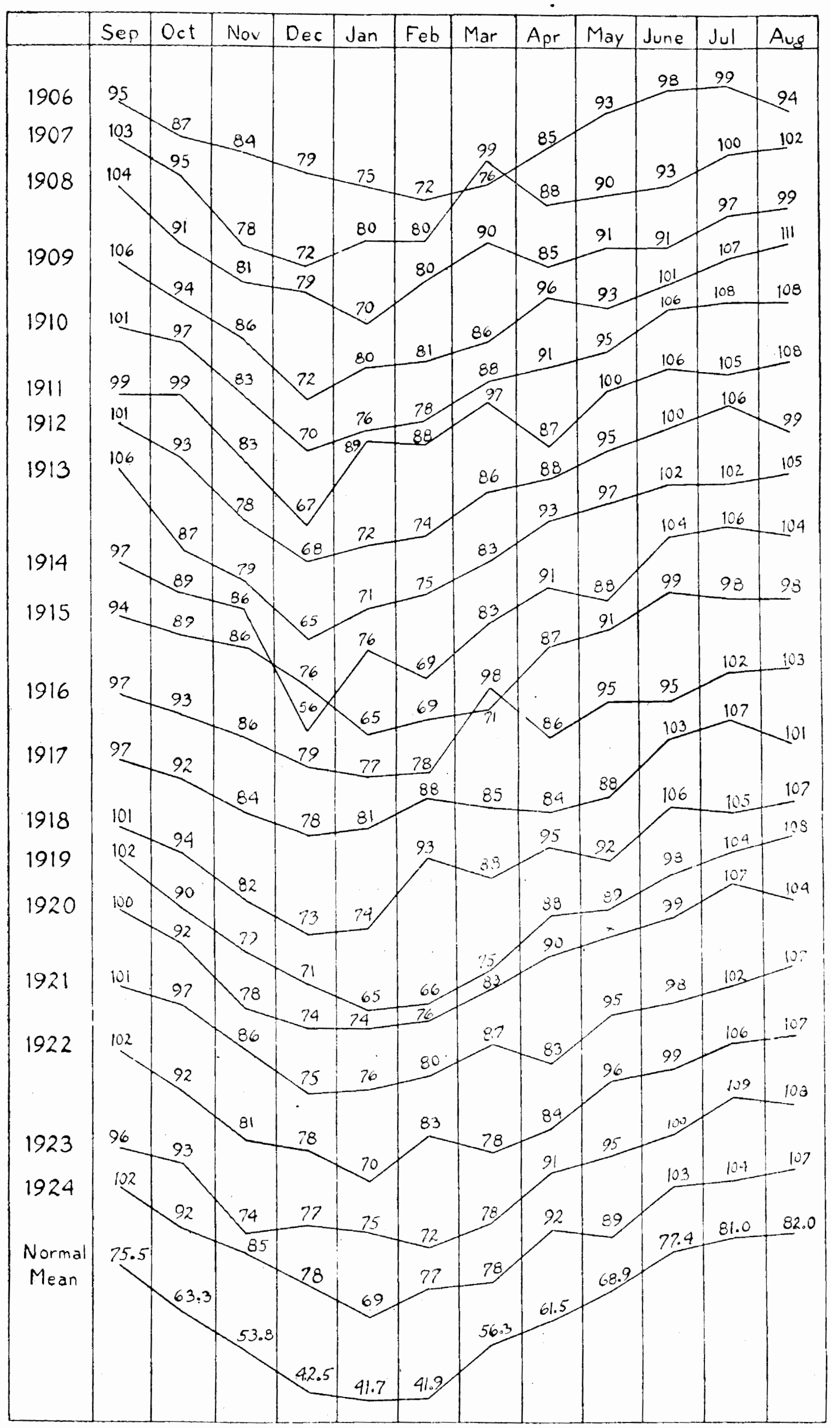

Plate VII. Maximum Temperatures as Recorded Each Month at Durant, Oklahoma, for the Years 1906 to 1924, inclusive.

conclude that no weevils could live through such weather, yet glance at Plate IV and it will be noticed that a sufficient number of weevils lived to increase the area of infestation the following summer (1919) beyond that of the previous year (1918).

