KANSAS STATE AGRICULTURAL COLLEGE.

Agricultural Experiment Station.

Bulletin No. 191.

THE CHINCH BUG.

MANHATTAN, KANSAS.
NOVEMBER, 1913.
5 1187

Table of Contents.

ANNOUNCEMENT.

SINCE this manuscript was submitted the following important changes in the station staff have occurred: Ed. H. Webster, director of the experiment station, resigned December 31, 1912, to become associate editor of *Hoard's Dairyman*, and has been succeeded by W. M. Jardine. Prof. L. E. Call has succeeded W. M. Jardine as head of the agronomy department. Dr. T. J. Headlee resigned as head of the departments of entomology and zoology, to become entomologist of the New Jersey Experiment Station, and has been succeeded by Prof. Geo. A. Dean, in the department of entomology, and by Dr. R. K. Nabours, in the department of zoology.

Summary.

1. The chinch bug was already in Kansas when the settlers came.

2. The chinch bug winters in bunch grass *(Andropogon scoparius* Michx.), big bluestem *(Andropogon furcatus* Muhl.), false redtop *(Triplasis purpurea* Walt.), and various other shelters.

3. With the coming of spring the bugs leave their winter quarters and locate in wheat and other small grains. Here young are produced that reach maturity shortly after harvest time. With the failure of food in the small-grain field these bugs migrate, usually on foot, into adjacent fields of corn and sorghum. Here young are produced that reach maturity by fall and establish winter quarters in the grasses.

4. The chinch bug, both as young and as adult, damages its food plants by piercing the rind, sucking the sap, and killing the tissue about the wound.

5. The chinch bug damages Kansas crops many millions of dollars in a single year, and may greatly reduce the wheat and absolutely destroy the corn and sorghums of the individual farmer.

6. The chinch bug thrives in dry seasons and dies in wet ones. Wet weather destroys it directly and indirectly— directly by burying the young and the eggs; indirectly by weakening the bug and rendering it more susceptible of disease, and by encouraging the growth of its terrible fungous parasite *(Sporotrichum globuliferum* Speg.).

7. The chinch bug has no efficient natural enemies other than certain parasitic fungi, the most active of which is *Sporotrichum globuliferum* Speg.

8. The parasitic fungi are well distributed throughout that part of the United States subject to chinch-bug outbreaks, and cause great epidemics when temperature and moisture become favorable. An average mean temperature of 75° F. and a moisture close to saturation are most favorable to the activity of *Sporotrichum globuliferum* Speg.

9. All the really careful work thus far done on the problem agrees with our own results in showing that it is not possible

by artificial distribution of the fungus materially to hasten the progress of the chinch-bug disease caused by *Sporotrichum globuliferum* Speg.

10. The advocacy of the control of the chinch bug by artificial distribution of the fungus has already cost Kansas many millions of dollars in staple crops through engendering the neglect of really efficient measures, and further advocacy of it is opposed to the best interests of Kansas agriculture.

11. All the most careful tests at this station and elsewhere show that twice during the year the chinch bug may be destroyed—while passing from wheat and other small grains into adjacent fields of corn and sorghum, and when just firmly established in winter quarters.

12. Destruction of chinch bugs in winter quarters by use of fire has proven, in our experience, the cheapest and most practicable method of solving the problem.

THE CHINCH BUG.

(Blissus leucopterus Say.)

By THOMAS J. HEADLEE, Entomologist and Zoologist,[1] and JAMES WALKER McColloch Special Agent.

INTRODUCTION.

THE chinch bug has damaged Kansas crops to a greater extent than has any other injurious insect, for from the time the settlers began to plant the prairie to the present it has exacted merciless toll. While in wet seasons its work has not been noticed, in dry ones it has destroyed a high percentage of both wheat and corn. Although there is no way to determine accurately the money value of crops destroyed by the chinch bug since Kansas was first settled, it is safe to assume that the amount reaches many billions of dollars. In a single year, under favorable conditions, it is conceivable that the chinch bug may do twenty-five million dollars' worth of damage to Kansas crops. The individual farmer may lose a heavy percentage of his wheat, barley and oats, and all his corn and sorghums.

The history of the chinch bug in Kansas reaches back to a point in time before the white man came. Coming from the south, say, the region of Panama, according to Webster's[2] ingenious and plausible theory, the bugs migrated along the east and west coast of Central America and Mexico. The west-coast strain continued northward into what is now California. The east-coast division passed northward, then eastward along the gulf coast, and here split, one section going northward into the Mississippi valley and the other continuing its movements along the gulf coast to the Atlantic and northward into New England. The Mississippi valley strain spread out over the Mississippi, Ohio and Missouri basins.

1. This bulletin was planned and written by the senior author and confirmed by the junior author. The work upon which it is based was planned and supervised by the senior author and partly performed by him. Some of the detailed work was performed by Mr. J. B. Parker, but the collection of the vast amount of data necessary to the conclusions stated is the result of the junior author's able and painstaking work.

2. Bul. No. 69, N. S., Bu. of Ent., U. S. Dept. of Agric., pp. 78-90.

The history of the chinch bug in Kansas has been one of ups and downs, due to favorable and unfavorable conditions of climate. Whenever the season has been dry and wheat and corn have been grown together, the chinch bug has been a

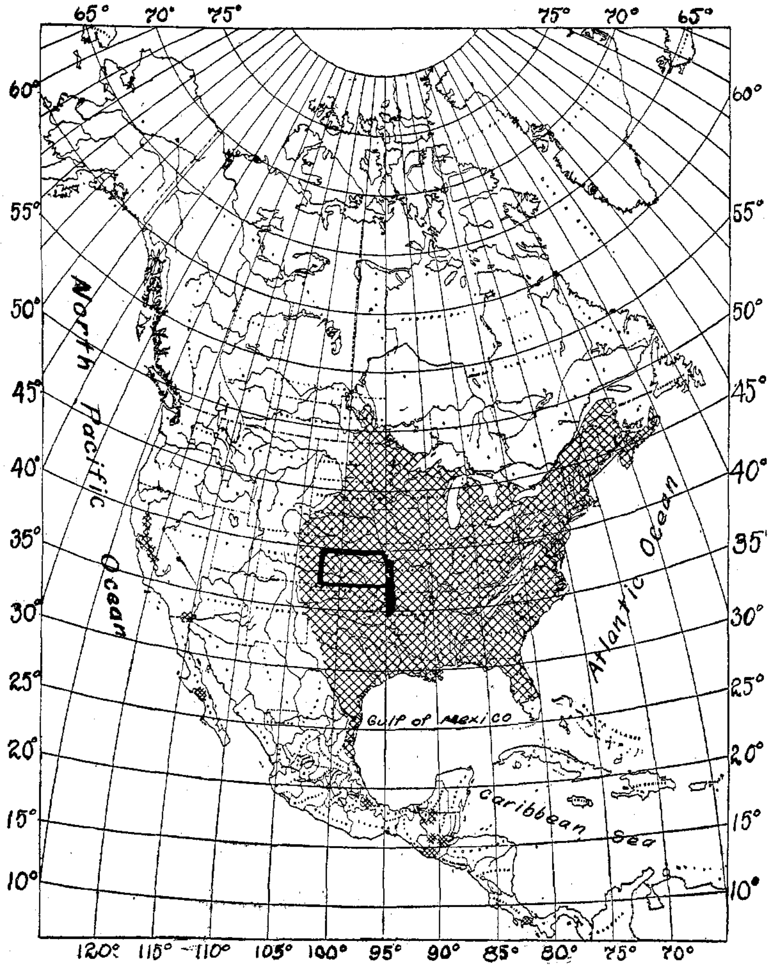

FIG. 1. Map of North America, showing distribution of the chinch bug. (After Webster).

pest. This is true because the dry season prevents the growth and activity of its fungous enemies, and because the wheat serves as the best kind of food from spring until midsummer, and the corn from then until fall. In fact, it is hard to conceive of any more favorable combination of food plants from the standpoint of chinch-bug life economy. Wherever wheat and other small grains alone are grown the chinch bug does less harm, for it finds extreme difficulty in obtaining food the latter part of summer. Where corn and similar grains alone

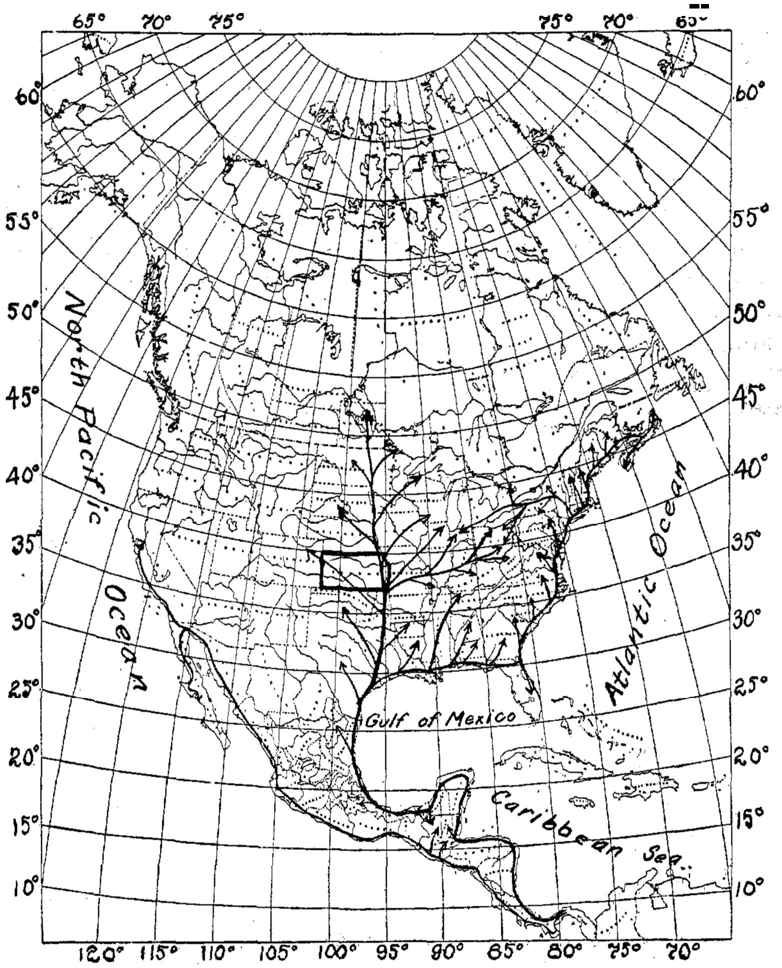

FIG. 2. Map of North America, showing the theoretical course of distribution of the chinch bug. (After Webster.)

are grown the bug does small damage, because food is very scarce in the early summer. Whenever the weather is very moist during the growing season the chinch bugs are reduced to a negligible quantity by the burying action of the rains and the growth of the chinch bug's really efficient natural enemy, the chinch-bug fungus *(Sporotrichum globuliferum* Speg.).

Assuming the publication in the agricultural papers[3] may be taken as an index of the severity of chinch-bug attack, we find that since 1870 there have been seven more or less serious outbreaks. Definite, clearly marked outbreaks came in 1871, 1874, 1875, 1881, and in 1887. From 1891 to 1901 the publication indicates constantly more or less trouble. The publication during this period was occasioned mainly by Snow's study of the chinch-bug fungi. The outbreak in 1908 was light, while that in 1910-1912 was severe. The chinch-bug range covers all parts of the state. In the past five years no damage of consequence has appeared in the northeastern part, some has occurred in the southeastern, much in the central, and practically none in the western part. The records show that the extreme western part of the state has rarely suffered damage from chinch bugs.

3. The files of the *Kansas Farmer* from 1870 were available and were the ones used.

HABIT AND LIFE HISTORY.

General.

For the purpose of giving a connected idea, the life history will be taken up at one time of the year, and the creature traced forward until the same date the following year. Just now (October 7), the chinch bugs are gradually leaving the corn, cane and kaffir fields, and are taking wing and making their way into grasses along fences, in waste places, in pasture lands and in meadows. By early November all of the bugs will have gathered in clumps of bunch grass and other clump-forming grasses, under rubbish, in the tangle of grasses along fences and in waste places, in corn shocks, cane piles and woodlands. In fact, where present in large numbers the chinch bugs appear to take shelter wherever it can be found, and in the late fall and early winter it is difficult to find shelter of any sort within a reasonable distance of corn, cane and kaffir fields entirely free from them. By the time, however, winter is well started the great mass of bugs are found in clumps of bunch grass *(Andropogon scopurius* Michx.), which forms a very characteristic feature of all native grass pastures, fence rows and waste places throughout most of that portion of Kansas suffering serious damage from the chinch bug. To a less extent it is found in other clump-forming grasses, particularly big bluestem *(Andropogon furcatus* Muhl.), except where these are situated in low areas liable to overflow. In the southeastern part of the infested territory both bunch grass and big bluestem are largely replaced by false redtop *(Triplasis purpurea* Walt.).

In 1895, Marlatt,[4] as a result of his study of chinch-bug hibernation in Kansas fields, says: "Failing to find them in the situations noted, I carried the examination further, and finally discovered what is probably the normal hibernating place of the chinch bug in the dense stools of certain of the wild grasses, such as bluestem and other sorts, perhaps including tame varieties which incline to the stooling habit.

4. Marlatt, C. L., Insect Life, vol. 7, pp. 232-234.

. . . In these situations only were chinch bugs found during the winter, and so numerously that a single stool of grass would conceal hundreds of insects. By tearing the grass apart, these hibernating bugs would be found massed between the stalks, well down into the earth, as thickly as they could force themselves into the crevices." Marlatt's observations were doubtless made where the chinch bugs sought winter quarters in medium numbers, or he would have found many bugs trying to hibernate in all sorts of cover. Indeed, about Manhattan in the winter of 1910-'11, when the bugs were present in comparatively small numbers, no specimens were found elsewhere than in clumps of bunch grass, of which there were the greatest abundance.

Of the clump-forming grasses the chinch bug unquestionably prefers the type popularly known as little bluestem, which botanically is bunch grass (*Andropogon scoparius* Michx.). This grass forms a dense upstanding cluster composed of many stems, from which spring narrow leaves that die and decay in the bunch. Leaves, pieces of decayed stems and wind-blown soil collect in the base of these bunches, forming a soft, porous mulch, ranging from almost nothing to an inch or more in depth. The crown of the bunch stands slightly above the general level of the ground about it. Thus a hiding place is formed, well above the flooding of ordinary surface water and protected from snow and wind. For the purpose of ascertaining the temperatures in the bunch-grass mulch where the chinch bugs prefer to winter, a soil thermometer bulb was inclosed in a typical unburned bunch of grass, at the point where the mulch was present, in such a manner that the only loss of heat would be through the mulch, as is normally the case. The result was surprising, showing that the chinch bug's choice has a very sound basis. While the temperature outside was ranging from 15° to -13° F., the temperature inside ranged from 21° F. to 13° F. Putting the same general matter in another way, the chinch bug outside would have from December to May to withstand average daily changes of 24.6 degrees and minimum temperature of -13° F., while the bug inside would have to endure 6.4 degrees daily variation and a minimum temperature of 13° F.

FIG. 3. A clump of bunch grass.

In the chinch bug scheme of things, wet weather is more to be dreaded than extreme cold, because wet weather encourages the growth of its terrible scourge, the chinch-bug fungus *(Sporotrichwm globuliferum* Speg.). Let us, then, inquire into the way in which this bunch grass protects it from the wet. In view of the readiness with which the mulch is wetted by even a light rain and the slowness with which it dries out, the bunch grass would appear under wet conditions to be hostile rather than hospitable to the chinch bug. But this is only apparent, because while the temperature is high enough to permit the growth of the fungus the bug is either not in the bunches or remains in them on top of the mulch. In the fall of 1909, Mr. J. B. Parker found that during the warm sunshine following a rain the bugs ascended the stiff stems of the bunch grass, apparently to dry off and escape the wet, and that with falling temperature and drying out of the clump they descended. Thus it is seen that bunch grass affords the bugs an opportunity to escape the bad effects of wet weather. The only exception to this fact was observed during the spring of 1912, when, owing to a very late spring, the bugs did not leave the mulch until a considerable number had perished with the fungus and from loss of vitality.

In the late fall of 1909, during a wet period, the chinch-bug fungus *(Sporotrichum globuliferum* Speg.) attacked and destroyed the bugs in large numbers when congregated under ordinary cover, while not one trace of the disease was discovered among the thousands of bugs in the clumps of bunch grass; nor were we able to produce it artificially, although dead bugs white with the fungus were scattered thickly in selected clumps. The only possible effective difference between cover where the bugs were dying and the bunch grass was in moisture. Under low-lying, ordinary cover the relative humidity was high, while in the bunch grass it was low. In the late fall of 1911 similar conditions with regard to the virulency of the fungus were found, but in this case traces of the disease were found in clumps of the bunch grass.

It thus be comes plain that the chinch bug finds in clumps of grass far better protection from the inclemencies of winter than anywhere else. As a matter of fact, most of the bugs that gathered in other types of cover during the winters of

1910-'11 and 1911-'12 perished it would seem that the preference of the chinch bug for bunch grass for hibernation bears the earmarks of having been developed by a process of natural selection, and that this strengthens the opinion that the chinch bug inhabited the prairies long before white men came or Kansas was born.

FIG. 4. An adult chinch bug. Enlarged 4 times.

Passing the winter principally in clumps of bunch grass and similar clump-forming grasses, the chinch bugs begin emerging with the advent of warm weather, and continue to come out with greater or less rapidity, depending on the weather, until all are out. Cold days put a temporary stop to this migration, but it is resumed as soon as the temperature moderates. During the period of spring migration the bugs may travel, considerable distances—just how far there are no conclusive data to show. Our observations indicate that they make their way to the nearest wheat or barley field, and that they do not travel farther than is necessary to secure a sufficient supply of food. Here, by thrusting their beaks into the tissues of the tender plants, they break their long winter fast.

