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The Cinch Bug and its Control

M. H. Swenk

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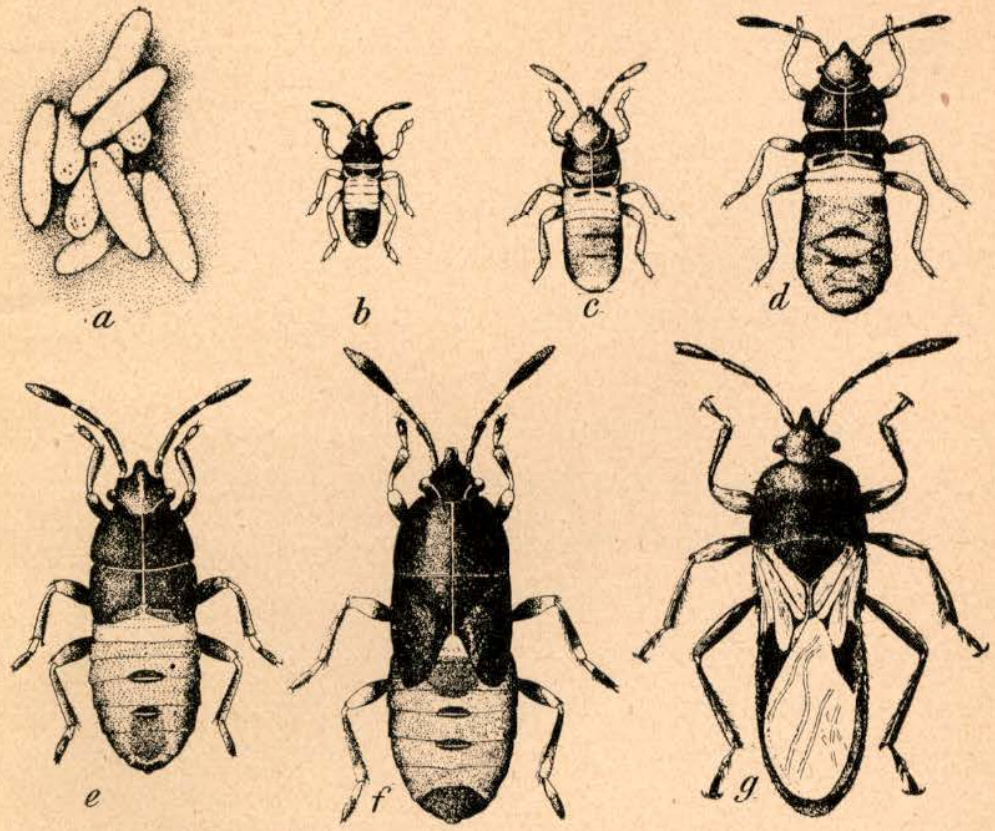

The chinch bug *(Blissus leucopterus)*: *a*, cluster of eggs; *b*, recently hatched bug; *c*, bug in second stage of growth; *d*, bug in third stage; *e*, bug in fourth stage; *f*, bug in fifth stage; *g*, adult bug; enlarged about 9 x. (Rearranged from Luginbill, Bul. 1016, U. S. D. A., 1922.)

AGRICULTURAL EXPERIMENT STATION
THE UNIVERSITY OF NEBRASKA
LINCOLN

CONTENTS

THE CHINCH BUG AND ITS CONTROL

By M. H. SWENK, STATION ENTOMOLOGIST

The chinch bug *(Blissus leucopterus)* is universally recognized as one of the most injurious insect pests of cereal crops in the United States, and probably there is scarcely a grain farmer in the entire Mississippi Valley that does not know of this notorious insect, by reputation if not by actual experience with it. The Hessian fly is its only serious rival for preeminence among the hundreds of insect enemies of cereal crops in this country. Very recently (1922) it has been computed that the average annual loss of crops in the United States thru attacks by the chinch bug is in excess of $40,000,000.

This enormous loss is not a steady one from year to year, but is the average loss over a long period of years. The chinch bug is much more abundant and injurious during some years than others. The years in which it appears in damaging abundance come irregularly in cycles of varying duration, and the length of these cycles is largely controlled by the direct or indirect effects of weather conditions upon the bugs. Continued dry weather favors them, while very wet weather brings about their destruction. During the last half century there have been five separated and well-marked chinch bug outbreaks, or periods of serious damage, in Nebraska, and we are now approaching the climax of a sixth such period. As to just how serious this present outbreak will be in 1925 no one can now say, because no one can exactly forecast the weather conditions of the summer, but the present situation is sufficiently menacing to make advisable the issuing of this circular, which aims to give the essential information concerning the chinch bug as a Nebraska pest, and the locally applicable means of control.

EARLY HISTORY OF THE CHINCH BUG

The chinch bug is not an imported pest, but one native to America, and probably occurred in Nebraska long before the settlement of the state by white men, subsisting on the native prairie grasses. It seems that these grasses did not provide sufficiently favorable living conditions to enable it to increase unduly, and moreover the practice of the Indians and early settlers of firing the prairies each year gave it a serious annual setback. Consequently, it did not come to be particularly noticed until the closer settlement of the state brought about a decrease in the prairie fires and an increase in grain growing, resulting in a conspicuous increase in abundance of the chinch bugs, with

accompanying injuries to the crops. Naturally such injuries were suffered earliest where grain growing and a plenitude of chinch bugs first came into contact. Hence we find the first records of serious injury by this insect in North Carolina as early as 1785, and in Illinois as early as 1840. Serious outbreaks occurred in Illinois and adjacent states in 1844-1850, 1854-1855, and 1863-1865, the crop loss in Illinois alone in 1864 having been computed to represent $73,000,000 worth of grain.

A HALF CENTURY OF CHINCH BUG HISTORY IN NEBRASKA

Outbreak of 1871-1874. By the time of the next general outbreak of the chinch bug in the Mississippi Valley, in 1871, southeastern Nebraska was included in the area of injury. The loss for that year in Indiana, Illinois, Wisconsin, Iowa, Missouri, Kansas, and Nebraska was computed at $20,000,000. In 1874, following a dry fall and during a dry summer, the injury in these states was again excessive, estimated at double the loss for 1871, and in Nebraska alone at not far from $750,000. After the outbreak of 1874 there was comparatively little loss for nearly a decade.

Outbreak of 1883-1887. In 1883 the chinch bug began to resume its injuries to Nebraska crops. Some serious damage was done in Lancaster County that year. In 1884, about ten days before harvest, these pests began to appear in great numbers in the grain fields of Cuming, Burt, and Washington Counties, causing much apprehension among the farmers, but shortly afterward several heavy rains fell in the infested district and the bugs were locally almost exterminated. In 1885 the bugs did some damage in Seward County. In 1886, influenced favorably by the drought of that summer, they became very numerous over a large area in south-central Nebraska — in Thayer, Saline, Saunders, York, Howard, Hall, Adams, and the included counties — causing much injury in the small grains and some in the corn. In August rains came and diminished the numbers of the bugs, as well as helping the corn in the infested area. This check was only temporary, however, for the winter of 1886-87 was close and severe, favorable to the hibernating bugs, and was followed by a warm, dry spring and a hot, dry summer in 1887, so that the pests again increased. By the beginning of the second week in July, reports of injury to small grains and corn began to become current and soon very serious damage to crops resulted. This infestation extended from Gage County to Redwillow County, along the southern Nebraska boundary, and north to Saunders, Butler, Platte, Howard, Hall, and Adams Counties, and the damage to Nebraska crops was estimated at $4,000,000. Not only was Nebraska affected but also the states of Kansas, Missouri, Iowa, Minnesota, Wisconsin, Illinois, Ohio, and

Kentucky, and the estimated damage for these nine last-mentioned states was computed at $60,000,000, thus equalling the previously unprecedented loss of 1871. Rains in August and September checked the pest and saved the corn in some localities.

Outbreak of 1892-1903. There are no records of serious chinch bug injuries in Nebraska during the years 1888 to 1891, inclusive, but by September of 1892 this pest had again increased in such numbers along the southern boundary of the state, especially in Nuckolls, Fillmore, and Franklin Counties, as to cause apprehension. By April of 1893 dry weather indicated the probability of serious injury by these pests during the summer, and the University began the experimental distribution of chinch bugs inoculated with the white-fungus disease. The infested area extended from western Richardson to Furnas Counties, north to Otoe, Lancaster, Seward, Platte, Valley, and Custer Counties, and the damage was serious. In 1894 the infested area was extended northward into Washington, Dodge, Nance, and Greeley Counties, and the outbreak reached its maximum intensity in that year, the crop loss being heavier than in 1893. In 1895 the outbreak declined in intensity, but the infested area was about as in the preceding two years. Because of heavy rains in May, 1896, over much of the infested area, injury was yet more reduced in that year, except in the block of counties extending from Saunders, Lancaster, and Gage Counties to the Missouri River, where it continued with great severity. By 1897, only scattering reports of injury were received, but these came from all parts of the area infested during the preceding four years, indicating that the subsidence was but temporary. In 1898 the chinch bugs again began to increase, and the sending out of diseased bugs, which had been discontinued in 1897, was resumed. Moderate injury by chinch bugs continued in 1899 and 1900, and by 1901 these pests were again doing very serious injury, about as heavy as in 1894. In 1902 the damage was greatly reduced because of an unusually wet summer, and heavy rains in May of 1903 caused the outbreak to abruptly subside in that year, after eleven consecutive seasons of trouble with chinch bugs in the state. The bugs were so reduced in numbers in 1902 and 1903 that no reports of serious damage in Nebraska were received for the next three years.

