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M. H. Swenk

H. D. Tate

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Control of the Chinch Bug in Nebraska

MYRON H. SWENK and H. DOUGLAS TATE
Department of Entomology

THE CHINCH BUG, *Blissus leucopterus* (Say), is one of the most injurious insect pests of cereal crops in the United States. Although some damage by it has occurred over a wide area in the United States, the greatest injury has been in the Corn Belt. The years in which the chinch bug appears in destructive 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 upon the bugs. Continued dry weather favors them, while very wet weather brings about their destruction. During the last seven decades there have been seven separated and well-marked chinch bug outbreaks or periods of serious damage in Nebraska, and an eighth one which began in 1938 is in progress at the present time.

CHINCH BUG OUTBREAKS IN NEBRASKA

The chinch bug is not an imported pest, but one native to America, and it probably occurred in Nebraska long before the settlement of the state by white men, and subsisted on the native prairie grasses. Conditions were not favorable for the production of destructive populations, however, until grain growing became a general practice. The first record of serious injury by this pest in the United States was as early as 1785, in North Carolina, and as early as 1840 in Illinois. Between 1840 and 1865 a number of outbreaks occurred in the central Mississippi Valley states, the damage in Illinois alone in 1864 being computed at $73,000,000. By the time of the next general outbreak, in 1871, southeastern Nebraska was included in the area of injury.

The outbreak of 1871, which was general in the Mississippi Valley, reached its height during the dry summer of 1874, when the crop loss in Nebraska alone was estimated at not far from $750,000. There was comparatively little damage by chinch bugs for nearly a decade after 1874, but in 1883 these pests began to resume their injuries to Nebraska crops, and continued to do so for the next five years over a large area in southern and central Nebraska, causing damage to Nebraska crops estimated at $4,000,000 during the hot and dry summer of 1887. There are no records of serious chinch bug damage in Nebraska during the years 1888 to 1891, but the pest again increased in the fall of 1892, bringing about severe crop losses in 1893 and 1894 and reduced injuries during the following three years. Losses were again increased in 1898 to 1901. In the latter year the damage was about as heavy as in 1894, and was followed by a wet summer and a general subsidence of chinch bug populations in 1902.

These pests again started to increase in south-central Nebraska in 1906, and continued at a population high enough to produce commercial damage through 1910 and 1911. There was practically no chinch bug damage in 1912, but the population of this pest again increased in the years 1913 to 1915, though repeatedly checked by periods of heavy rainfall. For four years following 1915, Nebraska was particularly free from injury by chinch bugs; but in 1920 they resumed damage to crops along the southern border of the state. This damage was gradually extended and increased during the follow-

ing five years, the loss in 1924 in the 18 Nebraska counties affected being estimated at $750,000, and that in 1925 about the same. Also an entirely separated outbreak developed in Knox, Boyd, and northeastern Holt counties in 1921 to 1923. Chinch bug numbers declined in 1926 and 1927, though the pest continued doing commercial crop damage, but there was no important commercial damage during the years 1928 to 1931. Then in 1932 another increase in chinch bug numbers began, and culminated in the highly destructive outbreak of the drouth year, 1934. After three years of comparative freedom from crop damage by chinch bugs, the present (eighth) period of increase and injury began in the summer of 1938.

The damage by chinch bugs in 1938 was local and confined to the extreme southeastern counties, especially Pawnee and Johnson. The winter of 1938-39 was favorable for survival of chinch bugs, and a mid-winter (late January) survey in Pawnee county showed that over 95 per cent of the bugs in hibernation were alive. They came out of their winter quarters in abundance, heavy flights being noted in mid-May, and favorable weather conditions early in the year prolonged their egg-laying and extended the hatching season, so that in 1939 there was a tremendous increase in the chinch bug population over southeastern Nebraska. They were reported injuring small grains in 11 counties in southeastern Nebraska in June and early July of 1939, and damaging corn, sorghum, Sudan grass, and a few other plants when the second brood was active in August. During September and October, all over southeastern Nebraska on favorable days the air was filled with chinch bugs in their fall flights. A survey made in November and December of 1939 showed a potentially severe infestation in 11 southeastern Nebraska counties with heavy to light infestations in 14 additional counties.

There was a good survival of the bugs during the winter of 1939-40, and an extensive control campaign was successfully carried out during the late spring and early summer of 1940 in 14 counties of eastern and southeastern Nebraska which reported damage by this pest. However, an extensive survey in 29 eastern and southeastern Nebraska counties in November, 1940, showed that a potentially threatening chinch bug population still existed in a large part of that area and that further trouble would be likely to occur.

FEEDING HABITS

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 throughout its active life, usually in as sheltered a position on the plant as it can find, such as in the leaf curls, back of the leaf sheaths, in the heads and on the roots. As a result of its feeding, a reddish discoloration is produced at the point of attack which usually is followed by death of the cells surrounding the point of puncture. Heavily infested plants are badly stunted, resulting in decreased yields in the case of grain crops, or else are killed outright, the whole plant wilting or falling to the ground. Drouth greatly accentuates the injurious effect of chinch bug attack, because of the double drain on the vitality of the plant.

In securing food the chinch bug practically confines its attention to plants of the grass family. Among these are small grains, corn, the sorghums (especially the milos), broomcorn, millet, Sudan grass, and other wild and cultivated grasses. The first generation of bugs usually begins its development in small grains and completes it on corn or sorghum. Barley and wheat seem to be preferred above the other small grains, although variations occur from year to year, because of the condition of the grains at the time of the spring flight. When confined on wild grasses for its food supply, the chinch bug usually does not flourish as well as in cultivated grain crops.

