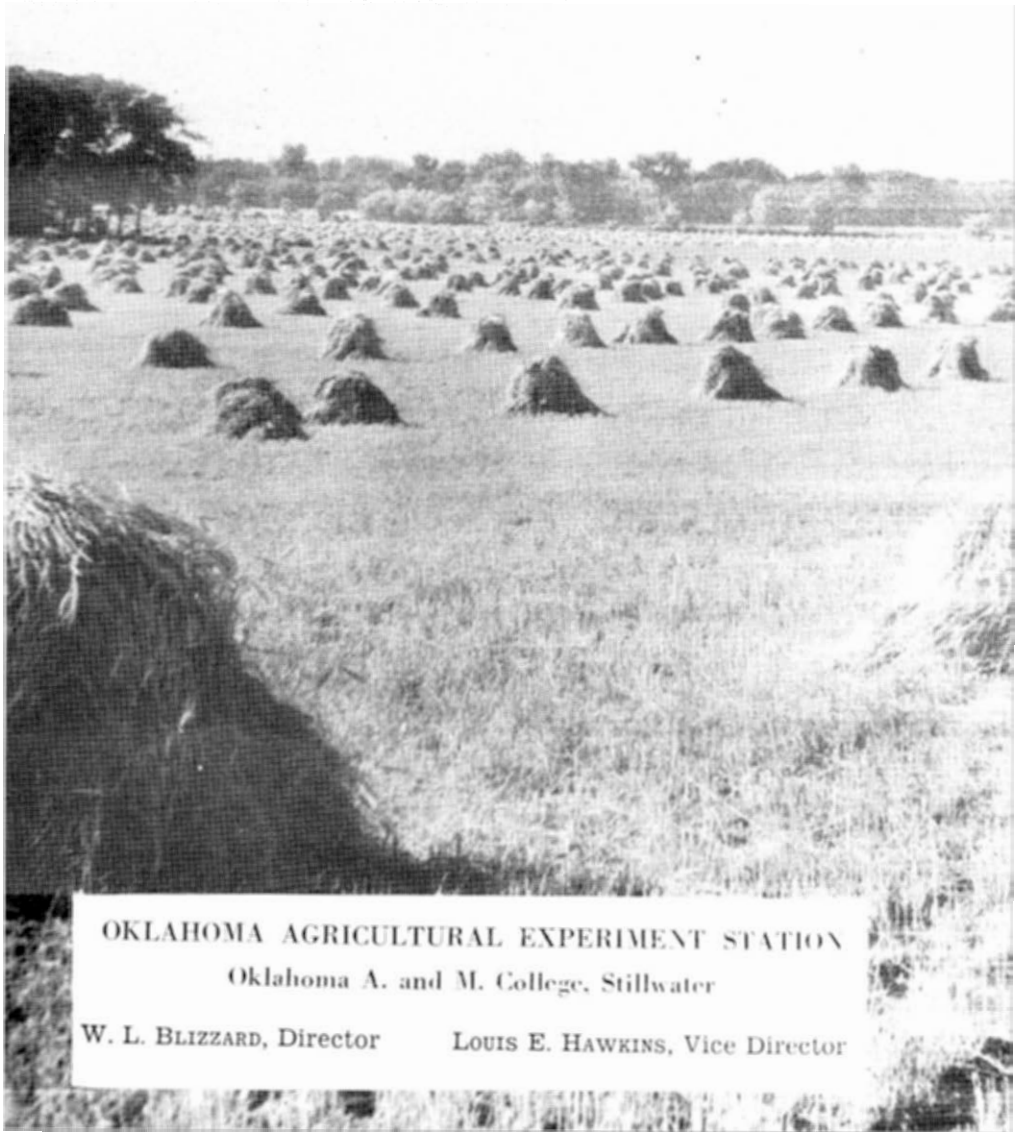
Experiment Station Bulletin B-275 January, 1944

CONTROL OF WHEAT INSECTS

By
F. A. FENTON and F. E. WHITEHEAD



OKLAHOMA AGRICULTURAL EXPERIMENT STATION
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Control of Wheat Insects

By F. A. FENTON and F. E. WHITEHEAD
Department of Entomology

Wheat is a major crop in Oklahoma. Because of its value as a food crop, especially during war time, the protection of the plants from insect attack is of vital importance. It is likewise important to control insects infesting the stored wheat in farm bins.

This bulletin describes the chief insect pests of wheat in Oklahoma, both in the field and in the bin, and gives methods for controlling them or for reducing the damage where complete control methods are unknown. Controls recommended, unless otherwise indicated, have all been tested by the Oklahoma Agricultural Experiment Station under conditions existing in this state.

Control or preventive measures depend upon quick and accurate identification of the insect which is causing damage.* To assist in identification, the bulletin shows, for each insect: (1) The part of the state where it is most likely to be found; (2) a description of the kind of damage done and of the insect in its injurious stage of development; and (3) the time of year when an attack can be expected to occur. Brief notes are given on life cycles, since a knowledge of the stages through which an insect passes during its development is often helpful in identifying and controlling it.

INSECTS INFESTING THE LEAVES, STEMS AND HEADS

Green Bug

The green bug has destroyed many thousands of acres of wheat, barley and oats in Oklahoma in recent years. In some years the insect spreads from local centers of infestation. For example in 1939 western Kay County was infested by winged bugs from infested fields in the eastern part of the county. There is also considerable local spread, as from an infested wheat or barley field to oats on the same or neighboring farms. The evidence strongly points to an infestation in southcentral and southwestern Oklahoma in 1942 being caused by bugs migrating in from infested fields many miles to the south.

* An insect identification service is maintained by the Oklahoma Agricultural Experiment Station, with about six thousand accurately identified species available for comparison. Identification can frequently be made by county agents or vocational agriculture teachers without the delay caused by sending a specimen to Stillwater.

IDENTIFYING CHARACTERISTICS

Typical green bug injury is first noticed in the fall and winter and consists of more or less circular spots in the field where the plants have been killed (Fig. 1). Close examination of such spots shows that there are rather distinct degrees of infestation and injury. Surrounding a central area where most or all of the plants are killed, are the still living but badly damaged and heavily infested plants which have lost most of their green color. Beyond them will be found plants with a lighter degree of infestation and which are apparently little if any damaged. These spots usually remain unchanged throughout the winter, but the following spring may increase in size as the infestation spreads and then join together, involving large portions of the field (Fig. 2). In some years fall planted grain fields in the paths of migrating swarms of these insects become generally infested, in which case the typical spots will not develop. In outbreak years spring planted oats become infested by green bugs flying in from heavily infested wheat

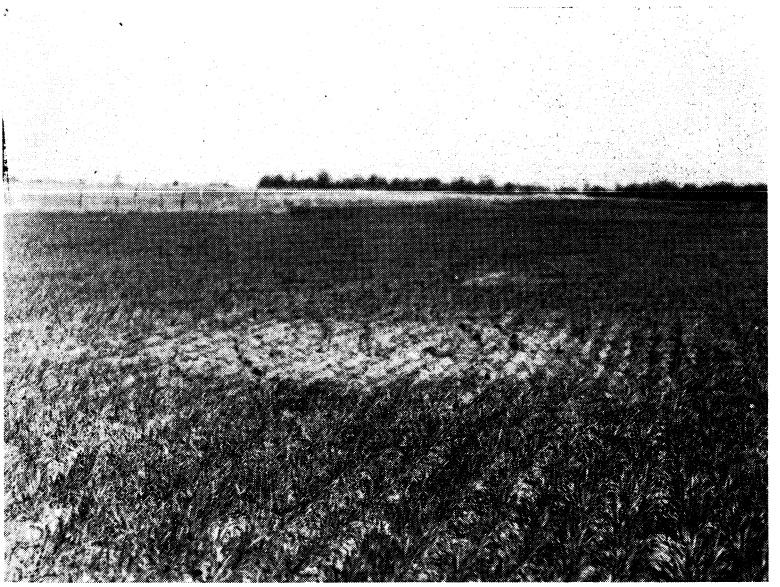

Fig. 1. Dead Spot Caused by Green Bugs.

Green bug injury to wheat and barley shows up in the fall as deadened spots, more or less circular, like the one pictured here. The spots are usually scattered over the field, with the rest of the field appearing normal through the winter. Fig. 2 shows what may happen to the rest of the field the following spring.

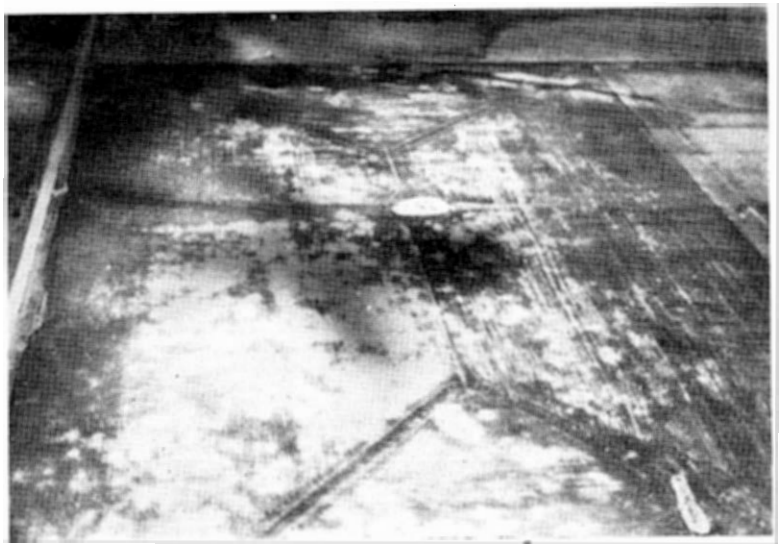

Fig. 2. Field Heavily Damaged by Green Bugs.

When early spring weather conditions favor development of the green bug (See below), the spots shown in Figure 1 spread over the rest of the field by April, as shown in the above airplane view of a barley field. Damage to wheat is similar. (Irregular white spots are injured areas. A paved highway lies to the left, with fence lines showing in upper background and to the right. The large white spot in the center of the field is a straw stack.)

and barley fields. Spring planted oats is a very susceptible crop and entire fields may be destroyed in a few days.