Outbreak of 1906-1911. In June, 1906, following a dry May, a few reports of some damage by chinch bugs came in from southern Webster and Franklin Counties, and sporadic complaints and requests for inoculated bugs were received until early in September. But the damage during 1906 was very small and mostly on corn. Early in July of 1907 reports were again received from the same counties, as well as from southern Nuckolls and Thayer Counties, indicating somewhat more severe damage than in the preceding year. The bugs were work-

ing in oats and wheat and going into the corn. In 1908 an extended outbreak developed along the southern border of the state from Jefferson to Frontier and Hitchcock Counties, the center of injury being Webster County. Heavy rains in June and July of 1908 checked this outbreak and there was a strong recession in chinch bug damage in 1909. The later winter and early spring of 1910 were very dry, and even during May, June, and July the weather was much drier than normal, which influenced the chinch bugs to a renewed abundance. Franklin, Harlan, and Furnas Counties were the center of injury but reports of injury were received from as far to the west as Redwillow County, as far to the east as Nuckolls County, and as far to the north as Dawson County. There were also local outbreaks in Custer and Seward Counties. The month of August, 1910, was marked by a phenomenally heavy rainfall, and the September rainfall was above the normal. As a result, what threatened to develop into an outbreak of extreme severity was checked by a heavy mortality among the chinch bugs of the second generation of 1910. But from October, 1910, to July, 1911, inclusive, the weather was rather dry, and especially June of 1911 was very dry, so that the bugs did not entirely fall back to normal numbers. The injury in 1911 was, on the whole, much less severe than in 1910. The months of August and September, 1911, had more than average rainfall, again acting as a check to the second brood of bugs, so that they fell back to practically normal numbers in spite of continued dry weather. The summer of 1912, tho dry, was practically free from chinch bug injury.

Outbreak of 1913-1915. The period from October, 1912, to April, 1913, was relatively dry, favoring the bugs, and by middle May of 1913 they were appearing abundantly in the Gage County wheat fields. But continued rains in May checked them and only a few reports of injury were received, these being received from Pawnee and Furnas Counties in June. A dry period following from June to August, inclusive, the bugs increased in the second brood of 1913, especially in Pawnee County, where they were injurious in the wheat in 1914 from June 27 to July 3. The infestation of 1914 extended, less intensely, to Jefferson County. A very heavy rainfall in June, 1914, followed by an unusual rainfall in September, prevented any undue increase in 1914, but, nevertheless, early in May, 1915, the bugs began to reappear in the wheat fields of Pawnee, Johnson, and Gage Counties. By middle May the fields in this district were swarming with them, and it seemed that a serious outbreak was impending. However, a few beating rains falling in latter May checked the outbreak, and only a few cases of injury were reported from Pawnee and Gage Counties during June. There was also injury in isolated areas in Custer and Douglas Counties, and one report of injury to fall wheat in Saline

County. Following the check in May there was a prolonged rainy period, the rainfall for the rest of the year being well above the average, with a particularly heavy rainfall during the critical period of development of the second brood in July and August, resulting in a complete subjection of the pest.

DEVELOPMENT OF THE PRESENT CHINCH BUG SITUATION

The present chinch bug situation began to develop five years ago. During the years from 1916 to 1919, inclusive, Nebraska was particularly free from injury by chinch bugs. In 1920, however, the bugs reappeared along the southern boundary of the state, from eastern Thayer to eastern Franklin Counties, and did some serious damage to small grains and corn between June 28 and July 22. The following year, 1921, allowed the bugs to gain no very serious advantage in this area, except that it became extended eastward across Jefferson County; but late in July, when chinch bug injury along the southern border of the state had practically ceased, an entirely separated outbreak developed in Knox County, in the northeastern portion of the state, the bugs starting chiefly in the fields of spring grain, and, when these were harvested, migrating into the corn and doing considerable damage in some cases. This northeastern infestation extended well into Bonhomme, Charles Mix, and Douglas Counties, South Dakota, and constituted the first serious chinch bug infestation in the history of that state.

Large numbers of chinch bugs went into hibernation in the fall of 1921 in both of the infested areas, and passed the winter of 1921-22 excellently, so that the outbreaks gained momentum and spread out in the summer of 1922. The southern area of infestation was extended eastward across southern Gage County and westward across southern Franklin and Harlan Counties to southeastern Furnas County, tho the center of injury remained in southern Thayer and Nuckolls Counties, and from June 23 to July 12 serious damage to the small grains and corn of the infested area was reported. The northeastern area of infestation extended westward over eastern Boyd County, and there was some local damage by both of the two broods of the chinch bug, between July 21 and September 14, but the numbers of the bugs had been quite seriously reduced in that region because of the wet spring, and as a result the injury was not as heavy as it otherwise would have been.

In 1923 the area involved in these two outbreaks was greatly extended. The southern area of infestation became extended eastward to cover all of Pawnee and Richardson Counties and most of Gage, Johnson, and Nemaha Counties, northward into northeastern Saline County and northwestward thru northwestern Harlan, most of Furnas

and western Gosper Counties to southwestern Dawson County. In this year the center of injury of this area of infestation shifted eastward into the newly involved areas, being especially pronounced in southern and northeastern Gage, Johnson, Pawnee, Nemaha, and eastern Richardson Counties, altho the bugs continued to do damage over the whole territory infested during 1920, 1921, and 1922, from June 26 to August 9. The northeastern area of infestation extended southward over eastern Knox County and westward across northeastern Holt and all of Boyd Counties into eastern Keyapaha County, and considerable serious damage was done in this area from July 12 to 30. Owing to unfavorable conditions in the winter of 1923-24, the chinch bugs practically disappeared as a pest in the northeastern area of infestation in 1924, only a few reports of injury having been received from Knox County during the second week in July. But the southern area of infestation extended yet more in 1924, and came to include northern Nemaha and Johnson, western Otoe, southeastern Lancaster, southern Saline, northern Jefferson, Nuckolls, Webster and Franklin, western Phelps, and southwestern Buffalo Counties. The first brood was especially damaging from June 23 to July 29, chiefly in the corn, and caused a heavy loss, considerably heavier than the loss in 1923. The loss in one Nebraska county in 1924 was estimated by the county agricultural agent at $100,000. No doubt the crops of several others of the infested counties were equally seriously injured, and the total loss in all of the eighteen Nebraska counties that were more or less concerned in the outbreak in 1924 could probably be conservatively estimated at $750,000.

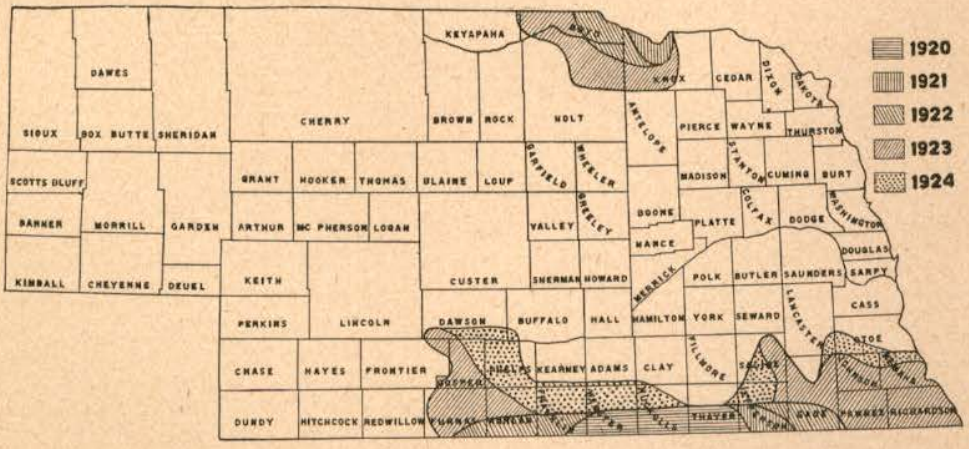

FIG. 1.— Progressive spread of the area in Nebraska injuriously infested by the chinch bug during the years 1920 to 1924, inclusive. (Original.)

From the information now at hand the chinch bugs survived the winter of 1924-25 very successfully. They spread abundantly to the small grain fields this spring, and the dry month of May, 1925, was

quite favorable for their increase. They became very abundant in many wheat fields, and more generally distributed over the whole infested area than they were in 1924. They now occupy not only all of the area that was seriously infested by them in 1924 but are abundant in some new territory, notably in Fillmore and Clay Counties. Very recent heavy beating rains in several localities have given them considerable of a setback, so that they are not now as menacing as they were a month ago, but enough bugs still remain in many fields to threaten serious injury to the corn.

DISTRIBUTION AND APPEARANCE OF THE CHINCH BUG

The chinch bug occupies almost the whole of the United States east of the Rocky Mountains (except the tip of the Floridian peninsula), as well as Nova Scotia, New Brunswick and parts of Quebec, Ontario and Manitoba. Isolated colonies also occur in New Mexico, Arizona, California, and Washington. South of the United States it is known to occur in parts of Cuba, the West Indies, Lower California, Mexico, Guatemala, and Panama. But it is not a serious pest over all of this vast area, and has proved destructive chiefly in the Carolinas, Virginia, Ohio, Indiana, Illinois, Kentucky, Wisconsin, Minnesota, Iowa, Missouri, Arkansas, South Dakota, Nebraska, Kansas, Oklahoma, and Texas.

There are two forms of the adult chinch bug — a long-winged form and a short-winged form. The long-winged form, in which the wings reach almost to the end of the body (frontispiece, *g*), occurs almost exclusively over most of the interior region between the Allegheny and the Rocky Mountains. The short-winged form, in which the wings reach only one-half or two-thirds of the distance to the tip of the abdomen, dominates on the Atlantic seaboard and westward along Lake Erie to northern Ohio, and, less commonly, to northern Illinois. The two forms are structurally much alike except in the length of the wings, both being about one-fifth of an inch long, with the body black and the wings white, the latter contrastingly relieved by a conspicuous black spot near the center and outer margin of each upper or front wing. The true chinch bug may readily be distinguished from several small bugs of similar general appearance, collectively known as "false chinch bugs," by its black-spotted white wings.