FIG. 5. Eggs of the chinch bug. Enlarged 4 times.

About three weeks after the first spring flight is noticed, the eggs begin to appear. They are deposited in cracks and crevices of the ground, mainly on or near the stems and roots of the plants, but sometimes widely removed from all plants. They are also often thrust in between the leaf sheaths and stems of the plants. In fact, the location of the eggs appears to vary with any factor that affects the distribution of the bugs. Where the bugs find food plentiful and conditions to their liking, they congregate, and there the eggs are laid. The egg is a tiny, oval, reddish object about .03 in. long and one-fifth as wide. One end is blunt, and bears four small, rounded lumps near the center.

Shimer 5 places the total number of eggs deposited by the

5. Riley, C. V., 2d Annual Rept. of State Ent. of Mo., p. 22.

female at 500. Johnson[6] found that six females under breeding-cage conditions gave from 98 to 237 eggs each. Twenty pairs collected in the field on June 9th, or about 24 days after egg laying began, produced an average of twenty eggs each during the remaining 16 days of their lives. Twenty-one females of the second brood, which were raised in the laboratory, and whose reproductive life last eleven days, produced an average of fourteen eggs each, with 1 and 59 as extremes. The relative number of unhatched eggs and mature female chinch bugs under field conditions from May 26 to June 6, 1908, were shown by six counts of four square feet each in a barley field to be 8 to 1.

In due time a tiny, pale yellowish-red bug, bearing an orange-colored spot on the dorsal aspect of the abdomen, emerges from each egg. The newly hatched bugs are very active, and quickly make their way to stalks of wheat, barley or grasses, from which they draw abundant sustenance by inserting their beaks into the sap stream. Like other insects, the outside part of the skin—which, by the way, is the only skeleton the creature possesses—is so hard that once the growth of the body taxes its capacity either the creature must stop growing or shed its skeleton-skin. When this stage has been reached the skin is split along the back, beginning at the head, and the animal wriggles its way out. Before the new outer skin—which, as the time for skin-shedding approaches, has been formed beneath the old—hardens into an exoskeleton, it is stretched sufficiently to accommodate future growth. This skin-shedding is generally designated as "moulting." The period of time between moults is spoken of as an instar. Thus the periods between hatching from the egg and the first moult, between first and second moult, and between the second and third moult, are designated, respectively, as the first instar, second instar, and third instar.

In the second instar the prevalent yellowish-red color of the first is replaced by a bright vermillion, which contrasts strongly with a pale band lying across the front dorsal region of the abdomen; the head and prothorax change to dusky, and dusky spots appear on the mesothorax, metathorax, fourth and fifth abdominal sutures, and tip of abdomen. The third

6. Johnson, W. G., 19th Rept. of State Ent. of Ill., pp. 177-183.

and fourth joints of the antennæ show dusky. In the third instar the bright vermillion gives way to a dull red or brown, the tranverse pale band, however, remaining quite distinct The head and thorax become darker and the dark triangular wing pads appear, one group projecting backwards from each side of the dorsoposterior face of the thorax. In the fourth instar the dull red becomes gray or almost black. The head, thorax and wing pads are brownish black. The legs and antennae are dark. With the fourth moult the bug becomes the

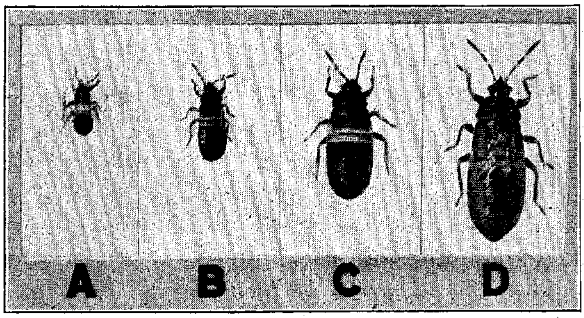

FIG. 6. Stages of growth of the chinch bug. Enlarged 4 times.

well-known adult. The dingy or grayish-black little pest is easily recognized by the fact that the white parts of the wings are so arranged, when the wings are folded, that it appears to be branded with a white X-shaped mark.

With the ripening of the wheat, the bugs, only a few of which have reached the adult stage, must seek food elsewhere or starve. Of course, when small-grain fields are weedy and grassy the bugs can obtain food from the grasses, but when compelled by hunger to leave, they start out on foot toward the nearest corn, cane, kaffir or millet field. Ordinarily the time of migration depends on the food supply, and begins when the wheat ripens or is cut. If food gives out while the majority of the bugs are still immature the migration is made on foot, but if the food supply holds out until the bugs mature, distribution takes place both on foot and on the wing. Bugs migrating on the wing can not be trapped and destroyed, while bugs migrating on foot can easily be killed. The farmer should, therefore, force the bugs to leave while yet immature, by cutting his wheat as soon as it will do and by disking or burning the grassy stubble.

When migration must be made on foot the bugs avoid the heated parts of the day and confine their travel to a few hours in the evening. On cloudy or cool days they passmore or less all day. During the past summer (1912) each day they began passing about 3 P. M., reached amaximum about 5:45 P. M., and ceased by 7:30 P. M. Where a stone fence or hedge afforded shade they began passing considerably earlier. They seem to make every effort to avoid exposing themselves to high temperature. Indeed, during the heated parts of the day the exposed soil becomes sufficiently hot to destroy them.

On reaching a field of succulent corn they congregate on the first few rows in sufficient numbers to blacken the stalks and to suck them dry of sap, and before the corn has become mature many of the outer rows of corn may be sucked dry and killed. Here the bugs feed until they reach maturity, when they rise on the wing and distribute themselves generally over cornfields and other sources of food supply. By the middle of July, at Manhattan, the females are depositing eggs, and eggs continue to appear until the middle of August. As in the spring, the eggs are deposited where the bugs habitually stay, and they are found between the leaf sheath and stalks of corn, cane and kaffir, in the leaf sheaths of grasses, and on the roots of weeds and grass in the corn, cane and kaffir fields.

From these eggs come the well-known tiny red bugs, which at once begin sucking the sap from the corn, cane or kaffir and from grasses in fields devoted to these crops. Here the young bugs continue to feed until the plants become too dry to serve as food. Usually by the time the supply of food is thus cut off most of the bugs are mature and the season is far enough advanced that they begin to seek winter quarters. At this time of year they sometimes concentrate on kaffir, which remains succulent much later than other crops of which they are fond. In some cases they have been known to attack and destroy early-sown winter wheat.

Although the chinch bug undoubtedly prefers certain species, all grains and grasses are used on occasion. Wheat, barley and corn are the ones most commonly attacked in this state, although millet and the sorghums are very acceptable. Of the last group, milo is usually the worst sufferer. Oats are sometimes attacked, but only when other foods are absent. If necessary, rice, rye, Bermuda grass, foxtail, timothy, blue grass, crab grass, bottle grass, and all wild grasses can be used. In Kansas the usual menu is about as follows: When just out of the winter quarters, wheat, barley, rye, oats, and occasionally corn and grasses are used, and when these sources of food supply give out in midsummer the bug turns to corn, sorghums, millet, crab grass, foxtail, bluestem, and other native grasses.

Life Cycle.

The time from the deposition of the eggs to hatching of the young bugs is variable, being longer if temperature is low or shorter if high. Riley[7] gives the average time under normal conditions as two weeks.

TABLE showing length of egg stage at different times of the year.

Date of deposition.	Number of eggs.	Average mean temperature.	Number of days.
6-13-'08	6	73.3°	18
6-16-'08	12	72.8°	18
6-19-'08	5	73.0°	16
Total	..	.....	52
Average for first brood	..	.....	17.3
8- 5-'08	3	78.1°	9.6
8- 6-'08	1	78.1°	10
8- 8-'08	9	77.7°	11.2
8-11-'08	16	77.8°	10.9
8-14-'08	5	74.5°	11.2
8-13-'08	6	73.3°	15.8
Total	..	.....	68.7
Average for second brood	..	.....	11.45
Average for both broods	..	.....	14.4

TABLE to show length of period from hatching to adult.

	Date of first hatching.	Date of first adult.	Number of days.	Average mean temperature.
First Brood.				
In field cage	5-22-'12	6-24-'12	33	70.6°
In wheat field	5-21-'12	6-14-'12	24	71.9°
Average	....	....	28.5	71.2°
Second Brood.				
In field cage	7-30-'12	9- 4-'12	36	.....
In corn field	7-16-'12	8-17-'12	32	.....
Average	....	....	34	.....

Thus it seems that the life cycle of the first brood from egg to adult, under known field conditions of temperature, is about forty-six days, and that of the second brood about the same.

7. Riley, C. V., 2d Rept. of the State Ent. of Mo., p. 22.

Number of Broods.

All students of the subject are agreed and all observations at this station thus far confirm the notion that the chinch bug produces two generations a year. At Manhattan the second or overwintering brood of adults appear during the latter half of August and early September and remain in the fields

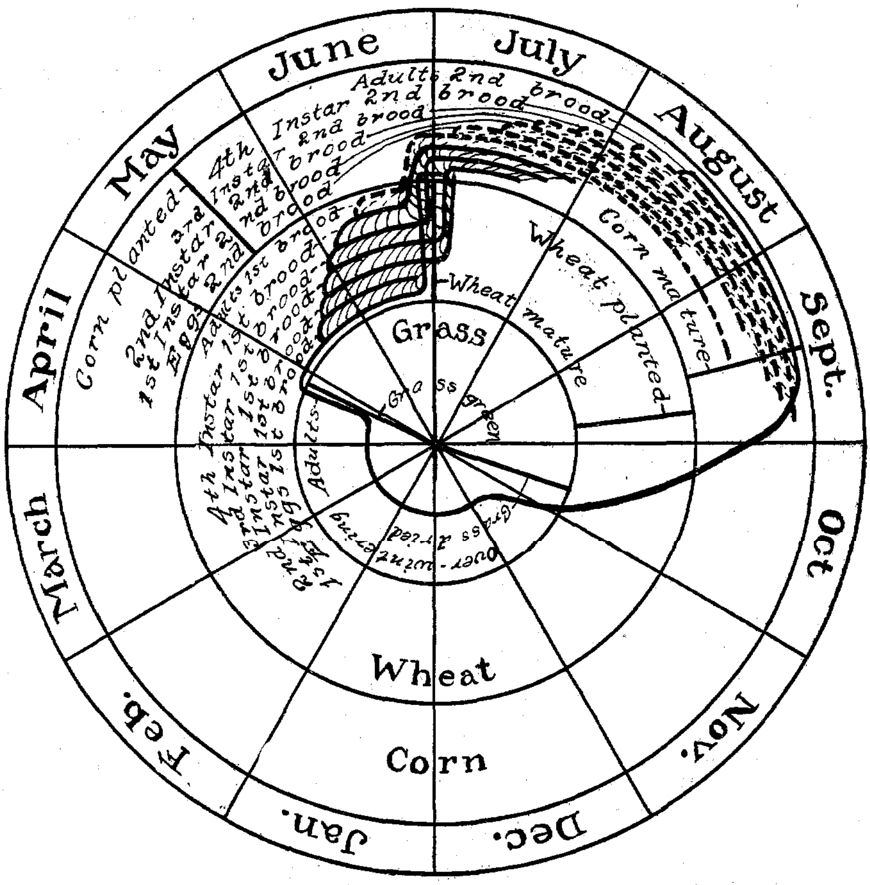

FIG. 7. Seasonal cycle of the chinch bug.

through the following June, or a period of ten and one-half months. The summer brood begins to appear about the middle of June and remains in the field to the middle of September, or a period of three months.

TABLE[8] showing succession of broods in the field at Manhattan, Kan, in the year 1912.

Stage of development.	Overwintered. Mo.	Overwintered. Da.	First brood. Mo.	First brood. Da.	Second brood. Mo.	Second brood. Da.
First mating	5	5	6	23	..	..
Maximum mating	5	28	7	24	..	..
Last mating	6	28	8	30	..	..
First death	5	2	6	30	..	..
Maximum death	6	21	8	22	..	..
Last death	7	5	9	12	..	..
First egg laying	..	..	5	14	7	6
Maximum egg laying	..	..	5	21	7	25
Last egg laying	..	..	5	26	8	23
First, 1st instar	..	..	5	21	7	16
Maximum, 1st instar	..	..	6	2	7	31
Last, 1st instar	..	..	7	5	9	20
First, 2d instar	..	..	5	24	7	23
Maximum, 2d instar	..	..	6	8	8	6
Last, 2d instar	..	..	7	17	9	29
First, 3d instar	..	..	5	27	7	29
Maximum, 3d instar	..	..	6	20	8	12
Last, 3d instar	..	..	7	22	10	10
First, 4th instar	..	..	6	4	8	5
Maximum, 4th instar	..	..	6	30	8	22
Last, 4th instar	..	..	7	30	10	22
First new adult	..	..	6	14	8	17
Maximum new adult	..	..	7	10	9	11
Last new adult	..	..	8	14	10	28

INJURY.

Nature.

Throughout its active life the chinch bug damages cultivated crops. It has no jaws, but it is furnished with a piercing and sucking beak, by means of which it pierces the rind of its food plants and sucks out their sap. It seems that thrusting the beak through the skin either directly or indirectly so kills the adjacent cells that a ring of dead tissue eventually surrounds each puncture. Of course, the damage done by the individual bug is negligible, but when, as is usually the case, great numbers work together, large damage results; the crop is always seriously shortened and sometimes completely destroyed.

8. This is the work of a very careful student assistant, Mr. H. Yuasa.

Extent.

In 1864 Shimer estimated the chinch-bug damage in the Mississippi valley at $100,000,000. In 1871 LeBaron estimated the damage in the state of Illinois alone as $10,500,000. Riley estimated the losses in Missouri in 1874 at $19,000,000. Thomas estimated the damage to corn alone in the year 1874 in the state of Illinois at $20,000,000. The same writer estimated the national loss in 1874 at $100,000,000. Qsborn estimated the 1887 losses in Iowa at $25,000,000. Howard re-

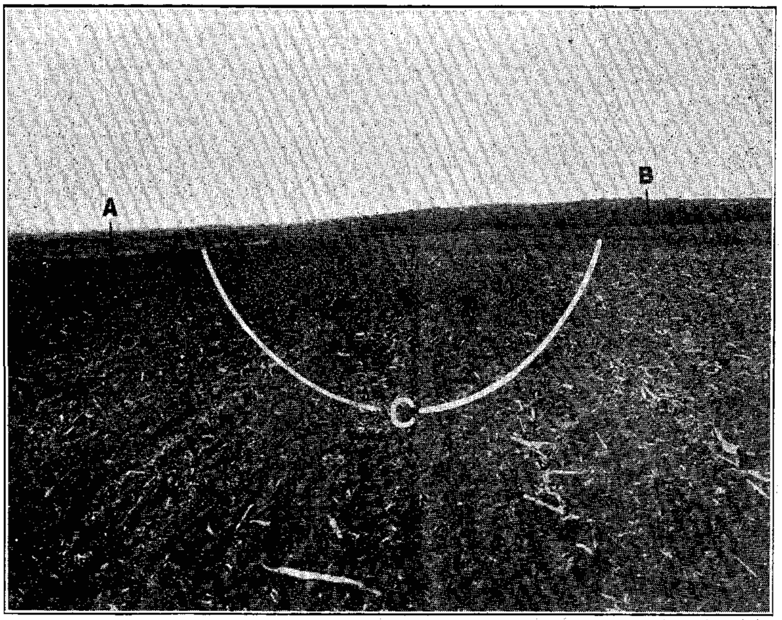

PLATE I. Chinch bug damage to unprotected corn. (A) Wheat field from which the bugs come. (B) Remainder of cornfield. (C) Corn destroyed by bugs.

ports the U. S. Department of Agriculture's statistician's estimate of chinch-bug losses in the states of Illinois, Indiana, Kansas, Kentucky, Minnesota, Missouri, Ohio and Wisconsin in 1887 as $60,000,000. Marlatt figures the average annual chinch-bug injury in the country at large at 2 per cent of the total corn crop and 5 per cent of the wheat, reaching in the year 1904 a total annual damage, to these two crops alone, of $40,000,000.

NATURAL CHECKS.

The checks to chinch-bug increase divide naturally into climatic factors and natural enemies.

Climatic Factors.

There can be no doubt that the climate has more to do with the limiting of the distribution and the numbers than any other of the environmental influences to which the chinch bug is subjected.

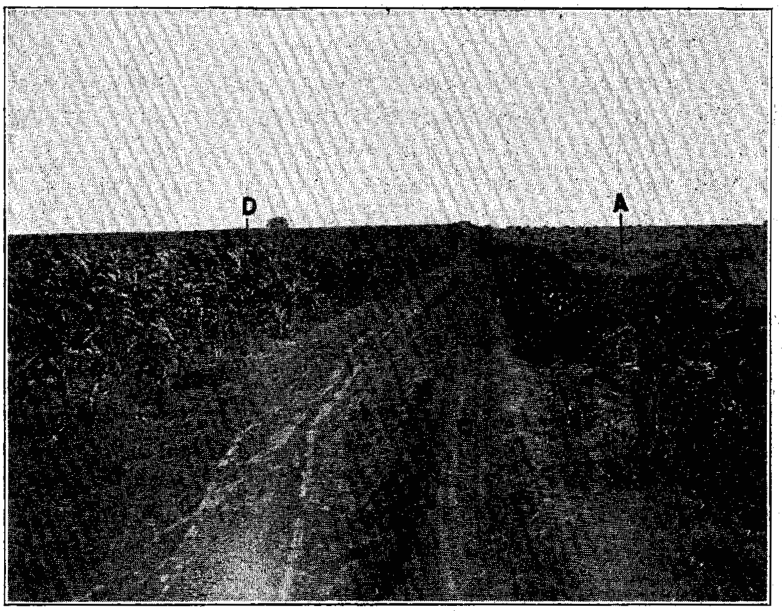

PLATE II. Corn protected by barriers from chinch bug injury. (A) Wheat field from which bugs come. (B) Backfurrow barriers. (C) Dust-furrow barriers. (D) Corn that was adequately protected.