Usually the time of the appearance of the injury and its general nature are sufficient to identify this pest. The insects are not over 1/16 inch long and are greenish in color (Fig. 3).

Factors Predisposing to Injury

Mild dry winters followed by cold, dry, backward springs are favorable to the green bug. This is especially true when such seasons follow a wet summer which is favorable for the growth of volunteer grains. Because of the migratory habits of this insect, local conditions may have little bearing upon the beginning of the infestation which may be dependent upon the weather some distance away. Where the crop is suffering from lack of sufficient soil moisture, conditions are more favorable for severe green bug damage. In experimental plantings of winter wheat, barley and winter oats near Blackwell in 1939 following plots of soybeans, corn, darso, wheat and

summer fallow, the injury was most severe where these small grains followed darso. This was because the latter crop had taken so much moisture from the soil that it was impossible to prepare a good seed bed, the soil being lumpy and dry. As a result the growth and vigor of the plants were poor at the time green bugs invaded the plots.

Spring-planted small grains are injured more severely by green bugs than fall-planted small grains. In the same plots near Blackwell all of the spring-planted oats and barley were much more severely damaged than the fall-planted grains. It is a common observance that in years of green bug damage spring-planted oats may be much more severely damaged than the older fall-planted barley or wheat.

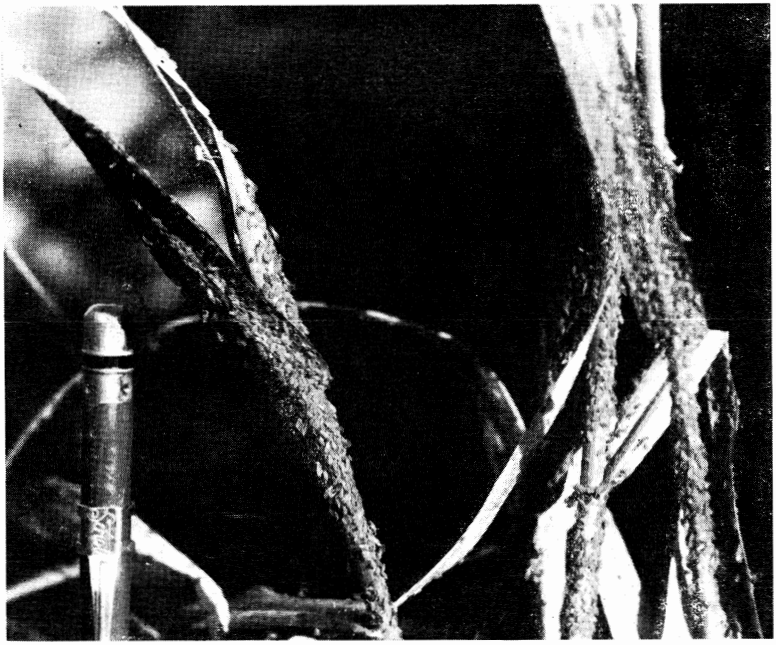

Fig. 3. A Heavy Infestation of Green Bugs.
Greenbugs are a kind of plant lice. They infest only small grains and certain grasses. The green bug found on alfalfa is a different species. The above picture shows the small-grain green bug on barley, with the top of a mechanical pencil in the lower left for comparison of size. The insect may develop from birth to maturity in six days. All are females, and each gives birth to as many as 93 young in a little over two weeks. This accounts for the rapid spread of the insect when conditions are favorable for it.

Crops Attacked

All small grains are susceptible. Barley is the most susceptible of the small grains, and spring-planted oats are severely damaged in outbreak years. Corn is seldom seriously injured unless planted next to heavily infested small grain fields. In 1939 in experimental plantings near Blackwell, Michigan winter barley was the most severely injured of the fall-sown grains, followed by the Lee winter oats and Tenmarq winter wheat In the same test Kanota spring oats and spring-planted Manchuria barley were entirely destroyed. Funk 90-day corn planted next to the spring-planted small grains was heavily damaged, especially those rows nearest to the small grains.

Life Cycle

In Oklahoma the green bug reproduces by giving birth to young, all progeny being females. The development of the insect from birth to the reproductive stage is very rapid at favorable temperatures, ranging from 6 to 16 days in the spring or summer and from 20 to 27 days in colder weather The females continue to reproduce for approximately 16 days, producing an average of 28 young with a maximum of 93.

Temperature has an important influence upon the rapidity of development of this insect. It can develop at temperatures between approximately 44° F. and 91° F., with maximum reproduction at a little above 71° F. It is killed at temperatures as low as 5° F. and as high as 107° F.

In Oklahoma the insect occurs in the field from November through May of the following year. Beginning with the first hot days and coincident with more rapid growth of the small grains, the insect disappears. Attempts to locate plants which might serve to maintain the green bug in Oklahoma during the summer have been unsuccessful It is known, however, to feed on a number of grasses such as orchard grass, little barley, and crab grass.

Steps Which Will Reduce Losses

Pasturing.—Where small grain fields have become so heavily infested as to make a profitable crop unlikely and no spring planted crop such as oats is near by, the field may be pastured so as to get some good out of it Since green bug infestation develops rapidly, most good will be secured by turning in as many animals as possible.

Plowing.—It is usually advisable to plow up heavily infested fields or portions of fields. If part of a field still has a

chance for a crop it may be left. A moldboard plow is recommended so as to turn under completely all infested plants.

Varieties.—Observations of barley and oat varieties in small experimental test plots indicate that some varieties are more tolerant to green bug infestation than others. Until more information is available, however, no recommendations can be made.

Treatment of Localized Spots

The value of treating localized infested spots in fields by spraying or burning is open to question. In the first place natural enemies or weather conditions unfavorable to the green bug may prevent much further development of these spots. In the second place winged forms have already been produced when these spots are first noticed and the insect has already spread to other portions of the field. In the third place there is also the possibility that even though the insect might be eradicated in a particular field it could be reinfested by aphids flying in from other fields.

Natural Control

The three most important natural controls of the green bug in Oklahoma are heavy rainfall, a parasitic wasp, and a lady beetle.

Abundant soil moisture with favorable temperature tends to improve vigor in the plants and particularly in the spring promotes rapid growth, thereby enabling the plants to withstand or outgrow green bug damage. Heavy dashing rains drown many of the bugs, thereby sharply checking the infestation.

The parasitic wasp is always present and is evidenced by the dried brown bodies of the aphids it has killed attached to the plant (Fig. 4). The parasites themselves are small clear-winged "gnats" which can be noticed in numbers in heavily infested fields on warm sunny days. This parasite is active principally at temperatures above which the green bug breeds freely. Thus so long as the temperatures are below approximately 65° F. the parasite is more or less inactive and the green bug will continue to develop. As soon as higher temperatures prevail the parasite may check the pest.

The larvae of the lady beetle are frequently found in large numbers in heavily infested fields. Their more or less warty grayish-blue and yellow checkered body markings are sufficient to identify them (Fig. 5). They are frequently mistaken for the "young" of the green bugs. Most people are familiar with the adult stage of the lady beetle and know that

Fig. 4.—Green Bugs Killed by a Parasitic Wasp.

Chief control of the green bug is by its natural enemies. The green bugs in the above picture were stung by a minute wasp a few days before the picture was taken, and the wasp grub feeding within their bodies has killed them. This parasite may completely check a threatening green bug infestation (See page 10). Another green bug enemy is shown in Figure 5.

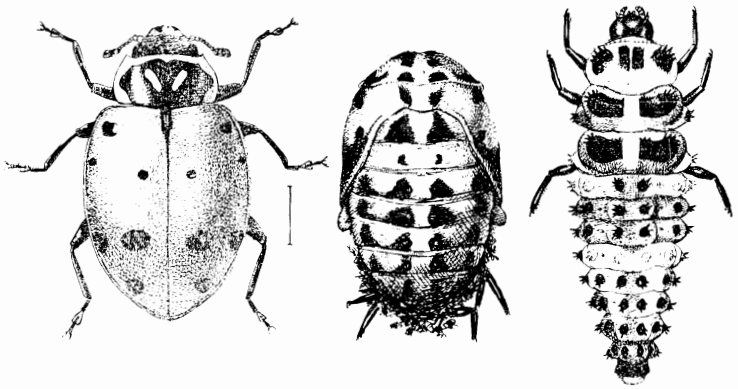

Fig. 5.—Another Green Bug Enemy, the Lady Beetle.
A favorable sign during a greenbug infestation is presence of lady beetles in the infested field. The above picture shows the adult (left) and two earlier stages of development.

these beetles are beneficial. In one of three years when the green bug was studied in Payne County the lady beetles were the most important check. In some years they are not very numerous.

Chinch Bug

The chinch bug is primarily a pest of corn and sorghums in Oklahoma. However it develops first in small grain, especially barley, and it may severely injure this crop in some years. The only severe damage to wheat has been observed in the fall of the year when the bugs may kill large spots in the fields in somewhat the same manner as green bugs. (Fig. 6 shows the distribution of this pest in Oklahoma). Adult chinch bugs range in length from 1/5 to 1/6 inch. They are black with white patches on their backs. The young are reddish at first, becoming grayish black as they increase in size. A characteristic is the strong odor present when numbers of these insects are at work. There is no effective control for chinch bugs when they are in wheat. Suggestions for prevention of chinch bug damage to corn and sorghums are given in Extension Circular 369 and Experiment Station Bulletin 232, revised.

Grasshoppers*

Injury

Wheat usually is so nearly mature in Oklahoma by the time the grasshoppers become abundant that comparatively

* For more detail in combating grasshoppers refer to Oklahoma Experiment Station Bulletin 233, "How to Control Grasshoppers in Oklahoma."