Minimum Temperature:

Generally speaking, zero weather is fatal to weevils. The same is true

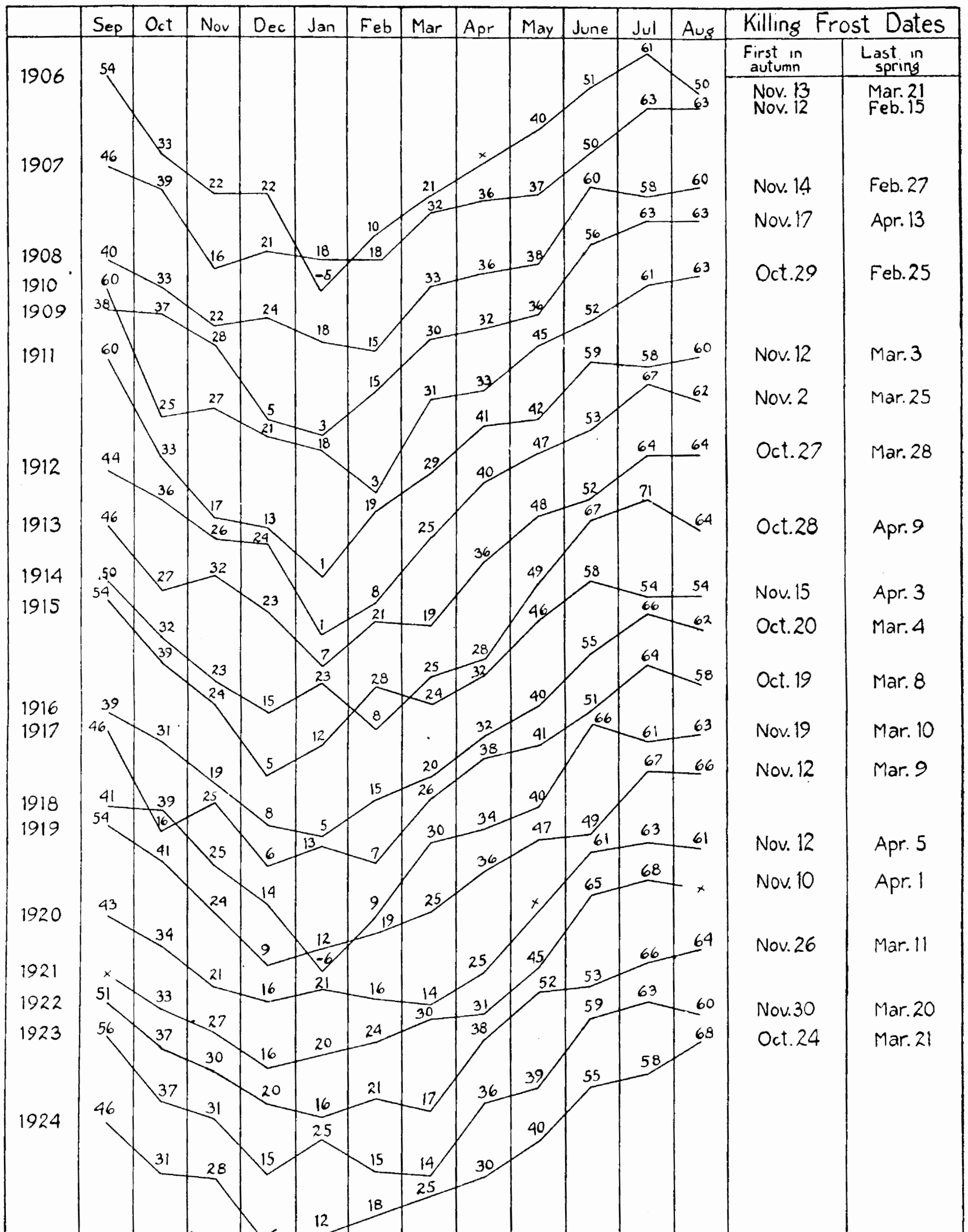

Plate VIII. Minimum Temperatures as Recorded Each Month at Durant, Oklahoma, for the Years 1906 to 1924, inclusive.