Of all the factors of climate, temperature and moisture are the only ones that thus far have been shown to be active checks on the bug's increase.

TEMPERATURE.

In a cold-blooded animal like the chinch bug the rate of metabolism depends upon the temperature of the surrounding air.

If the temperature goes too high the bug's activity will decrease, and finally cease altogether, causing death. If the temperature goes too low the bug's activity will gradually decrease, and finally cease entirely. The highest temperature which the bug can undergo and yet live is said to be its maximum, and the lowest which it can stand is known as its minimum. Somewhere between the maximum and minimum temperatures is a temperature under which the bug can obtain its food and reproduce itself to the best advantage, and this temperature is known as the optimum. "Low temperature" will be used to designate temperatures ranging from the optimum downward to and below the minimum, while "high temperature" will mean those ranging from the optimum upward to and above the maximum.

Low Temperature. Low temperatures of the late fall and winter season reduce the activity of the bug to such an extent that the normal summer cycle of three months is extended to ten and one-half months. The effect of low temperature in lowering metabolism and lengthening life was shown in the course of some experiments in inoculation. Bugs kept in lantern-globe cages and supplied with the greatest abundance of young and growing wheat, under a relative humidity of almost saturation, perished in twelve days when subjected to a constant temperature of 90° F., in thirty days at 70° F., and less than half had died in forty-seven days at 50° F. Frozen clumps of bunch grass have frequently been brought from the field and allowed to stand outside where the temperature fell below 0° F. without any of the bugs perishing. Chinch bugs have been frozen in ice, and yet recovered when released.

High Temperature. As the temperature ascends from the optimum, it at first increases the metabolism, but later decreases, and finally stops it altogether. Temperatures above optimum, while they may be such as to increase the metabolism, will decrease the length of the life cycle and the number of young produced. As shown by the previously quoted experiment, bugs subjected to a constant temperature of 90° F., although furnished with the greatest abundance of their natural food and kept in a humid atmosphere, perish too quickly to effect reproduction. Forbes has shown that bugs are unable to withstand the heat in a dusty furrow during the hot parts of the day, and observations made as the bugs passed from wheat and other small grain to corn in 1911 and 1912 confirmed Forbes' conclusion, and showed that bugs knocked from the corn stalks upon the surface of clean cultivated land perished before they could reach shelter. During the harvest of 1912, where wheat was cut close to the ground millions of bugs were destroyed by being knocked to the hot ground. The temperature of the soil in these instances was about 132° F.

RECORDS of chinch-bug resistance to high temperature.[9]

Number of bugs.	Temperature in degrees F.	Length of exposure.	Number dead.
20	127.4	30 min.	20
20	119.3	60 min.	20
20	103	24 hrs.	20
20	102	24 hrs.	20
20	98	24 hrs.	19

The chinch bug responds to maximum of heat by avoiding it and undertaking the passage over unprotected soil only in the late afternoon or during cloudy, comparatively cool days.

MOISTURE.

In a general way, the chinch bug bears a relation to moisture similar to that which it bears to temperature. There are maximum, optimum and minimum relations, and in discussing these relations the terms "low" and "high" as applied to moisture have the same meaning as when applied to temperature.

Low Moisture. It is commonly thought by the general public and by students of the subject that dry weather can be counted a great aid to the chinch bug's wellbeing, and, within limits, our experience bears out this impression. On the other hand, it is difficult to see what factor or factors other than low moisture can be responsible for the absence of serious numbers of bugs in the extreme western part of our state. Four groups of twenty mature bugs were, early in July, 1910, placed in constant temperature incubators, as follows: One group, in a fine-wire gauze cage over a pot of good young wheat, was placed under a temperature of 70° F. and a relative humidity of 40 per cent; another at 70° F. and 60 per cent relative humidity; another at 70° F. and 80 per cent relative humidity another at 70° F and 100 per cent relative humidity.

9. On February 4, 1910, these bugs were taken from hibernation, raised to activity, enclosed in cotton-stoppered glass vials, and treated in an ordinary bacteriological incubator.

'The bugs under 40 per cent and 100 per cent relative humidity died more rapidly than those under either 60 per cent or 80 per cent; those under 60 per cent died less rapidly than those under 80 per cent—so 60 per cent relative humidity, of all the percentages tried, must be considered the most favorable to life economy of the chinch bug when living under a temperature of 70° F.

High Moisture. From the preceding experiment it seems that high relative humidity is directly unfavorable to the chinch bug, shortening its life. Heavy rains frequently bury eggs and young so deeply that neither the young which later hatch nor those already hatched are able to make their way out of the ground. Adult bugs seem rarely, if ever, to be destroyed directly by rains of any sort. High moisture, operating indirectly through supplying favorable conditions for the growth of its most powerful enemy, the chinch-bug fungus *(Sporotrichum globuliferurn* Speg.), is the most fatal of all climatic factors. So powerful is this factor that wherever high moisture conditions prevail during the growing season the chinch bug becomes a negligible factor in crop production.

Natural Enemies.

ANIMAL.

For an insect of such wide distribution and great abundance, the chinch bug has few natural enemies. No internal animal parasite is known to attack it. Seven different ladybird beetles are recognized enemies—the spotted ladybird *(Megilla maculata* DeG.), the trim ladybird *(Coccinella sanguinea* Linn.), *Hippodamia convergens* Guer., *Hippodamia glacialis* Fab., *Hippodamia 13-punctata* Linn., two species of *Scymnus,* and the lace-winged fly *(Chrysopa plorabunda* Fitch)—have been recorded as chinch-bug foes. The insidious flower bug *(Triphleps insidiosus* Say) and the many-banded robber *(Milyas cinctus* Fab.) have been known to destroy the pest. In two instances the junior author observed the adults of the false chinch bug *(Nysius angustatus* Uhl.) feeding upon the nymphs in the field. During the past year three ground beetles *(Hargalus compar* Lee., *Evarthrus sodalis* Lee. and *Anisodactylus harpaloides* Laf.) have been found feeding on chinch bugs of all ages. A centipede and a young cricket

(Gryllus sp.) were both observed feeding on adults. A small yellow ant *(Solenopsis* molesta Say) was often observed carrying chinch-bug eggs, and a little black ant *Monomorium mininzum.* Buckleyj was seen carrying bugs of all sizes. Bugs were often entangled in spider webs—sometimes as high as ten or twelve bugs in a web. The quail has long been recognized as the most important of the bird enemies of the chinch bug. Other feathered foes are the prairie chicken, red-winged blackbird, catbird, brown thrush, meadowlark, house wren, tree swallow, horned lark, and flicker.

PLANT.

GENERAL STATEMENT.

There can be no question that among the enemies of the chinch bug certain fungi stand preeminent. Two species of fungi—Entomopthora (Empusa) aphidis Hoffman and *Sporotrichum globuliferum* Speg.—are known to reduce its numbers.

HISTORY OF PREVIOUS WORK.

The discovery of the chinch-buy bacillus, and the investigation of its nature and efficiency, are the work of Forbes.[10] Further investigation was stopped by the discovery that it was normal to the insect and that similar bacteria are found in the corresponding appendages of a large number of other species of bugs.

In 1867 Sllimer,[11] of Mount Carroll, Ill., described an epidemic among chinch bugs, accompanied with a common white mold. His description is such as to render it reasonably certain that *Entomopthora* or *Sporotrichum,* or both, were present and probably the cause of the destroying plague.

About ten years later Thomas, at that time state entomologist of Illinois, supported Shimer's contention and advanced the idea that the fungus encouraged by moist weather destroyed the bugs.

In 1873 Le Contel[2] advanced the idea that a careful study of the fungoid diseases of insects might prove of great importance in insect control, and recommended careful consideration of them.

10. Forbes, S. A., 12th Rept. State Ent. Ill., pp. 45-53.

11. Shimer, Henry, Proc. Acad. Nat. Sci., Phila., 1867, vol. 19, pp. 75-80.

12. Le Conte, J. L., Proc. A. A. A. S., 1873, Pt. 2, p. 10.

In 1882 Forbes[13] observed the work of *Entomopthora* on chinch bugs, and in 1887[14] he found still another (*Sporotrichum globutliferum* Speg.), which has since become known as the most effective of all natural enemies.

The earliest attempt to use these two fungi in the field as a means of chinch-bug control was made by Lugger in Minnesota in 1888. At this time Lugger sent many packages of fungus-killed bugs to correspondents, and in summing up his results says, that while the disease appeared in parts of the state where the fungus was sent, it also appeared in parts where it was not introduced.

In 1889 Snow started a distribution of fungus-killed bugs among his farmer correspondents, that lasted several years. About fifty were sent out in 1889 and thirty-eight in 1890. The legislature of 1891 was sufficiently impressed with this method of killing chinch bugs that it passed a bill authorizing the establishment of an experiment station, under the direction of Snow, and making appropriations therefor. Small packages of diseased bugs were sent out to each applicant, accompanied by directions for the making and management of a contagion box, by means of which other bugs could be given the disease until enough for distribution in the field had been produced. From this laboratory small packages of diseased bugs were sent out as follows: In 1891, 1400; in 1892, 1848; in 1893, 3803; in 1895, 3006; in 1896, 2019. In 1894 fifty substations were established and diseased bugs furnished to about 15,000 farmers.

Most of the evidence advanced by Snow relative to the question of the value of this work of artificial distribution is drawn from the reports of farmers who received the fungus and applied it. This evidence is invalidated by the fact that the good results attributed to artificial distribution were in many cases unquestionably due to fungus already naturally in the field. The upshot of Snow's own carefully conducted experiments in the field, and of his observation and study to and including the year 1895, was to the effect that the chinch-bug fungus is always present to a greater or less extent in every locality, that dry weather results in a large increase in the number of the bugs without a corresponding increase in the

13. Forbes, S. A., 12th Rept. State Ent. Ill., pp. 53-57.

14. Forbes, S. A., 16th Rept. State Ent. Ill., pp. 46-49.

fungus, and that under such conditions the artificial distribution of the chinch-bug fungus will bring about the death of a greater number of bugs than would otherwise be possible. On pages 43 and 44 of his fifth report[15] occurs the following:

It is very probable that where *Sporotrichum* and *Empusa* are present serious epidemics may occur if certain conditions are present, These conditions we do not know exactly, but it is probable that the following tend to promote epidemics:

1. Humidity, resulting-

(a) From sufficient rain or cloudy weather.

(b) From conditions of soil or surrounding vegetation which tend to retain moisture.

2. Increased susceptibility of insects to diseases. This possibly may come about—

(a) From exhaustion after breeding, laying of eggs, etc., and the weakening of the insect at old age.

(b) From the weakening effect of unfavorable meteorological conditions.

(c) From the effect of otherdiseases or pathological conditions of some kind.

It is more than probable that *Sporotrichum* is always present to a greater or less extent in any locality, and that the amount of it depends primarily upon the number of chinch bugs and the condition of the weather.

Since dry weather favors the multiplication of the chinch bug and is detrimental to the development of *Sporotrichum,* the assumption seems reasonable that a series of dry years would result in an increase of chinch bugs without a corresponding increase of *Sporotrichum.*

In such an event we would conclude that the artificial introduction of *Sporotrichum* would result in the destruction of more bugs than would naturally occur.

In his next report he. presents the following summary of his whole work:

1. Chinch bugs in any of their stages of development scarcely run the slightest risk of death on account of heavy rains, even when these are of long duration. They are inconsiderably affected by extremes of heat and cold.

2. We know of no contagious bacterial disease of the chinch bug.

3, There are two parasitic, contagious fungoid diseases that kill chinch bugs, namely, *Sporotrichum globuliferum* ("white fungus") and *Empusa aphidis* ("gray fungus").

4. These two diseases show their greatest virulence where the ground is damp and shaded from the direct rays of the sun and the air is humid.

5. We do not know to what extent the spores of these diseases are normally present in any given region. When they are present, whether naturally or artificially introduced, and the weather conditions are as

15. Snow, F. H., 5th An. Rept. Dir. Kans. Uni. Exp. Sta.

given above, and the bugs are massed together, an outbreak of the diseases will occur. The number of chinch bugs killed in any field is approximately proportionate to the number of bugs in the field.

6. *Sporotrichum* can be artifically communicated to healthy chinch bugs.

(a) It attacks bugs of all ages, but the older the bug the more easily does it succumb.

(b) Bugs of any age that have been weakened from any cause, or injured, fall more easy victims to the disease than do those individuals that are in perfect condition.

(c) The adult of the second brood, which, in the ordinary course of events, winter over and lay the eggs for the brood of the succeeding spring, are much more successful in resisting the disease than are the adults of the first brood.

(d) The fungus is not active in winter, and, though it be present with the bugs in their winter quarters, they do not die of it, even though the winter be as mild and humid as was that of 1895-'96.

In 1891 Forbes began a series of experiments with the chinch-bug fungi to determine their value as a means of chinch-bug control. During each of the four years the spontaneous occurrence of the chinch-bug fungus *(Sporotrichum globuliferum* Speg.) was observed. During these years, for the purpose of determining the nature and value of this disease, he carried out 285 carefully conducted experiments. The work of the first two years was devoted mainly to laboratory study, and included only one field experiment. In 1893 special attention was devoted to experiments on methods of artificial introduction into the field. In 1894 a general program of field distribution was entered upon, and about two thousand were made. All data regarded as authentic by Forbes were collected by himself, his regular assistants, or by persons personally known to him as capable of doing the work, In 1894 he summarized his results (19th Rept. State Ent. Ill., pp. 27-29) as follows:

SUMMARY OF ECONOMIC RESULTS.

The principal economic outcome of this whole investigation may be thus briefly summarized:

1. White muscardine of the chinch bug is a contagious disease due to parasitism by the fungus species *Sporotrichum globuliferurn.* It affects a large number of other insects as well, and probably never dies out entirely over any large area of the state, but is always sufficiently prevalent and common under all conditions to furnish a suitable beginning for spontaneous spread wherever an insect species, like the chinch bug, becomes for a time superabundant under conditions favorable to the growth and reproduction of the fungus characteristic of this disease.

2. The conditions necessary to its appearance among chinch bugs on the epidemic scale are an abundance of the bugs themselves, and a considerable amount of wet weather, with not too low average temperature.

3. Its hidden presence among bugs, which as observed in the field seem to be wholly free from it, may often be demonstrated by shutting up such bugs for two or three days in a moist atmosphere; but, on the other hand, as this procedure often fails to develop it, it is not always and everywhere present.

4. Its characteristic fungus may easily be cultivated on certain mixtures of animal and vegetable substances, or on either of these substances alone—plain beef broth or simple agar-agar, for example. The cheapest and most satisfactory mixture thus far used is corn meal saturated with beef broth.

5 . . . .

6. Propagation of this fungus to living insects is easy if the atmosphere is kept moist. We have found as yet little, if any, reason to believe that the cultivated *Sporotrichum* is any less active as an agent of infection than that grown on the insect body. Its spores will germinate on the surface of infected insects, sending their thread-like outgrowths through the cuticle; but soft-bodied forms, like caterpillars, are, as a rule, more easily infected than those with a hard crust.

7. The distribution of the *Sporotrichum* in the field will have no immediate effect if the weather is dry, but spores may live in a dry state for many months, and may thus give origin to an outbreak of muscardine, if the weather changes, long after they have been distributed.

8 . . . .

9. The precise economic value of this method is not as yet, by any means, fully known. It seems to be in Illinois, at best, a means of hastening the appearance of the muscardine and of accelerating its spread among chinch bugs under favorable weather conditions; but how much it may actually hasten either the appearance or the spread semains yet to be ascertained.

We may say, in brief, that the agricultural effect of a chinch-bug attack is to hasten and intensify the evil consequences of drouth; and that the contagious disease of that insect here treated has merely the effect to hasten and intensify the beneficial consequences of wet weather.

In 1895-'96, in his next report, page 74, Forbes summarizes the whole matter of chinch-bug control by use of natural forces, as follows:

Economic Conclusions.

As a general result of these investigations, we certainly have no warrant for asserting that the natural agencies effective in reducing an extraordinary outbreak of the chinch bug can now be definitely controlled by us for economic ends. So far as ascertained, the final causes of unusual natural destruction of this insect are meteorological ; and until the weather of the season, or even of the year, can be foretold with approximate definiteness and certainty, we can not forecast the course of events with respect to injuries by the chinch bug. Economic entomology must wait at this point upon meteorology. Whether the fungi of contagious disease can be artifically made use of to hasten or intensify the serviceable effects of favorable weather, with a frequency or to an extent to make this procedure economically worth while, I am not yet prepared to say. The methods of distributing these fungi in the field have hitherto been too crude to make their substantial failure conclusive as to the whole subject. It now seems quite clear that they can at best be used only as secondary to other measures, especially the midsummer measures described in the third article of this report. If applicable at all, however, they can be brought to bear at a point now entirely defenceless; and it seems the duty of the American economic entomologist to spare no pains to investigate to a final indisputable conclusion anything which promises so much as a remote possibility that the chinch bug may be attacked even to occasional advantage after it has settled itself in fields of small grain.