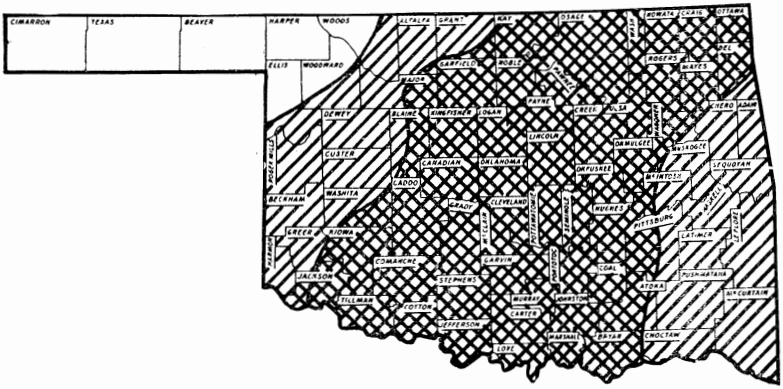

Fig. 6.—Area Subject to Chinch Bug Damage.

Chinch bug infestations were most severe in a wide belt of Oklahoma extending diagonally across the state from the northeast to southwest. Of greatest importance as a pest of corn and sorghum, chinch bugs may injure wheat in the fall and again the next spring.

light injury is suffered at this time. The greatest injury usually occurs in the fall after the young plants have emerged from the ground and before the first killing frost. At this time grasshoppers from surrounding fields move into the wheat and devour the young plants.

Factors Predisposing to Injury

While a great many factors are involved in bringing about conditions favorable to high grasshopper populations, weather conditions during the preceding years appear to be the most important. Most of our grasshopper outbreaks have occurred following a series of years in which there has been a deficiency of rainfall. Such conditions appear to be favorable for the grasshoppers and unfavorable to the development of the diseases that attack them.

Life Cycle

The life cycles of all grasshoppers commonly injurious in Oklahoma are very similar. Egg deposition occurs during the latter part of the summer and throughout the fall. The eggs are most commonly deposited in the soil along roadsides, in pastures, the margins of alfalfa fields, and other places where the ground is hard. These eggs, which are from ½ to 1½ inches beneath the soil surface, hatch during the latter part of April or May. The young grasshoppers immediately begin feeding upon the surrounding vegetation. Later they move

out from such areas into the cultivated fields and serious injury then occurs. They begin reaching maturity during the latter part of June, and during July and early August the adult forms become more and more numerous. When they reach the adult stage their wings are fully developed and thereafter they are definitely more difficult to control. Most species have but one generation a year; however, one of the most injurious grasshoppers in Oklahoma may have two generations.

Preventive Measures

The most important preventive measure against grasshoppers is the destruction of their eggs during the winter or early spring before hatching occurs. Any time grasshoppers are numerous, farmers should make observations at every opportunity during the late summer and fall as to where the eggs are being deposited. If possible these areas should then be plowed, disked, or harrowed with a spring toothed harrow. When the soil is thus treated the egg masses are broken up, some are brought to the surface and others covered too deep for the young grasshoppers to emerge. As a result a very small proportion of the eggs will develop into grasshoppers and the following season's infestation may thereby be materially reduced. Late summer or early fall poisoning may also decrease the number of eggs deposited and at the same time protect the young wheat plants.

Control

The one method that has proven most effective in controlling these insects is to kill them with a poisoned bran bait. The bait most commonly used is made up of the following:

Mill-run bran	25 lbs.
Sawdust (3 times bulk of mill-run bran)	3½ bu.
Liquid sodium arsenite*	2 qts.
Water	10 to 12 gals.

The above formula was used in mixing the bait that has been furnished by the federal government the past several years in areas where grasshopper outbreaks were severe. Considering its cost as well as effectiveness it is a very satisfactory bait.

In case the ready mixed bait is not available it can be easily and readily mixed. The sawdust is spread out to a depth of four to six inches on a floor, in a wagon box, or on

* Four pound material containing 4 lbs. arsenious oxide (32%) to the gallon. NOTE: Due to war-time restrictions arsenic may not be available. A good substitute is sodium fluosilicate at the rate of 4 lbs. per 100 lbs. base.

some other smooth surface. The bran is then placed in a layer over the sawdust. It is then turned by shovels until evenly mixed. The sodium arsenite is then poured into the water, thoroughly stirred and then poured evenly over the mixture of bran and sawdust. The mixture is then again turned with shovels until every particle has been moistened; it is then ready to spread in the infested fields. The finished bait should be flaky and break up in small particles when scattered.

The bait is finely and evenly spread over the infested fields at the rate of 10 to 15 pounds per acre (dry basis). It may be broadcast by hand, by an end gate seeder, or by any other device that may be constructed for the purpose. Specifications for the construction of a bait spreader may be obtained from the Oklahoma Agricultural Experiment Station. Best results may be expected by spreading when the temperature approaches 68° F. after a cool night. This means that during the cool periods of late spring and early summer the spreading of the bait should be completed by eight or nine o'clock in the morning and earlier during warmer weather.

It is extremely desirable to start baiting for grasshoppers as soon as hatching has occurred. At this time the grasshoppers have not scattered nearly as much as they will be later; and therefore less bait, labor, and expense will be required to poison them. Also as the season advances weather conditions for poisoning are not likely to be so favorable as earlier. When the nights become hot, fewer grasshoppers seek the warmth of the soil at night. Instead they roost on fence posts, tall weeds and shrubbery. Under such conditions it is more difficult to obtain good kills.

Where grasshoppers are invading wheat fields in the fall, the bait is best spread where they are feeding. Control of these insects at this time not only protects the wheat but kills the grasshoppers before they have had time to lay eggs.

Work conducted at this Station has definitely shown that bait spread evenly at the recommended rates will not injure poultry, birds or livestock. One must be exceedingly careful where the bait is mixed or stored, for if animals are permitted to reach it under such circumstances there is no doubt that it will kill them. Care should also be taken to see that the bait breaks up finely when spread because large lumps constitute a hazard.

Army Worm

The army worm is a very serious pest of wheat, corn and sorghums in Oklahoma during some years It has caused damage to crops throughout most of the state except the Panhandle section.

Identifying Characteristics

When full grown, the army worm is a striped caterpillar with a smooth, hairless body 1½ inches long. Seven stripes can be seen in most specimens, three black or dusky ones and four that are yellow, orange or brown (Fig. 7).

Damage to wheat from army worms usually occurs in May at about the time the wheat is heading. Damp rainy weather is favorable to the pest which thrives in heavy, rank growing wheat, particularly in the bottom fields along streams. The worms feed first on the leaves, which they completely destroy if sufficiently numerous. Then they feed on the head. In some cases, particularly with barley, they cut through the stem, thus severing the head. As much as 80 percent of the plants may be headless as a result. At about the time the wheat ripens, the grains become too hard for the worms to damage them and they may either migrate from the field in search for other food or burrow into the ground to pupate.

Crops Attacked

In addition to wheat, the army worm feeds on other small grains such as barley, rye and oats and is very destructive to corn and sorghums. In some cases in Oklahoma large numbers are developed in little barley. All members of the grass family are attacked. Some slight damage may be caused to cotton if it is planted next to a heavily infested grain field, but most of the so-called army worm damage to cotton and alfalfa is caused by a different species.

Life Cycle

The adult is a tan colored moth with a wing expanse of 1½ to 1¾ inches. The upper wings are fawn colored and marked with a conspicuous white dot near their centers. The eggs are laid in masses on the leaves, from 25 to 100 being glued to a single blade. The caterpillars when abundant form "armies" and migrate from the wheat fields in all directions in search of food or they may invade hitherto non-infested parts of the same field. During the day they hide in cracks in the soil, or under clods of soil, cow chips, etc. Late in the afternoon they start crawling up the wheat plants or migrating. On cloudy days they may feed throughout the day.

Fig. 7.—Army Worms on Wheat.

These striped caterpillars will be found in wheat fields in May at about heading time. During the day they hide beneath mats of fallen wheat and other objects resting on the soil surface. Late in the afternoon they crawl up the wheat plants to feed on the leaves, stem and head. When numerous they form "armies" and migrate to row crops. They can be controlled by poison bait (See page 18). Row crops can be protected by trench barriers (Page 19).

Under favorable conditions the worms become full grown in 26 days. Studies have shown that 80 percent of all the leaf tissue is eaten during the last 8½ to 9 days feeding period of the army worm and amounts to 34 square inches of leaf tissue. This tremendous capacity for plant destruction over an 8-9-day period explains the great destructiveness of this insect and the apparent suddenness of the attack.

After completing its feeding period, the army worm burrows a short distance into the soil where it constructs a small, smooth-lined cavity. Here it remains motionless for a day or so, then casts its skin, revealing the pupal stage which turns a dark brown in a few hours. The moths emerge from these pupæ in a few days, but since at this time the wheat and small grains are mature the second generation is very small and it is possible that the moths fly considerable distances until they find green, unripened wheat fields again.

Control

Wheat fields can be protected from damage by army worms by scattering poisoned bait. The simplest and most practical formula which has been tested in Oklahoma is as follows:

Wheat bran	100 lbs.
Sodium arsenite	2 qts
Water	8-10 gals.

This formula is mixed according to the methods described on pages 12-13. The inclusion of sawdust in army worm baits decreases their effectiveness. This bait should be scattered beginning in the late afternoon, an hour or so before sundown, and the field should be baited before the worms start to crawl up the plants Twenty pounds of the dry base (bran) are required per acre to give control. It is usually only necessary to bait those portions of the field where the worms are the thickest. The bait may be scattered by hand or from the rear end of a wagon or truck driven over the field. One application is usually sufficient.

The worms should be detected in the crop while they are still small and the field baited at that time. If the baiting is delayed until the worms have already destroyed most of the leaves and are working on the heads, it will not prevent serious damage to the wheat crop even though a high percentage of the caterpillars may be destroyed. It is therefore extremely important that observations be made 10 days to two weeks before serious injury normally occurs. If there are as many as 40 worms per square yard, damage to wheat will be done.

Corn or sorghums growing next to infested wheat fields can be protected by plowing a furrow either around the entire field or between it and the row crops. The sides of this furrow should be smooth and perpendicular so that it is impossible for the worms, once in the trap, to escape. Post holes are dug at intervals in the bottom of the furrow to trap the worms as they crawl along its bottom. Usually the heat from the sun will destroy many worms in the holes but kerosene or oil poured in will suffice otherwise.