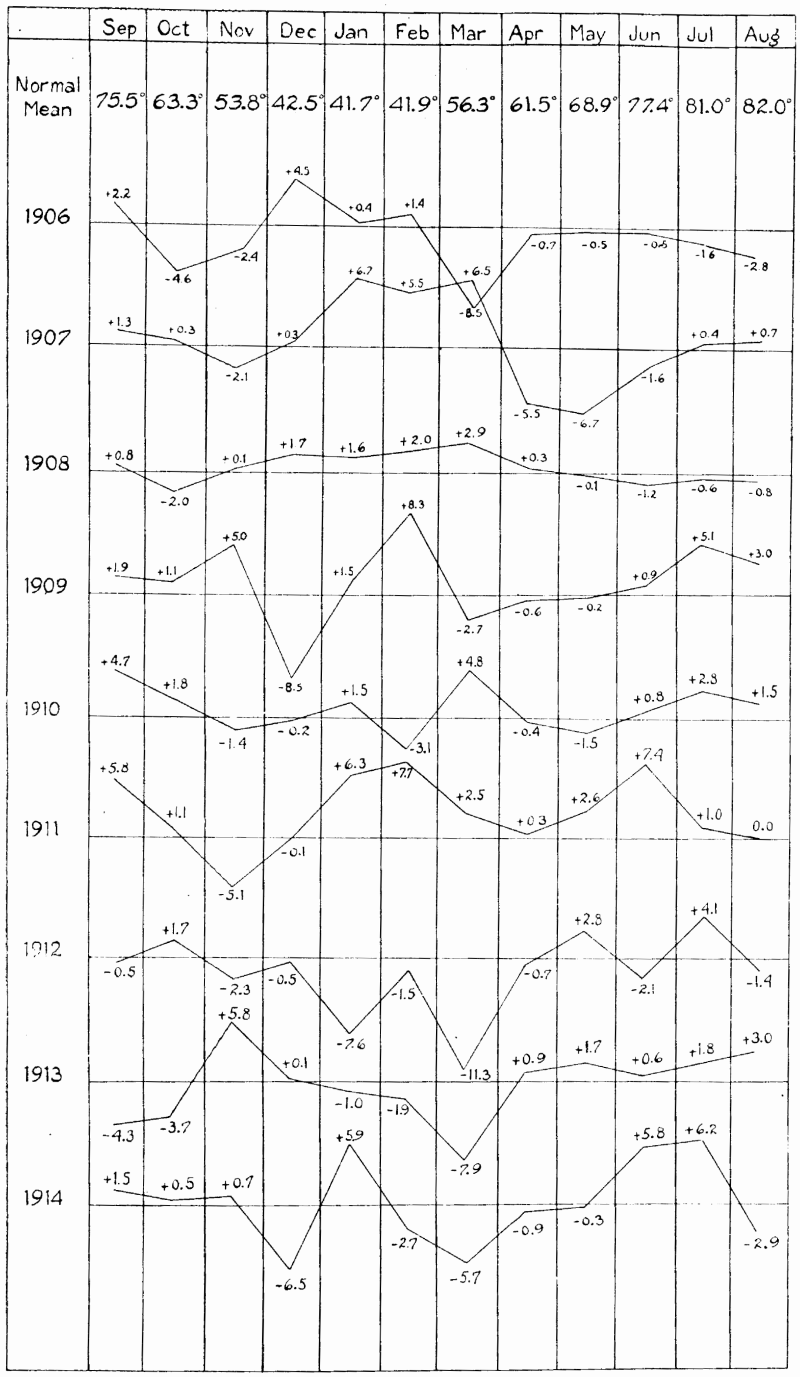

Plate IX Departures of Mean Temperatures from Normal as Recorded Each Month at Durant, Oklahoma, for the Years 1906 to 1914, inclusive.