In 1889 Webster began a study of one of the chinch-bug fungi *(Entomopthora)* at Lafayette, Ind. In the course of these studies he tested the effect of atmospheric moisture and temperature on the growth of the fungus and the effect of varying weather conditions on its efficiency. He found that to be effective the fungus must have an abundance of atmospheric moisture and a massing of the bugs. Later, as an officer of the Ohio Agricultural Experiment Station, Webster distributed the chinch-bug fungi in Ohio, as did Lugger in Minnesota, Snow in Kansas, Forbes in Illinois, Brunner in Nebraska, Stedman in Missouri, and Osborn in Iowa. Still later, as a member of the Bureau of Entomology, we find him making the following general statement:[16]

Regarding the practicability af utilizing these entomogenous fungi in agriculture, there seems no reason to revise a statement made ten years ago, viz.: that this can be done only in cases of excessive abundance and during wet weather, the basis for infection being provided by some central propagating station from which farmers can receive promptly an abundant supply. The writer believes that, for himself, he could manage to get considerable benefit from their use in destroying chinch bugs, provided he were located within the area of the frequent occurrence. This could only be done by watching the seasons carefully, and in case there should occur two years in succession wherein the breeding periods were covered by drouth, then every preventive measure known should be adopted, notably, the burning of leaves, dead grass, and other rubbish during winter or early spring, followed by the sowing of small plats of early millet, Hungarian grass, or, better yet, perhaps, spring wheat, in low, damp places in the fields with a view of attracting the females or in fact massing the

16. Bul. No. 69, N. S., Bu. of Ent., U. S. Dept. of Agri., p. 58.

bugs, and then freely applying the fungi in their midst. Whether the average farmer, with his somewhat crude ideas of entomology, can do this successfully or not is very uncertain. It is almost impossible to determine even a few weeks in advance whether a season is to be favorable or unfavorable to the development of the chinch bug, which would of itself cause occasional false alarm, and the precautionary measures rendered entirely unnecessary by a few timely drenching rains just at the critical time. Before we can expect to be eminently successful in this matter, not only the farmer but also the entomologist and meteorologist have much to learn,

In 1910 the University of Kansas authorized an investigation of the value of artificial distribution, of the chinch-bug fungus (*Sporotrichum globuliferum* Speg.), with the idea of contributing to the settlement of this much-vexed question. This experimental work was placed in charge of F. H. Billings and P. A. Glenn, and was prosecuted during the single season of 1910. The conclusions' of these workers are presented herewith:[17]

1. The chinch-bug fungus is present naturally in fields everywhere throughout the infested area in Kansas.
2. It is present in such great abundance that any artificial distribution of infection in the field would be too insignificant, by comparison, to be of practical use.
3. Its distribution naturally through a field is much more uniform than any artificial distribution can be made.
4. The amount of fungus used experimentally in both wheat and corn fields was so far in excess of any that would be used by the farmer in infecting his own fields that he could not reasonably expect to succeed.
5. The fungus shows little tendency to spread from centers of artificial infection. The apparent rapid spread of the fungus is due to favorable conditions bringing it into activity simultaneously over considerable stretches of territory.
6. In fields where the natural presence of the fungus is plainly evident its effect on the bugs can not be accelerated to any appreciable degree by the artificial introduction of spores.
7. In fields where the fungus is not in evidence, spores introduced artificially have no measurable effect.
8. Apparent absence of fungus among chinch bugs in a field is evidence of unfavorable conditions rather than lack of the fungus spores.
9. All the benefits of the *Sporotrichum* disease of chinch bugs may be realized by merely letting the fungus naturally present in the soil do the work of extermination as far as it will.
10. Moisture conditions have much to do with the appearance of chinch-bug disease in a field; artificial infection nothing.

17. Billings, F. H., and Glenn, Pressly A., Bul. No. 107, Bu. of Ent., U. S. Dept. Agri., p. 45.

11. Spent adult chinch bugs succumb to attack more readily than younger ones, but as the old bugs have finished depositing their eggs, their loss by fungus disease accomplishes little else than increasing the amount of the infectious material.

12. Laboratory experiments can be made to prove that artificial infection accomplishes results upon bugs confined in cramped quarters and without food, but in the field, where fresh and usually drier air prevails and food is abundant, an entirely different situation is presented.

13. Advocating artificial infection, or encouraging it by sending out diseased chinch bugs, does not serve the best interests of the farmer, since his attention is thus diverted from other and more efficient methods of combating the pests.

14. The reported successes of former years on the part of farmers are believed to be due to the following causes: (1) Failure to recognize spontaneous outbreaks of the disease because of previous artificial sowing of infection, and also failure to use check, or untreated, fields as a basis of comparison, thus claiming the outbreak as directly due to artificial infection; (2) failure to distinguish the skins of moulted bugs from dead bugs; (3) mistaking the scattering of chinch bugs in cornfields for evidence of their death by fungous disease, when carcasses were not present as proof.

CONCLUSIONS DRAWN FROM PREVIOUS WORK.

Thus it appears that all this investigation and experiment serves to show that the chinch-bag fungi in the presence of abundant atmospheric moisture, summer temperature, and a great abundance of bugs produce great epidemics that sweep the pest away ; that these epidemics arise in regions where the fungus has never been artificially disseminated as well as in regions where it has at some time been distributed; that artificial distribution is of doubtful value even under the most: favorable conditions; that the chinch-bug fungi, if present even in greatest abundance, are utterly powerless to destroy bugs in dry or cold weather; and that the fungus has always been very widely disseminated over that part of the United States subject to serious chinch-bug injury.

The fact that all the states whose officers participated in these chinch-bug fungus experiments have discarded the artificial distribution of the fungi as a means of chinch-bug control, clearly shows that later experiments has only borne out the unfavorable report of earlier workers.

WORK AT THIS STATION.

In giving an account of our own studies of chinch-bug plant parasites, it should be said that we have found *Sporotrichum* *globuliferum* Speg. not only the prevailing but almost the only form. The grayish *Entomopthora* has only rarely been recognized.

Artificial Distribution by Farmer Correspondents.

For the purpose of showing the type of evidence on which claims for the efficacy of artifical distribution usually rests, we will review our experience during the year 1910. Beginning April 7 and running to September 21, we sent out 193 cultures of the fungus and 589 packages of diseased bugs. Of the 307 persons who described their experience with the fungus, 21 were uncertain, 87 were successful, and 148 unsuccessful.

Seventeen of the persons who claimed to have had success with the fungus gave more or less of explanatory comment, the types of which we reproduce:

L. R. TREGO, Winfield. Weather very favorable.

JOHN A. BURKE, Harper. Fairly effective, though weather was dry.

S. W. BENNETT, Geneseo. Had splendid success.

C. H. CREGO, Sterling. Good success in both cane and corn.

JOHN MUSTARD, Houston. Bugs disappeared while neighbors had plenty of them.

HENRY WEBER, Reamsville. Gave about twenty-four neighbors some of diseased bugs, and they all had good success.

ALVA EVANS, Luray. Best of success, though weather was very dry.

C. E. PLYMIRE, Beloit. Bugs were not so plentiful after distributing diseased bugs.

J. C. MANSPEAKER, Mount Ida. Bugs died in a day or two after distributing diseased bugs.

C. E. HALL, Scandia. Short time after distribution of diseased bugs all disappeared.

Of the unsuccessful ones who gave explanatory comment, 42 laid their lack of success to dry weather; 16 to the disappearance of the bugs before or just about the time the fungus was introduced; 11 to the presence of fungus already in the field at the time of introduction; 9 to failure to inoculate bugs in contagion box; 7 to inability to give fungus a fair trial, and 1 to the falling of heavy rains at the time of introduction.

The comments of the persons claiming success for artificial distribution of the fungus are mostly statements of opinion, and, in so far as they throw any light on the matter, show that something other than the fungus may have been at work.

This is true because (1) the mere disappearance of the bugs is not good evidence of their death by fungus, the only conclusive evidence being the presence of their carcasses covered with it; (2) fungus destruction of the bugs following within a few days after artificial introduction simply shows that the introduced fungus is not responsible, because a considerable time must elapse before the introduced fungus can get started. To obtain conclusive evidence of the value of artificial introduction one must (1) select a part or the whole of a field of wheat, oats, millet, corn or sorghum in such a way that all parts are at the time and will remain equally dry, and that all parts shall have exactly the same size and type of growth; (2) introduce the fungus over about one-half of the chosen area; (3) keep daily watch on the number of chinch bugs that die from fungus on the treated and untreated parts of the chosen area. If the number of bugs dying with the fungus on the treated area be much greater than that on the untreated, the difference can be fairly assigned to the work of artificially introduced fungus. None of the explanations show that experimenters have conformed to these elementary rules of evidence-getting. These facts, taken with the record of the ill success of 70 per cent of all who reported, do not give us ground for belief in the efficacy of artificial distribution of the chinch-bug fungus as a means of controlling the chinch bug. Yet this is the type of the evidence on which claims for its efficiency have been and are yet mainly based.

Statement of the Problem.

There can be no question as to whether the chinch-bug fungus *(Sporotrichum globuliferum* Speg.) will, under favorable conditions, destroy chinch bugs, for all students of the subject are agreed that it will. The question is merely whether by artificial distribution of the fungus, chinch-bug attack can be materially checked and controlled. The solution of the problem involves a complete knowledge of the life economy of the chinch-bug fungus in relation to its environment, of which the chinch bug is just one element, and a complete knowledge of the chinch-bug life economy in relation to its environment, of which the chinch-bug fungus is just one element. To summarize the whole matter, we may say that at present the complete life economy of these organisms, particularly the chinch-bug fungus, is not understood, and that until it is no final solution of this problem is possible.

Life Economy of the Chinch-bug Fungus.

It is with this thought in mind, and for the purpose of contributing to our knowledge of its life economy, that the study of the chinch-bug fungus was taken up at this station.

Field observations during 1908, 1909, 1910, 1911 and 1912 in all parts of Kansas seriously infested by chinch bugs have never failed to reveal bugs killed by the chinch-bug fungus. Whether in wheat, corn, or winter cover, whether in wet season or dry season, where the bugs are, traces of the fungus are to be found.

What, then, is the life economy of the chinch-bug fungus in the fields of Kansas? The answer to this question involves the solution of some very knotty problems, such as the effect of largely varying elements of Kansas climate on the metabolism of the fungus, the hosts which it uses, and the activity and efficiency of its natural enemies.

Relation to Climate.

Temperature, moisture and light appear to be the only factors sufficiently variable to be likely to produce marked changes in the fungus' activity, and are therefore the only ones that have received consideration.

TEMPERATURE. Field temperatures may influence the fungus in two ways—the extremes may cripple and destroy it, and the optimum encourage and further its growth.

Careful laboratory studies at this station have shown that the exposure of spores of the fungus to 104° F. to 105° F. in a saturated atmosphere for twenty-four hours does not prevent strong growth, that an exposure for forty-eight hours destroys most of the spores, and that an exposure for seventy hours does not kill them all. Spores allowed to develop for forty-eight hours, and then exposed to this temperature and moisture, perish. Spores previous to germination, in a comparatively dry atmosphere, may be exposed for five hours to as high as 209° F. without injuring the germination.

Spores, dry or wet, may be exposed over night to low temperature, even when the mercury reaches as low as —18° F., without apparent injury. Spores freshly sown were exposed to changing temperatures from January 5 to February 12, during which time the temperature changed from freezing to thawing, or *vice versa,* twenty-one times—the daily mean was below 32° F. for nine days, and the minimum temperature -15° F.—without injury. Growing fungus threads subjected to repeated freezing and thawing temperatures are not destroyed.

While these facts render it quite possible that the fungus growth, encouraged by moist, cool weather in exposed and cultivated fields, might be destroyed by succeeding hot weather, for the exposed dusty soil will reach about 135° F. at the surface, it is very unlikely that the ordinary foci of the disease, sheltered as they are beneath heavy growth of weeds and grass, would be even seriously injured, for in such location the temperature rarely or never reaches 91° F. It is not likely that the fungus, even in cultivated fields, would be eradicated by dry, hot weather, because while exposed mycelium would perish, the dry spores can withstand far higher temperatures than they would experience, and in the process of cultivation much of the fungus must be thrown beneath the surface of the ground, where the temperature rarely exceeds 100° F. The following table shows the maximum temperatures in places where the fungus often develops, while the maximum temperature in the shade was above 100° F.

In view of the fact that the maximum air temperature of the last twenty-five-year period at Manhattan has been 113° F. and the minimum —35° F., it does not seem probable that extremes of temperature such as the fungus is likely to experience .in Kansas will ever seriously reduce, not to say eradicate it.

On beef-broth agar the fungus makes good growth at 70° F. and 80° F., less vigorous growth at 90° F., and no growth at all at 50° F. and 100° F. The growth comes a little more quickly at 80° F. than at 70° F., but it seems to be a little heavier and more vigorous at 70° F. than at 80° F. The optimum temperature for its growth and spore production on this medium is therefore between 70° F. and 80° F., probably about 75° F.

As might be expected, the temperature for best growth on chinch bugs is the temperature for best growth on this medium. Only three temperatures were given careful trial—

Location of Thermometer.	July 27—Hour p. m. 2:30	3:00	3:30	4:00	4:30	July 28—Hour p. m. 1:30	2:00	2:30	3:00	3:30	4:00	July 30—Hour p. m. 2:00	2:30	3:00	3:30	4:00	4:30
1. In sheath of corn	94	95	94	94	93	96	97	97	97	94	87	90	91	92	98	97	96
2. Under pile of corn ears and stalks	91	91	90	90	87	85	85	84	86	86	85	84	85	86	85	85	87
3. Under pile of mowed grass	83	83	82	82	88	82	87	82	82	81	81	86	87	81	79	79	78
4. Bunch of grass along a dried creek bottom	80	81	81	80	80	83	83	83	85	81	80	82	79	82	81	83	82
5. On surface of dusty ground	131	129	124	120	116	126	128	129	123	104	92	124	123	121	117	114	109
6. In bunch of grass	92	89	87	87	85	89	91	91	90	86	83	89	89	88	87	88	84
7. Air in direct sunshine four feet from ground	105	102	102	103	104	103	102	103	100	97	..	98	98	98	98	99	99
8. At three inches below surface of ground in plowed field	97	99	100	101	102	95	96	97	98	99	99	90	91	92	93	94	95
9. At six inches below surface	96.5	98	99	100	101	93.5	95	96.5	98	99	99	90	91	92	93	95	96

Location of Thermometer.	July 31—Hour p. m. 2:30	3:00	3:30	4:00	4:30	September 5—Hour p. m. 2:00	2:30	3:00	3:30	4:00	4:30	5:00	September 6—Hour p. m. 2:30	3:00	3:30	4:00	4:30	5:00
1. In sheath of corn	94	94	94	95	94	86	88	89	89	90	93	90	90	92	91	93	98	99
2. Under pile of corn ears and stalks	84	84	85	85	84	82	83	81	80	83	83	82	83	84	84	84	84	84
3. Under pile of mowed grass	80	79	80	80	78	80	80	80	79	79	78	78	79	80	80	79	78	78
4. Bunch of grass along a dried creek bottom	84	81	83	81	80	81	80	80	79	79	79	78	82	81	80	80	80	80
5. On surface of dusty ground	126	124	117	114	109	125	122	120	115	111	106	101	129	127	122	117	112	108
6. In bunch of grass	92	87	88	87	86	81	79	81	81	78	78	77	79	78	77	77	77	77
7. Air in direct sunshine four feet from ground	101	101	101	100	99	99	99	101	100	100	100	98	103	102	100	100	101	100
8. At three inches below surface of ground in plowed field	93	95	96	97	97.5	94	95	96	97	97.5	98	97	93	95	96	97.5	98	97.5
9. At six inches below surface	92	94	95	96	97	93	94	96	97	97.5	97.5	98	92	94	96	97	98	98.5

50° F., 70° F., and 90° F. The bugs succumbed to the disease most readily in 70° F.

In general, the average mean temperature in this state is such that the fungus can grow well from April to October, while it is more or less completely dormant from October to April.

MOISTURE. Moisture of two sorts appears to influence the growth of the chinch-bug fungus—relative humidity and water.

The fungus will not grow in a relative humidity of 90 per cent or less, but will remain dormant for an indefinite period. We have kept it in dried corn-meal culture for more than eighteen months, and found it perfectly virile at the end of that time; found it would grow readily and would destroy chinch bugs. It is hardly conceivable that the chinch-bug fungus could have too much moisture in a state of nature. Dashing and washing rains might carry much of it away, but would serve merely to distribute it, and enough would in all probability be left to carry the disease on. The best degree of moisture for germination seems to be a film of water, although germination will take place in a relative humidity of a little less than 100 per cent.

These facts indicate that while the fungus can not grow in dry weather, it is unlikely to be eradicated by any extreme of moisture it is likely to experience in Kansas. As a matter of fact, this agrees with universal experience with this fungus. It thrives in wet weather, disappears during dry periods, and springs up again on the advent of sufficient moisture.

LIGHT. General germination of the spores in a film of water required, under a temperature of 75° F., twelve days, while subjected to the normal daylight coming through north windows, and when in complete darkness germination became general in one day less. In a confirmatory experiment general germination was made simultaneously in thirteen days. Ordinary daylight is thus shown not to be seriously hostile. This also is borne out by field experience.

Relation to Hosta.

The chinch-bug fungus can live on a great number of different hosts. In the course of laboratory studies, Forbes[18] found that the following insects could be artificially given the

18. Forbes, S. A., 19th Rept. Sta. Ent. Ill., pp. 33-60.

chinch-bug disease with fatal results: saw-fly larvae, cabbage worms, plant lice, fall web worms, caterpillars of the genus *Hemaris,* grasshoppers, *cecropia* moths (experiment does not show conclusively that the fungus killed the moths, but it does show that it grew on their bodies after death), and caterpillars of the genus *Datana.*

Billings and Glenn[19] found the fungus growing on the common snout beetles *(Trichobaris texana* Lec., *Conotrachelus erinaceus* Lec., and *Anthonomus fulvus* Lee.), a common flea beetle *(Disonycha triangularis* Say), a common lady beetle *(Hippodamia convergens* Guer.), a minute beetle of the genus *Olibrus,* three species of true bugs (one an undetermined bug of the family Phymatidae, *Microtoma carbonaria* Rossi, and *Coriscus ferus* Linn.), and also on many common pentatomids.