Army Cutworm

There are a number of species of cutworms which damage wheat in Oklahoma but the two most important species are the army cutworm and the pale western cutworm.

The army cutworm occasionally causes serious damage to small grains. Losses have been reported principally from the southwestern part of the state, from Harmon and Jackson counties to Grady County. The insect has, however, been recorded as far east as Payne County and north to Grant County (Fig. 8).

Identifying Characteristics

The army cutworm when full grown is from 1½ to 2 inches long. Considerable color variation is shown from pale greenish gray to brown, but the principal distinguishing marks are two brownish stripes on each side of the body and two choco-

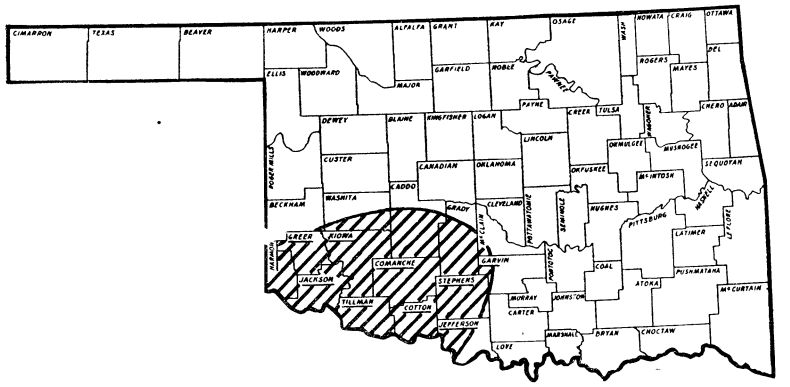

Fig. 8.—Area Where Army Cutworm Damage is Probable.

Most injury by army cutworms occurs in southwestern Oklahoma. Localized damage has also been reported in Kay and Payne counties. The injury caused by this pest is typical cutworm work, the young wheat plants being destroyed in the spring. Many other crops are also attacked. Control by baiting (See pages 14-15).

late stripes on the back, separated by a narrow line of gray.

It feeds above the ground but when food is scarce it will sometimes feed on a plant in the soil after having destroyed that part above the ground level. When these worms occur in large numbers they may migrate into and destroy every wheat plant in a field in two or three days. Cutworm injury is first observed in the spring in the form of bare areas where the plants have been damaged by these pests eating into the crowns.

CROPS ATTACKED

The army cutworm will attack many different cultivated plants and crops, including oats, barley, rye, alfalfa, vegetable crops, and the foliage of fruit trees, in addition to wheat.

LIFE CYCLE

The adult of the army cutworm is a small, stout bodied moth with a wing spread of from 1½ to 1¾ inches which is in flight in Oklahoma from early May to early June. These moths are derived from an early brood of cutworms which are injurious to the small plants earlier in the crop growing season. There are probably two or more generations of this insect in Oklahoma. In northern states the partly grown cutworms overwinter and it is possible that this holds true here.

CONTROL

The army cutworm can be controlled by the use of poisoned bait as recommended for army worm control (page 18). To protect fields from invasion either scatter a broad band of bait in front of the worms or protect the field from invasion by plowing a furrow around it as described on page 19.

Pale Western Cutworm

The pale western cutworm is a major pest of grain crops throughout large portions of an area involving Montana, Wyoming, Colorado and contiguous areas in the Dakotas, Nebraska, Kansas, Utah and New Mexico. In Oklahoma it has been reported as causing serious damage only in the Panhandle (Fig. 9).

IDENTIFYING CHARACTERISTICS

Damage is indicated by surface wilting and death of the plants which as they dry up and blow away leave bare spots in the field. In severe infestations these bare spots enlarge and large portions or the entire field may be destroyed. The worms

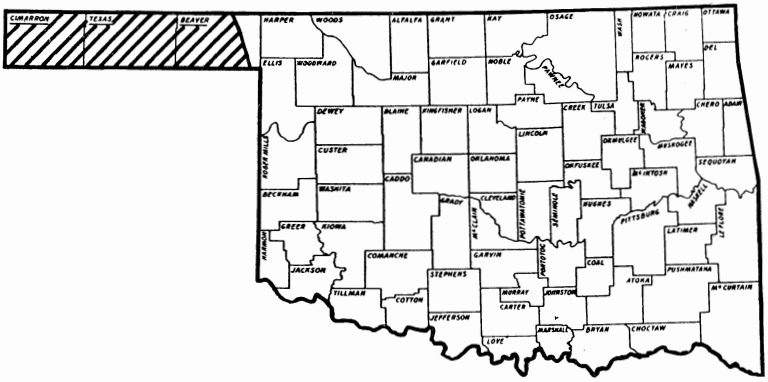

Fig. 9.—Where Pale Western Cutworm Has Damaged Wheat.

The panhandle section is the only part of Oklahoma where pale western cutworm injury occurs. These cutworms live entirely within the soil, cutting off young plants below the soil line. Baiting is not effective. Wheat should follow a row crop or one year of fallow and be planted late in October to escape damage.

usually follow along the drill rows where the soil is looser than elsewhere in the field. As one worm eats only a small portion of a plant the rate of spread of the infestation is rapid.

The most characteristic feature of this species is its habit of feeding on the plants about ¼ to 1 inch beneath the soil surface, which is in contrast to the work of other cutworms which feed on parts of the plant above ground. In addition the color and lack of distinctive markings also serve to identify this species. When full grown, the worms are 1¼ to 1½ inches long. They have a transparent skin and are devoid of markings except for three pairs of faint greenish-gray stripes along the back and sides. On the head are two black lines that follow the grooves and resemble an inverted V. The body is clothed sparsely with minute hairs which are visible only with the aid of a magnifying glass.

Factors Predisposing to Injury

Dry springs are favorable for this pest. Excess moisture during the spring favors the spread of a disease which destroys large numbers of them. Wet soil also drives the worms to the surface where they are exposed to attacks by their natural enemies. A succession of dry springs may result in an increase so that an outbreak develops.

Crops Attacked

The pale western cutworm feeds on the stems of native grasses and such weeds as Russian thistle. Crops which may

be attacked are all of the small grains, corn, Sudan grass, alfalfa and many vegetable crops.

Life Cycle

The pale western cutworms become grown after wheat harvest, at which time they enter a long resting period which enables them to escape the extreme heat of summer. This stage is spent in a small cell from two to six inches deep in the soil. This period lasts from 1½ to 2½ months and is followed by transformation into the pupal or intermediate stage between the cutworm and moth. In the Panhandle the period of moth emergence covers the last two weeks of September and first two weeks of October. The moths fly at night and and feed on blossoms of various weeds which may be in bloom at that time. Eggs are deposited during the late afternoon and early evening in the loose soil of cultivated fields and in sandy spots in the uncultivated fields. The insect overwinters in the egg stage, the eggs hatching during the first warm days of the following spring.

Preventive Measures

Poisoned bran mash which is so successful as a control for other species of cutworms and army worms is ineffective against the pale western cutworm due to its underground feeding habits. Because of this, preventive measures must be used to minimize injury. It has been noted that wheat following a row crop such as sorghum or following summer fallow usually escapes damage by this insect. It therefore is recommended that during periods when this cutworm is injurious, seriously damaged fields should either be left fallow the following year, or a row crop grown before they are again sown to wheat. Before the next wheat crop is planted, the fields should be plowed in late May and all weeds kept down until approximately August 1. After this date animals and machinery of all kinds should be kept out of the fields to prevent breaking of any soil crust that rains may have formed, since well crusted fields are avoided by the cutworm moths while depositing eggs.

The planting of the wheat will of course break the protective crust, thereby making conditions favorable for egg deposition. Therefore this should be delayed until after the eggs have been laid, which is not until late in October.

If the wheat crop is destroyed, sorghum may be planted on or after June 10, by which time most of the worms will have stopped feeding.

Hessian Fly

The hessian fly fortunately is not a very serious wheat pest in Oklahoma. In some years a certain amount of damage is caused in the northern counties, especially those bordering the Kansas state line (Woods east to Ottawa, Fig. 10), and in these counties there have been occasional years during which extensive losses occurred.

Identifying Characteristics

This insect first damages the young wheat plants in the fall. There is a general unthrifty appearance to the wheat, skips in the rows, and many dead or badly injured plants. If the fly is the cause of this condition, the pointed, greenish-white maggots may be located between the leaf sheath and stem at or just below the soil surface. Later, the brown "flax seeds" are found in the same location (Fig. 11). The following spring another generation of the fly may continue to damage the wheat. At this time of the year the maggots and "flax seeds" are located higher up on the stem. This causes lodging and also reduces yield in all plants attacked.

Crops Attacked

The hessian fly is primarily a pest of wheat but it will attack barley and rye and will breed in certain grasses.

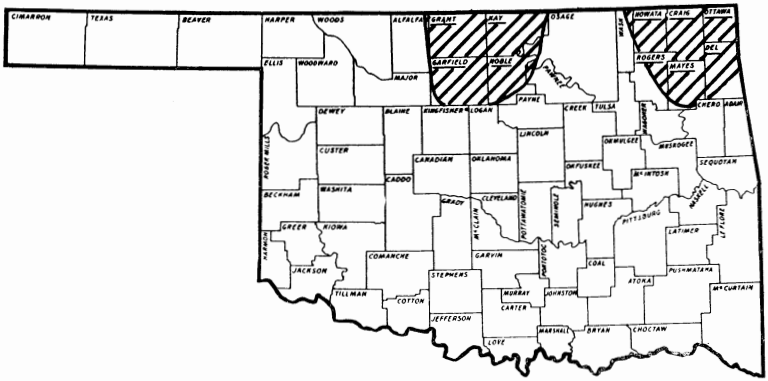

Fig. 10.—Sections Where Most Damage from Hessian Flies Occurs. Hessian fly damage is restricted to the north central and northeastern counties. Years when heavy damage is likely can be fairly accurately predicted by Experiment Station entomologists. In those years, plant wheat about October 10 to escape infestation. Prepare a good seed bed to conserve soil moisture and plow under wheat stubble deeply.