of many animals, including man, if they are not properly protected. It depends then largely as to whether weevils have good winter protection or not during cold weather. During some years there is a much greater accumulation of grass, weeds and undergrowth in forests than others. Such accumulations generally develop during wet years. It can be observed that 1918 (see Plate VI) was abnormally wet. This could have been one reason why the weevils survived the winter so well, notwithstanding the extreme cold weather. Plates IX and X are charts which show the departures of mean annual temperatures from normal as recorded at Durant, Oklahoma. Plate IX contains this data by months for the years 1906 to 1914 inclusive, and Plate X contains it for the years 1915 to 1924 inclusive. Each plate also contains the normal mean temperature for each month.

As previously stated, zero weather is thought to have a marked effect on the boll weevil. If, however, it has good protection, it may not suffer if the zero weather is only of short duration. On the other hand if the duration of temperature is below normal for a long time it is apparent that the weevil is less likely to survive. Compare 1912, a winter below normal, for instance, with a year, 1908, above normal, on Plate IX. Also notice the 1912 fall weevil boundary line on Plate IV. It will be noticed that the area of infestation was much less extensive during the summer following the winter 1912 below normal than it was following the winter 1908 above normal. Other comparisons might also be made but there are few that are as typical of radical departures as these.

Effect of Frost:

The boll weevil can not depend upon any other plant than cotton in Oklahoma for development or subsistence. Since cotton is easily affected by frost during the fall of the year it follows that it must have a remarkable effect on the termination of boll weevils' propagation and subsistence. Indeed no other factor is more effective during the fall except the hand of man in the fall destruction of green cotton plants. As previously stated, the progeny of one pair in the spring may equal four or five millions by fall. It follows consequently that every day given to weevil development in the fall means a tremendous output for hibernation and consequently increases the percentage of the following spring infestation.

There are a great many factors which bear upon probable damage that may be done by the weevil which must be considered in advance if we are to know whether the future crop is to be seriously infested or not. The effectiveness of fall frost is one of these. By referring to the minimum temperature chart (Plate VIII) the "killing frost dates" will be noticed in the two right hand columns.

Unfortunately this data cannot be relied upon entirely for the present consideration. The data is no doubt accurate but there is sometimes a great difference in time between the first killing frost and frost sufficiently uniform and severe to kill all of the cotton in Oklahoma. This variation was extraordinarily observable during the fall of 1924. Many fields of cotton under protection of woodlands or in some instances under peculiarly unexplained conditions remained green until very late in the season (December 15th) which indicated that the early frosts were not uniform.