ITS FEEDING HABITS AND FOOD PLANTS

In all of its stages the chinch bug possesses a jointed beak, fitted to pierce the tissues of green plants and liberate the sap, which is sucked up and forms the exclusive food of the pest. It feeds liberally on this plant sap thruout its active life, usually in as sheltered a posi-

tion on the plant as it can find, such as in the leaf curls, back of the leaf sheaths, in the heads, on the roots, etc. As a result of feeding on a plant, the chinch bug causes a reddish discoloration at the spot punctured by it and also the death of the plant cells at that spot. Attacked plants are badly stunted, with resulting diminished or suppressed yields in the case of grain or field crops, or else are killed outright, the whole plant wilting or falling to the ground. Drought greatly accentuates the injurious effect of chinch bug attack because of the doubled drain on the sap and vitality of the plant. When not feeding, the bugs hide under clods, fallen leaves or other rubbish, or bury themselves just beneath the top soil.

In securing food the chinch bug practically confines its attention to plants of the grass order. Among cultivated crops it prefers wheat and corn (maize), the first generation usually beginning its development in wheat and completing it on corn. The other small grains — rye, barley, oats, emmer, and spelt — are also attacked, but are usually less damaged than wheat. In addition to corn, these bugs can complete their development on the sorghums, including cane, kafir, milo, shallu, feterita, Sudan grass, kaoliang, durra, and broom corn, and on the millets, including Hungarian grass. In the northeastern United States, timothy is a favorite food plant of this pest, and in Mexico, sugar cane is attacked by it. Other grassy food plants of the chinch bug are Johnson grass, the blue-stem grasses, sand-bur grass, foxtail grass, crab-grass, barnyard-grass, witch-grass, oat-grass, bottle-brush grass, and blue-grass. It is also reported as sometimes feeding on false buckwheat and currant, but such feeding habits are exceptional. When confined to wild grasses for its food the chinch bug does not as a rule flourish like it does in cultivated grain crops. Leguminous crops, such as alfalfa, clover, soybeans and cowpeas, are not attacked by the chinch bug, nor are buckwheat, rape or fodder beets injured by them. An increase in the acreage of these immune crops tends to diminish the numbers of the chinch bugs in that locality.

ITS LIFE CYCLE

Over the region lying between the Allegheny Mountains and the Rocky Mountains, where the long-winged form of the chinch bug either occurs exclusively or dominates and where the greatest damage to cereal crops by this pest takes place, it passes thru at least two complete but more or less overlapping generations each year. In the more southern parts of this region a third generation is started in the fall, but these belated young chinch bugs apparently fail to attain maturity, and perish during the early winter. Where the short-winged form dominates there may be but a single generation annually. As a rule, only the adult bugs survive the winter, and they are able to do

so only if they find adequate hibernating quarters before the coming of cold weather.

As winter approaches, chiefly during November, the adult chinch bugs locate themselves in the nearest places that will provide at least adequate shelter, and preferably also, if possible, a little supply of green food for the remaining warm days and for the spring days to come before they will leave their retreats. Naturally, the exact character of the cover thus used by the bugs will vary according to locality. In the timothy meadows of New England, New York, and northern Ohio they mostly remain for the winter in the same fields that they fed in during the summer. Farther west they find satisfactory winter quarters by moving to the grass, weeds, and drifted leaves along the roadsides, edges of fields, ditch banks, and ravines, and hiding there or under the logs, stumps, stones, and other objects along the protected southern edge of woodlands, or else they merely crawl under the shocks of corn or fodder crops left in the field during the winter or locate down in the base of the fodder stubble or under the leaf sheaths and husks of the standing corn in the field. Their favorite and most successful wintering place in the plains states, however, is to fly to the nearest dense tufts of bunch-forming prairie grasses, especially the blue-stems and Johnson grass, and tuck themselves down among the crowns.

After the warm spring days have sufficiently revived the adult chinch bugs that have succeeded in surviving the winter, that is, after the temperature has risen to 70° or 80° F., they move just as far as may be necessary to find a plentiful supply of green food, either by crawling or by flight, tho chiefly by the latter method. Sometimes the air is filled with them. This movement usually begins early in April and in Nebraska continues thru May. The bugs do not all desert their winter quarters at once, but come out gradually, so that the first ones to leave have begun egg-laying before the last ones have come forth, several weeks later. Fields of growing wheat and to a less extent other small grains, and of timothy and other grasses, close to their recent wintering quarters, furnish food plants for the hungry bugs, which gather near the roots of these plants and suck out the sap. Some of the last bugs to leave establish themselves in oats fields and in old corn fields given over to an abundant growth of grassy weeds.

After the recently revived bugs have reached their feeding ground in May, they mate, often repeatedly at intervals of several days, and soon the females begin to deposit their eggs in rows of several eggs each on the roots of the grain or grass plants and in the soil about them, as well as largely back of the lower leaf sheaths and on the stem. The egg of the chinch bug is about one-thirtieth of an inch long by one-third as wide, elongate bean-shaped with one end rounded and

the other end flattened and bearing from three to five tiny tubercles, dull white in color at first but in a few days darkening to amber and finally to reddish as the young bug develops in it (frontispiece, *a*). The average female chinch bug lays from 100 to 200 eggs during her life, tho some prolific individuals may lay more, as many as 500 or thereabouts. The eggs hatch in from twelve to forty-three days after being laid, according to weather conditions, sooner if the weather is warm, later if it is cool, the average time being about twenty-one days. Thus hatching begins in latter May or early in June. As the young bugs hatch they begin to feed and grow rapidly.

The newly hatched chinch bugs are a trifle longer than the egg from which they hatched, and are brownish in color with the first two abdominal segments and most of the third segment pale or whitish, the following segments being light red with the tip of the abdomen black (frontispiece, *b*). As they grow, and before they become adult, the growing bugs usually pass thru four additional stages, the first of which resembles the newly hatched bug except that it is about one-twentieth of an inch long and has only the first two abdominal segments pale (*c*), the second of which is about one-fourteenth of an inch long and has tiny wing pads and two distinct dark spots on the fourth and fifth abdominal segments (*d*), the third of which is about one-twelfth of an inch long with the wing pads distinct and the mostly dark red abdomen with two conspicuous black spots (*e*), and the fourth of which is one-eighth to one-sixth of an inch long with the well-developed wing pads reaching the third abdominal segment and the whole thorax above shining black (*f*). Each stage is preceded by a molt, and the cast skins may be observed abundantly on the food plants of the bugs. By the time the small grains begin to ripen and dry, the adult bugs that survived the preceding winter have nearly all died and the young bugs have not as yet gained their wings. Hence, to prevent starvation, there is a general concerted migration of the chinch bugs on foot, from the small grains to the nearest field of corn, millet, cane, kafir, or other sorghum crops.

As the crawling masses of unfledged chinch bugs in all stages of development reach the green crops, they concentrate on the outer rows, until the plants are nearly black with them, and usually the plants thus first attacked are soon killed. They like to gather on the brace roots of the corn in such numbers that the weakened plant falls. The predominatingly immature bugs of the first generation finish their development on the corn and feed crops, most of them having become winged and mature by the end of July, tho some late ones, especially in northern Nebraska, do not gain their wings until well into August. It requires from fifty-one to ninety-four days, with an average of sixty days, from the time of hatching for the individual bug to reach

maturity. This second generation of adults deposits its eggs during latter June, July, and August on the roots and in the soil around the roots and on the lowest leaves of corn, the millets, and the sorghums. The eggs of this generation, which are often much more numerous than those of the first generation, mature from the middle of August thru September and October, sometimes doing serious injury to crops. In the North there is usually not much egg-laying after the end of August, but the adults linger about in the corn and fodder shocks, and in the stubbles, until cool weather drives them to seek their hibernating quarters in late October and November. (See Fig. 2 for diagram of life cycle.)

CAUSES OF ITS VARYING ABUNDANCE

It has been stated above that the chinch bug does not become seriously destructive to crops thruout its range, but for the most part only in the central Mississippi Valley region, and that while certain years or series of years are marked by conspicuous crop losses in the susceptible regions because of this pest, in other years it does but little if any damage. This localization and irregularity of injuries by the chinch bug is due to the influence of the varying favorable or unfavorable conditions of its environment, especially during certain critical periods of its life cycle. The most important of these influencing conditions seem to be (1) the abundance and quality of its hibernating cover; (2) the character of the weather during its reproductive periods; (3) the acreage of the cereals and grasses that furnish food for it; and (4) the efficiency of its contagious diseases, parasites, and predacious enemies.

The continuity of an outbreak of the chinch bug from season to season depends upon its ability to survive the winter in large numbers, and that ability is dependent upon the plentiful presence of hibernating cover of a proper quality. The shelter best includes enough green plant tissues to supply some food to a large number of bugs during that period following their entrance to the shelter and before cold weather comes on, and again in the spring before they emerge from their winter quarters; it must be dry enough to protect the bugs from repeatedly getting wet during warm winter thaws and then freezing in a wet condition when the weather again turns cold; and the cover must be dense enough to protect the bugs from the cold, sweeping winds of mid-winter. If these conditions are met, a large percentage of the wintering bugs will survive; otherwise, they will largely perish during the winter, in spite of their resistance to cold. They have been known to survive temperatures of fifteen to twenty degrees below zero for a time, even when incrusted with a coat of ice.