Fig. 11.—"Flax Seed" Stage Identifies Hessian Fly.
These small, brown, pointed "flax seeds" are found on wheat stubble and on wheat plants in the fall. In stubble, they are located just above a joint. On the plants, they are found between the leaf sheath and the stem. The fly larva and pupa are found within these "flax seeds."

LIFE CYCLE

Adult hessian flies, which are small gnats, 1/10 of an inch in length, emerge from the "flax seeds" in wheat stubble in the fall, usually in greatest numbers during September and early October. Eggs are glued to the upper surfaces of the young wheat leaves at this time. The egg is very delicate and subject to dessication by hot dry winds. The larva or maggot which hatches from the egg crawls along the leaf until it reaches a position between the leaf and the stem, usually at or near its basal attachment. At this point it becomes stationary and rasps the tender portion of the stem and feeds on the exuding sap. Upon reaching maturity the soft, greenish white maggot changes into a hard, shell-like, pointed, brownish object commonly known as a "flax seed." This is the stage in which the insect overwinters. These will usually be found just above the roots and below the surface of the soil. The following spring the larva pupates within this "flax seed" and a few days later the spring generation of flies begins to emerge. At this time the plants may be taller, and if so the eggs are laid on leaves further up the stalk. As a result the maggots and later the "flax seeds" may be located higher on the stem. When the wheat is harvested many of these are left behind in the stubble where they remain throughout the summer. In the fall, flies emerging from these "flax seeds" in the stubble infest the new crop of wheat. In some years when rainfall is abundant during the summer, there may be one or more small generations produced in addition to the above two.

PREVENTIVE MEASURES

As soon as conditions permit, plow under the wheat stubble. This buries infested plants so that it is impossible for flies to emerge later in the year. If summer rains cause a growth of volunteer wheat, destroy these plants by disking or surface cultivation. The same rains that make conditions favorable for volunteer wheat also produce a generation of flies which will infest this wheat. This supplemental generation greatly multiplies the number of flies that will attack the wheat that fall.

Prepare a good seed bed. In Oklahoma this is especially important as a means to conserve soil moisture, of vital importance if the wheat is to be planted late.

The most important single practice to reduce infestation is to plant wheat late at a safe seeding date. Table I shows that in 1927, a year of severe fly infestation, wheat in Woods, Alfalfa and Garfield Counties planted October 10 or later was comparatively free from hessian fly infestations. The southwestern limits of the hessian fly infested area in the United

*TABLE I.—Percent Fly Infestation at Different Planting Dates; Oklahoma, 1927.**

County	Sept. 15	Sept. 20	Sept. 26	Sept. 30	Oct. 5	Oct. 10	Oct. 15	Oct. 20
Woods	16	22	16	4	3	½	0	0
Central Alfalfa	17	10		6	14	0	0	0
Southern Alfalfa	15	14	40	--	4	0	0	0
Eastern Garfield	80	74	--	81	62	½	0	0

* From Oklahoma Extension Circular 242.

*TABLE II.—Percentages of Wheat Culms Infested in the Fall by the Hessian Fly in Experimental Plantings; Oklahoma, 1916-35.**

Locality	No. of years of records	No. of years hessian fly infestation was found	Maximum infestation	Average infestation
Alva	11	4	15.2	1.7
El Reno-Kingfisher	4	0	--	--
Enid	10	5	31.3	3.6
Miami	15	14	28.1	7.1
Muskogee-Wagoner	5	2	0.4	0.1
Newkirk-Ponca City	14	13	28.1	5.1
Tulsa	12	8	18.0	4.9
Vinita	5	5	17.2	6.6

* Condensed from Table 3, Circular 687, U. S. Dept. Agriculture, Nov. 1943.

States* occur in Oklahoma. As a result of less favorable conditions for the fly, the infestations in Oklahoma are more sporadic and less severe than in states to the north and east. These facts are brought out by Horton, Jones and Wadley** in a recent publication. From 1916-35, experimental plantings of wheat were made in selected localities in Oklahoma to determine the date for planting this crop in these areas to escape hessian fly damage. The conclusions reached from this information are: (1) Infestations were more frequent in the Miami, Newkirk-Ponca City and Vinita plots; (2) these plots were the heaviest infested; and (3) "there is little evidence of consistent reduction of yield from delaying the sowing until the safe date." (Tables II and III.)

Safe dates for planting wheat to avoid hessian fly damage as indicated by the available data are as follows: Northeastern Oklahoma, shown by results at Miami and Vinita, October

* Infested areas also occur in the West Coast states.

** Horton, J. R., E. T. Jones and F. M. Wadley, 1943, U. S. Department of Agriculture Circular 687.

*TABLE III.—Yields of Wheat in Bushels per Acre in Experimental Date of Seeding Plots for Hessian Fly Control; Oklahoma, 1916-34.**

Locality	Pre-date	Safe date	Post-date
Alva	23.2	24.1	22.2
Enid	16.6	17.0	16.1
Miami	14.4	14.4	--
Muskogee	9.2	--	9.0
Newkirk-Ponca City	14.5	15.5	13.3
Tulsa	13.0	13.2	
Vinita	18.2	16.9	15.6

* Condensed from Table 5, Circular 687, U. S. Department of Agriculture, November, 1943.

16. (This date will also apply to the Tulsa and Muskogee areas). North-central Oklahoma, October 10, based upon data obtained at Newkirk and Ponca City. The hessian fly infestation as far west as Alva is exceedingly sporadic and as a rule can be disregarded. However, in years when the infestation extends into this area, October 6 appears to be the safe date.

Finally, community cooperation in all of these practices is essential for the greatest success in combating this serious wheat pest.

Wheat Stem Maggot

A not uncommon sight in nearly mature but still green wheat fields is the occasional whitened and dead wheat head which shows up in vivid contrast against the green background of normal heads. There are a number of things which can cause this condition, but among the insects the wheat stem maggot may be the principal one. The conspicuous nature of the injury may cause fear that this insect is causing considerable damage, but as a matter of fact it is a minor problem.

Identifying Characteristics

Injured heads and shoots are light straw color, are stiff, brittle and spreading, and do not extend upwards from the glumes as in normal plants. Typically other heads on the same plant may be normal, a condition not always the case if a plant disease is causing the trouble. Confirmation of the cause of the injury may be obtained by firmly pulling on the injured head. If the stem slips out of the sheath the wheat stem maggot may have caused the trouble. In this case the stem will be found to have been eaten away, thus effectively girdling the plant above the point of attack.

The full grown larva is a slender, glassy, pale-green mag-

got averaging somewhat less than ¼ inch long. No head or legs are present but at the more tapering end will be found the mouth parts, a pair of black toothed hooks which are attached to a brownish or blackish wishbone-like structure which extends back into the second and third segments of the body. This larva can usually be located by carefully splitting lengthwise the main stalk at or slightly above the upper node.

Crops and Grasses Attacked

In addition to wheat, the stem maggot also infests barley, rye, oats, and such common grasses as quack grass, little barley, wild rye grasses, green foxtail, and yellow foxtail.

Life Cycle

The adult is a small fly a little less than 1/5 inch long, light green in color when freshly emerged from the pupa, becoming pale yellow or straw colored as it becomes older. These flies emerge in the early spring and lay their eggs on various parts of the wheat plant. The maggots after hatching penetrate the plant at a point where the leaf sheath clasps the stem. Entering between the sheath and the stem, the maggot continues downward until it reaches the node. In feeding during this downward migration it girdles the stem, severing the food conducting elements and causing the blasted head. It pupates an inch or so below the junction of the leaf blade and stem at a point where the emerging fly can easily escape. There are several generations a year.

No Preventive Measures Needed

Fortunately the wheat stem maggot is not sufficiently injurious in Oklahoma to warrant special control measures. Crop rotation would be of little value, since the fly breeds in wild grasses.

Brown Wheat Mite

In 1936 and 1937 this pest was very prevalent in southwestern Oklahoma (Fig. 12). It has, however, been found as far east as Stillwater.

Identifying Characteristics

Wheat fields heavily infested with brown mites present a scorched, withered appearance. Close examination of the plants reveals tiny brownish specks on the leaves These are the larvæ and adult mites. They are very active, quickly disappearing when the plants are disturbed. In windy weather they remain on the soil surface at the bases of the plants and

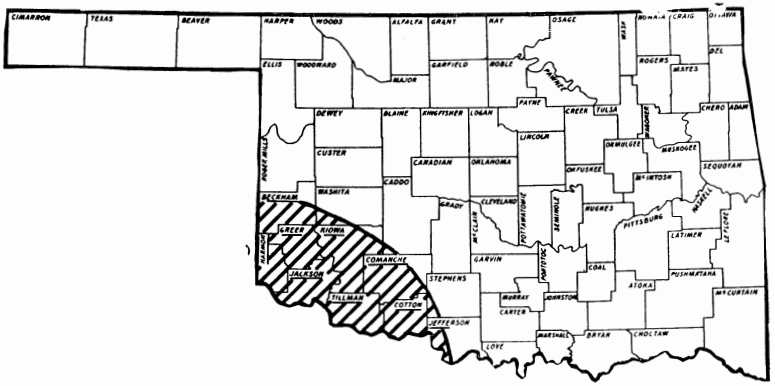

Fig. 12.—Area Most Damaged by Brown Wheat Mite.

Southwestern Oklahoma has most brown wheat mite damage. The mites thrive in dry seasons and suck the sap from the young plants, thereby increasing drouth damage. They look like tiny brown specks on the leaves, but quickly disappear when the plants are disturbed by winds or rains. Good seed bed preparation checks mites because eggs on trash in stubble fields are buried too deep for mites to emerge.

may be overlooked entirely except by one who is familiar with their habits. The mites are very sensitive to rains. They have been observed to leave the wheat leaves and to disappear during a period when a light sprinkle of rain fell. In 1937 a general rain occuring over most of the wheat belt abruptly terminated a rather heavy mite infestation.