SEASONAL HISTORY

Hibernation

Chinch bugs overwinter in the adult stage in various types of protected places. Naturally, the exact character of the cover used by the bugs will vary according to locality. Their favorite and most successful wintering place in the plains states, however, is deep down in the dense tufts of bunch-grass, especially the bluestems (*Andropogon* sp.). They will hibernate also in other clump-forming grasses, such as timothy, orchard grass, dropseed, and the sedges, particularly where the bunch-grasses do not occur. They may live through the winter in various other situations, including such places as the leaves and litter under hedges or borders of woodlots, in dense covering of bluegrass, in shocks of corn and sorghum, and even under the leaf sheaths and husks of standing corn in the field. In Nebraska the winter mortality under these conditions, however, usually is quite high, especially during cold open winters.

Spring Migration

With the advent of warm weather in the spring, the adults begin to migrate from their overwintering quarters to fields of small grain and grasses. This movement usually starts when temperatures for a few days in succession attain 70° F. or more, which in Nebraska usually extends from early April through May. As a rule the bugs do not all desert their winter quarters at the same time, 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.

The migrating bugs settle down in fields of small grain, most commonly in wheat or barley. If the spring flight is delayed by cool weather, the bugs occasionally fly directly to early corn plantings. When extremely heavy infestations are present, or in years of drouth, the overwintering bugs may seriously injure or even completely kill the small grain, but as a rule relatively little or no damage is evident. If conditions become unfavorable for them in the originally infested field, as a result of drying up of the plants or other factors, they may migrate to other more suitable fields.

Development of First Generation

Within a short time after arrival in the small grain field, mating occurs and soon the females begin to deposit their eggs, usually in rows of several

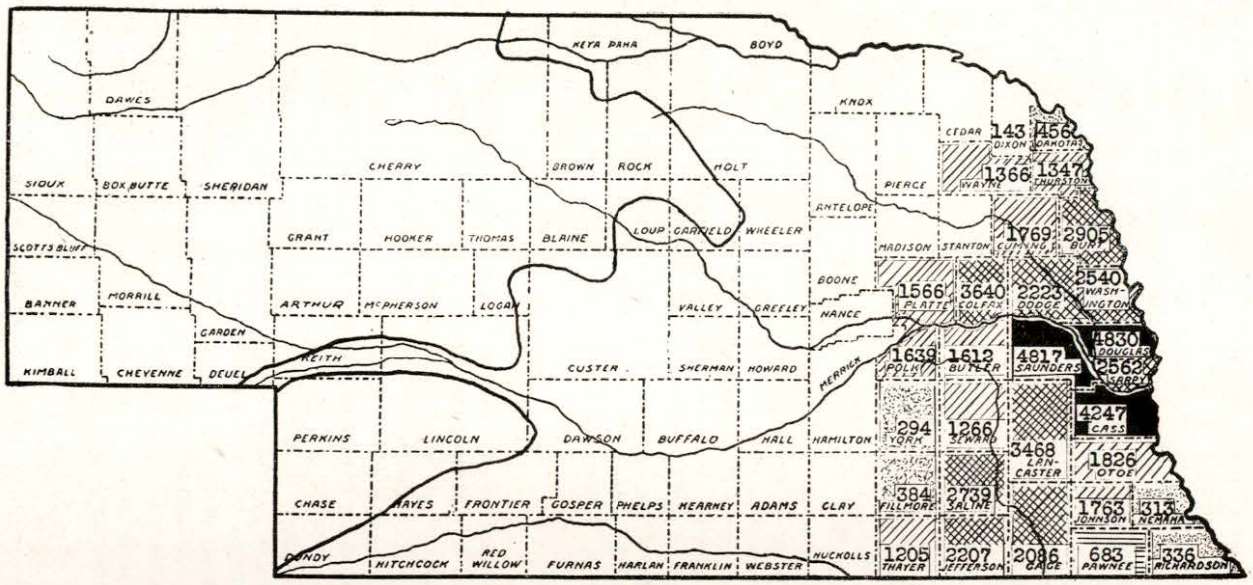

FIG. 1.—Chinch bug populations hibernating in bluestem bunch-grasses in 29 eastern-Nebraska counties, according to a survey made in November-December, 1940. Numerals indicate for each county the average number of bugs per square foot of bunch-grass. Very severely infested counties are in solid black, severely infested ones cross-hatched, heavily infested ones with diagonal lines, moderately infested ones with horizontal lines, lightly infested ones stippled and normally infested ones white. Heavy line marks western limits in Nebraska of the chinch bug as a destructive pest.

eggs each, behind the lower leaf sheaths of the plants. During dry seasons when the soil is cracked, eggs may be deposited on the roots at a depth of one to several inches. As a rule the eggs hatch in one to two weeks, but during very cool spring weather several weeks may be required.

By the time the small grains begin to ripen and dry, the adults 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, sorghum, or millet, or other grassy vegetation.

As the crawling mass of bugs of various ages reaches the green crops, they concentrate on the outer rows, and usually the plants thus first attacked are soon killed. Development is completed on the newly invaded crops, most of the bugs having become mature by the end of July or early August. It requires from 51 to 94 days, with an average of 60 days, from the time of hatching for the individual bug to reach maturity.

Development of Second Generation

Upon reaching maturity, which usually is from two to four weeks after the small grain is harvested, there is a general flight during which the adults become more or less evenly distributed in fields of corn or other large grain crops. A preference is shown, however, for thinner stands, apparently to avoid shade and dampness. Eggs of the second generation are deposited principally during July and August on the roots of the plants upon which chinch bugs have been feeding, and in the surrounding soil. The bugs hatching from these eggs often cause serious injury to corn and other crops. With the advent of colder weather, usually during October and early November, a general mass flight from grain fields to winter quarters occurs (Fig. 2).