If, after the successful emergence of a considerable number of the bugs from their hibernating quarters in April and May, they encounter

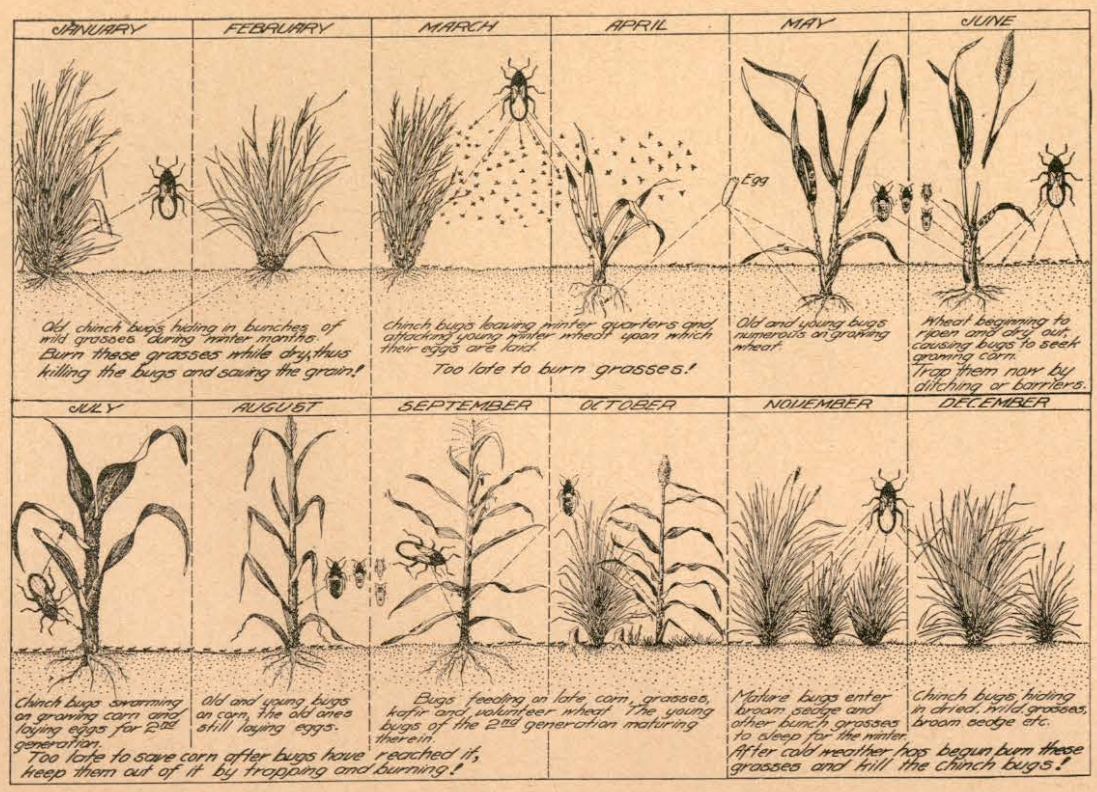

FIG. 2.— Life cycle of the chinch bug by months. (From chart of the Bureau of Entomology, U. S. D. A., 1918.)

a period of weather that is warmer than normal, especially if accompanied by an absence of heavy beating rains during the period of the hatching and growing of the young bugs in latter May and June, a rapid increase in numbers is likely to result, tho that will not necessarily be the case. If there is also a deficiency of rainfall during the late spring and summer the favorable conditions are considerably enhanced, but if weather conditions are otherwise favorable the chinch bug can increase toward or into an outbreak when the rainfall is normal or even considerably above normal. The character, rather than the amount, of rainfall is the important factor. If, furthermore, the summer is warm and there are no beating rains during latter July and August, the critical period for hatching and young bugs of the second generation, the increase in numbers is again likely to be greatly augmented. A few generations under these favorable conditions and an outbreak of the chinch bug usually develops, provided other conditions are also favorable. But if, on the other hand, the late spring and summer is cooler than normal, with the rainfall above normal and falling in repeated beating storms during latter May and June or August, or both periods, the chinch bug is quickly checked. The cool weather greatly delays the hatching of the eggs, and the young bugs, and even the adults, are killed by being imbedded in the mud during the beating rains, while frequently the terrible contagious fungous diseases of the chinch bugs are caused to appear among them.

In two areas where weather conditions are approximately equally favorable, the chinch bug will increase more rapidly in the area having the larger acreage of wheat, oats, corn, and forage grasses, the crops upon which the pest can freely develop, and especially where these crops are so well distributed that the bugs emerging from hibernation in the spring can easily find their way to the wheat fields from their wintering places, and later on their progeny can find it easy to move from the wheat to fields of corn or other summer crops when the wheat harvest arrives. If the acreage of cereal crops is small, especially the acreage of wheat, upon which crop the chinch bug largely depends for food in the spring, and if the comparatively few grain fields are widely scattered and separated from the corn fields by hills and ravines, conditions are not very favorable for chinch bug increase, even tho the weather be warm and without beating rains.

The natural enemies of the chinch bug, when efficient, may exercise a great influence in its control. Its contagious diseases constitute one of the most effective types of its natural enemies, and will be discussed fully a little farther on in this circular. Its only important parasite is a tiny sirphid egg-parasite, known scientifically as *Eumicrosoma benefica*, which was discovered in Kansas in 1913 and has since been found doing good service elsewhere in the Mississippi Valley. It is a

tiny, black and yellow, wasp-like insect that is active during the entire period of egg-laying covered by both generations of the chinch bug, from late April to early October. It deposits its minute eggs in the eggs of the chinch bug, and its larva feeds on the contents of the chinch bug egg. It transforms to the wasp-like adult within the shell of the chinch bug egg and then emerges to start another generation. The length of the entire life cycle is about two weeks in the spring, gradually shortening to about ten days in the summer, and then again lengthening to about twenty-eight days in the fall, thus enabling about nine generations in a year. Each of the two broods of chinch bug eggs is subject to attack by four or five successive generations of the parasite, making the total percentage of parasitism for each brood of chinch bug eggs sometimes as heavy as fifty per cent. The predacious enemies of chinch bugs, including various predatory bugs and beetles, lace-winged flies and ants, often destroy large numbers of them. In central Illinois it has been estimated that, in an average forty-acre stubble field during July, these predacious enemies destroy daily about two million chinch bugs. Owing to their disagreeable taste, corresponding no doubt to their unpleasant odor, chinch bugs are not much relished by birds, tho a few kinds of birds, like the Bobwhite, feed freely upon them. Toads and frogs also eat them freely. It is probable that these predatory enemies, together with the egg-parasite, are an important natural force in keeping down the chinch bug for a number of years after it has been reduced in numbers by adverse weather conditions, following a period of abundance and injury.

THE FUNGOUS DISEASES OF THE CHINCH BUG

For over half a century, it has been known that under certain conditions the chinch bug is very susceptible to epidemic diseases produced by parasitic fungi, and that these diseases, on occasion, play a deadly part in the natural control of this pest. The first epidemic of this sort on record is one that was observed in northern Illinois in 1865, following a period of warm, moist weather. Following this epidemic of 1865, there is no record of the prevalence of a fungous disease among chinch bugs for the following seventeen years. When epidemics of chinch bug disease were again observed, in later years, it was discovered that there were two distinct kinds of fungous diseases that attacked this pest. One enveloped the dead bug in a grayish white covering and was called the gray-fungus disease, while the other enveloped the dead bug in a white cottony mass and was called the white-fungus disease. An epidemic of the gray-fungus disease occurred in Illinois and Kansas in 1882, and epidemics of the white-fungus disease were noted in 1887 and 1888 in Illinois, Ohio, Iowa, Minnesota, and Kansas. Immediately after these latter epidemics these diseases became the subject of much

interest and investigation in several of the chinch bug infested states, especially in Illinois and Kansas, and these studies continued intensely for the next decade, by which time the general nature of the diseases was fairly well understood. The white-fungus disease was soon found much the more frequent and important disease of the two.

The theory first obtained that these diseases were not as yet widely disseminated over the chinch bug infested sections of the Mississippi Valley, but were only in process of spread, and that the distribution of diseased or inoculated chinch bugs would serve to introduce the disease widely, and especially in those fields where the bugs were proving injurious. The first effort to artificially spread the white-fungus disease was made in Illinois and Minnesota in 1888. During the period from 1888 to 1896, the distribution of diseased or inoculated chinch bugs was taken up actively in several states, notably in Illinois, Minnesota, Kansas, Ohio, Nebraska, Iowa, and Missouri. Chinch bugs were allowed to contract the disease by confining them for a time with obviously diseased bugs, and then were placed in packages and sent to various localities in the state, where they were liberated in the fields. The results appeared at first to be successful, for a little later the chinch bugs in these localities where inoculated bugs had been liberated were found to be dying with the disease. In fact, the disease spread so rapidly as to give rise at the time to a very strong suspicion that the malady was already present in these localities, and that the rapid spread was due to disease spores already there, rather than those introduced by the inoculated bugs that had been sent in and liberated. Nevertheless, many thousands of packages of inoculated chinch bugs were sent out to farmers during the late eighties and early nineties in several of the Mississippi Valley states mentioned above. In Nebraska, the distribution of inoculated chinch bugs began in 1893, was continued thru 1894, 1895, and 1896, was suspended in 1897, was again resumed in 1898 and continued thru 1899, 1900, 1901, and 1902, and was again discontinued with the final subsidence of the prolonged outbreak of 1892-1903. When the outbreak of 1906-1911 developed, a few lots of inoculated bugs were sent out, upon urgent request, up to 1910, when the practice was finally and completely discontinued in Nebraska.

For the first few years that inoculated chinch bugs were being distributed, that is, up to about 1896, it was believed by many that the artificial distribution was accomplishing worth-while results. But gradually it became apparent that the spores of the fungus causing the white-fungus disease were naturally widely distributed over the areas subject to serious injury by the chinch bug, and that as a rule, when weather and other conditions were favorable, the disease spread and killed the bugs as effectively in fields where no inoculated bugs had been introduced as in fields where such diseased bugs had been dis-

tributed. Frequently shipments of chinch bugs sent by farmers in tight boxes with green vegetation, thereby forming moist conditions in the box, for inoculating with the disease, arrived at the laboratory already heavily attacked by it; or, on shipments being isolated, they developed the disease without having been confined with diseased bugs. But it was yet thought possible in 1896 that the artificial distribution of the disease might accelerate or intensify its progress during periods of favorable weather. After 1896 the chinch bug injuries in the Mississippi Valley subsided, and when this pest again began to cause trouble the tendency of the states was to resume the distribution of inoculated bugs less enthusiastically, if at all, and with greatly reduced confidence that any results of real value would follow. When, in 1909 and 1910, another recrudescence of the chinch bug took place, apparently only three states sent out chinch bug fungus, the other states having abandoned the method as impractical, because the disease was known to be generally present in the fields, where it would break out naturally if the temperature was 70° to 80° F., the air practically saturated with moisture (that is, with a relative humidity of over 90 per cent), and the bugs very plentiful and massed, while no amount of distributing inoculated bugs would cause an outbreak of the disease if the weather was too cool, too hot, too dry, or the bugs too scatteringly distributed.