Injury is associated with drouth conditions and many fields show both serious drouth and mite damage. It is sometimes difficult to determine which of the two is the more damaging to the wheat. Serious damage, however, has been seen in wheat and barley fields where there was plenty of soil moisture. Furthermore, large numbers of mites colonized on potted wheat plants growing in moist soil will kill or seriously injure the plants.

Crops Attacked, and Native Food Plants

Wheat is the most important crop infested and barley is also attacked. The mites have been found on little barley grass and crested wheat grass.

Life Cycle

The mites lay from 70 to 90 eggs in a three-week period. The eggs hatch in six to seven days under indoor laboratory conditions and the development to the adult stage requires

eight to nine days. The mites also under very dry conditions lay a type of egg on minute objects on the soil surface. This egg is different from the usual type and may be the means of perpetuating the mites in wheat fields from the drying up of the plants just before harvest to the appearance of the young plants in the fall. It is not known in what stage this mite passes the winter.

PREVENTIVE MEASURES

Field observations indicate that mite damage is worse where there has not been careful seedbed preparation, leaving much stubble and trash unturned. This suggests a possible preventive measure; e. g., complete turning under of wheat stubble sometime between harvest and planting.

Grain Bug

IDENTIFYING CHARACTERISTICS

The injury from this insect occurs when the grains are in the milk stage. At this time the bugs insert their beaks into the developing grain and withdraw the milky fluid, causing a badly shriveled grain that fails to develop further. A few cases have been observed where such a high percentage of the heads had been attacked by the bugs that those remaining were not worth harvesting. Fortunately such outbreaks in Oklahoma have been found only in the extreme western part of the state and here the observed outbreaks have been local in nature rather than general. The last observed outbreak occurred in Cimarron and Texas Counties in the spring of 1940 and only a few fields were seriously attacked at that time (Fig. 13).

The grain bug averages a little over ½ inch in length with some specimens not over ⅜ inch long. Most individuals are deep green in color but some are pale yellowish green or reddish brown. There is a thin line of yellow or red around the margin of the insect when viewed from above. The characteristic triangular area typical of stink bugs is easily located. Across the base of this triangle are three dots of yellow or red and the apex of the triangle is similarly colored (Fig. 14).

FACTORS PREDISPOSING TO INJURY

Outbreaks of this insect have not appeared with sufficient regularity to offer opportunity of making a close study of the factors leading to or causing such outbreaks. However, observations indicate a close relationship between the condition of Russian thistle or tumble weed at the time wheat

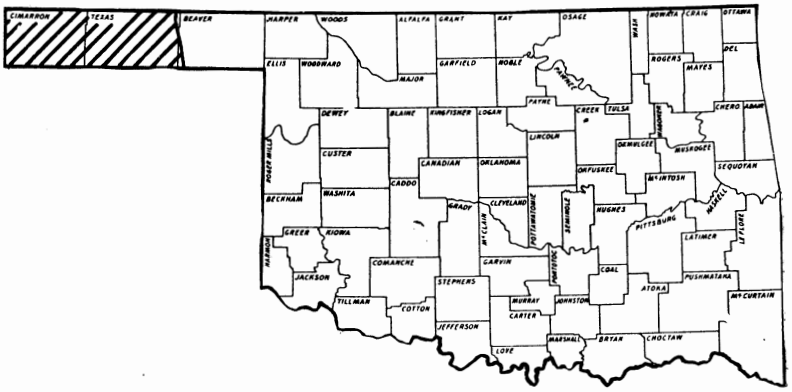

Fig. 13.—Grain Bug Damage Is Localized in the Panhandle. Crosshatching shows where the grain bug occurred in 1940. The grain bug is a "stink bug" (See Figure 22) which propagates in Russian thistles or tumble weeds. It injures wheat by puncturing soft kernels, resulting in light, shriveled grain. Late planted wheat is vulnerable to their attacks.

reaches the milk stage and injury from these insects. Russian thistle is one of the favored wild hosts of the grain bug, and in the areas where the outbreaks have occurred the thistles have been very abundant It is thought that if for any reason the thistles become less attractive to the bugs at the time wheat is entering the milk stage, they will swarm into the wheat, causing the damage previously described.

Fig. 14.—Grain Bug. Grain bug is a typical "shield" or "stink bug." The insects are greenish or brown in color, with a thin line of yellow or red around the margin and three yellow or red dots on the back.

Crops Attacked

The grain bug will attack wheat, barley, rye, oats, grain sorghums, cotton, and many vegetables It feeds on many weeds,of which Russian thistle appears to be the favorite in the Oklahoma Panhandle

Life Cycle

Winter is passed in the adult stage. The most common place of hibernation found in Oklahoma was under large

clumps of Russian thistle. The following spring, usually in April, the overwintered adults emerge from hibernation. After feeding a few days, they deposit their eggs in double rows along the under surface of the plants on which they are feeding. Five to seven days later the nymphal forms emerge from these eggs and begin feeding. At the end of approximately six weeks they have completed their development and become winged adults. There are three to four generations per year; and, since the adult bugs live for several weeks, adult forms are present throughout the year.

Preventive Measures

Since Russian thistle is the most common wild host of the grain bug any procedure that will discourage the growth of these plants in proximity to wheat fields should lessen the chances of the wheat becoming infested.*

Control

During the 1940 outbreak a few farmers in Cimarron County constructed hopper dozers which were placed on the front of a truck or tractor and run through the wheat during the time the bugs were feeding on the heads. Although many bushels of bugs were thus collected and killed, this method did not appear to constitute a really effective control (Fig. 15).

INSECTS INFESTING THE ROOTS

Wheat White Grub

Identifying Characteristics.

This soil-infesting insect during certain years causes severe losses to wheat by destroying the roots and killing the plants. It is found throughout most of Oklahoma, but most serious injury has been reported from the western part of the state (Fig. 16).

Grubworm injury is first noticed in the fall of the year in the patches of dead and dying plants scattered throughout the field. Examination of the surface soil near or beneath recently killed plants will reveal the presence of the fat, curved grubs (Fig. 17) of this insect if they are the cause of the trouble. In mild winters the grubs will continue to work after cold weather sets in, and the injury becomes progressively more severe from week to week. In the spring after

* In 1940 it was observed that the earlier maturing wheat had passed the milk stage at the time the bugs migrated from the Russian thistle and was therefore no longer attractive to these insects. This suggests that the earlier planted wheat will be less subject to injury by the grain bug.

Fig. 15.—A Homemade Grain-bug Catcher.
Many bushels of grain bugs were trapped in this machine during the infestation in the Panhandle in 1940. Infestation can be prevented by destroying Russian thistles around the edges of wheat fields.

the plants become larger they may not be killed by the grubs but will fail to produce heads.

FACTORS PREDISPOSING TO INJURY

Continuous planting of wheat in the same field favors multiplication of the pest. Under such conditions, the grub population will continue to increase until damage may be so severe that the major part of a crop is lost. Usually the destructive cycle lasts one or two years, after which natural enemies reduce the grub population to a non-injurious level. However in some fields this may not occur. Warm, dry winters favor injury as the soil temperature is sufficiently high for the grubs to continue to feed and it is too dry for the development of a good root system on the plants. A severe freeze will drive the grubs deeper in the soil below the point where injury will occur, and rains will favor root development.

CROPS ATTACKED.

By Grubs.—Wheat is the crop principally injured by the grub stage. However, laboratory tests indicate that rye is also damaged; and there have been occasions where serious losses occurred to oats seeded in a field heavily infested with grubs.

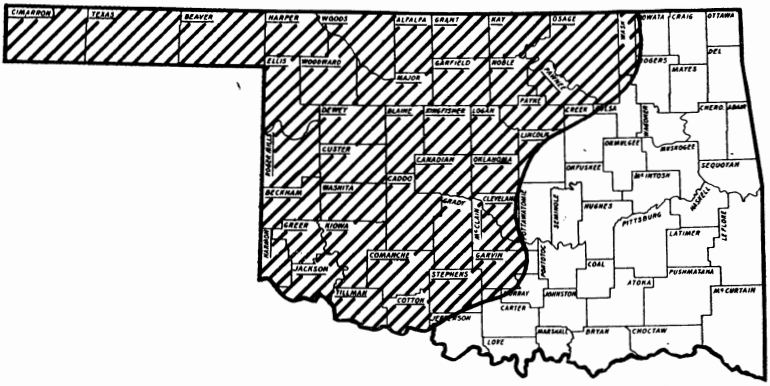

Fig. 16.—Area Where Wheat White Grub Has Caused Damage.

The most serious injury by wheat white grub has been reported from the western part of the state. Wheat is most likely to be attacked, but serious losses to oats have also occurred in fields heavily infested by grubs.

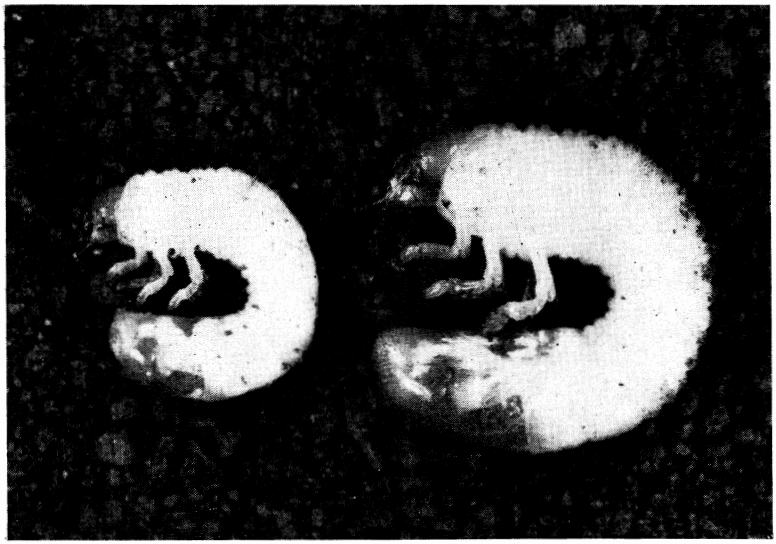

Fig. 17.—First- and Second-year White Grubs.