Because of the fact that practically all stages may be observed throughout the summer months, growers, as well as others, are often inclined to feel that a number of generations are produced each year. There are, however, only two complete, but more or less overlapping, generations annually in Nebraska. When conditions are particularly favorable, a partial third generation may occur, but its development is of little economic significance in this state.

LIFE STAGES

Each female chinch bug may deposit a total of several hundred eggs over a period of from three to six weeks. They are about one-thirtieth of an inch long, dull white in color at first, but change to amber and finally to reddish as completion of the incubation period approaches (Fig. 3, *a*). The eggs hatch in from 7 to 45 days, depending upon weather conditions. The newly hatched bugs are a trifle larger than the eggs from which they hatched, with a bright red color predominating, except for a transverse white band near the middle of the body (Fig. 3, *b*). In the course of development the skin is shed and renewed five times. Following each change a darker color is assumed until, in the stage before wings are acquired, the general color is dark grayish black (Fig 3, *c-f*).

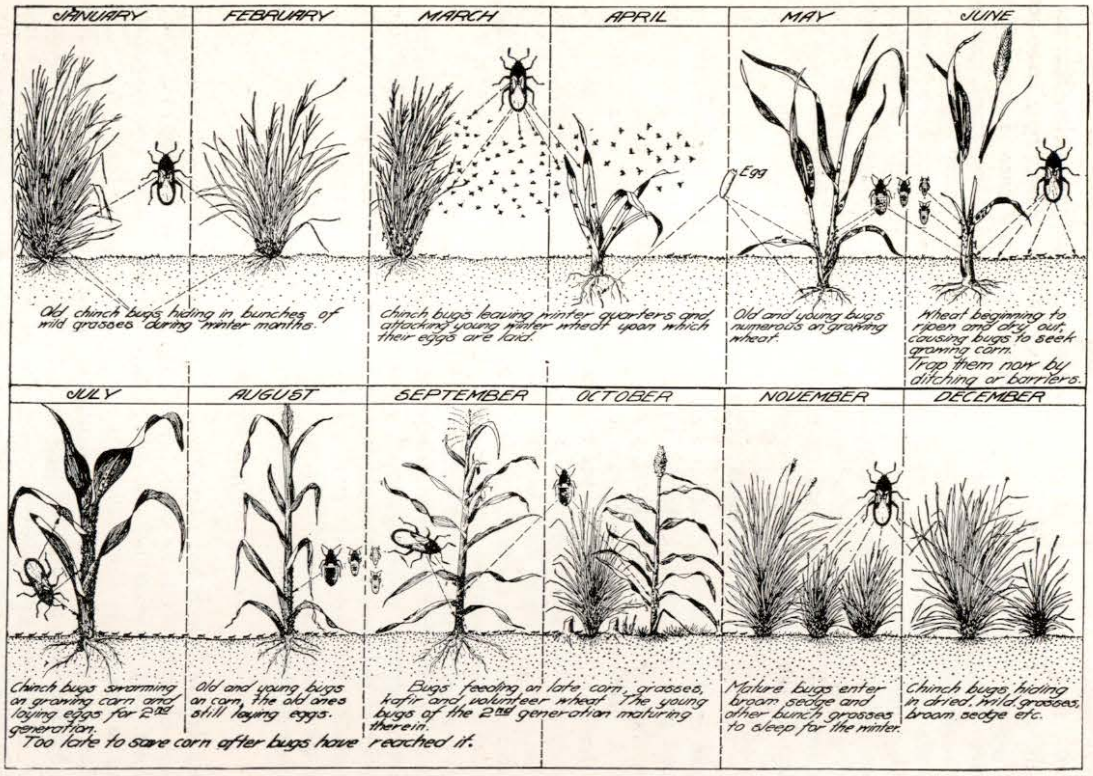

FIG. 2.—Seasonal history of the chinch bug by months. (From chart of the Bureau of Entomology, U. S. Department of Agriculture, 1918.)