Among the last extensive distributions of diseased chinch bugs by a state agency seems to have been that which took place in Kansas in 1910. Altogether, 1,363 packages of diseased bugs were sent into seventy-five Kansas counties, representing all sections of that state, in that year. But, before any of these diseased bugs were distributed, field investigations were made to learn if the white-fungus disease, which had been found very generally present in Kansas fields in 1895 and 1896, had maintained itself in those fields thru the fourteen-year period during which no diseased bugs had been distributed, and also to secure data to decide whether the results obtained by artificial infection justified the labor and expense involved. It was found in these field investigations that before the chinch bugs emerged from hibernation, in latter March, they were already affected with the white-fungus disease in thirty-two Kansas counties, and after the distribution of the diseased bugs had begun early in April, and from then up to the end of June, diseased bugs were found in twenty-seven additional counties, in fields where no artificial distribution had taken place. In other words, the white-fungus disease of the chinch bug was found to be present naturally in fields everywhere thruout the chinch bug infested area in Kansas. It was also found to be more uniformly distributed thru the fields than any artificial distribution could have effected, and in such great abundance that artificial distribution became, by comparison, insignificant and impractical.

These and subsequent field investigations have shown that the appearance of the white-fungus disease among the chinch bugs in an infested field is largely influenced by moisture conditions, and that its artificial introduction into a field has no measurable effect either in producing the disease where it is not already in evidence or in accelerating its effect on the bugs where its natural presence is plainly evident. The disease shows little tendency to spread from centers of artificial introductions, its apparent rapid spread being due to favorable conditions bringing it into activity simultaneously over large areas. The apparent absence of the disease in a field is considered as evidence of unfavorable conditions, rather than due to any lack of fungous spores. The apparent successes in the introduction of the disease into fields in the nineties were undoubtedly largely due to the failure to make due allowance for the spontaneous outbreaks of the disease, simply because inoculated bugs had been introduced into the field, and to the failure to check and compare the supposed successfully treated fields with untreated fields, as well as to the mistaking of molted skins for dead bugs. All of the benefits of fungous disease may be realized by merely allowing the fungus naturally present in the soil to do the work of extermination as far as it will, and the sending out of diseased bugs, or even the advocating of it, does not serve the best interests of the farmer, since it diverts his attention from the other more dependable methods of fighting the pests. The present attitude of entomologists toward the artificial propagation and spread of chinch bug disease fungi is practically unanimously in conformity with the judgment just set forth — that the results cannot compensate for the expense and labor involved. So far as the writer is aware, no institution in the United States has engaged in the propagation and distribution of chinch bug fungus, or the sending out of inoculated bugs, for the past ten years or more.

GENERAL METHODS OF CHINCH BUG CONTROL

There are three periods in the life cycle of the chinch bug when it may be successfully attacked by the use of artificial methods of control. The first of these periods is when the ripening or cutting of the wheat and other small grains forces the bugs to migrate, mostly on foot, in search of corn and other green crops, and they may be stopped and destroyed by the use of various kinds of barrier traps. A second vulnerable point in the life cycle of this pest is when the migrating bugs first enter the corn fields and cluster thickly on the outer rows, when they may be killed by spraying or dusting. The third method of control, and probably the most important one, is the destruction of the bugs in their winter retreats by fire, supplemented with a general clean-up of all hibernating cover that cannot well be destroyed by burning.

PREPARATIONS FOR THE USE OF BARRIER TRAPS

The use of barrier traps to stop and destroy migrating chinch bugs is a much more valuable method of control in southern Nebraska than in northern Nebraska, for the reason that in the northern part of the state harvest is sufficiently late, as a rule, to permit a considerable number of the bugs to have developed to the winged state, so that they can fly directly from the small grains to the corn, and not be forced to make the migration on foot. As the barrier traps are designed to destroy only bugs that make this migration by crawling, it naturally follows that the greater the proportion of winged bugs at harvest time the less valuable is the barrier trap method of control.

Even in southern Nebraska it occasionally happens that some fields of small grains are so delayed in ripening that the bugs have largely become matured before impending starvation forces them to migrate. In general, however, barrier traps may be used very effectively over the whole of the South Platte region of Nebraska. It also sometimes happens that the stand of the grain is so thin that enough grass-like weeds have been able to spring up all over the field to furnish abundant food for the bugs after the grain has ripened, thereby delaying the migration. In such instances the grain should be cut as soon as possible, removed from the field, and the weeds and stubble mowed and burned off as soon as they are dry enough, or else they should be destroyed by a thoro disking. If a heavy growth of weeds and stubble is burned off, enough heat may be generated to kill large numbers of the bugs directly. Such a treatment will leave the bugs nothing to feed upon, and will compel an early migration and enable the use of a barrier trap.

It is very important that the owner of a field of wheat, oats, or other small grains in the South Platte region that is infested by chinch bugs should realize its menace to adjoining or nearby fields of corn or feed crops, and as harvest time draws near, that he should prepare a plan of defense for the latter. Corn planted near to such infested small grains is very likely to be entered and badly injured or destroyed, so that the use of the land for the season, the seed, and all of the labor required to bring the corn to a good height will be largely or completely lost, unless the field is given protection from the threatened invasion.

As has been stated, the bugs will usually become restless a week or so before the ripening grain is ready for harvesting and will begin to migrate in search of more succulent food. There are various kinds of chinch bug barriers that may be constructed to stop such migrating bugs, and either such a barrier should be prepared around the infested field to catch and destroy the bugs as they try to escape, or the threatened area should be protected by a barrier along the side or sides

closest to the infested field. Before the bugs begin to move, the strip where barriers are to be made should be freed from weeds, so that when the proper time comes the soil of this strip will be mellow enough to break up and pulverize easily. The necessary materials for an oil-line barrier should be secured, or plans made for quickly obtaining such materials in case they are needed. As the small grain begins to ripen, the infested fields should be closely watched, and, as soon as the young bugs are observed moving out, the barrier should be constructed, the dusty barrier first, if one is to be used, and outside of it or between it and the field to be protected the smoothed path or furrow that is necessary when an oil-line barrier is employed. The expense of maintaining the barrier will depend upon the proportion of the day during which the bugs are moving and the number of days the movement continues, and this will vary with the weather and other conditions.

MIGRATION OF THE YOUNG BUGS

After the migration of the young chinch bugs out of the ripened or cut small grain fields begins, it does not continue uninterruptedly. The bugs do not migrate at night. Neither do they migrate during the whole of a bright, hot day. They usually begin about 3:30 to 4:00 p. m., continue to move in increasing numbers up to 5 or 6 p. m., when the migration is at its maximum, and then gradually quiet down so that none are moving by 7 p. m. There may also be a slight movement in the morning, beginning about 7 or 7:30, after the temperature has reached 74° F., but ceasing by 10 or 11 a. m. For four or five hours during the middle of a bright, hot day, there is no movement. During cloudy and cool weather the bugs may move more or less all day, beginning at about 9 a. m. The number of days consumed by the bugs in moving from a field also depends largely upon the weather. If the period is dry, so that the food in the infested small grain field is soon exhausted, the entire passing may take place in six to ten days. If the period is rainy, the passing may be so leisurely as to spread over a month. The usual period is ten to eighteen days. Also, the character of the infested fields may shorten or prolong the migration period. If the bugs are coming only from wheat fields the period is much shorter than when they are coming from barley or oats also. Finally, if there are no intervening food plants between the infested small grains and the corn, the passing is short, but if there is considerable grass between the infested field and the barrier, in which the bugs may slow up and feed for several days, the period of maintaining the barrier may need to be prolonged to that extent.

EXTENT AND GENERAL TYPES OF BARRIERS

If the barrier is constructed only between the infested small grain field and the field to be protected, as is often the case, it will, of course, largely or entirely prevent the wingless bugs from getting at once to the growing crop and injuring it, and at the same time it will cause the death of millions of the bugs, a combined service of enormous value. However, it should be kept in mind that when the bugs leave a ripening or cut small grain field they do so in all directions, and that if the barrier is erected along one side only of the infested field many of the bugs will easily escape from the other sides and make their way to grassy weeds or other cropped fields, where they can subsist until they get their wings. They will then fly into the cornfields and injure them, largely developing a second generation in them. But if the barrier is constructed entirely around the infested field there is no escape for them and they are practically all trapped and killed if the barrier is kept effective.

There are three general types of chinch bug barriers, (1) the dust barriers, (2) the oil-line barriers, and (3) the gas barriers. If the weather is hot and dry at harvest time, and especially if it is necessary to throw up a barrier quickly, or if the materials for making an oil-line barrier are not available, a dust barrier is the type that is usually employed. Should the entire period during which the bugs are deserting the ripened and cut small grains continue to be hot and dry, the dust barrier will in most cases be found adequate and effective, and being the simplest and least expensive barrier known, its use is to be recommended under such circumstances. But if the weather turns rainy the dust barrier becomes immediately ineffective, so that if the bugs are to be kept out of the corn an oil-line barrier must be resorted to promptly. Because of this unreliability of the dust barrier, many farmers will prefer to use an oil-line barrier from the start.

MAKING A DUST BARRIER

The longest-known kind of chinch bug barrier is the dust barrier. It is made by plowing or deeply disking a strip eight or ten feet wide, either around the infested field or between it and the threatened field, afterward harrowing or dragging this strip until the soil is finely pulverized. With a plow or lister a deep furrow is then thrown out on the side of the pulverized strip nearest to the field to be protected, making round corners if the strip surrounds the infested field. A barrel, a log, or better yet, if the time is available to make one, a specially constructed trench drag, is then hitched up to a horse and dragged back and forth in the furrow until its sides and bottom have been reduced to a fine dust. (Fig. 3.) The specially constructed trench

drag may be made by spiking a 2 x 12 inch plank, four feet long, to a 2 x 14 inch plank of similar length, flush with one end at right angles with it, thus forming a trough-like or V-shaped drag with 14-inch sides that can be reinforced by a short piece nailed across each end and weighted down as much as may be desired with sacks of sand. Two of these trench drags may be held parallel and about a foot apart by a couple of strong 2 x 4 inch pieces nailed firmly across the top, and operated to form a double furrow with no more work than it takes to make a single one. By frequent dragging the furrow is kept in the requisite dusty condition. This type of dust barrier provides not only a dusty furrow but also forces the bugs to cross several feet of dusty soil before they can reach the furrow and an additional space on the other side of the furrow for such few bugs as succeed in crossing it. This causes many more of the bugs to perish from the heat, or thru suffocation from the fine dust, as with much effort they make their way over the pulverized soil, than when a simple dusty furrow is maintained.