Although the killing frost date is given in the fall of 1924 as October 24th,

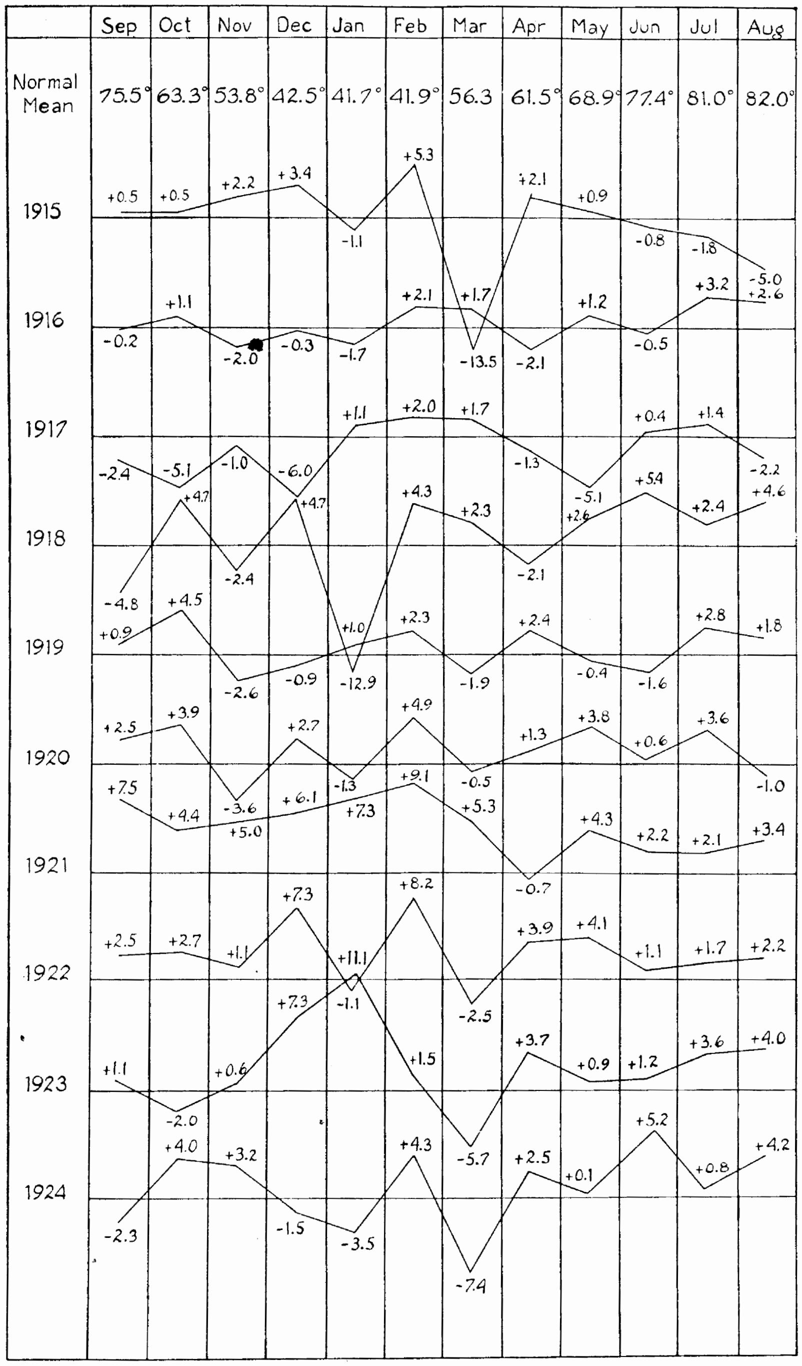

Plate X. Departures of Mean Temperatures from Normal as Recorded Each Month at Durant, Oklahoma, for the Years 1915 to 1924, inclusive.

it is a significant fact that a great deal of cotton continued to develop squares sufficiently later for the development of a large crop of weevils.

The boll weevils left the frosted dead fields and congregated by the millions in green cotton fields. Under such conditions the following season's supply could have been eradicated to a very marked extent by the plowing under of the green plants, or by the less advisable plan of uprooting, piling and singeing or burning them.

When cotton is killed by frost or other cause it no longer furnishes food for the weevils and the latter must starve or hibernate. If this happens late in the fall with the advent of cold weather the weevils can hibernate. If it happens long before the advent of cold weather the weevils apparently attempt to seek food instead of hibernation quarters and on account of a lack of food may perish.

Such conditions as above indicate show that dry hot weather or cool damp weather during June, July and August, are only partial factors which may govern the abundance of a following year's supply of boll weevil. There are so many angles in boll weevil prevalence that a single important governing factor can not alone be used decisively. All angles to the problem must be considered and reckoned with as accurately as possible before conclusions can be rendered.

HIBERNATION

As far as known the weevil remains practically inactive during the main part of its hibernating period (December to April inclusive) in Oklahoma. Those individuals which during late summer and fall develop or disseminate northward into Zone 3, Plate V, are not known to survive our ordinary winters. This zone, therefore, is a sort of a death trap for the annual horde of weevils which enter it from the "overflow" of Zones 2 and 3.