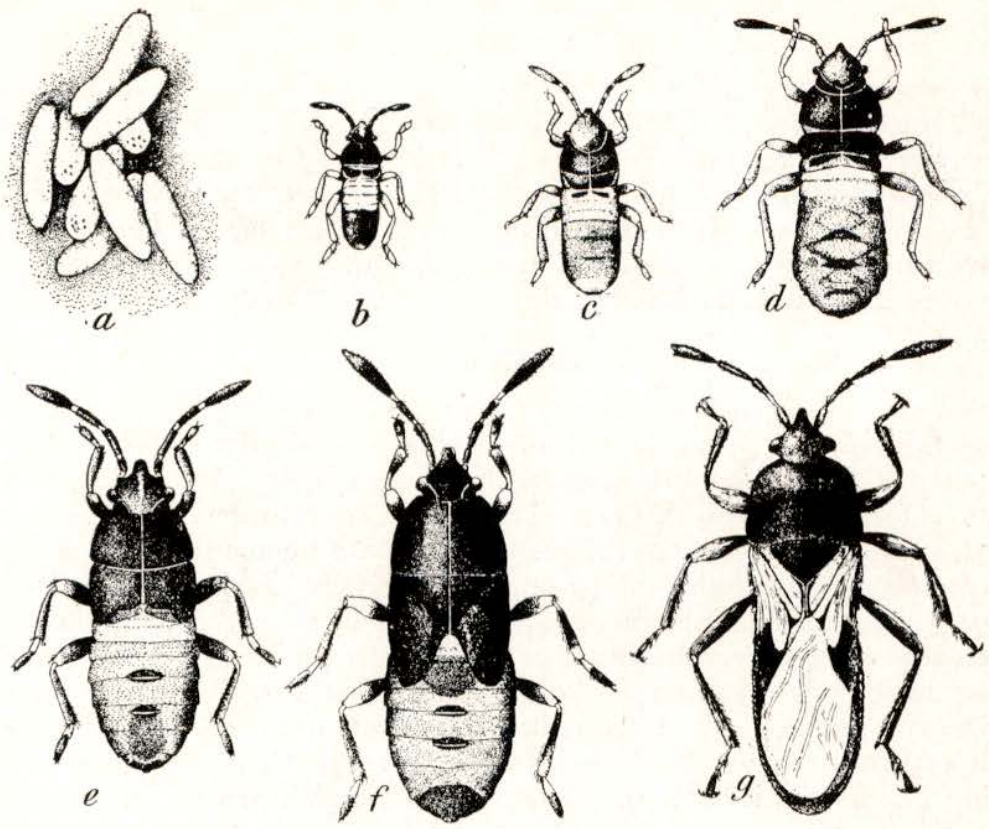

FIG. 3.—The chinch bug: *a*, cluster of eggs; *b*, recently hatched bugs; *c*, bug in second stage of growth; *d*, bug in third stage; *e*, bug in fourth stage; *f*, bug in fifth stage; *g*, adult bug; enlarged about 9 x. (Rearranged from Luginbill, Bul. 1016, U. S. D. A., 1922.)

The adult is about one-sixth of an inch long and dark in color except for the white wings, each of which is marked with a triangular black patch at the middle of its outer margin (Fig. 3, *g*). When crushed, the insect gives off a vile odor which is somewhat characteristic of the species.

CAUSES OF VARYING ABUNDANCE

The chinch bug does not become seriously destructive to crops throughout its range, but for the most part only in the Mississippi, Missouri, and Ohio River Valley regions. 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 commercial damage. This localization and irregularity of injuries by the chinch bug is due to the influence of the varying favorable or unfavorable conditions of the 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 and during hibernation; (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.

NATURAL CONTROL

A number of insects prey upon the chinch bug, and a small parasitic wasp, *Eumicrosoma benefica* Gahan, attacks the chinch bug eggs and often becomes of considerable economic importance, occasionally destroying 30 to 50 per cent of the eggs in local areas. Several kinds of insectivorous birds are also known to feed to a limited extent upon chinch bugs, some important ones of which are: the bobwhite quail, eastern and western meadowlarks, horned lark, red-winged blackbird, and brown thrasher.

DISEASES

For more than 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 occasionally these diseases play a deadly part in the natural control of this pest. During the last two decades of the nineteenth and the first decade of the present century, a number of states engaged in attempts to control the chinch bug by artificially distributing the "white fungus" disease organism (*Beauveria globulifera* Speg.), occasionally with apparently successful results. Further studies revealed the fact, however, that the spores of this organism are continuously present in the fields wherever the chinch bug is a pest and that it attacks a variety of insects. Its development is dependent upon weather conditions, wet weather being favorable while during dry periods it becomes practically inactive. When weather conditions are suitable, this fungus is capable of quickly reducing heavy chinch bug populations to harmless proportions. Because of its endemic nature and its dependence on prevailing weather, the artificial distribution of "diseased" or "inoculated" chinch bugs is considered as a worthless procedure, and was abandoned quite generally about thirty years ago.

Not infrequently individuals report that large numbers of chinch bugs have been killed by cutting a few rows of corn or sorghum and placing a continuous pile of it across the path of the migrating bugs. On hot days they often collect under such material temporarily and, while there, shed their skins. The observance of cast-off skins under the corn or sorghum stalks frequently leads to the erroneous conclusion that the empty skins are dead bugs.

WEATHER

Weather is the most important factor affecting chinch bug populations. A review of the history of chinch bug outbreaks reveals that the more destructive outbreaks have occurred during periods characterized by relatively low rainfall. The seasonal occurrence of rainfall, and its intensity, exert a particularly significant influence on the development of chinch bug populations. Frequent and heavy beating rains during the hatching period and period of growth of the early nymphal stages destroy many of the nymphs, principally as a result of beating them into the mud from which they cannot escape. Also, many of the eggs may be destroyed by such occurrences. Epidemics of the "white fungus" disease are encouraged by periods of warm, damp weather.

Until recent years the chinch bug was generally considered as an insect fully capable of withstanding the hazards of winter weather. It has been shown that winter mortality under some conditions may vary from 15 to 20 per cent to practically 100 per cent. Winter survival is influenced by the availability of suitable cover which offers adequate protection against extremely low temperatures, sudden changes in temperature, and the formation of ice in their hibernating quarters. In areas where the cropping system is suitable for the chinch bug, apparently winter temperatures constitute the chief limiting factor in its northward distribution. Open wet winters, characterized by marked sudden changes in temperature, are far more fatal to the hibernating bugs than uniformly cold ones with a heavy snow cover.

CONTROL

Immune or Resistant Crops

It is generally recognized that, whenever conditions permit, the cheapest and most effective method of preventing losses from chinch bug attack is through the use of immune or resistant crops. All members of the grass family are susceptible, while all of the legumes and a variety of other plants can be grown without danger of injury by the chinch bug. Some of the more important and commonly grown immune crops are alfalfa, clovers, soybeans, cowpeas, field peas, lespedeza, vetch, sweet clover, flax, buckwheat, rape, beets, potatoes, and other field, garden, and truck crops that are not members of the grass family.