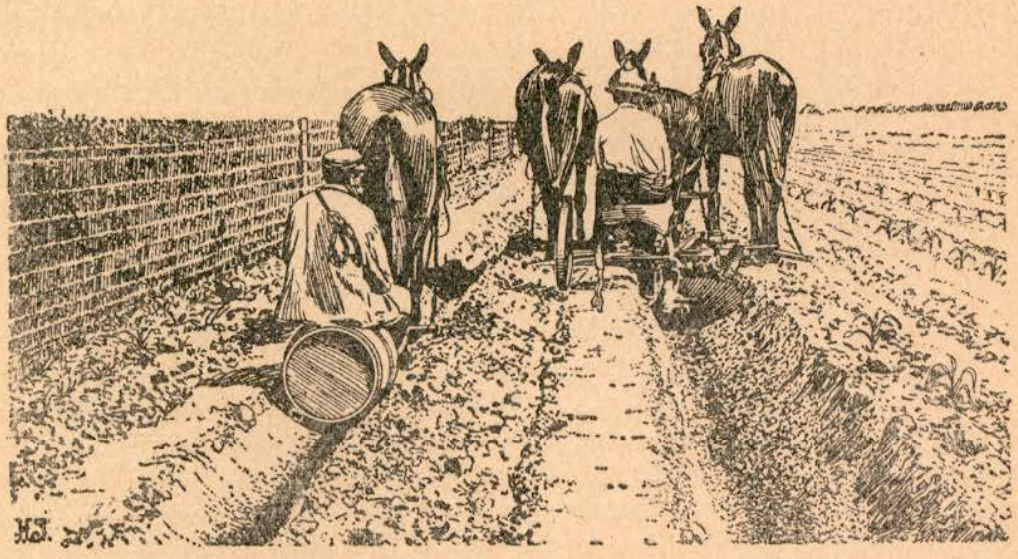

FIG. 3.— Making a dust barrier with a barrel drag. (From circular of the Bureau of Entomology, U. S. D. A., 1918.)

Whenever the migrating chinch bugs reach a dusty furrow, they enter it but are unable to readily crawl out the other side because of the fine particles of dust rolling under their feet. They then tend to begin crawling back and forth in the bottom of the furrow. They can then be destroyed by continuously crushing them with the drag, by scorching them with a gasoline torch, or by trapping and killing them in post holes. If the gasoline torch method is used, the sides and bottom of the dusty furrow are flamed at regular intervals with a gasoline blast torch that throws a strong, blue flame six or eight inches long and two or three inches broad that fills the furrow with

the flame and heats sufficiently to kill all of the bugs in it. A torch with a small flame is not practical because it works too slowly and may be blown out by the wind. If the bugs are killed by this method, the furrow can be dragged to renew its dustiness as often as may be necessary without any inconvenience. The gasoline, however, is likely to prove a fairly expensive item. If the post hole method is used, holes twelve to eighteen inches deep are dug with a post hole auger in the bottom of the furrow every fifteen to twenty feet, according to the abundance of the bugs in the furrow. The mouth of each hole should be flared a little and kept smooth and dusty to cause the bugs to fall into it, and once they are in, to prevent them from getting out again. As the bugs move in the furrow, if they do not previously die of heat or suffocation, they eventually are crowded into these post holes, and cannot get out again because of the fine dust at the mouth of the hole. They can then readily be killed by pouring kerosene over them, each evening, with enough water added to float the oil to the top of the mass of bugs, by dropping a small quantity of calcium cyanide flakes into each hole, or else by filling the hole with dirt which is immediately tamped down and a new hole dug close by. The chief disadvantage of the post hole trap method of killing the bugs is that by their persistent efforts to climb out of the furrow the bugs will gradually pull down the dust on its sides, while small animals crossing it will make trails that the bugs can follow and escape, or the wind may blow out the loose dust, all of which make necessary the redragging of the furrow to renew its dusty condition. Each such dragging makes necessary the digging of new post holes, or the cleaning out of the old ones, adding greatly to the labor of maintaining the barrier.

The dust barriers, as has been mentioned, have one unfortunate weakness — that is, they become ineffective at once if the weather becomes rainy. Even a moderate shower so encrusts the soil in the furrow that the chinch bugs can readily pass on out of it or thru it, and they will of course continue to do this until the soil again becomes dry enough to permit repulverizing with a drag. This weakness of the dust barriers has led to the development of a type of barrier that will be effective in rainy as well as dry weather, namely the oil-line barriers. Of these there are three principal types, (1) the coal-tar or gas-tar line, (2) the road-oil line, and (3) the crude creosote line.

MAKING AN OIL-LINE BARRIER

There are two types of oil-line barriers in common use, (1) the smoothed-path type and (2) the furrow type. To construct a smoothed-path oil-line barrier, a smooth, firm, path about six inches wide entirely free of vegetation is formed around the infested field or along the threatened side of the field to be protected, by dragging a broad, thick,

heavily weighted plank back and forth and then tamping or rolling the space, or else by using a hoe and shovel to make such a path. An empty buggy is then driven along the path so that the wheels on one side run in the center of the path and form a narrow tire groove. Post holes twelve to eighteen inches deep and twenty to thirty feet apart are dug on the very edge of the tire groove nearest to the bug-infested field, to trap the bugs as they crowd along the oil-line that is then poured in the tire groove, unless, as is also fairly satisfactory, the bugs are to be destroyed by flaming with a gasoline blast torch as they run back and forth along the edge of the oil-line. The bugs will not cross the oil-line. This type of oil-line barrier may be used with either coal-tar, road-oil, or crude creosote (Fig. 4). The furrow type of oil-line

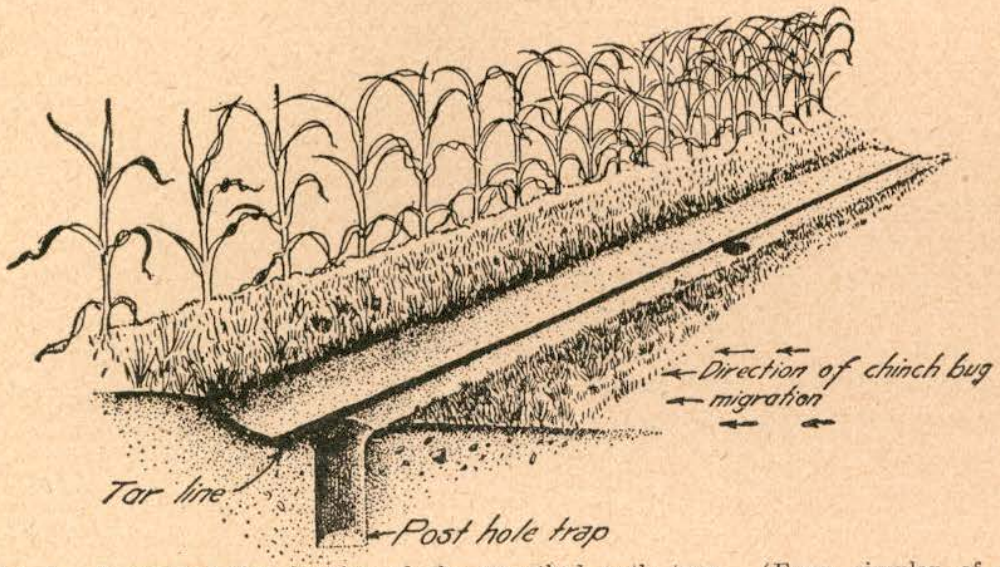

FIG 4.— A coal-tar line barrier of the smoothed path type. (From circular of the Bureau of Entomology, U. S. D. A., 1918.)

barrier is used chiefly in connection with a line of crude creosote. A dust barrier, constructed as has already been described, instead of having the furrow dragged and pulverized has the vertical or land side of the furrow farthest from the oncoming bugs made straight, firm, and smooth with a spade or hoe, and a line of crude creosote is laid in a groove on that side, three-fourths of the distance up from the bottom of the furrow. The post holes are dug in the bottom of the furrow (Fig. 5). The bugs can be killed in the post holes by dropping a small quantity of calcium cyanide flakes into each hole or by pouring kerosene over them, just as in connection with the dust barrier.

THE THREE TYPES OF OIL-LINE BARRIERS

The coal-tar or gas-tar line was the first oil-line barrier to be developed. Coal-tar or gas-tar is a by-product in the manufacture of illuminating gas, and can be obtained from any gas manufacturing plant on short notice. However, the supply at such plants is usually limited and cannot be increased to take care of an increased demand, while the price, which is normally high for use in chinch bug barriers, will usually sharply advance if the demand becomes unusual. Frequently the limited supply soon becomes exhausted and resort to other materials is necessary. When a coal-tar line is first put out it performs very efficiently, being so sticky that ordinarily the bugs do not attempt to cross it, and are quickly held and killed if they do make the attempt. But at the usual spring and summer temperature the coal-tar becomes so fluid that it soaks rapidly into the soil and thru exposure to the air forms a surface film upon which the bugs can and do cross without injury. That means that to maintain the coal-tar line effectively it must be spread upon a very firmly compacted surface and renewed twice a day, or oftener if the weather is very hot and dry, at a considerable cost for material and labor.