Zone 2 is a very unfavorable weevil winter resort. Comparatively few are able to survive an ordinary winter. As far as known, however, some have always been able to survive winters in Zone 1, since their first advent there in 1905.

It is apparent that the ordinary cotton gin building is one of the ideal hibernating places. Weevils are brought to the gins in great quantities in cotton from infested fields. Sometimes the "trash piles" of a gin contain so many weevils which have passed through the ginning machinery that they are literally alive with them. This is most obvious late in the season when weevils are thickest in cotton fields and are beginning to seek hibernating quarters. It is apparent that during the cool weather of this particular period of the year they will seek winter protection in the vicinity of the gin.

Accumulating piles of the trash, also other by-products arising and accumulating from the ginning of cotton make the gin yards very well adapted for weevil hibernating quarters. It follows that all worthless litter should be regularly destroyed by burning. The store houses and sheds should be so constructed as to prevent the escape of weevils except into screen traps especially designed for their capture.

Weevil Latitude:

It is apparent from the variable geographical location of the northern boundary line of the weevil, that temperature has a great deal to do with its prevalence. It is also apparent that weevil latitude is not parallel with ordinary geographical latitude, but extends in a general direction of southwest and northeast. For a good example of weevil latitude, notice the annual boundary lines for the years 1913, 1912, 1914 and 1911 respectively (Plate VI).

Hibernation Cages:

Now in order to arrange hibernation cages for winter tests, it has been deemed advisable to follow this "weevil latitude" northward in the distribution of cages in order to obain the overwintering percentage as far north as the weevil is likely to live through the winter.

The size of the cages until 1925-26 was about two feet square and six feet long and made of wire screen through which the weevil could not escape. They were provisioned with such local materials as occurred in the given locality in which the weevil might hibernate. The predominating materials used consisted of leaves and grass among which brush, stalks of cotton and corn or weeds formed a loose framework for permitting easy entrance of the weevils into the leaves and grass. Each cage was placed lengthwise on the ground so that the natural temperature of the soil could have its normal effect, the same as would be expected to prevail under natural conditions.

Live weevils were collected from cotton fields as nearly at the same time as they were entering natural hibernation as possible. Ordinarily 500 weevils were placed in each cage. Each cage was opened the following spring not later than April 15th, the material carefully inspected and all the weevils accounted for. The percentage of live ones in each cage was considered as representing the percentage of overwintering forms for the respective locality in which the individual cage was located. In the future the same plans will probably be followed in annual hibernation tests except that the cages will be three feet square.

Presumptions:

There is a possibility of straining one's judgment in computing the probable severity of weevils in a locality in advance of their appearance on account of factors which may enter the problem that cannot be easily calculated. For instance, a small percentage of overwintering weevils might become more severe during an abnormally cool and damp spring and summer than a large percentage would during a dry hot spring and summer. On the other hand many times as many more weevils might normally enter hibernation quarters one year than another so that a very small percentage of overwintering forms in a cage might prove to be a very inferior index to the severity of an infestation the following summer. Consequently it must be noted that the relative abundance of weevils above or below normal entering hibernation quarters throughout the country will cause the following season's supply to vary accordingly, even though a normal percentage (about 3%) in each instance might survive.

The following table contains the data on hibernation tests for the winters and localities as shown:

For the Spring of the Year	No. of Weevils Placed in Cages	Locality	Percentage of Survival
'21-'22	82	Antlers	1.2 plus
	100	Durant	0.0
	100	Marietta	0.0
	100	Stillwater	0.0
'22-'23	500	Antlers	6.8
	500	Durant	0.2
	500	Shawnee	0.2
	500	Stillwater	0.2
'23-'24	1,500	Antlers	0.066 plus
	1,500	Durant	0.0
	1,500	Coalgate	0.0
	2,000	Shawnee	0.0
	800	Stillwater	0.0
'24-'25	500	Antlers	0.0
	500	Durant	0.0
	500	Coalgate	0.0
	500	Shawnee	0.0
	500	Oklahoma City	0.0
		Stillwater	0.0

This table shows that during the spring of 1922 the only live weevils in four different locality cage experiments were at Antlers. It followed also that the summer of 1922 was very favorable for cotton production in Oklahoma since there were few boll weevils, notwithstanding the fact that perhaps a greater area of infestation (not especially numerous locally) prevailed during the previous summer (1921) than ever before in the history of Oklahoma.