Although no member of the grass family is immune, there is a wide range in the degree of their susceptibility. The small grains are attacked in about the following order: barley, spring wheat, winter wheat, oats, and rye. Of the larger grass crops, Sudan grass, millet, corn, sorghum, and broomcorn are attacked approximately in the order listed.

In some states varietal resistance of corn to chinch bug injury has been studied rather extensively. A considerable range in susceptibility has been found. As yet, however, the factors involved are not completely known, and the probability of any particular strain or variety having resistant qualities is not accurately predictable. Generally speaking, those varieties which have proved relatively resistant are late maturing types, none of which are adapted to Nebraska conditions.

Relation of Chinch Bugs to Sorghum Production

During the drouth period of recent years, sorghums have become increasingly important in Nebraska as a substitute for corn because of their markedly greater drouth-resistant qualities. Along with this change in the cropping system, there has developed an additional factor for consideration in chinch bug control.

Generally speaking, sorghums are susceptible to chinch bug injury, but there is a wide range in the degree of susceptibility among different varieties. Also, the extent of damage may be considerably influenced by certain cultural

practices, such as time of planting and condition of the soil with respect to its effect on growth vigor.

Extensive investigations have been conducted in Kansas [1] and Oklahoma [2] relative to the resistance of sorghums to chinch bug injury. In general, the milos are considered as being very susceptible, the feteritas moderately susceptible, and the kafirs and sorgos fairly resistant. These findings have been confirmed by agronomic experience in Nebraska.

The factors involved in determining the response of different varieties to chinch bug attack are not definitely known. The number of insects that attack resistant varieties and the number that occur on susceptible varieties do not appear to be appreciably different under similar conditions. Some varieties seem to have an innate ability to withstand and recover from an attack that would prove fatal to more susceptible types.

On the basis of data presented by State and Federal workers in Kansas and Oklahoma, combined with observations made in Nebraska, the following tentative rating is given of those varieties more commonly grown in this state, with respect to chinch bug resistance:

Resistant	*Intermediate*	*Susceptible*
Grain varieties:	Grain varieties:	Grain varieties:
Western Blackhull	Kalo	Sooner milo
Club	Early Kalo	Day milo
Pink kafir	Hegari	Colby milo
Cheyenne	Forage varieties:	Wheatland
Forage varieties:	Leoti	Feterita
Atlas sorgo	Black Amber	Sudan grass

Such a grouping as is given above is of value largely from a comparative standpoint. Under some conditions, any or all of these sorghum varieties may be damaged. However, in areas of the state where chinch bug damage commonly occurs, particularly during outbreak periods, it is considered highly advisable to select insofar as is practical those varieties that are known to have the more resistant qualities.

The severity of chinch bug damage to a given variety may be greatly minimized, if not practically evaded, by early planting. Although the plants are susceptible in all stages of growth, the capacity to overcome the effects increases with maturity.

Crop Rotation

As previously stated, the first brood of chinch bugs depends for its food supply principally upon small grains, such as wheat, barley, and oats; and those of the second generation feed largely upon corn, sorghums and a few other somewhat similar plants. Because of these habits, crop rotations which reduce the food supply at a vital point may be used under some conditions. In areas where corn is the principal crop a substitution of immune crops for small grain would tend to minimize losses, and in heavy small-grain-produc-

[1] U. S. D. A. Technical Bulletin 585 (1937).
[2] Oklahoma Station Bulletin 232 (1937).

ing areas a reduction in acreage devoted to corn would have a similar effect. In arranging a rotation to prevent chinch bug injury, the growing of as large an acreage as possible of immune crops is the essential consideration.

Modification of Farm Practices

Under some circumstances it may be impractical to substitute immune crops for the susceptible grain crops. Often certain modifications in farm practices will aid greatly in alleviating losses from chinch bug attack. Although the comparative attractiveness of the small grains varies considerably in different seasons and under different conditions, usually barley and spring wheat are particularly susceptible. It is considered advisable during chinch bug outbreaks, whenever feasible, to avoid planting these crops and to substitute either immune crops or oats, winter wheat or rye.

Planning the cropping system so as to reduce to a minimum, or entirely to avoid, adjacent plantings of small grain and corn or sorghum is a problem of major importance during severe outbreaks. Frequently neighbors on adjoining farms can cooperate to advantage in the arrangement of crops from this standpoint.

Since chinch bugs tend to avoid heavy, rank growths of vegetation, any practice which encourages this condition will aid in their control. This may be accomplished through such methods as thorough tillage, adequate fertilization, and timely planting. A damp, shady condition, which is detrimental to chinch bugs, often can be promoted by the growth of clovers in small grains. Thickly planted corn, or other crops which increase shadiness, tend to discourage chinch bug attack. Also, early planting of corn and sorghums tends to decrease or evade chinch bug injury.

Permitting the growth of certain grasses, such as foxtail and barnyard grass, which are more readily attacked than corn, frequently has been observed to serve as a protection for corn. A growth of weeds not susceptible to attack, however, offers no protection and will reduce corn yields. Following the destruction of grain crops by bugs of the first generation, frequently the field can be disked or plowed and some immune crop planted. Before plowing such fields, it is advisable to prepare a barrier, as described beyond, to prevent migration of the bugs into other grain fields.