In the course of field work of the last two years, the chinch-bug fungus has been found on chinch bugs, on the larvæ of the corn-ear worm *(Heliothis obsoleta* Fab.), the larvæ of the codling moth *(Cydia pomonella* Linn.), the potato beetle *(Leptinotarsa decemlineata* Say), red-legged grasshoppers *(Melanoplus femur-rubrum* DeG.), dung beetle *(Aphodius* sp.), leaf hopper (Jassidæ), a stink bug *(Thyanta custator* Fab.), a flea beetle *(Disonycha collaris* Fab.), a snout beetle (Curculionidæ), ladybird beetle *(Megilla maculata* DeG.), stink bug *(Solubea pregnax),* a small beetle (Cucujidæ), a cricket *(Gryllus* sp.), striped cucumber beetle *(Diabrotica vittata* Fab.), a ground beetle *(Lebia bivittata* Fab.), a bug *(Coriscus punctipes* Rent.), a snout beetle *(Dorytamus* sp.), the carpenter ant *(Cumponotus pennsylvanicus* DeG.)., a pupa of *cecropia* moth *(Samia cecropia* Linn.), a noctuid pupa, a differential locust *(Melanoplus differentialis* Thos.), plum curculio *(Conotrachelus nenuphar* Herbst.), a wild bee *(Chloralictus illinoiensis* Rob.), a May beetle *(Lachnosterna* sp.)., house-fly puparia *(Musca domestica* L.), a larva of a sphinx moth (Sphingidæ).

The study of this question by means of field collections during the spring of 1912 shows that fungus-killed insects other than chinch bugs are mainly species that share the winter quarters of the chinch bug.

19. Billings, F. H., and Glenn, P. A., Bul. No. 107, Bu. of Ent., U. S. Dept. of Agri., p. 20.

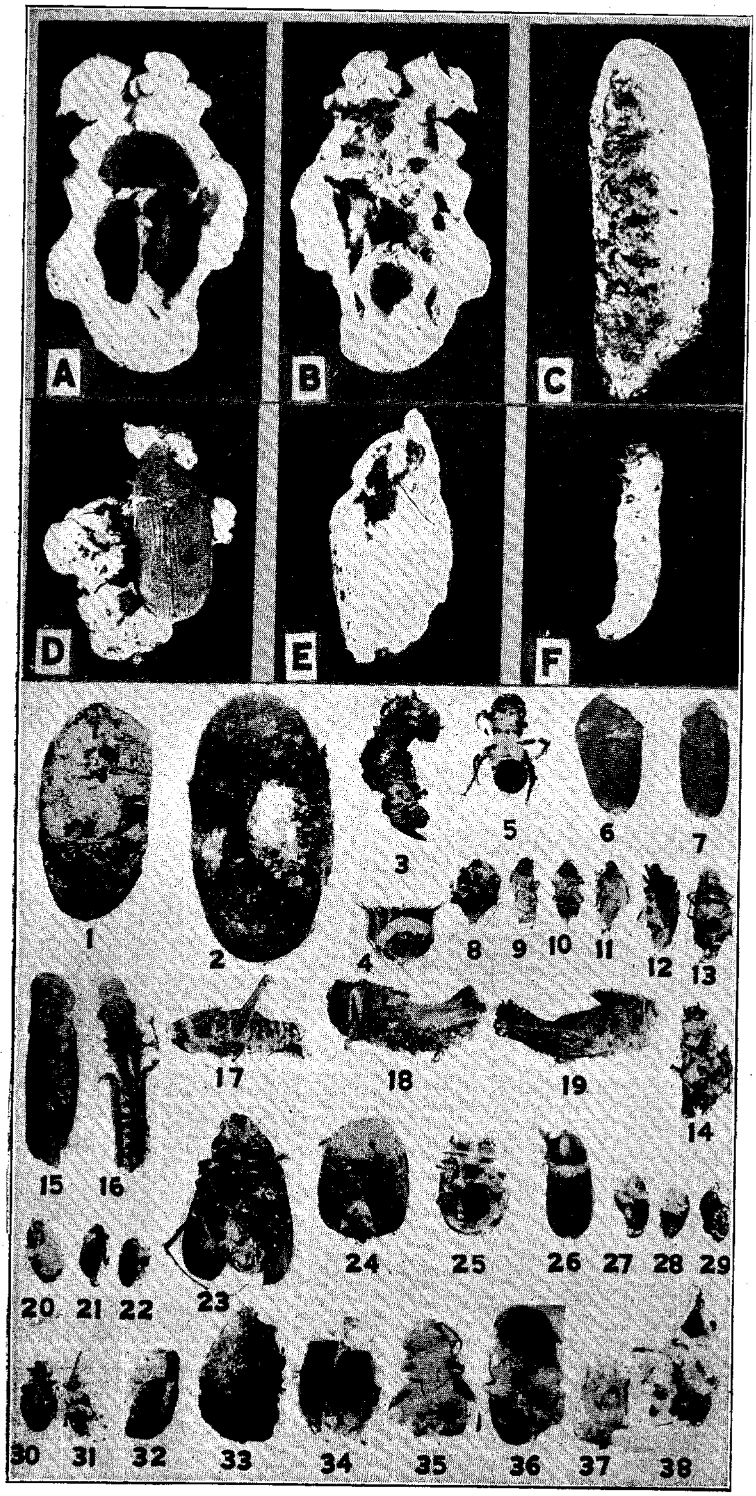
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PLATE III. (A) A beetle (*Nitidula* sp.). (B) Ventral view of same specimen. (C) Larva of the codling moth (*Cydia pomonella* Linn.). (D) *Trichobaris texana* Lec. (E) Undetermined. (F) Larva of the corn-ear worm (*Heliothis obsoleta* Fabr.). (1) Pupa of the cecropia moth (*Samia cecropia* Linn.). (2) Cocoon of the cecropia moth. (3) Larva of the sphinx moth (Sphingidæ). (4) Larva of the corn-ear worm (*Heliothis obsoleta* Fabr.) on a velvet leaf (*Abutilon avicennæ* Gærtn.) pod. (5) Wild bee. (6 and 7) Puparia of the house fly (*Musca domestica* Linn.). (8) A stink bug. (9-11) Chinch bugs (*Blissus leucopterus* Say). (12 and 13) Stink bugs (Pentatomidæ). (14) A cricket. (15) A grasshopper (*Melanoplus* sp.). (16-19) Grasshoppers (*Arphia* sp.). (20) Chinch bug. (21) A dung beetle (*Aphodius granarius* Linn.). (23) A May beetle. (24 and 25) A Colorado beetle (*Leptinotarsa 10-lineata* Say). (26) An engraver beetle (Scolytidæ). (27) A flea beetle. (28) Undetermined. (29) A scarabæid. (30) A striped cucumber beetle (*Diabrotica vittata* Fab.). (31) A snout beetle (Curculionidæ). (32-33) Plum curculios (*Conotrachelus nenuphar* Hbst.). (34) A ladybird beetle (*Megilla maculata* DeG.). (35) A leaf hopper (Jassidæ). (36) Circulionid (*Dorytamus* sp.). (37) A flea beetle (Chrysomelidæ). (38) A ground beetle (*Lebia bivittata* Fab.).

In the course of laboratory tests, working with the inoculation of sterile cultures, we have grown the fungus on corn blade, corn tassel, split cornstalk, corn silk, corn cob and grains of corn, soil from ground about bases of cornstalks, shed elm leaves, oat stems, stems and leaves of bunch grass, and mulch from clumps of bunch grass. Field observation and collection have shown it growing on stems of bunch grass, rotten wood on under side of fence posts, sunflower stem, weed stub, cottonwood bud and cornstalk. In none of these cases, except where growing on corn grains and rotten wood, has the growth been vigorous. Spores are produced abundantly on the corn, but in small numbers or not at all on other substances. It thus appears that the chinch-bug fungus has a wide range of hosts other than the chinch bug, but that animal tissue offers the fungus more encouraging conditions for growth than does plant tissue. It also appears that with such a range of hosts the fungus would be unlikely to starve out.

Relation to Natural Enemies.

Although the growth of the fungus is interfered with in contagion boxes by the activity of a small mite and perhaps by the accumulation of too great bacterial life and other fungous life, we have never seen any evidence in the field of the operation of any such limiting factors.

Field Study.

Beginning early in the spring of 1912, a careful effort was made to determine the distribution of the fungous foci about Conway Springs. The tabular statement of collections which follow will serve to show the variety of the situations in which the fungus was found, and the map, which also follows, will show the distribution of these foci.

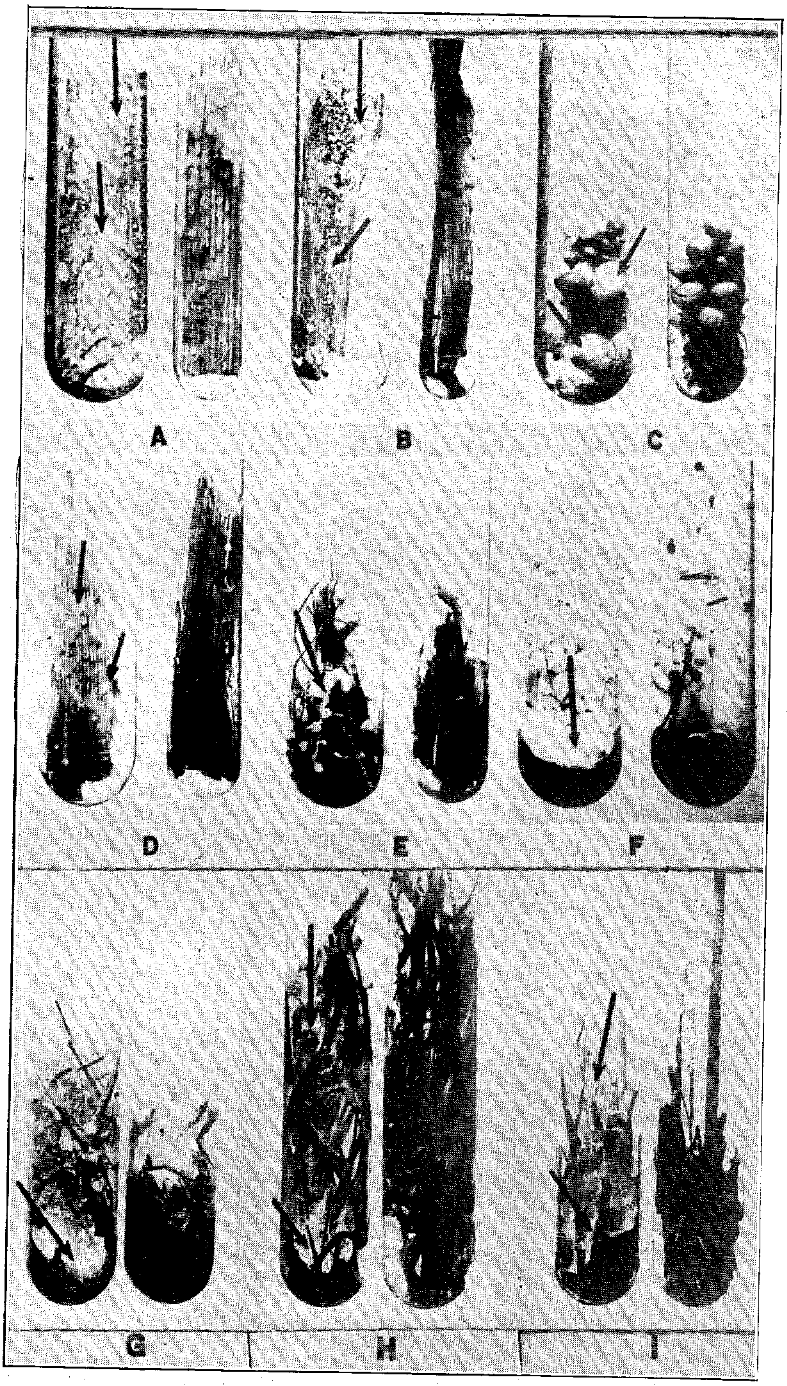


PLATE IV. Common substances on which the chinch-bug fungus grows. The left-hand tube of each pair is the one inoculated, the right one is the check. The arrow points indicate the fungus. (A) Split cornstalk. (B) Base of corn leaf. (C) Ripe corn on cob. (D) Corn husk. (E) Corn silk. (F) Soil from about base of cornstalk. (G) Sunflower stem. (H) Stem of big bluestem grass. (I) Mulch from base of bunch grass.

Specimen No.	Date of collection.	Remarks.
1	4- 8-'12	Stem of bunch grass (*Andropogon scoparious* Mich.), showing a white growth of chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken along Slate creek.
2	4- 8-'12	Chinch bugs (*Blissus leucopterus* Say) covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.), taken under cottonwood leaves (*Populus deltoides* Marsh) along Slate creek.
3	4- 9-'12	Grasshopper (*Melanoplus femur-rubrum* DeG.) three-fourths covered with a white growth of the chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken along Slate creek.
4	4- 9-'12	Bunch-grass stem (*Andropogon scoparious* Mich.) with white growth of chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken along Missouri Pacific right of way.
6	4-10-'12	Chinch bugs (*Blissus leucopterus* Say) covered with the chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cottonwood leaves (*Populus deltoides* Marsh) along Slate creek.
7	4-10-'12	Small beetle (*Aphodius* sp.) about half covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under a board along the roadside.
8	4-10-'12	Chinch-bug fungus (*Sporotrichum globuliferum* Speg.) on rotten wood on under side of a fence post along a roadside.
9	4-10-'12	Chinch bugs (*Blissus leucopterus* Say) practically covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); found under cottonwood leaves (*Populus deltoides* Marsh) along Slate creek.
10	4-10-'12	Chinch bugs (*Blissus leucopterus* Say) practically covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); found under cottonwood leaves (*Populus deltoides* Marsh) along Slate creek.
11	4-10-'12	Chinch bugs (*Blissus leucopterus* Say) attacked by the chinch-bug fungus (*Sporotrichum globuliferum* Speg.); found in the shell of a cottonwood bud (*Populus deltoides* Marsh) along Slate creek.
12	4-10-'12	Leaf hopper (Jassidæ) practically covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cottonwood leaves (*Populus deltoides* Marsh) along Slate creek.
13	4-10-'12	Chinch bugs (*Blissus leucopterus* Say) attacked by the chinch-bug fungus (*Sporotrichum globuliferum* Speg.); found in earthworm burrows (*Lumbricus terrestris*) along Slate creek.
14	4-10-'12	Pentatomid (*Thyanta custator* Fab.) about one-third covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.), and also a gray fungus (*Entomopthora*); taken under cinders.
15	4-10-'12	Flea beetle (*Disonycha collaris* Fab.) well covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cottonwood leaves (*Populus deltoides* Marsh) along Slate creek.
16	4-10-'12	Curculionid practically covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cottonwood leaves (*Populus deltoides* Marsh) along Slate creek.
17	4-11-'12	Lady beetle (*Megilla maculata* DeG.) half covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in an earthworm burrow (*Lumbricus terrestris*) along Slate creek.
18	4-18-'12	Stink bug (*Solubea pregnax*) one-fourth covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in bunch grass (*Andropogon scoparious* Mich.) along roadside.
20	4-10-'12	Chinch-bug fungus (*Sporotrichum globuliferum* Speg.) on rotten wood on under side of fence post along a roadside.
21	4-18-'12	Small beetle (Cucujidæ) one-fourth covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under osage orange leaves (*Toxylon pomiferum* Raf.) along hedge.
22	4- 9-'12	Sunflower stem (*Helianthus annus* L.), showing a white growth of chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in a patch of bunch grass (*Andropogon scoparious* Mich.)
23	4-16-'12	Pupa case, probably of noctuid, with small amount of chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under osage orange leaves (*Toxylon pomiferum* Raf.) along hedge.
24	4-17-'12	Cricket (*Gryllus* sp.) with a small amount of chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cinders along railroad.
25	4-17-'12	Weed stub with a white growth of the chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken along railroad.
26	4-17-'12	Striped cucumber beetle (*Diabrotica vittata* Fab.) one-third covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cinders along railroad.
28	4-17-'12	Chinch bugs (*Blissus leucopterus* Say) with grayish fungus (*Entomopthora aphidis* Hoffm.); taken under cinders along railroad.
29	4-17-'12	Ground beetle (*Lebia bivittata* Fab.), showing a little chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cinders along railroad.