There were between five and six times more weevils which lived through in hibernation cages at Antlers in the spring of 1923 than the previous year. Cage tests also showed that weevils lived through the winter as far north as Stillwater.

During the spring of 1924 the percentage of overwintering forms was found to be somewhat similar to that of the spring of '22. The severity of infestation began similar to that of 1922 but was quickly checked by hot dry weather which began in June and continued throughout the cotton production season.

The tests for the spring of 1925 indicated that conditions would be similar to those of 1924, except that the infestation was expected to begin rather severely in local areas, in Zone 1, where some cotton fields remained green after others were killed by frost during the fall of 1924. Later results verified these predictions. The summer of 1925 was not a serious boll weevil year.

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SUMMARY

A three year test with calcium arsenate as a dust spray for controlling the boll weevil indicates that it is not a satisfactory control in Oklahoma.

An average gain of 45 pounds of seed cotton per acre was obtained. The cost of the treatment averaged $6.30 per acre. Any profit, therefore, would be represented by a price above 14 cents per pound for cotton. Likewise any loss would be represented by a price below 14 cents per pound. Since 8 cents was the estimated price at which the gain in yield (45 lbs.) sold, it is apparent that there was a loss of $2.70 per acre.

Results were also obtained from other experiments conducted in connection with this one. They were as follows: Molasses arsenate, gave a profit of $13.31 per acre; nicotine arsenate gave a loss of $10.51 per acre; Hill's Mixture gave a profit of $0.46 per acre; the Florida plan gave a loss of $1.09 per acre. It is apparent, therefore, that of all the experiments conducted, the molasses arsenate treatment might be considered as the most advisable one to apply under Oklahoma conditions.

From general observations made in connection with these experiments and at other times since the advent of the weevil in Oklahoma, the following ideas are suggested.

Persons without much experience in cotton culture are advised to consult the local county agent relative to an early maturing variety of cotton and time of planting it.

Retain a continuous soil mulch until the bolls begin to open.

In case of serious alarm in a community on account of what appears to be extreme weevil damage, it may be advisable to gather early infested squares. A two fold advantage may come from gathering infested squares. One is that money may not be needlessly spent for the purchase of some needles, worthless concoction or device which is generally put on the market at such times.

A parasite cage can be made with very little expense, and will doubtless be more profitable than any other contrivance that can be used, other than proper culture. Gather punctured squares until not later than six weeks after the first punctured forms appear, and place them in the cage.

Complete the final picking of cotton as early in the fall as possible. Destroy the plants immediately thereafter unless they have already been killed by frost.

Institute a fall clean-up. Plow under or burn all brush, leaves, and overgrown grass, if the latter is not to be used for fall pasturage.

After cotton ginning is completed in infested localities renovate all gins and prepare enclosures for seed and hulls so that hibernating weevils can only escape into screen traps.

Prepare the cotton field seed beds in advance so that they will be compact, moist and warm so as to insure uniform germination and quick growth.

Be careful about introducing seed not advised by the local county agent. At any rate obtain his opinion before doing so, on account of cotton diseases and insects.

It is suggested that no more cotton should be planted by anyone than can be judiciously cared for. By this is meant that other field crops, gardens and fruits should not be forced out of their essential primary consideration.

In other words, man must live before he can accomplish anything. In order to live, the fundamentals on the farm must be established. They are garden, orchard, chickens, milk cows and hogs. In some localities a few colonies of bees might be added.