Barriers

Corn and sorghum crops can be protected from the bugs of the first generation, which migrate from small grain at about the time of harvest, by the construction of artificial barriers. Three general types of chinch bug barriers have been used: (1) the treated-paper barrier, (2) the oil-line-furrow barrier and (3) the dust-line or furrow barrier. To obtain effective control of chinch bugs by means of barriers the major points that should be kept in mind are timely and proper construction and adequate maintenance. Failure to give sufficient attention to one or more of these points may be and often is responsible for disappointing results.

When to construct the barrier.—Since chinch bugs depend on green or succulent plants for their food supply, migration from small grain will begin

as soon as ripening has advanced to the point where it no longer furnishes suitable food. Usually this occurs only a few days previous to harvest. However, in view of the fact that various circumstances may produce alterations, the only dependable criterion for detecting the beginning of migration is through frequent field inspections. The barrier should be constructed before mass migration begins. Many failures are due to the fact that barrier construction was delayed until a majority of the bugs already were in the crop to be protected.

How to construct the barrier.—A barrier has the two-fold purpose of stopping the forward advance of the bugs and the concentration of them so that they can be destroyed economically. The barrier should be constructed in accordance with proved methods and should form an unbroken line, in order to stop the advance and trap the bugs. In connection with both the treated-paper barrier and the oil-line-furrow barrier, the placing of post holes at intervals along the barrier line, on the side facing the source of migration, has proved an effective means of concentrating the bugs. If these are not used, the bugs tend to mass in front of the line, and many of them finally succeed in crossing because of the pressure of the heavily concentrated bugs. Many others may succeed in passing around the extremities of the barrier.

How to maintain the barrier.—After migration from the small grain has started, it is not a continuous process. The principal movement occurs between approximately 3:30 P. M. and 5:00 or 6:00 P. M. Except on cloudy and unusually cool days, movement practically ceases during the hot part of the day. Little or no migration occurs at night. There may be a slight movement in the morning beginning around 7:00 or 7:30, after the temperature has reached about 70° F., but usually it ceases by 10:00 to 11:00 A. M. It is while the migration is actively in progress that the barrier should be watched carefully and repaired or renewed when necessary. During periods of heavy migration, a special effort should be made to prevent the formation of bridges over the barrier by stems of grass, weeds or other objects carried by the wind.

Treated-Paper Barrier

The treated-paper barrier, developed within recent years, is proving to be the most efficient type. The paper barrier consists of a strip of paper placed upright in a groove or small furrow in the ground and the soil pulled against it and tamped to the same level on both sides. It is effective in all kinds of soil and weather conditions, and less labor and materials are involved in maintenance. In addition to forming a chemical barrier which repels the bugs, it acts in some degree as a physical or mechanical obstruction, which prevents individuals or masses of bugs congregated in front of the line from being pushed across or from being blown across by the wind.

Types of paper that may be used.—There are a number of commercially prepared papers which may be used, among which are: Red Rosin building paper (30-pound grade), tarred felt (14-pound and 15-pound grade), un-

treated felt of comparable weight, single-faced corrugated paper, and certain reinforced building papers. The choice of paper should depend to a large extent upon cost and availability. Generally speaking, however, the tarred felts and Red Rosin papers have proved most adaptable. Some or all of these papers usually are available locally at establishments which handle building materials.

Preparation of paper.—The paper may be purchased in rolls and sawed into strips, preferably about four inches in width, with a hand or crosscut saw. As experience will prove, this is rather a tedious task in some cases, but it can be accomplished with considerably less effort if the saw is kept well oiled during the operation. When Red Rosin or other non-water-

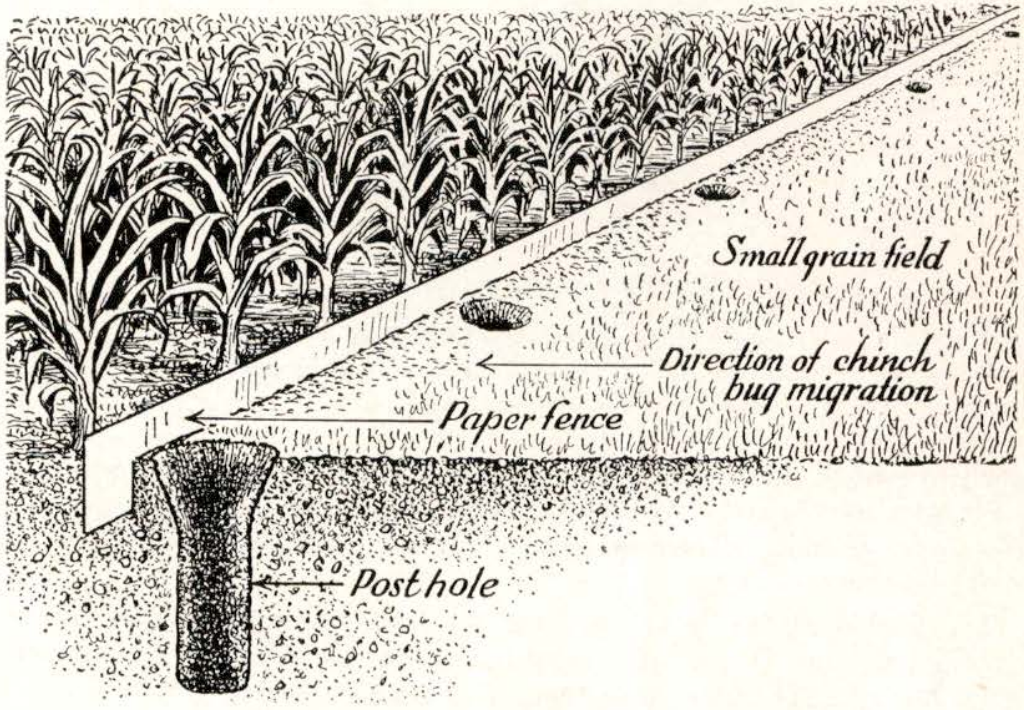

FIG. 4.—A creosote-treated paper fence barrier. (From Drake, Decker, and Worthington, Ext. Circ. 213, Iowa State College, 1935.)

proofed papers are used, it is highly desirable that the paper be thoroughly soaked in creosote before being placed in position, otherwise rain or even heavy dews may cause the paper to roll and fall over on the ground. Although it is generally advisable to soak other paper in creosote before using, treatment may be delayed with some of the waterproofed types, such as tarred felt, until the barrier is in position.