Specimen No.	Date of collection.	Remarks.
30	4-17-'12	Chinch bugs (*Blissus leucopterus* Say) covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cinders along railroad.
31	4-23-'12	A true bug (*Coriscus punctipes* Rent.) nearly covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cinders along railroad.
32	4-23-'12	Chinch bugs (*Blissus leucopterus* Say) covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in an earthworm burrow (*Lumbricus terrestris*) along Slate creek.
33	4-23-'12	A snout beetle (*Dorytomus* sp.) covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in an earthworm burrow (*Lumbricus terrestris*) along Slate creek.
35	5-13-'12	Abdomen of ant resembling carpenter ant (*Camponotus pennsylvanicus* DeG.), partly covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); found under rubbish in orchard.
36	5-13-'12	Grasshopper (*Melanoplus* sp.) one-third covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under cinders along railroad.
37	5-13-'12	A stink bug (*Thyanta custator* Fab.) one-fourth covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under osage orange leaves (*Toxylon pomiferum* Raf.) along hedge.
38	5-13-'12	A stink bug (Pentatomidæ) partially covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under apple leaves in orchard.
39	5-13-'12	Flea beetle (*Disonycha collaris* Fab.) partially covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under apple leaves in orchard.
40	5-15-'12	Chinch bugs (*Blissus leucopterus* Say) covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken under apple leaves in orchard.
40a	5-13-'12	Cottonwood bud (*Populus deltoides* Marsh) with a white growth of chinch-bug fungus (*Sporotrichum globuliferum* Speg.); found under osage orange leaves (*Toxylon pomiferum* Raf.) along hedge.
41	5-21-12	A number of small Hemiptera covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); found under maple leaves (*Acer saccharinum* Linn.) in a meadow.
42	5-23-'12	Chinch bugs (*Blissus leucopterus* Say) covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in bunch grass (*Andropogon scoparious* Mich.) along Slate creek.
47	5-21-'12	Chinch bugs (*Blissus leucopterus* Say) covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in wheat field.
48	5-21-'12	Do.
49	5-21-'12	Do.
50	5-21-'12	Do.
51	5-21-'12	Grasshopper (*Melanoplus femur-rubrum* DeG.) two-thirds covered with chinch-bug fungus (*Sporotrichum globuliferum* Speg.); taken in bluegrass (*Poa pratensis* L.) along roadside.

From these data it is perfectly evident that the fungus in the mycelial form was limited to certain foci wherein the moisture was sufficiently high to permit its growth, and that elsewhere it existed only in the nonvegetating stage. This, of course, does not mean that the spores are not spread over the fields generally. With high winds of fall and spring, it is hard to see how spore distribution could fail to become general. Many times while studying fungus distribution the authors have uncovered a focus of fungus-covered bugs, only to have it whisked away by the wind as a puff of yellowish-white spores and spread over the fields. Rains also played a part in the distribution of the spores, and often after a washing rain very little fungus could be found where it had been thick before.

The spring was so backward that the fungus in the more moist foci along Slate creek made a growth and destroyed 15 per cent or 20 per cent of the hibernating chinch bugs before they left winter quarters, and infected a large per cent of the

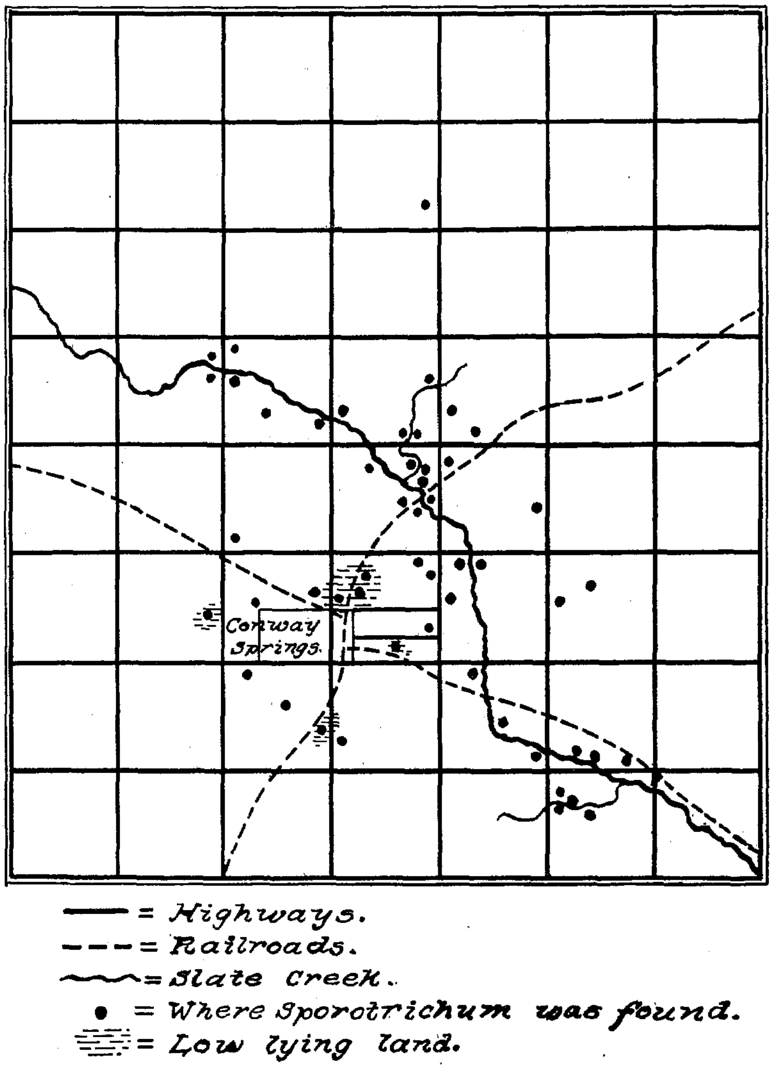


FIG. 8. Map of area studied at Conway Springs, Kan., showing the foci of the disease.

remaining bugs. These infected bugs made their way into the small-grain fields along Slate creek. The fungus in less moist foci away from the region of Slate creek did not make a growth of any consequence, and comparatively few infected bugs left the winter quarters. After the heavy spring rains soaked the ground and made all parts of the area lying equally low about equally wet, the fungus appeared in the fields close to Slate creek in greatest abundance, while those well removed from that group of foci showed very little or none. Later, however, as the weather continued wet, it appeared in all fields of the area where the bugs were at work.

With the advent of dry weather the growth of the fungus in all exposed places will decrease, and finally stop altogether. The drier and hotter the weather becomes the fewer and fewer the number of places where the moisture will remain sufficient for its growth. That degree of moisture necessary to its vegetation will remain longest in dense cover in shaded places and nearstreams. Consequently the foci of the fungus will be found at the beginning of cold weather in the tangle of grass and weeds along the fences, in waste places, in pastures and meadows, along brooks and streams. Growth will decrease as the temperature falls, and probably cease entirely. The dormancy will continue until the advent of higher temperature. The chinch bug establishes winter quarters in the very places in which the fungus is likely to be growing. It carries the fungous infection with it from winter quarters, and on the advent of wet weather and proper temperature is attacked by the parasite it and other species have brought from winter quarters, and by the parasite which has been lying dormant in the fields. Thus with the advent of proper conditions of moisture and temperature, the chinch bug's deadly enemy, the chinch-bug fungus, which is always lying in wait, springs up and destroys it.

In the light of this life economy it is hard to see how the placing of several thousands of bugs dead with the disease can increase the number of foci sufficiently to change the result materially.

In an experimental way, we have repeatedly distributed infected and dead bugs over a given area, or sprayed plots with the spores of the fungus in water, or dusted areas with the spores of the fungus mixed with wheat flour, and have never been able to see that the bugs died from the fungus on the treated areas more rapidly than on the untreated areas.

General Conclusions.

We, therefore, hold that the facts of the life economy of the chinch bug and of the chinch-bug fungus and evidence of properly conducted experimental tests unite in showing that artificial distribution of the chinch-bug fungus, either on diseased bugs or on artificial cultures, is not worth the time and trouble that it takes.

MEASURES OF CONTROL.

General Statement.

During the 125 years that the chinch bug has been recognized as a crop pest, the most diverse measures have been proposed for its prevention and control. Most of these measures are, of course, absurd on the face of them, others are close enough to the truth to render them pernicious, and others are really efficient. With the first class we have no occasion to deal. The second we must consider, in order that their frequent recurrence here and there may not lead some to neglect the efficient measures. The third we will treat fully as the measures that should be incorporated into farm practice.

Among the pernicious measures must be included the ever-recurring suggestion that almost invariably follows a couple of years of chinch-bug losses, to the effect that the farmers of a large area agree not to plant wheat for a period of one or two years. This suggestion is wrong because it entails unnecessary loss. It is quite within the bounds of possibility to raise wheat and corn and yet escape serious harm.

Much time and money has been spent in well-meant attempts to utilize the chinch-bug fungi as a method of controlling the chinch-bug ravages, but, as has been shown under the head of natural enemies, no one who has given sufficient time and care really to get at the truth holds that artificial distribution is ordinarily worth the time and trouble it requires.

Many careful students of this subject very justly hold that not only has the artificial distribution of the chinch-bug fungi for the control of chinch-bug outbreaks been a waste of time and money, but the neglect of really effective measures, which a reliance on this method has engendered, has cost the farmers of Kansas many millions of dollars in staple crops.

The most careful and extensive studies of the chinch bug's life economy have revealed only two times in the year when the chinch bug can be struck really effective blows. The first comes when the immature bugs attempt to pass from wheat and other small grains into adjacent fields of corn and sorghums, and the second comes just after the bugs have become firmly settled in their winter quarters. The former comes when the farmers are busy with the harvest, but also when the dullest can not fail to see the damage. The latter comes when work is slack and the farmers have plenty of time, but also at a time when damage is only a remote prospect.

There can be no question but that general winter destruction is by far the cheaper and the more satisfactory method, and if properly carried out should render summer destruction unnecessary.

Summer Measures.

The problem of summer destruction involves the necessity of getting the bugs to pass from the small grain while yet immature, the necessity for the construction and maintenance of efficient dry-weather or wet-weather or both types of barriers, during the period for which the bugs are passing, and the necessity for the destruction of all bugs that get over the barrier and congregate on the first few hills or rows of corn.

PASSING.

The problem of getting the bugs to pass while still immature does not usually arise, for ordinarily the small-grain field ceases to yield chinch-bug food before the bugs mature, and they are compelled to migrate on foot or starve. In some instances, however, the wheat is so delayed in ripening that the bugs are mostly mature before starvation compels them to leave. In such cases they leave on the wing, and nothing can be done to prevent their movement or to destroy them. In some cases the wheat is so thin on the ground that a growth of grass and weeds comes on in sufficient quantity to furnish the chinch bugs with food, after the small grain dries up, until maturity is reached and winged distribution can take place.

In such instances harvest should be hastened, the wheat removed, and the stubble mowed and burned off as soon as dry, for such procedure would leave the bugs nothing to live on and would compel them to migrate in search of food, as well as destroy large numbers in case the weeds and stubble were heavy enough to generate great heat. When for any reason the mowing and burning of weedy stubble is impracticable, the weeds and grass should be destroyed, and chinch-bug food eliminated by thorough disking.

BARRIERS.

Investigations of this subject to the present time show that two types of barriers are efficient—the dusty furrow for dry weather, and the coal-tar or oil line for wet weather.

Dusty Furrow.

Essentially the dusty furrow is a shallow ditch between the infested and noninfested fields, made with a plow, lister or trough drag, the sides and bottom of which have been reduced to a deep, fine dust. In some cases a strip five or six feet wide between the infested and noninfested fields is pulverized and a furrow made by dragging a heavily laden trough back and forth from end to end, or the furrow is made by plowing a dead furrow from end to end. The sides and bottom of either type of furrow are then reduced to a deep, fine dust by dragging the trough or log black and forth. Experience during the last several years at this station indicates that the use of a double-trough drag is more satisfactory than either the single trough or the dead furrow, because the bugs that get over the first furrow are caught by the second, and because, owing to the greater steadiness of the double trough, the furrows can be made free from abrupt turns, and consequently more uniformly dusty. Two troughs three or four feet long are made of heavy lumber, and held parallel and twelve inches apart by a couple of strong 2 x 4-inch pieces nailed firmly across the top. In other cases the furrow is prepared by plowing a deep lister furrow between the infested and noninfested fields and reducing the sides and the bottom to a deep, fine dust by dragging a log back and forth. The first type of dusty-furrow barrier is likely to prove more efficient, because not only does the bug have to pass a furrow, but may have two instead of

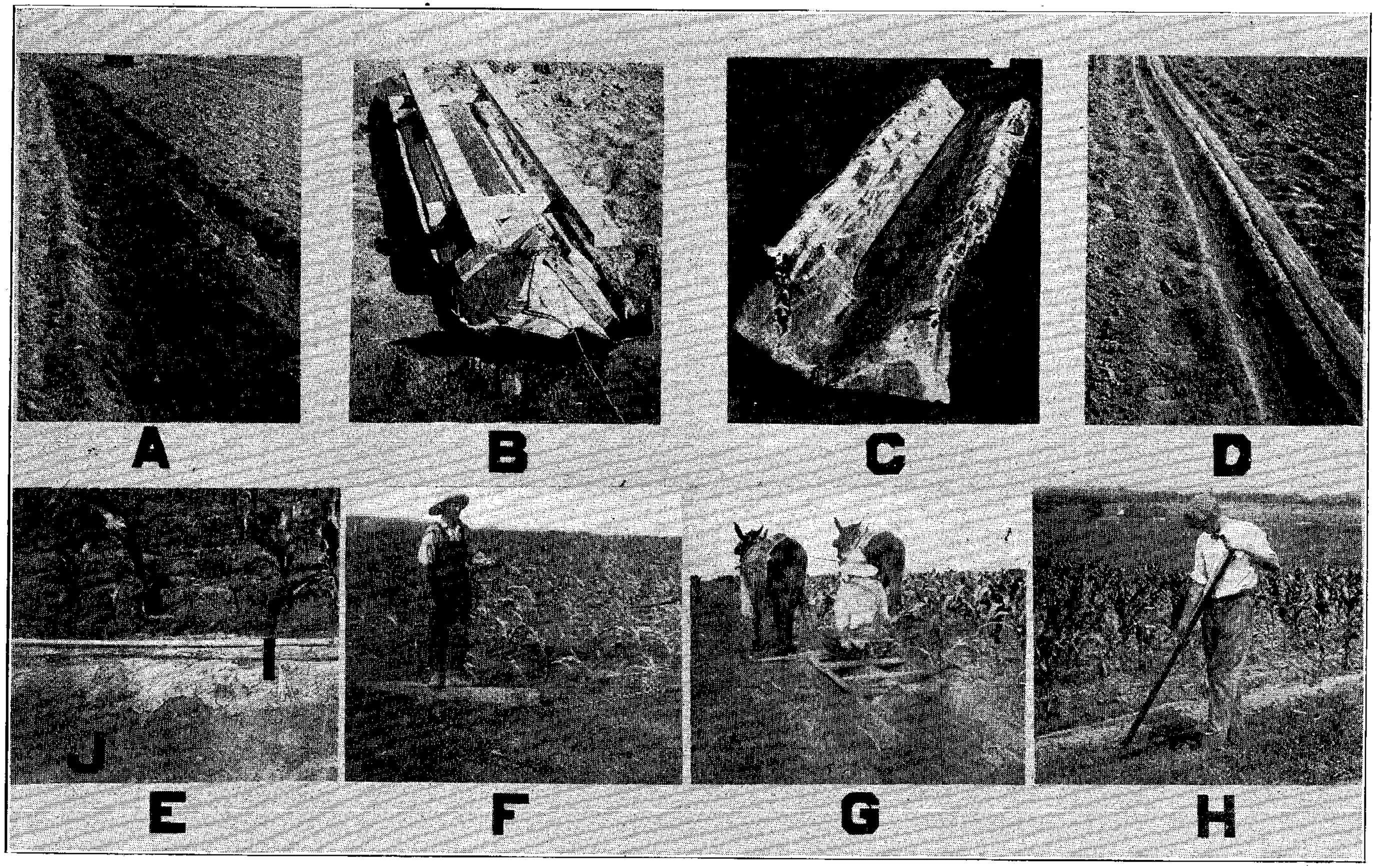


PLATE V. (A) Backfurrow just thrown up. (B) Drag for shaping the backfurrow. (C) Under view of drag. (D) Backfurrow properly shaped with some tar in place. (E) Combined backfurrow and dust furrow; I, backfurrow; J, dust furrow. (F) Making the single dust furrow. (G) Making double dust furrow. (H) Flaming the bugs in the dust furrow; same method used on backfurrow.

one, and, in any case, it must cross some feet of dusty soil before reaching the furrow and several feet more after leaving before reaching the corn toward which it is migrating.

Thus far provision has been made for temporarily stopping the progress of the advancing horde. To the dusty barrier, as already described, must be added a plan for killing the bugs which collect in it. Several methods have been suggested for doing this, but in our experience only one has proved efficient at all times, and that is flaming the sides and bottom of the dust barrier at regular intervals with a strong gasoline torch. Another way is to dig post holes at intervals of ten feet in the bottom of the furrow and destroy the bugs that collect in these holes by pouring kerosene over them. The post-hole method is a laborious process, in our experience, for the activities of rabbits, land, turtles and snakes, and the blowing of the wind necessitates extensive repair of the dusty bed at least once a day. The gasoline blast-torch method has proven itself admirably adapted to our needs, for not only are we able to destroy the bugs by simply passing the flame along in the furrow where they have collected, but without inconvenience the furrow can be repaired as often as is necessary by dragging a log or trough through it.' The most efficient torch that we have used is known as the "Locust 'Torch," and is manufactured by the Turner Brass Works, of Sycamore, Ill. It is the most efficient because it furnishes a strong, blue flame six or eight inches long and two and one-half to three inches through, which fills the dusty furrow where the bugs are struggling with a strong blast of blue flame, and is not blown out by the wind. The purchaser should insist on getting a torch having these specifications, as the modified tinner's torch is likely to prove unsatisfactory, because the flame is too small and is easily blown out by the wind.

TAR OR OIL LINE.