In order to obviate this expense of very frequent renewals of the coal-tar oil-line, road-oil barriers were first developed. The road-oils are thick, viscid petroleum residues containing varying percentages of asphaltic materials, and known as road oils Nos. 5, 6, 7, 8, and 9, according to whether they contain 50, 60, 70, 80, or 90 per cent of asphaltic materials. Experiments conducted in Illinois show that road-oils Nos. 5 and 6 are too fluid for the best results, requiring as frequent renewal as coal-tar. On the other hand, road-oils Nos. 8 and 9 are so viscid that they may require heating to make them fluid enough to pour from the vessel used in making the line, and moreover are not soft enough after pouring to prevent the crossing of the line by the bugs at the lower temperatures at which migration of the bugs may take place. Road-oil No. 7, containing 70 per cent of asphaltic materials, combines the desirable qualities of sufficient fluidity for easy pouring without heating, and yet sufficient viscosity to prevent its soaking into the soil rapidly and thereby requiring frequent renewals, and at the same time forms a virtually impassable barrier. It is that grade of road-oil that is recommended for use in oil-line barriers. Compared with coal-tar, road-oil No. 7 requires only about one-fourth as many renewals under the same conditions, but it requires for its successful use the same firm, compact, vegetable-free, level, smoothed path as coal-tar does. Its greater lasting qualities, as compared to coal-tar, are partly offset by the fact that road-oils of this viscosity are hard to secure, and must be ordered well in advance of the expected need for them.

The hard, smooth path required for the successful and economical use of coal-tar or road-oil No. 7 as a chinch bug barrier is not especially difficult to construct on bare, hard ground along the roadside, but on plowed ground or in stubble fields much rolling, tamping, and dragging may be required to obtain a suitable path, especially during hot, dry weather. With either the coal-tar or the road-oil, heavy rains wash away the lines and cover them with dirt, while in dry weather blowing dust or rubbish sticks to the line, forming bridges upon which the moving bugs can cross, in either case necessitating a prompt repair or renewal of the line. The barrier of crude cresote largely obviates both of these difficulties. Rains increase rather than destroy the efficiency of the creosote barrier, because the water floats the creosote that has soaked into the soil to the surface again, and blowing dust and rubbish do not make bridges for the bugs to cross over upon. These advantages are due to the fact that crude creosote checks the moving bugs, not because of any sticky or caustic properties, but because of its exceedingly odorous vapor, which is repellent to the bugs. When poured on the soil the creosote soaks in, slowly evaporating on exposure to the air, but the bugs will not cross the line as long as the odor remains strong. On encountering the creosote line they will nearly always turn and crawl in another direction, usually up and down in front of the creosote line or in the furrow bottom, finally lodging in one of the post hole traps. The creosote needs renewing only when the odor becomes so faint that it will no longer repel the bugs, usually about once a day. Midday is the best time to renew it, because there are but few bugs massed against the line at that time, and when the creosote is poured many of the bugs became confused by the strong smell of creo-

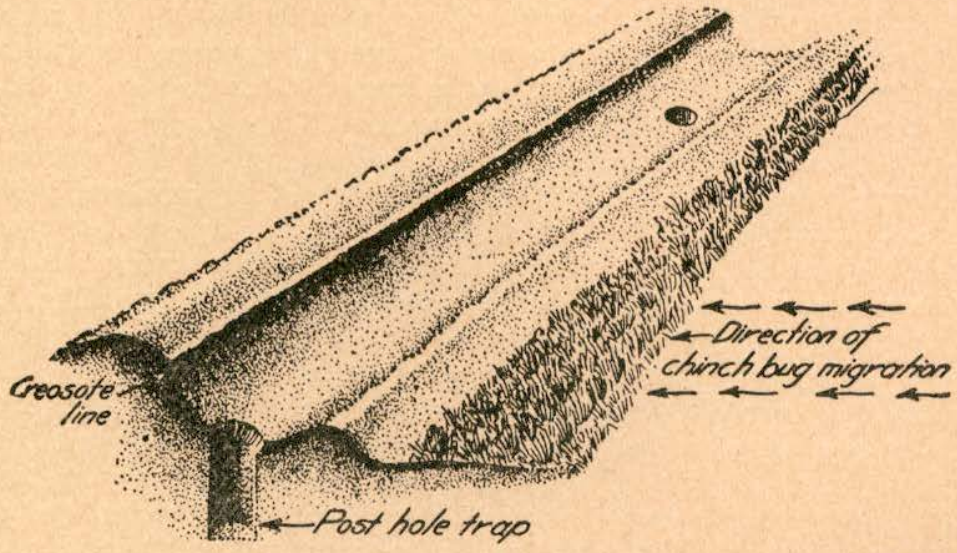

FIG. 5.— A creosote line barrier of the furrow type. (From circular of the Bureau of Entomology, U. S. D. A., 1918.)

sote in the air and run over the line. A few bugs will venture to cross a creosote line, and do so without evident injury to themselves, but not enough of them will do so to cause any noticeable injury to the corn. Crude creosote is readily and generally obtainable in any desired quantity on short notice from several large dealers in coal-tar products, and in general, presents so many advantages that it is now regarded as the best kind of oil to use in a chinch bug barrier.

In applying a line of coal-tar, road-oil, or creosote, a pail or bucket with a hole of suitable size punched in the bottom or side can be used. For road-oil the hole should be about a half inch in diameter, for coal-tar a little smaller, while a six penny nail hole is sufficiently large for pouring creosote. A sprinkling can with the rosette removed, or a large coffee pot, will better serve the purpose with road-oil or coal-tar, especially if the oil is thick and viscid, than a pail or bucket with a hole. If a large amount is to be laid, a five-gallon can may be mounted between the wheels of a two-wheeled truck and fitted with a stop-cock that can be set to allow a sufficient flow of oil to fill the groove as the truck is driven along. Laying the oil in a groove will cause it to spread out less and sink into the soil more slowly than if simply poured on a flat surface. After applying an oil-line, all subsequent applications should always be made over the original line.

THEIR COMPARATIVE COST

The cost of an oil-line barrier depends upon the price of the oil, the total amount needed, and the labor involved in renewing the oil-line. The initial effort in preparing the barrier is about the same in all cases. As a basis of comparison we may take a quarter of a mile of barrier for the normal migration period of ten days. Figuring on the renewal of the coal-tar line two or three times a day, it will take from fifty to seventy gallons of by-product coal-tar or gas-tar, which will cost at current prices in southeastern Nebraska ($7 a barrel) about $7 to $10 for materials. In the case of road-oil No. 7, figuring a renewal once or twice a day, it will require about forty gallons, making the cost a little less than that of coal-tar. Crude creosote oil can be obtained in southeastern Nebraska in fifty-five-gallon drums at a cost of about thirty cents a gallon, and renewed once a day would require about twenty-five gallons, making a cost of about $7.50 for the oil. These figures are of course for materials only. The labor cost for a road-oil line would be the same or slightly greater than that for a creosote line, while the labor cost of a gas-tar line would be two to three times as great as that of a creosote line. If calcium cyanide flakes are to be used for killing the bugs trapped in the post holes, and that seems to be a very satisfactory method of accomplishing this, a supply of about twenty-five pounds should be secured for each quarter of a

mile of barrier to be maintained for ten days, which will in all such cases add about $5 to the cost of maintaining the barrier.

MAKING A GAS BARRIER

Where and when atmospheric moisture conditions are favorable, calcium cyanide flakes may be used in connection with a furrow barrier to kill chinch bugs. The furrow barrier is constructed much like the furrow type of oil-line barrier, being at least five inches deep and having the vertical side of the burrow farthest from the oncoming bugs made straight, and the calcium cyanide flakes are distributed in a line on the furrow bottom farthest from the direction of approach of the bugs, using at least one pound of the flakes to each four rods of furrow length. Application should be repeated each afternoon when the migration begins, and for each quarter mile of such barrier, at least twenty pounds of calcium cyanide flakes will be needed each day. To be used effectively in this way, the soil upon which the calcium cyanide flakes are laid must be damp and the wind must not be blowing down the furrow strongly enough to quickly disseminate the fumes. Under Nebraska conditions, where July weather is apt to be dry and windy, especially during chinch bug years, this method is not likely to be dependably efficient, since on dry soils the flakes generate their fumes too slowly and on windy days the fumes are dissipated from the furrows in fifteen or twenty minutes after the flakes are applied. Used at the minimum effective rate of one-fourth of a pound a rod daily, and figuring the price of the calcium cyanide flakes at twenty cents a pound, it will cost at least $4 a day for a sufficient amount of calcium cyanide flakes to maintain a barrier a quarter of a mile long, or $40 to maintain one for a ten-day period. If the flakes have to be renewed two or three times a day, as on windy days, or if the migration period is prolonged beyond the ten-day period, the cost is correspondingly increased. The calcium cyanide gas barrier is, therefore, several times as expensive to maintain as the creosote oil-line barrier. Because of these points, the calcium cyanide gas barrier does not seem very well adapted for use under Nebraska conditions.

USE OF TRAP CROPS

The plan is sometimes practiced of thickly planting a trap crop, usually of Sudan grass or rye, in a strip four feet to a rod wide between the infested small grain field and the threatened corn, long enough before the wheat harvest that the plants will be about six inches high at that time. When the chinch bugs migrate from the small grain they will stop in the green trap crop to feed. Sometimes, when the trap crop is wide and thick and the bugs are not too numerous, it will hold

most of them until they mature. Again, when the trap crop is filled with the held migrating bugs it can be profitably plowed under and the bugs buried. Usually, however, the bugs are killed as they gather in the trap crop by daily applications of an insectide dust, such as calcium cyanide and sulphur cyanide. Calcium cyanide dust, used at the rate of one pound to each sixty to 150 linear feet, when the heaviest movement is on, has been found successful under certain conditions and in certain localities. But since it will cost from $22 to $45 to destroy the bugs daily for ten days on a trap crop four feet wide and a quarter of a mile long, it is obvious that this method, like the gas barrier, is considerably more expensive to maintain than the creosote oil-line barrier, and not nearly so dependable.