Construction and maintenance.—The initial step in constructing a paper barrier is to select or prepare a clean level surface, one foot wide or more. A wheel-hoe or garden cultivator, a corn cultivator with all but one shovel removed, or other suitable implement may be used for opening a furrow in

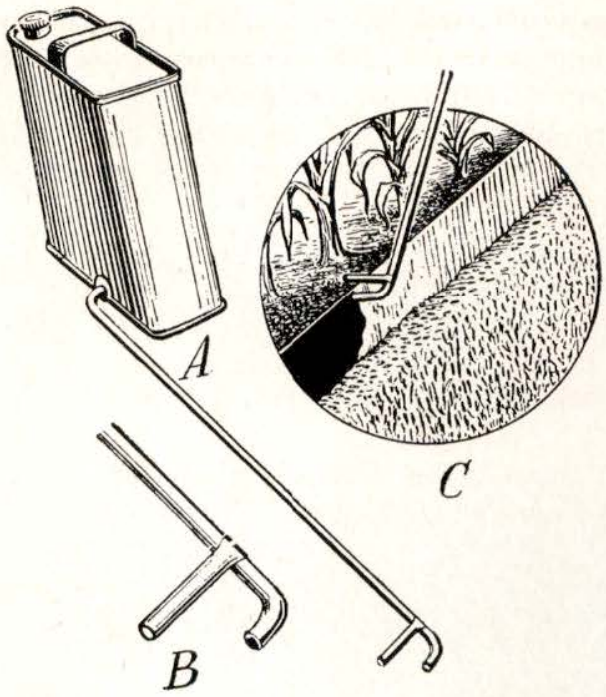

FIG. 5.—Renewing creosote on paper fence: *A*, receptacle with a copper tube; *B*, guide prong soldered near end of tube; *C*, applying creosote to paper fence. (From Drake, Decker, and Worthington, Ext. Circ. 213, Iowa State College.)

which to anchor the paper. Following this the paper is unrolled in the furrow, and while held in an upright position the soil is packed evenly and firmly on both sides. Not more than about two inches of the strip of paper should be above ground.

The final operation in constructing the barrier is digging post holes for trapping the bugs. These holes should be placed 25 to 50 feet apart, depending on the intensity of the migration, at a distance of from four to six inches from the paper line and about 20 inches in depth. The ground around the top of each hole should be cut into a funnel shape with a trowel or some such instrument, so that the beveled edge extends almost to the barrier. Since the purpose of beveling the top of the post hole is to project the bugs, as they move along the line, into the hole and prevent their escape later, it should be quite steep and continuously blanketed with a film dust.

After the paper barrier is in operating condition, additional treatments with creosote are necessary every day or two, the exact time of which can be determined by observation. When bugs begin crossing in significant numbers, a reapplication is advisable. For making these applications, various devices may be employed, a simple, effective, and inexpensive one being a tin pail of about one-gallon size having a nail hole near the bottom on the side and with a handle attachment. A convenient and labor-saving device may be constructed as shown in Figure 5.

Cost of materials.—A paper barrier a quarter of a mile long can be erected by two men in three to four hours. The papers recommended usually are obtainable in strips 150 to 250 feet long and three feet wide. One roll of 150-foot paper, the average cost of which is from $1.50 to $2.50, sawed into nine strips of four inches each, is sufficient to construct about a quarter mile of barrier. As a general rule, 25 to 35 gallons of creosote are sufficient to build and maintain a quarter-mile barrier through the migrating period. The price of creosote, as used in barrier construction, ranges from about 15 to 45 cents per gallon, depending largely upon quantity purchased, local source of supply, and distance from storage centers.

Oil-Line-Furrow Barrier

The initial step in preparing the oil-line-furrow barrier is to plow a furrow alongside the field to be protected, throwing the soil away from the source of bug migration. Following this, the soil on the furrow side should be well pulverized by means of a harrow or some other convenient implement so that it is free from cracks, trash, or clods. The top and side of the ridge should then be made firm, by rolling or packing with a shovel if necessary, leaving a flat surface two to four inches wide at the brow as a place for applying creosote. Whenever information is sufficient to warrant advance action, it is advisable to plow and prepare the furrow a week or two before migration begins.

The oil line should be applied along the brow of the ridge (Fig. 6) so that the bugs will be climbing upwards as they approach the line, thus minimizing the likelihood of individuals being pushed across by crowding or blown across by the wind. From 50 to 60 gallons of crude creosote are needed to build and maintain a quarter-mile oil-line barrier for the season, which may extend over a period of 12 to 18 days.

For trapping the bugs post holes should be dug in the furrow, slightly toward the furrow side, as described previously. The efficiency of the post hole and thus the efficiency of the barrier depends on the presence of a film of dust on the flared edge. During wet weather, when field soil is not suitable for this purpose, a supply of dust usually can be secured from the dirt floor of a barn or shed. Proper construction and maintenance of the post holes for destroying the bugs is fully as important as the oil line which halts their march. In actual practice, this point often is neglected.