Essentially the tar- or oil-line barrier is a slender line of tar or oil poured along a smooth surface between the infested and the noninfested fields. In some instances the smooth surface is the upper edge of 6 x 1-inch boards laid on edge continuously lengthwise between the infested and noninfested fields. In other instances the smooth surface is merely a narrow path on the surface of the ground, smoothed by dragging a broad, thick, heavily weighted plank back and forth, or by use of hoe and shovel. In still other instances a smooth surface elevated above the general level is made by plowing a backfurrow, compacting the sides, and forming a shallow trench along its crest by use of shovel or by dragging over it an inverted convex-bottomed trough or boat.[20] Two two-inch planks, six or eight feet long and twelve and fourteen inches wide, are nailed together hog-trough fashion; that is the twelve-inch plank is laid flat on the sawhorses or the ground, and the fourteen-inch is set on edge along one side. After careful adjusting, so that the ends of the planks are even, the fourteen-inch plank is spiked to the twelve-inch. The front end of the trough thus made is rounded off like a sled-runner. In order that it may slip well, the inside of the trough is lined with galvanized iron. A straight, smooth pole at least two and one-half inches in diameter is then nailed into the bottom in such a manner that it extends from the front end to a point eight or ten inches behind the rear end of the trough. It is probable that the apparatus might be improved by placing the pole beneath the galvanized iron. A narrow, rectangular platform running the length of the trough and extending six to ten inches beyond the rear end is then constructed on the ridge of the now inverted trough. The platform is intended for the carriage of the driver and for the placing of stones when additional weight is needed. This platform consists of three 2 x 4-inch. pieces a little shorter than the trough is wide, and two other 2 x 4-inch pieces a little longer than the trough. One of the short 2 x 4-inch pieces is set in and spiked on crosswise near the front end, another near the middle, and the third near the rear end. On one side one of the long pieces is nailed crosswise the short pieces and parallel to and three to five inches distant from the ridge of the trough, and the other in a corresponding position on the other side. By means of strong wire an attachment is made to the clevis, and the inverted trough is ready to work.

Regardless of the method of smoothing the place to receive the tar or oil line, post holes are dug along the bug-infested side at varying. distances—some students recommend 100[21] feet

20. The use of the backfurrow and an apparatus for giving it shape was first suggested by Snow (Snow, F. H., 5th Annual Rept., p. 45), but as no description of the apparatus was appended, it has been necessary to work it out experimentally, and the apparatus herein described was thus worked out in the early summer of 1912.

21. Snow, F. H., Fifth Annual Rept., p. 45.

and others 20 22-very close to the line along which the tar is to be poured. (In the course of the experimental work at this station the gasoline blast torch has been found more satisfactory than the post holes. The bugs running back and forth along the tar or oil line were destroyed by flaming.) The tar or oil is then poured from an old teakettle; or, better, from a sprinkling can, the nozzle of which has been removed and the opening reduced in size by a plug with a hole in it. The opening is usually large enough to admit a stream of sufficient size to make a line one-half to three-fourths of an inch in width. The post holes used with the backfurrow type of tar-line barrier are placed at the foot of the slope, and one experimenter used two short tar-line wings to guide the bugs into each of them.

The backfurrow type is likely to prove more successful than any other, because, being above the general surface of the country, it is less likely to be bridged by blowing trash and broken by wandering animals, and it costs but little more to make than any other type. In a recent letter, Prof. S. A. Forbes described his test of the Standard Oil Company's No. 8 road oil as a substitute for tar. This substance (in this case road oil No. 7) was given a thorough trial by us during the summer of 1912 and found to be a highly satisfactory substitute. This is manufactured and sold by the Standard Oil Company at $3.50 a barrel, and can be obtained from the Standard Oil Refinery at Whiting, Ind. This eliminates what has always been the main difficulty with tar—its scarcity and its high price.

OPERATION OF BARRIERS.

The farmer must know his danger and have his barrier materials ready before the small grain begins to ripen. He should keep the strip between the infested and the noninfested fields, where he plans to place his barriers, free from weeds, in order that it may, when the time comes, break up mellowly and be easily pulverized. The moisture in it should, of course, be conserved by the dust mulch, or the compacting necessary to the tar-line type will be difficult. The farmer must plan to use both types and must have all the apparatus necessary to the making of each. As the wheat begins to ripen he should

22. Forbes, S. A., 24th Rept. of the State Ent. of Ill., p. 37.

watch the bugs closely, and on the first indication of movement of the young ones the dust furrow should be constructed, if dry enough, and the backfurrow should be thrown up and compacted. The backfurrow should be between the dusty furrow and the field to be protected. The tar or oil line should not be run until, owing to wet weather, the dusty furrow will not hold the bugs.

'The wheat should then be cut and the bugs compelled to pass without delay. While the bugs are passing there must be one or more persons, depending on how much barrier is to be looked after, in the field constantly burning those that have collected in the dusty furrow, if the weather be dry enough for its use, or burning or otherwise destroying those that have collected along the tar line, when it is in use. The persons operating the barriers must keep a sharp watch for any accidental breaks and repair them promptly. Of course, the cost of operating the barrier will depend on the proportion of the day during which the bugs run and the number of days their passing continues.

In the course of careful studies of this phase of the question Forbes[23] found that the bugs never passed at night; that they passed more or less all day if cloudy weather, and that they passed only for a part of the day when the sun shone. During the barrier work on the college farm in 1911, the weather was very dry and the days almost cloudless. The bugs usually began passing about 4 P. M., reached a maximum between 5 and 5:30 P. M., and ceased entirely by 7 P. M. During the entire period of chinch-bug migration it was necessary to attend to the barriers constantly for only three hours a day. This was also true in 1912, except during the very heaviest run and also during one or two cool and partially cloudy days, when the bugs ran more or less from 9 A. M. The following table, made during one of the heaviest runs, shows clearly the influence which the temperature has on the movement of the bugs.

As a result of his study of the period of passing, Forbes says that the bugs run from ten days during a dry season to thirty days in wet weather. The number of days during which the bugs pass depends on the rapidity with which the food in the small-grain fields is exhausted. On the college farm in

23. Forbes, S. A., 24th Rept. of the State Ent. of Ill., p. 35.

RECORD of temperature in relation to migration of chinch bugs, on June 28, 1912.

REMARKS.—Temperature was read by tested standard Fahrenheit thermometers on the agronomy wheat field at the Kansas Experiment Station. One in the shade of wheat, one hanging in the air, and two in the dust barrier, which ran from north to south.

TIME, P. M. MOVEMENT OF BUGS.	Thermometer on east slope of dust barrier, bulb exposed to direct sunshine	Thermometer on east slope of dust barrier, bulb buried in dust	Thermometer hanging in the air, direct sunshine	Bulb on surface of ground in the center of shading wheat bunch	Temperature in shade	Wind	Sun
	Deg. F.	*Deg. F.*	*Deg. F.*	*Deg. F.*	*F.*		
2:00 Bugs of all stages at a standstill; some feeding, others resting.	.....	126.5	.....	95.9	94	Breeze from southeast.	Bright sunshine.
2:15	132.8	130.1	....	94.1			
2:25 A very few bugs moving up and down wheat stems. None moving on ground.	139.1	131.9	101.3	93.2			
2:35	139.1	131.9	99.5	92.3			
2:55	134.6	130.1	99.5	94.1	95		
3:20 Numerous bugs moving in the shade along west stone fence. No bugs moving out from the shade.	124.7	118.4	100.4	93.2			Shaded by passing cloud.
3:30 Some bugs crossing road from dried rye field into young corn. A few bugs began regular march to corn, but remained close to shade.	122.9	120.65	96.8	92.3			
3:50 Bugs reached middle of road at southwest corner of wheat field, where waving black ribbons of bugs were marching out.	127.4	119.3	99.5	93.2			
4:00 A few bugs trying to climb up the east slope of dust barrier under direct sunshine.	128.8	121.1	102.2	94.1	95		
4:15 A number of bugs are running out in the sun.	127.4	122.9	96.8	94.1			
4:30 Bugs moving everywhere. About 35 per cent of the bugs in the field are running.	122.45	122.9	96.8	94.1			
4:45	129.2	121.1	96.8	96.8			
5:00 About 45 per cent of the bugs moving. Quite a few bugs in the barriers.	118.4	118.4	95.9	94.1	92		
5:15 About 50 per cent of the bugs moving.	123.8	126.5	95.0	95.2			
5:30 About 70 per cent of the bugs moving.	118.4	121.1	95.0	94.1			
5:45 About 90 per cent of the bugs moving.	116.4	120.2	93.2	93.2			

RECORD of temperature in relation to migration of chinch bugs, June 28, 1912—*Concluded.*

TIME, P. M. MOVEMENT OF BUGS.	Thermometer on east slope of dust barrier, bulb exposed to direct sunshine	Thermometer on east slope of dust barrier, bulb buried in dust	Thermometer hanging in the air, direct sunshine	Bulb on surface of ground in the center of shading wheat bunch	Temperature in shade	Wind	Sun
6:00 A large per cent of the bugs have reached the dust barrier.	*Deg. F.* 115 7	*Deg. F.* 118.2	*Deg. F.* 92.3	*Deg. F.* 93.2	*F.* 91		
6:15 Most of the bugs have reached the barriers and are struggling in the dust.	112.1	115 7	91.85	92.3		Cooling wind from east.	Sun down. No direct sunshine.
6:30 Bugs are moving a little slower. Only about 30 per cent of them are moving in the field.	108.5	113.0	89 6	88.7			
6:45 The movement of the bugs decreasing fast. Only about 5 per cent are moving in the field and they are getting scarcer on the ground. Barriers still full of bugs.	100.4	108.5	87 8	85 1			
7:00 Only about 1 per cent of the bugs moving in the fields. Bugs that have left the field are seeking shelter.	94.55	103 1	84.2	86.0	88		
7:15 Practically all bugs at a standstill. Most of them have taken shelter under clods, crab grass, weeds, etc. A good many bugs still struggling in dust.	89.6	99.05	83 6	85 55			Twilight falling.
7:30 No bugs moving in open except in dust barriers, where they are trying to get out. These are being destroyed with torch.	87.5	95.9	82.4	84 2			
7:45 All movement has ceased and all bugs in barriers killed by thorough flaming of barrier with torch.	85.1	93 2	81.5	83.3			

1911 the passage of bugs from wheat did not continue longer than six days, but when they passed from barley, then from wheat, and finally from oats, the whole period covered about three weeks. In 1912 the run, which came from wheat alone, continued fifteen days, due to the fact that there were wide alleys containing grass between the wheat and the barriers, and the bugs stopped for several days in these places.

During the past year (1912) the dust barrier and gasoline torch were given a thorough trial on the Experiment Station farm. A furrow about two miles in length was plowed between all wheat and corn fields. This furrow was six or eight inches deep and was dragged with a heavy log wrapped with a log chain, until the sides and bottom of it were reduced to fine dust. This barrier was in use for eighteen days, with the exception of three days, when, owing to rains, the oil barrier was resorted to.

The first movement of the bugs began on June 19, but as this consisted of overwintered adults, little effort was made to stop them. On June 22 the first immature bugs began to move, and the barrier was used for a couple of hours a day. The wheat harvest began June 25, and from then on until July 8 the ground was black every afternoon with moving bugs.

With the beginning of the heavy run of bugs the management of the barriers was systematized. The barriers were thoroughly dragged every day before 2 o'clock, and then gone over with a hoe and all clods, sticks and rubbish removed from the furrow. Two men were employed to operate the two torches, which were used continuously every afternoon from 3 to 7:30. On two or three cool and partially cloudy days it was necessary to flame the furrows several times during the morning, and on a couple of days when the run was heaviest it was necessary to use three torches for an hour or two. Ordinarily one torch, however, will protect a mile of barrier.

At no time during this run did more than one bug in a thousand get across the barrier, and most of the time the per cent was lower than this. Not a single row of corn was damaged by the bugs, while in near-by fields where no barriers were used as high as 200 rows of corn were destroyed. The cost of constructing and maintaining the barrier is itemized as follows:

Plowing furrow, 1 man and team, 5 hours	$2.10
Dragging to get dust, 1 boy and horse, 6 hours	1.50
Dragging to keep barrier in shape, 1 boy and horse, 5 hours for 15 days	18.50
Running torches, 2 men, 4 hours a day for 15 days	24.00
Running torches, 1 man, 4 hours a day for 4 days	3.20
Gasoline, 140 gals., at 11 cts.	15.40
Total	$64.70
Cost of preparation and maintenance per rod for 15 days	.10
Cost per day	.006

Rain on July 1 and 5 ruined the dust barriers, so that the oil-line barrier was used for about three days. The barrier was constructed according to the method described on page 333.

Post holes and the torches were used, but the post holes did not prove effective except where a ridge of dust was worked up around the holes, causing the bugs to roll in, and also preventing them from crawling out again. The use of the torch proved very successful, except that it served to dry out the oil. As a whole, the oil barrier did not prove as efficient as the dust barrier. As high as ten bugs out of every thousand were able to get across. It required constant watching to keep grass and rubbish from blowing onto it and forming a bridge for bugs to cross. However, where wet weather prevails it is to be recommended. The cost of maintaining the oil barrier is shown in the following statement:

Throwing up ridge and shaping, 1 man and team, 6 hours	$2.10
Spreading oil, 35 hours	7.00
Running torches, 2 men, 4 hours per day, 3 days	4.80
Keeping barrier in shape, 1 man, 4 hours per day, 3 days	2.05
Road oil for 2 miles, 115 gals., at 7cts	8.05
Gasoline for torches, 24 gals., at 11 cts	2.65
Total	$26.65
Cost of preparation and maintenance per rod for 3 days	.04
Cost per day	.013

DESTRUCTION OF THOSE BUGS THAT GET ACROSS THE BARRIERS.

Usually, despite utmost care, some bugs will get over the barriers, and they will begin to work on the first few rows of corn. Various experimenters have recommended that the few infested plants be thoroughly sprayed with kerosene emulsion, soapy sprays, or flamed with a gasoline torch. Of the three, the kerosene emulsion has been the most highly recommended. An extended series of tests made during the summer of 1911 clearly showed that satisfactory kerosene emulsion was so difficult to make, and that so much injury followed its necessarily free use, that recommendations of it as an Agent for this purpose in the hands of the inexperienced man would be followed by unsatisfactory results. Careful tests of the blast torch showed that while practically all of the bugs behind the leaf sheaths were killed, the corn was seriously scorched. However, were it impossible to spray, the flaming of the infested rows is to be recommended.

During the same period careful study showed that eight pounds of whale oil or laundry soap dissolved in fifty gallons of water would destroy every chinch bug thoroughly wetted by it, and would not injure the corn plant from ten inches to four feet high, even when used to drench it, provided it did not fill the curl. In using this mixture it was customary to fill the pockets formed by the leaves and the stems. In the course of another series of experiments with a tobacco decoction known. as "Black Leaf 40" we found that one part of "Black Leaf 40" to 500 parts of water, to which whale oil or laundry soap has been added at the rate of 4 pounds to 50 gallons, is as effective for the bugs and as harmless to the plants as the soapy solution just described. It was used in the same way. The addi-

FIG. 9. Killing the bugs that get across the barriers by spraying the first few rows of corn.

tion of soap to the "Black Leaf 40" mixture seems greatly to increase its insecticidal powers. Without soap, a dilution of 1 to 50 is required to do the same work a dilution of 1 to 500 will do with the addition of soap.

Recommendations regarding the means of applying these mixtures range from the tin cup to the regular field sprayer. In our experience, the knapsack sprayer was found most satisfactory, because (1) by placing the liquid under pressure and delivering it as a mist, a better distribution of the mixture was possible than by merely pouring; (2) it is more easily handled than a field sprayer. The mixture was used freely, for economy of spray and time while attempting to kill the hardy bugs that have crossed the barriers is foolish. The bugs should be destroyed without delay, for each female allowed to escape will produce many young.

DESTRUCTION OF ALL THE BUGS.

Where the wheat fields are partly or completely surrounded with grassy fence rows or fields, the barrier between the wheat field and the corn may not prove a sufficient protection for the latter, for, although all bugs that attempt to cross the barrier may be destroyed, enough may congregate in the surrounding grass, mature, and migrate into the corn on the wing to do large damage. In such instances the infested wheat field should be surrounded by barriers and all bugs destroyed as they attempt to escape.

Winter Measures.

EXPERIMENTAL TESTS AND THE RESULTS.

Destruction of chinch bugs while in winter quarters, by burning the cover in which they have taken refuge, is one of the earliest of the measures recommended for chinch-bug control. This recommendation seems to have been based upon the hibernating habits of the creature rather than upon any definite tests of its efficiency. This is true despite the fact that every writer on the subject with whose work we are familiar recommends it as one of the effective methods of controlling the chinch bug.

Apparently, the first person to recommend the burning of clump-forming grasses as a method of control under Kansas conditions was C. L. Marlatt.[24] His recommendations were based upon an excellent study of the creature's life history, carried out while connected with this station. During the years 1908, 1909, and 1910, careful study of chinch-bug hibernation in various parts of the state confirmed and extended Marlatt's conclusions with regard to the reason for and the probable value of winter burning. Of course, the spring and midsummer migration of the chinch bugs materially affect the extent to which the value of winter burning may appear in later freedom from the pest, but it seems likely, from general observations made by us in the last three years, that when bugs are relatively scarce the individual farmer may realize considerable benefit from destruction of the chinch bugs in cover on his own place, while in years of great abundance the good effects of isolated treatments will be swamped by mi-

24. Marlatt, C. L., Insect Life, vol. 7, pp. 232-234.

gration from surrounding territory. In the fall of 1910 we set before ourselves the problem of determining the extent to which these migrations would overcome the good effects of general destruction of chinch-bug cover over an area of considerable size.

An area was secured near Conway Springs, in which a sufficiently large number of farmers were willing to cooperate and where the bugs were sufficiently abundant. In this area the bugs averaged, in counts made November, 1910, about 1000 per clump of bunch grass three inches in diameter.