Injury by wheat white grub is first noticed in the fall in patches of dead and dying plants. Fat, curved grubs like those shown above will be found just under the soil surface close to injured plants. The grubs need two years to mature, so two sizes will usually be found. The large, second-year grub shown at the right matures the following spring into the beetle pictured in Fig. 18.

By Beetles.—The beetles will feed upon and defoliate such crops as cotton and soybeans if these are planted in or near heavily infested wheat fields.

LIFE CYCLE.

The adult of the grub is a grayish striped bettle from ½-¾ on an inch long (Fig. 18). The females are wingless, hence the tendency for the infestation to be localized in certain fields or portions of fields. They are found in northern Okla-

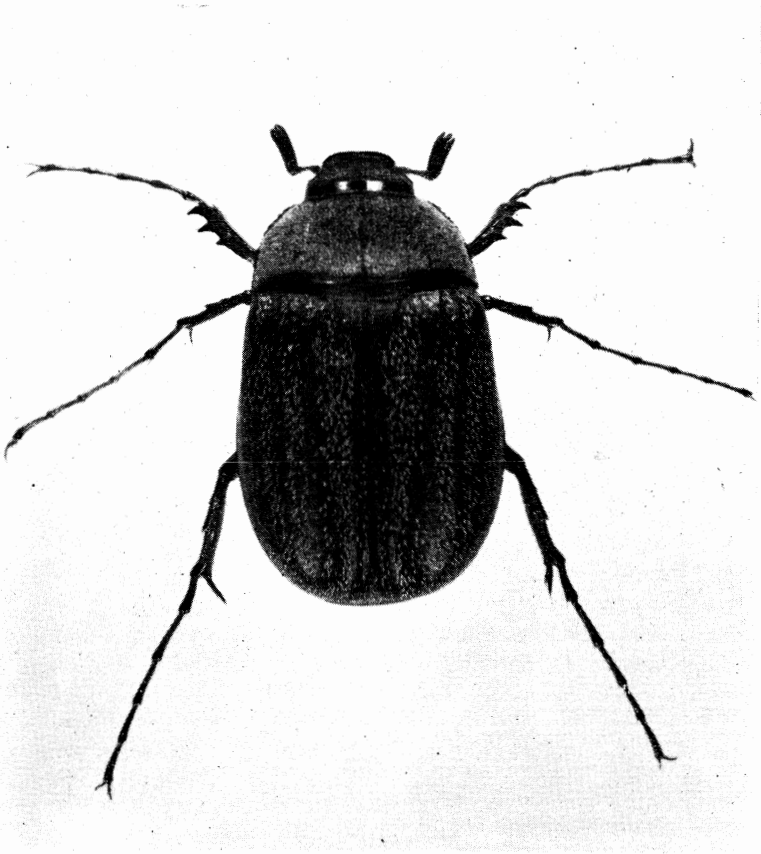

Fig. 18.—Adult of Wheat White Grub.

This wingless "May beetle" lays its eggs in wheat stubble during the summer, and grubs develop in time to attack wheat growing on the same ground in the fall. Rotation of crops, where possible, breaks up this cycle. Cotton or soybeans cannot be used in the rotation, however, because these crops are attacked by the adult beetle.

homa from late May to late June and prefer to feed on yellow evening primrose, a plant which usually thrives in the bare spots in wheat fields where the wheat plants have been destroyed. The beetles will, however, feed on a wide range of weeds, especially pig weed, sunflower, whorled tickweed, knot weed, sensitive briar, black-eyed susan and pepper grass. They are also fond of cotton and soybeans, as previously indicated. The eggs are laid in the soil in wheat stubble fields and hatch into grubs which will become large enough by fall to injure wheat which may be planted in the field. The grub requires almost two years to mature, and two sizes will usually be found in any wheat field. The pupal or inactive transformation stage is found in the soil from late April to late May in northern Oklahoma. The life cycle is completed in two years.

PREVENTIVE MEASURES.

If possible, rotate wheat with some other crop except cotton or soybeans. (These two crops will be injured by the beetles.) The general cropping plan will of course depend upon the locality and local recommendations. If the field is so heavily damaged that it is unlikely to produce a profitable crop, it should be plowed up and it may be left in clean fallow throughout the following summer. It is especially desirable in this case to destroy all weeds by frequent disking. Corn or sorghum may be planted in the field without risk of serious injury (Fig. 19), but a small grain crop like oats, barley or rye should never be planted in a heavily infested wheat field. This is likewise true for cotton and soybeans. A suggested rotation to rid a heavily infested wheat field is as follows: First year, corn or sorghum; second year, oats followed by wheat in the fall.

Wireworms

IDENTIFYING CHARACTERISTICS.

Wireworm injury to wheat usually consists of a thinning of the stand of young plants in the fall of the year. In years when there is sufficient soil moisture the surviving plants may partially replace the loss by tillering. As contrasted to damage caused by white grubs, wireworm injury may be more or less uniform throughout large portions of the field. There is a lack of the "patchy" effect caused by grubs. The cause of the trouble can be determined by examining the surface soil for the wireworms, which are easily identified by their rather slender brown bodies which are hard and wire-like (Fig. 20). They will be found in the drill rows, where close examination has revealed skips and dead plants.

Fig. 19.—Corn Is Not Affected by Wheat White Grub.
This corn is making vigorous growth on land heavily infested with wheat white grub. Sorghum will do equally well. These crops may be used in rotations to control this wheat pest.

CROPS ATTACKED.

Wireworms are very general feeders and will seriously injure many kinds of crops which may be planted in a heavily infested field. They are especially injurious to potatoes and corn.

LIFE CYCLE.

The familiar "click beetle" or "snapping jack" is the adult stage of wireworms. In general these beetles are not injurious to plants. The growth of the worm is slow and may re-

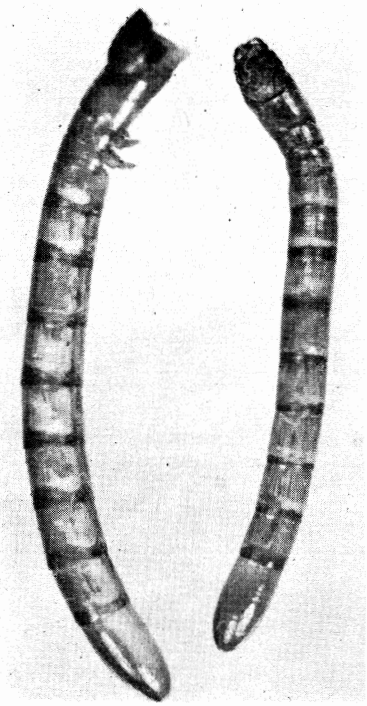

Fig. 20.—Wireworms.

quire several years. The pupal or transformation stage is spent in the soil.

PREVENTIVE MEASURES.

No experiments have been made in Oklahoma on measures to reduce wireworm infestation in wheat fields. However tests in other states have shown that certain measures can be recommended. Those that would apply to Oklahoma conditions and would be practical are as follows:

Planting Depth.—Shallow planting results in less injury because it promotes seed germination and growth. The warmer and drier soil near the surface is less attractive to the wireworms. The seed must be in contact with adequate moisture, however, and in a well prepared seed bed. Loose soil should be packed about seed planted at shallow depths.

Amount of Seed.—Wheat should be drilled rather thickly in infested fields. This provides for an over abundance of wireworm food, thus more plants can survive and reach maturity. The amount of wheat destroyed is the same at 50, 80 and 110 pounds of seed per acre, so that the denser sowings provide a more nearly normal crop. Where it is known that wireworms are numerous, an extra five to ten pounds of seed per acre should be drilled, to provide sufficient seed for a normal crop.

Time of Planting.—Wireworm damage will be less if there is sufficient moisture at seed depth to insure immediate germination and plant growth. If sufficient moisture is not present, wait for rain; when moisture conditions are good, seed moderately early. More injury occurs in dry soil because wireworms eat only the softer part of the grain and the germination period is longer.

Replanting.—If soil moisture conditions are favorable it is usually safe to reseed at once in case fields have been so severely damaged by wireworms that this becomes necessary.

False Wireworms

IDENTIFYING CHARACTERISTICS.

The damage to wheat caused by false wireworms is very similar to that caused by wireworms. These pests may feed on the seeds before germination, may destroy the tender sprouts just as they are pushing out of the seeds, or they may feed on the stems of the young plants just below the soil level. The injury is most evident during dry years when the seed remains in the soil several weeks before sprouting. These soil infesting insects closely resemble wireworms, being slender, elongate, tan or brownish in color and with horny bodies. They are most prevalent in nine northwestern counties (Fig. 21).

FACTORS PREDISPOSING TO INJURY.

Most severe damage is caused to wheat in land which has been planted to this crop for a number of successive years. Such a condition favors multiplication of these insects and they may cause serious damage in years of high temperatures and low rainfall.

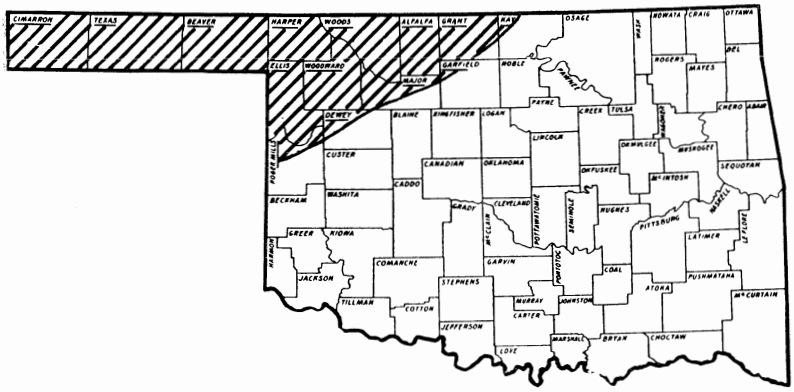

Fig. 21.—Area Most Subject to Damage by False Wireworms.
Most injury by false wireworms has been reported in the northwestern and panhandle sections of the state. These worms eat the seed, tender sprouts and underground parts of the wheat plants. Damage shows up in the fall. False wireworms resemble true wireworms (Fig. 20). The adults are shown in Fig. 22.