After the bugs have been trapped in the holes, they should be killed at frequent intervals, usually once each day and preferably in the late afternoon. Of the various methods which may be used, one of the simplest and more practical is to put two or three tablespoonfuls of kerosene in each hole. Movement of the bugs will distribute the oil sufficiently to kill all of them.

Chemicals Used for Barrier Construction

A great variety of materials have been experimentally tested for their effectiveness in chinch bug barrier construction. Those having the greatest promise include coal-tar creosote, naphthalene, and certain naphthalene derivatives and, to a minor extent, pine tar oils. Of the materials which have

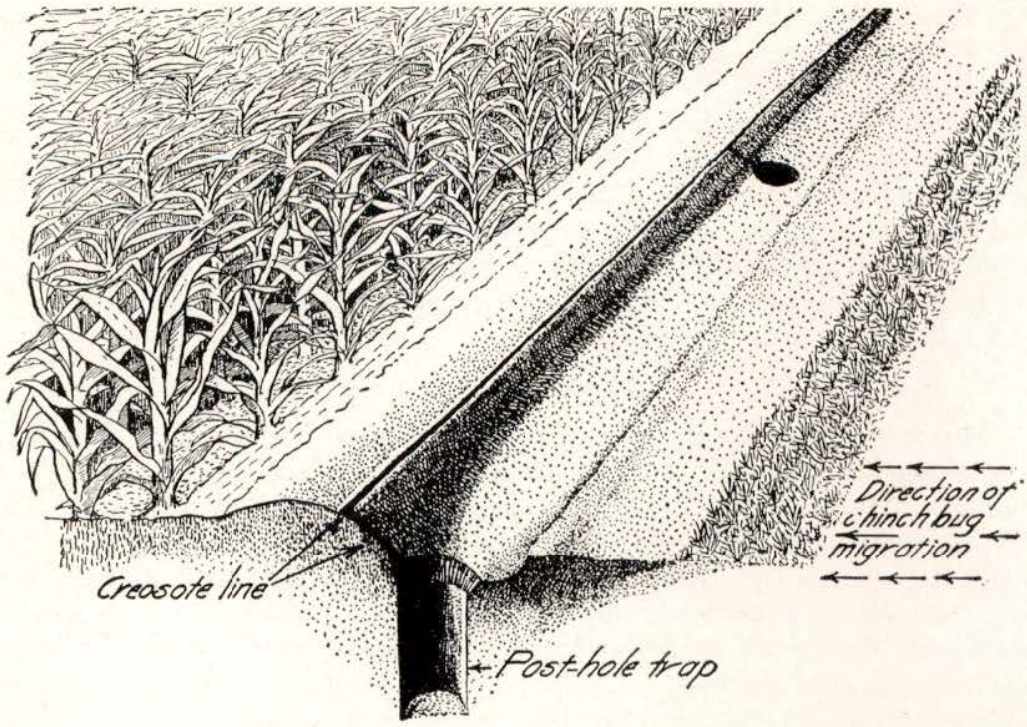

FIG. 6.—A creosote oil-line-furrow barrier. (From Packard and Benton, Farmers' Bul. 1780, U. S. D. A., 1937.)

been employed, crude coal-tar creosote has proved by far the most satisfactory. According to the reports of various workers, crude oils of petroleum have little or no practical value for this purpose. In some instances "gas drip" from local water-gas plants has given satisfactory results but its composition is so variable that the use of it ordinarily should not be considered. Creosote or other materials purchased by the farmers should meet Federal specifications.

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 8 to 10 feet wide between the source of migration and the field to be protected, afterwards harrowing or dragging the 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. A barrel, log or specially constructed drag is then dragged back and forth in the furrow until its sides and bottom have been reduced to a fine dust (Fig. 7). Frequently only the dust furrow is used. Occasionally parallel furrows are plowed. No post holes are used in connection with the dust mulch barrier.

During dry weather and on soils which can be finely pulverized, dust barriers are quite satisfactory. Obviously they are of no value in wet weather. It is necessary to drag the dust furrow at frequent intervals, particularly during periods of heavy migration. Although construction of the dust barrier does not require expensive equipment or materials, the added labor and con-

stant care involved in maintenance, combined with lack of dependability and decreased efficiency, result in its being considerably less desirable than the treated paper or oil-line-furrow barriers employing creosote.

FIG. 7.—Making a dust barrier with a barrel drag. (From circular of the Bureau of Entomology, U. S. D. A., 1918.)

Control by Means of Sprays and Dusts

Because of the cost of materials and equipment, and the labor involved, the use of sprays and dusts for controlling the chinch bug on a general field crop basis has proved impractical. In some cases where they have collected in large masses on a few of the outside rows of corn, however, sprays may be resorted to with profit. Also, sometimes it is practical to apply such materials for the protection of especially valuable crops, such as seed corn.

Of the various materials that have been tested, nicotine-soap combinations are considered the most satisfactory. An effective spray may be prepared by adding one-half ounce (three teaspoonfuls) of 40 per cent nicotine sulphate plus one ounce of some good laundry soap to one gallon of water. For larger quantities, use one quart of 40 per cent nicotine sulphate plus three pounds of soap to 50 gallons of water.

A nicotine sulphate dust, composed of about 2.5 per cent nicotine, has been recommended as effective by workers in some states. The dust can be prepared by mixing at the rate of 47 pounds of hydrated lime with three pounds of 40 per cent nicotine sulphate. This dust may be purchased in ready-mixed form also.