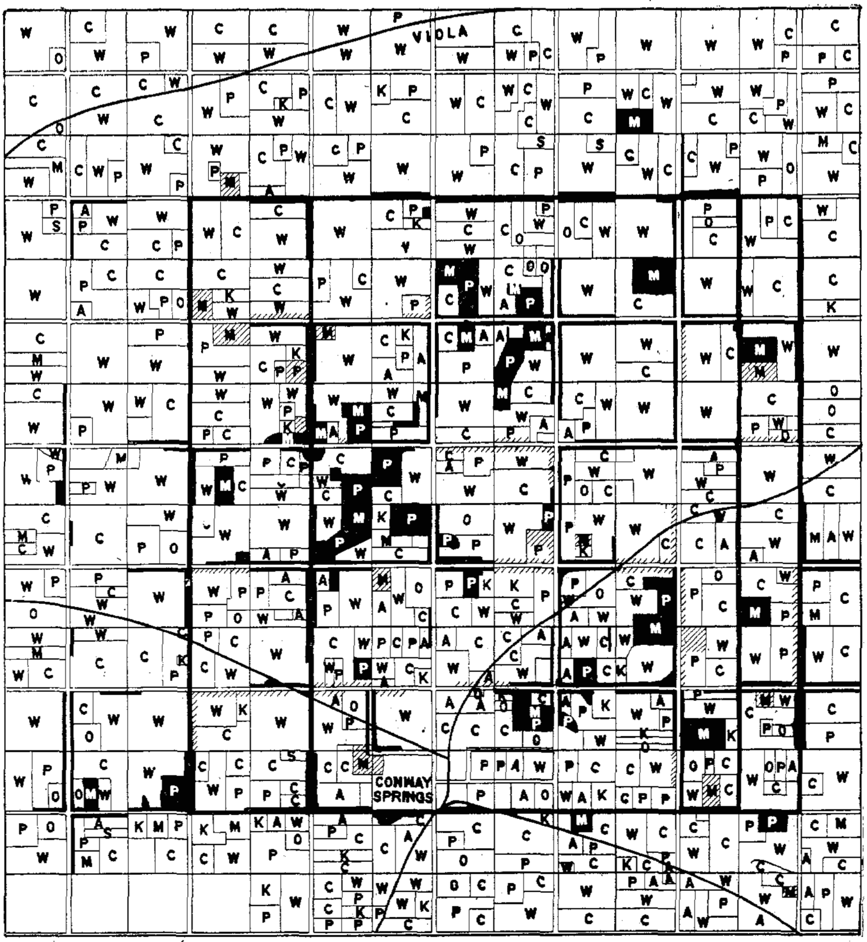
During the months of November and December most of the clump-forming grasses in waste places, along fences, in pastures and in meadows were burned off a square block of land five miles wide by five miles long. Chinch bugs had established winter quarters in bunch grass, big bluestem, and turnips, beneath hedge balls, under dry pieces of manure, under bark of Osage orange trees, in rubbish such as leaves, etc., among corn husks and between corn blades and stalks, in cane stubble and fall-sown wheat. During the winter which followed practically 100 per cent of those bugs which tried to winter in all types of cover, except bunch grass and bluestem, perished. Bugs found in cane and fall-sown wheat were destroyed by plowing under, but there is no reasonable doubt that their fate would have been that of those under cornstalk cover.

In the winter of 1911-'12 the mortality in false redtop *(Triplasis purpurea* Walt.) was found to be very low, and the mortality in general considerably lower than in 1910-'11.

This means that practically all bugs which congregated in cover other than that easily reached by fire were destroyed by the weather. The percentage of bugs killed by the firing varied with the closeness of burning—the closer the burning the greater the percentage destroyed.

Wherever the grass clumps burned to a point within less than one inch of the crown, all, or practically all, of the bugs were destroyed, but it can easily be understood that much of the grass was not burned so closely, and consequently that a considerable number of the bugs must have survived the firing. This conclusion is abundantly supported by the following tables.

MAP OF BURNED AREA



■ = BURNED AREAS; ▨ = SHOULD HAVE BEEN BURNED BUT WAS NOT;
▭ = AREA WITHOUT CROP AND UNINFESTED WITH CHINCH BUGS; A = ALFALFA
C = CORN; K = KAFFIR; M = PRAIRIE MEADOW; O = OATS; P = PRAIRIE PASTURE;
S = SORGHUM; W = WHEAT.

FIG. 10. Map of area burned at Conway Springs, Kan.

Starting November 11 with an average of 1000 living bugs per bunch, we have the following results based on preceding table: (1) About 502 bugs out of every 1000 perished through climate alone; (2) when average fall burning was practiced, about 714 out of each 1000 were destroyed by the fire alone; (3) when fall burning was practiced, about 880 out of each 1000 perished from the burning and the climate; (4) spring

RECORD of average mortality in different types of cover.

1910–'11.

Type of cover and number of bugs which established winter quarters therein.	Per cent of bugs which perished.
Bunch grass (*Andropogon scoparius*): As many as 3000 to 4000 bugs per clump, an average of about 1000 per clump	65
Bluestem: About one-half as many as in the bunch grass	65
Corn husks and stalks: Very few	100
Dry pieces of manure: 3 to 50 bugs per piece	98
Osage oranges: Few	99
Osage-orange tree bark: Few	100
Rubbish, such as leaves, etc.: Few	99
Turnips: 5 to 50 bugs under each plant	99

1911–'12.

Bunch grass: Average 1936 bugs for 23 bunches	35
Bluestem: Average 739 bugs for 23 clumps	39
False redtop: 100 to 200 bugs	15.4
Shells of cottonwood buds: 3 to 20 bugs	35
Cottonwood leaves: Thick	60
Cinders: 50 to 500 per cinder	95
White-ant tunnels in fence post: Few	50
Solidago galls: 10 to 15 per gall	90
Earthworm burrows: Few	100
Osage-orange leaves: Fairly numerous	55
Apple leaves: Fairly numerous	75
Corn husks, stalks, etc.: 6 to 20	95
Crab grass; 5 to 20	98
Willow leaves: Few and scattered	75
Dry pieces of manure: 1 to 30 bugs per piece	98

TABLE showing chinch-bug mortality at Conway Springs due to the weather and to burning of cover when working separately and together.

Date of burning.	Number of bunches examined	Average diameter of bunch examined	Date of count.	Average degree of burning of crown	Number of living bugs	Number of dead bugs	Total number of bugs	Average number of bugs per clump	Per cent of bugs dead
		In.		*In.*					
11-9 to 11-11	5	2.7	11-10 to 11-11	1.3	1,597	3,335	4,932	986	......
11-9	1	3	12-16	1.5	174	1,098	1,267	1,267	......
Per cent killed by fall firing						738	....	1,033	71.4
11-9 to 12-12	4	2.6	1-24	.8	17	397	414	104	......
11-9 to 12-10	7	3.3	2-9	1.5	206	1,393	1,599	227	......
11-9 to 12-15	11	3.5	3-14	1.3	102	620	722	66	......
11-9 to 11-15	9	3.7	3-31	1.2	112	988	1,100	122	......
Per cent killed by fall firing and climate						109	....	124	88
3-7	3	4.3	3-31	1.6	144	385	526	175	......
3-7	1	4.5	3-14	1.6	352	488	835	835	......
Per cent killed by spring firing and climate						215	....	340	63
Unburned	1	5.5	1-24	....	909	1,144	2,053	2,053	......
Unburned	4	4.7	2-9	....	2,269	2,001	4,270	1,068	......
Unburned	3	4.5	3-14	....	212	273	485	162	......
Unburned	2	4.8	3-31	....	243	241	484	242	......
Per cent destroyed by climate alone						366	....	729	50.2

TABLE of results from burnings made in Sumner county, November 11, 1910.

Diameter and degree of burning.	Total bugs.	Total killed.	Per cent killed.
Clump No. 1.—3½ in.; 1¼ in. of crown	2,574	2,134	86.4
Clump No. 2.—2½ in.; 1 inch of crown	111	83	74.7
Clump No. 3.—3½ in.; 1¼ in. of crown	1,074	434	45
Clump No. 4.—2 in.; 1 inch of crown	211	175	83
Clump No. 5.—2½ in.; 1¼ in. of crown	960	459	43

NOTE.—The slightly greater destruction in clumps No. 1 and No. 4 than that in clump No. 2 is due to the fact that clumps No. 1 and No. 4 were burned in stronger fire and the bugs therein subjected to greater heat.

burning destroys only about 130 out of each 1000. As a matter of fact, the percentage of mortality is unquestionably higher than 88, as evidenced by the facts that the average number of bugs per clump in clumps fall burned and late counted is only one-eighth as great as that in the fall counted, and one-sixth as great as that in the unburned and late counted. This decrease is due to the disintegration of the bugs that perished in the fire. The true percentage is better indicated by assuming that the average number per clump is 1000, and counting the difference, 876, as destroyed by fall firing and climatic factors, making a destruction of 98.5 per cent. Thus it is seen that 985 bugs out of every 1000 were destroyed by the combined effects of late fall burning and the winter climate. Had the burning been closer, say within an inch of the crown, all would have perished. The practical value of winter destruction of 98.5 per cent of the bugs should appear in the decreased numbers infesting the burned area and in the increased crop yield. Examinations of the burned area on April 17 and[18] showed very few bugs in wheat in burned area, and eight times as many in wheat in the unburned area. Examinations made May 25 to May 30, 1911, showed 308 young and 4 adult bugs per square yard of wheat in burned, as compared with 1839 young and 38 adult bugs per square yard in the unburned area. Examinations made from August 24 to September 30 showed bugs ranging from an average of 1500 bugs per stalk of corn in the unburned area to 100 per stalk of corn in the burned area. In parts of the unburned area the bugs reached as many as 2000 per stalk. The bugs entering winter quarters the fall of 1911 in the burned area were 100 per bunch, as compared with 500 per clump in the unburned area.

The average yield of wheat on thirty-five sections, all of which are within three miles of the edge of the burned area, was 14.3 bushels per acre, as compared with an average of

17.4 bushels inside the burned area. The average oat yield outside the burned area based upon records from twenty-five different sections, all within three-miles or less of the edge of the burned district, was 24.2 bushels per acre, as compared to an average of 24.9 bushels inside. Many cornfields outside the burned area showed one to forty rows of corn, adjoining wheat or other small-grain fields, utterly ruined by chinch-bug attack following harvest, while nothing of the sort was noted inside the burned area.

Because of the opinion held by many that fall and early winter burning of native grass meadows and pastures will reduce the yield the following summer, the burned meadows and pastures were carefully watched. On April 17 the field notes are as follows: "Coming back I examined the fields of Russell, Barry, Clark, Walmsley, Dickson, and Joe Duncan. . . . The burned areas look much better than' the unburned. Talked with several farmers, and they are well satisfied with results." On May 20 the following notes: "A. E. Barry says that he has seen very few bugs. He thinks the burning did a vast amount of good, but may have made the pastures and meadows a little weedy. Joe Lange reports very few bugs, and does not think his meadow or pasture was injured by the burning. Fred Wolfe says he finds few bugs and that his meadow was not injured by burning. Mr. Little is well pleased with the burning, He says pasture is a little weedy, but lays it to dry weather." On April 29 the following notes recorded: "The burned pastures are all very weedy and the grass is short, but all of them have been pastured heavily. A comparison, however, with unburned pastures does not show any great, difference. The unburned pastures are also very weedy and many of them are yet weedier than the burned. At Lange's, where one large pasture was burned and one was not, we had an excellent chance to note the effect of burning, and if anything the unburned is the weedier. "Examined several meadows that were burned last fall. These show practically no injury and have a good crop of hay on them now. Mr. Little and Mr. Lange say that burning did not hurt their meadows and that it may have helped them a little."

Thus it appears that the burning of pastures and meadows durinq the late fall and early winter of 1910, although the fall and winter were extremely dry, did not, in the opinion of the owners or in our observation, appreciably damage the resulting crop.

In general, the farmers are well pleased with the results, and one of them, Mr. A. E. Barry, claims that the burning made a thousand dollars for him. The following farmers actively cooperated with us in this test: L. F. Alloway, A. E. Barry, John Beal, Charles Boylan, Lincoln Clark, Henry Dudey, Jesse Duncan, H. E. Ewing, James Grier, Orla Halsey, M. E. Hemphill, J. S. Hedrick, Lewis Hobson, J. A. Jenkins, Edward Lange, David Little, John Marshall, Isaac Mayfield, H. G. Porter, Edward Small, C. A. Stitt, N. N. White, A. A. Wise, Fred J. Wolfe, Thol. Wolfe, Argus Lund, John Crabill, Jefferson Rinehart, L. E. Allyn, T. L. Ellis, John Gould, J. W. Cordell.

METHOD OF PROCEDURE.

It is imperative for the farmer to find out whether his grasses are harboring a dangerous number of bugs. This he can determine in one of two ways, the first being intended to find the bugs if they are numerous and the second to find them if present at all. In using the first method he should part the stems of the bunch grass close to the place from which they start. Ordinarily a mulch of soil and decayed grass will have gathered at the base of the stems. He should look carefully in this and should not give up the search at once, because the bugs "play 'possum," and are not easily seen until they move. If the bugs are abundant they will be revealed by this search. In using the second method he should take up clumps of bunch grass, roots and all, and pick them to pieces over a large sheet of white paper or cloth, watching for the bugs. If they are present in any numbers worth considering, this should reveal them.

Having found that the bugs are present in considerable numbers, say an average of fifty or more per bunch, the next step is to determine where on the farm these clump-forming grasses are to be found. Then a practicable method of destroying the bug-infested clumps, which will at the same time destroy the bugs, must be selected. Fire at once occurs as the most practical and efficient agent to be employed for this purpose. Obviously fire must destroy the bugs in one of two ways: First by killing them directly, and second, by destroying their cover

PLATE VI. Winter measures.

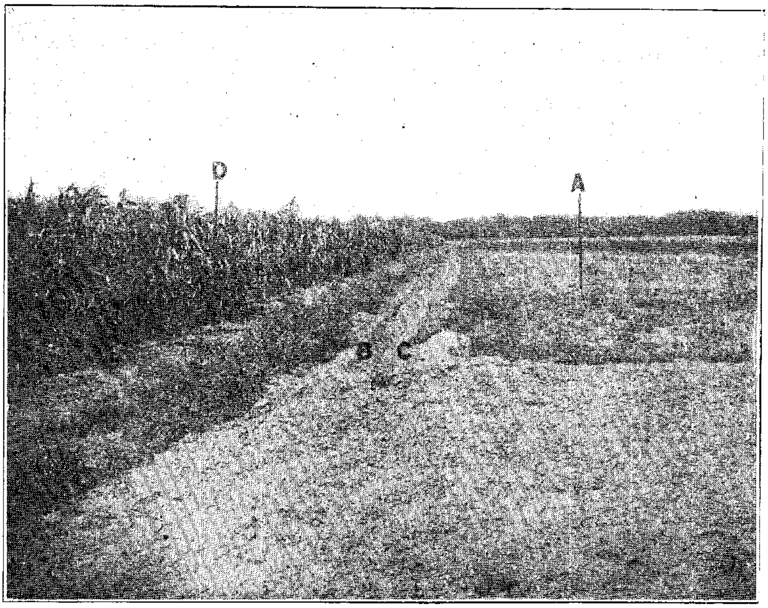
and leaving them exposed to the rigors of winter. The first method requires either that sufficient heat shall be generated to effect their destruction or that they actually shall be partly or completely consumed by the fire. The former requires an unusually hot prairie fire, such as might result in the consump-

FIG. 11. Destroying chinch bugs in their winter quarters.

tion of a heavy cover, while the latter requires close burning—consumption of the stems to within about half an inch of the crown.

The prime requisite, then, in firing infested clumps of grass, is so to handle the fire as to make it burn close to the crown from which the stubble grows. The type of firing which gives this desirable result appears to vary with weather conditions, and must be selected by the individual farmer at the time of treatment.

The bug-infested grasses should be burned late in the fall or early winter, because most of those bugs not killed by the fire perish from exposure, and because, owing to the greater dryness of the grass and consequent more nearly complete consumption, a much larger percentage is destroyed. November and December burnings have given best results.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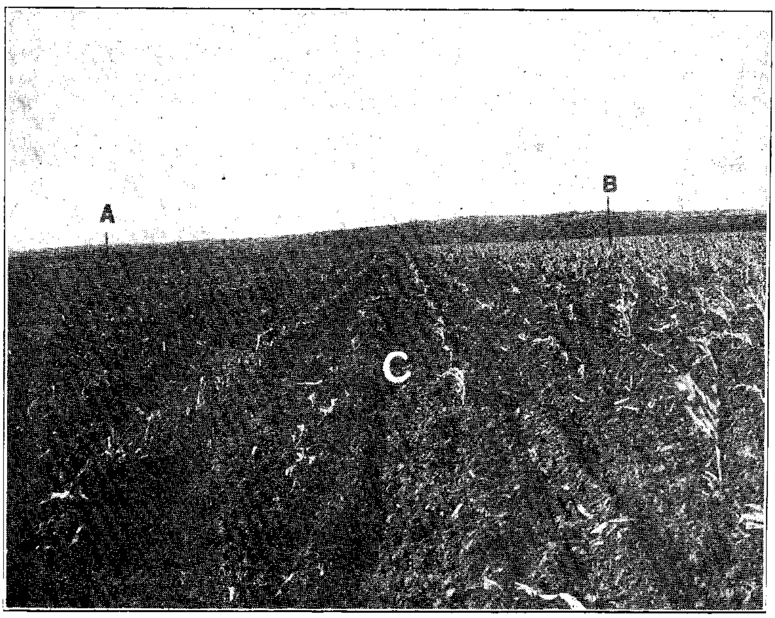
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