KILLING MASSED BUGS ON THE OUTER ROWS OF CORN

In some cases it so happens that before the farmer realizes that the migrating chinch bugs are on the move they have already invaded his corn field in abundance. Or again, in spite of the use of well constructed barriers and the taking of all reasonable care in maintaining them, the efficiency of nearly any barrier may become temporarily impaired so as to allow numbers of the bugs to cross. Ordinarily the number of bugs that thus manage to cross a well-made and carefully maintained barrier is not sufficient to cause any serious injury to the corn; but sometimes the number is large enough, especially when combined with the early maturing bugs that have gained their wings by the time of the small grains harvest and have consequently been able to fly directly into the corn, to make their prompt destruction advisable. When the bugs first reach a cornfield they do not at once scatter thru it, but they mass on the outer rows, sometimes until the plants are fairly black with them. Later on, as these outer plants are killed, the bugs move steadily inward to fresh plants and gradually spread thru the field. Consequently prompt action while they are concentrated on the first few rows is important. If the corn plants are yet small and the owner is willing to sacrifice them they may be plowed under carefully and deeply, and the majority of the bugs upon them may thus be entrapped. But usually the corn is too tall at this time to make the plowing method feasible, and in that case the alternative is to kill the bugs by spraying or dusting them with contact insecticides.

The sprays that have been successfully used for this purpose are (1) kerosene emulsion, (2) nicotine and soap solutions, and (3) plain soap solutions. Kerosene emulsion was the first contact insecticide to come into general use against chinch bugs on corn. To make kerosene emulsion for this purpose, one-half pound of common laundry soap is dissolved in one gallon of boiling (if possible, soft) water, two gallons of kerosene are added to the hot suds, and the mixture is then pumped

back into itself thru a spray pump for several minutes, or until a uniform, creamy emulsion is formed, from which the oil will not separate on standing. This stock emulsion is then diluted at the rate of one gallon to fifteen and one-half gallons of water to make a four per cent kerosene emulsion. At this strength most of the bugs will be killed, and the corn will not be injured to any extent if the spray is kept out of the cone-shaped leaf "curl" at the top of the plant. Great care must be taken to secure a complete emulsion. It is sprayed on the corn so as to hit and thoroly wet the bugs. If there is no expectation of saving the plants, a ten per cent kerosene emulsion, made by diluting the stock emulsion at the rate of one gallon to four and one-half gallons of water, had better be used. The complete loss of the outer rows of corn would be less than that which would follow if the bugs were allowed to continue their destructive invasion of the whole field. Kerosene emulsion is so difficult and laborious to make properly, and its necessarily free use is attended with so much injury in most cases, that it is scarcely to be recommended if the purpose is to kill the bugs but save the corn.

Nicotine and soap sprays are also effective against the chinch bugs, even more so than is kerosene emulsion at strengths not seriously injurious to the corn, and they have the advantages of being more easily prepared for use than kerosene emulsion and of not injuring the sprayed corn at all. Spraying corn with a forty per cent nicotine sulphate concentrate diluted at the rate of one part to five hundred parts of water, with four pounds of soap dissolved in each fifty gallons of diluted spray, makes a wholly effective spray. If the soap is omitted it requires a dilution at the rate of one part to fifty parts of water to accomplish as good results as a dilution of one to five hundred would do with the soap. These nicotine sulphate sprays are especially valuable where the spraying must be extensive, and therefore the application needs to be made freely and rapidly, without fear of injury to the plants. Homemade tobacco sprays are comparatively ineffective against the chinch bug.

The use of strong soap solutions, without the addition of kerosene or nicotine sulphate, has also been found to be effective in killing chinch bugs. Such soapy sprays obviate the labor of emulsifying the spray, as is necessary in making kerosene emulsion, and are not so caustic in their action on the corn plants. They are much cheaper than nicotine and soap sprays. Either laundry soap or whale oil soap dissolved at the rate of eight pounds to fifty gallons of water forms a spray that kills all of the chinch bugs thoroly wetted by it, and that at the same time will not injure corn plants even tho they are drenched and the leaf pockets are well filled with the spray. Filling the "curl" of the young plants, however, produces injury and should be avoided. It seems

certain that for emergency work, when nicotine sulphate is not available, strong soap solutions will make a very satisfactory spray.

Where only the outer rows of a corn field are to be sprayed, as will usually be the case, an ordinary knapsack or other portable one-man sprayer will probably give the best results, provided the field is not very large, because it is more easily handled under the difficult conditions that obtain than a field sprayer would be. Such portable sprayers cost about $4 to $6 each, retail. The spray should be applied freely under high pressure over the entire plant, wherever bugs are seen, only taking care not to lodge the spray in the leaf "curl" at the top of the plant if either kerosene emulsion or a strong soap solution is being used. The spray should be applied copiously as a fine mist. Many of the bugs will be concealed back of the leaf sheaths, where they are hard to reach with the spray. It is advisable to apply the spray to the soil surrounding the base of the corn plants, where the bugs often swarm, as well as upon the plants themselves.

A dust insecticide that has recently come more or less into use in killing massed chinch bugs on corn is calcium cyanide. When this method is used the calcium cyanide dust is applied with a dust gun at a time when there is little or no wind and when the corn plants are dry, usually in the late afternoon. Windy weather precludes the use of this method. Each plant is given a light application with the dust gun. It requires from thirty to fifty pounds of the dust, costing from $6 to $10, to treat an acre of corn. Also, it nearly always gets into the leaf "curl" and severely burns the plants or even kills them. For these reasons it is not to be recommended. A yet more recently used cyanide dust is sulphur cyanide, which kills the bugs with a lighter application and is apparently less injurious to the plant than calcium cyanide dust. It is therefore probably a better dust to use for this purpose than is calcium cyanide. However, it also burns the plants if it gets into the leaf "curl," and must be applied carefully. A two per cent nicotine dust is just as effective in killing the bugs as is calcium cyanide dust, is cheaper, and will not injure the corn.

DESTRUCTION OF THE BUGS IN THEIR WINTERING RETREATS

After a season of crop losses because of chinch bugs, there should be cooperation in a general farm clean-up and burning campaign over the entire infested area. If this campaign is well done, the wheat crop will be protected from injury the following spring and the use of barriers and sprays at harvest time may not be necessary. As a first step, during the early fall, in any fields where the corn has been picked or the feed crops have been harvested before the bugs have deserted the fields for their winter quarters, whenever conditions will permit, the stalks should be broken down, and, together with the stubble

in the case of feed crops, plowed under deeply and packed to bury and entrap the bugs. The accumulated dead leaves and husks under brushy hedges and thickets and along edges of woodlands should be cleaned out and burned. Corn shocks should be used up during the winter, and the cornfields should be pastured. Pastures should be grazed close, since such will harbor few bugs. Blue-grass pastures should never be burned, even tho they may harbor some bugs.

In November and early December, after the first heavy freezes have killed the grass tops, a thoro and simultaneous burning off of all cover for wintering chinch bugs should be carried out. Whenever clump-forming grasses are growing on prairies or waste land, in meadows, pastures, ravines, rights of way, or along roadsides, or in any other place where the chinch bugs occur in numbers, they should be closely burned over, down to the very crowns of the grass. Clumps of bunch grass, bluestem, and similar clump-forming grasses harbor ninety-eight per cent of the successfully wintering chinch bugs. If present, they may easily be discovered by parting the stems close to the crown of the plant or by pulling a clump of grass to pieces over a newspaper. If there is an average of ten or fifteen bugs to the clump the area should be burned over. Meadows that have been mowed late in the year, and pastures that have been grazed close, usually do not harbor many bugs and do not require burning. The heat from the burning grass will kill many of the bugs, practically all of them if the burning is done very closely on a warm day. If the burning is done early in the season, most of the bugs that escape immediate death by heat at the time of the burning will perish during the winter from exposure. The full value of this control method is secured only when thru organized co-operation the complete destruction of the hibernating cover of the bugs is obtained over large infested areas. Several men should work systematically as a group under an efficient leader. Individual and desultory early burning, while of some help, permits the bugs that are driven from one farm to move to suitable cover elsewhere, repeatedly if necessary, but eventually to survive the winter in large numbers. But if the burning is general and simultaneous the bugs will be unable to find cover promptly, if at all, and most of them will perish during the winter weather close at hand. Repeated experiments in many localities and over a period of years show that burning between November 1 and December 15 results in the destruction of 985 out of every 1,000 bugs in the burned-over grass.

The best conditions under which to do the burning is on a warm, dry day when there is just wind enough to blow the fire along slowly, so that the grass will burn closely. If the wind blows strongly the flames spread rapidly and do not burn closely, and but few bugs are killed by the heat, while sufficient cover is left for winter protection

for the survivors. Moreover, burning in a strong or shifting wind is dangerous, and serious damage may result from careless burning to destroy chinch bugs. Probably the best results are obtained by burning the grass with a back fire, against the wind, as a back fire burns more closely, holds the heat longer and is easier to control than a head fire, with the wind. A head fire sweeps over the ground rapidly, does not burn closely, and often gets out of bounds. The method of burning, however, will vary somewhat with the different areas and must be determined by the individual at the time. The principal requirement is to handle the fire in such a manner as to burn close to the ground. Since fire is always a dangerous agent, certain precautions should be mentioned. Never attempt to do extensive burning alone, but have one or two men to assist with the work. Always have a barrel of water and plenty of gunny sacks along; a spade is also very useful for fighting fire. When burning over large areas, it is advisable to have a team and plow along. Then, should the fire get away, it can be stopped by plowing a furrow some distance ahead. Burning should never be attempted when there is a high wind. All buildings and woodlands should be guarded and the flames should be carefully watched to quench wild flames. When parts of the field are not dry enough for wholly effective burning, the use of a gasoline blast torch, such as has been mentioned as useful in killing accumulated chinch bugs at furrow barriers, may be helpful in burning moist, heavy clumps of grass.

SECURING OF MATERIALS

The names of concerns manufacturing or dealing in coal-tar, road-oil No. 7, crude creosote, calcium cyanide, sulphur cyanide, nicotine sulphate concentrate and nicotine dusts can be secured by requesting same from the Department of Entomology of the Nebraska Agricultural Experiment Station.

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