CROPS ATTACKED.

Wheat is the principal crop attacked. However, serious spring damage to oats, barley, sorghums and corn has been reported in Idaho; and in Nebraska these crops have been observed to be heavily damaged when planted on ground where winter wheat had been destroyed the previous fall.

LIFE CYCLE.

The adults are medium sized brownish to black beetles (Fig. 22). In Oklahoma, records show that the adults of five species of most economic importance are found in the fields from April to October but are most abundant in July and August. The beetles are not injurious. They feed on a great variety of living and dead plant and animal matter, such as weed seed, grain chaff, straw, and dead or dying insects. The beetles are wingless but are quite active. They may be found in or under wheat shocks, in burrows of small animals or other insects. The larger species have a characteristic habit when disturbed of tilting up their bodies in a nearly vertical position with the head nearly to the ground, tail erect, and when touched they give off an offensive odor which in one case resembles that of decaying wood.

The eggs are laid in the soil and are coated with a sticky substance which causes particles of soil to adhere to them. Several species deposit the eggs in dry soil where it joins the moist subsoil. Species with a one-year life cycle become nearly full grown by fall, completing their development the following spring. Some species have a two-year cycle in which case a year is required for the larval stage to be completed. The pupa is found in the soil within a small cell or cavity located from one half inch to three inches deep.

PREVENTIVE MEASURES.

Rotation.—McCollough* recommends that where fall wheat has been destroyed the land should be worked in the spring and planted to a row crop. If this crop is kept cultivated and free from weeds and grasses, it may be possible to return the land to wheat the following fall. A rotation of wheat two years, grain sorghums one year, and summer fallow one year increases yields in Kansas and at the same time reduces false wireworm injury.

Fallowing.—Summer fallowing has proved successful in Kansas provided the land is worked sufficiently to keep down weeds. In Idaho, on the other hand, summer fallowing to pre-

* McCollough, J. W., *Journal of Economic Entomology* 12(2):183-194 (1919).

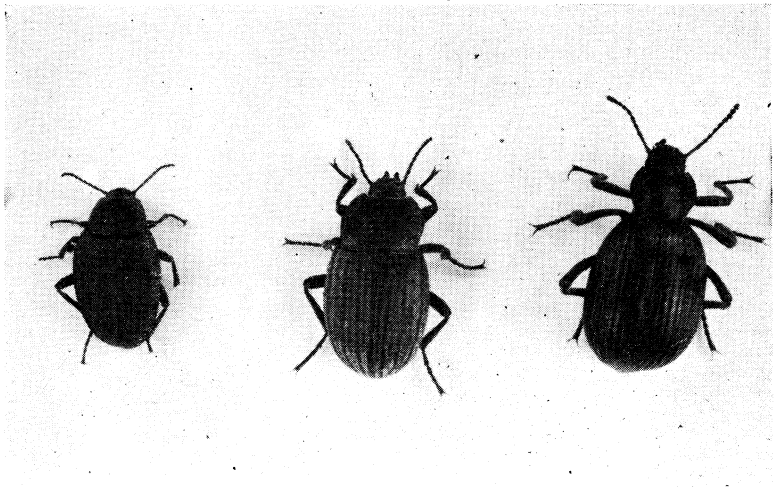

Fig. 22.—Adults of False Wireworms.
These wingless beetles lay their eggs in the ground and the larvae, false wireworms, may attack wheat the following fall. To break up the cycle, follow two crops of wheat with a row crop like sorghums, and then clean fallow.

vent damage has been found unprofitable as it is impossible to eliminate weeds and all organic matter and the worms of some species can survive six months without food.

Good Seed-bed Preparation.—Any measures that will hasten growth and improve vigor of the wheat will reduce injury from these insects. Injury may therefore be lessened by planting in a well prepared seed bed with plenty of moisture. Planting should be delayed until there is sufficient moisture to favor germination.

Plowing and Disking.—Where the worms have destroyed the wheat and row crops are to be planted, plowing or disking the fields in May destroys large numbers of these insects.

POISONING BEETLES.

Laboratory and field tests in some other states indicate a possibility of controlling false wireworms by means of killing the beetles with poisoned bait. This method, however, has not been tested in Oklahoma.

INSECTS INFESTING STORED WHEAT[3]

Because stored wheat insects injure the grain after all the labor and expense of growing, harvesting and threshing have been incurred, the injury they cause is more serious than earlier losses. It is therefore doubly important that their injury be held to a minimum.

Detecting Infestation

The most of the important stored wheat insects are so small that they are difficult to see or find in the wheat bin. Their presence may first be indicated by noting either an unusual amount of flour-like material in the wheat or that the grain is beginning to heat. Sifting a few pounds of wheat through a 16-mesh screen over some canvas or light-colored paper and examining the siftings is a good method of determining their presence before the above symptoms occur. Most of the insects infesting wheat are sufficiently small to pass through a 16-mesh screen while the whole grains of wheat will not, and thus the insects may be separated from the wheat and readily seen.

Species Causing Damage

The insects that attack stored grain are known to the grain trade as weevils and "bran bugs" (Fig. 23). Weevils bore into and destroy whole grains of wheat, while most "bran bugs" feed only on broken or injured grains and waste particles found in the wheat. The injury of the "bran bugs" would not be serious were it not for the fact that when large numbers breed up in the bin their bodies give off a sufficient amount of moisture to start heating of the wheat. The weevils likewise may cause heating in addition to the wheat they destroy. The two insects classified as weevils that are common in Oklahoma bins are: (1) the rice weevil, which can be recognized by its distinct snout; and (2) the lesser grain borer, characterized by its head being set well back under the fore portion of the body.

The more common of the bran bugs are: (1) the flat grain beetle; (2) cadelle beetles; (3) saw-toothed grain beetle; (4) a fungus beetle; and (5) flour beetles. Since the same treatment is satisfactory for all, the recognition of each species is not essential.

Factors Predisposing to Injury

Excessive moisture in wheat at the time it is stored is more important than all other factors combined in creating

[3] See also Oklahoma Agricultural Experiment Station Circular C-95, "Protecting Stored Wheat Against Insects."

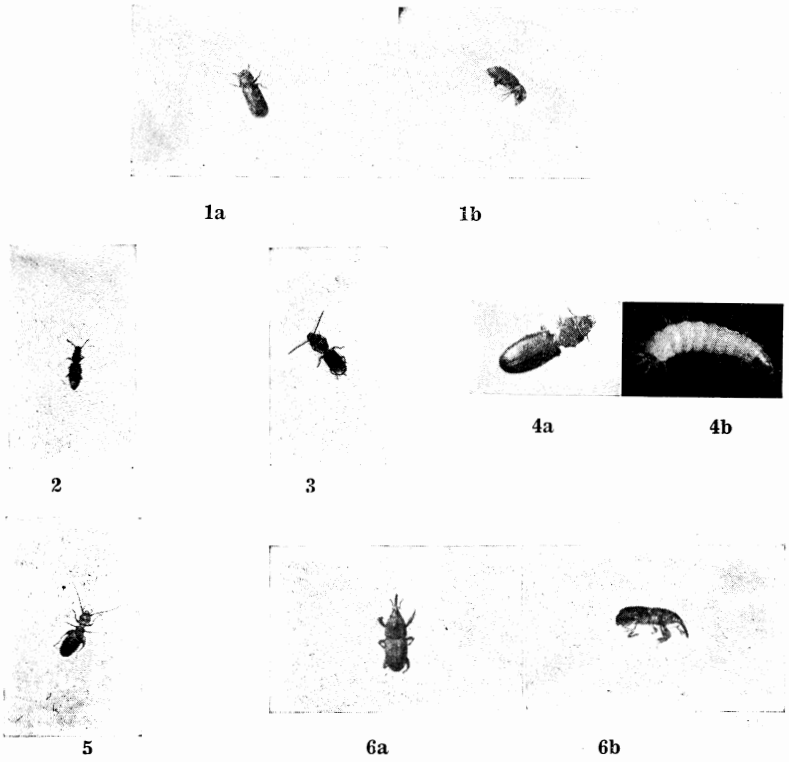

Fig. 23.—Typical Insects Found in Stored Wheat.
Bran bugs feed on broken kernels. Weevils and borers attack whole grain. All cause heating, which results in spoilage. Infestation can be avoided by storing wheat dry and cleaning up bins prior to storage. Pictures above show 1-a and 1-b, top and side view of the lesser grain borer (twice actual size), 2, saw-toothed grain beetle (twice actual size); 3, flat grain beetle (three times actual size); 4-a and 4-b, cadelle beetle and larva (about natural size); 5, book louse (about six times actual size); 6-a and 6-b, top and side view of rice weevil (slightly enlarged).

conditions favorable to heavy insect infestation. When the wheat is high in moisture content (14 percent or higher) conditions are more favorable for both insect infestation and heating. Insects in turn produce more moisture, causing further heating, attracting additional insects, and causing favorable breeding conditions for those present. Thus a vicious circle is started which unless broken may result in the spoilage of the entire bin of wheat.

LIFE CYCLE

The life cycles of these insects are all completed in the grain. In the case of the weevils, the eggs are deposited inside the grain they have hollowed out in feeding; and in the case of the bran bugs and the lesser grain borer they are laid in cracks, in refuse, or directly on the grain itself. The eggs hatch in a few days into tiny, whitish colored larvae that feed on or within the wheat. They reach maturity in from three to five weeks and enter the pupal stage. After several days as pupae, the adults emerge, begin feeding, and soon produce eggs for another generation. There may be as many as five or six generations during the summer and early fall; and if through heating or for some other reason the grain remains warm, breeding will continue throughout the winter.

PREVENTIVE MEASURES

It is extremely important that the grower should do everything possible to hold down the moisture content of the wheat at harvest. Avoid: (1) cutting the grain too green; (2) harvesting in the morning until the dew has dried; (3) starting too soon after showers or rains; and (4) permitting any combined or threshed grain being rained on. It is also extremely important that there be no leaks of any kind in the bin where the grain is stored. If through unavoidable circumstances the threshed or combined wheat contains more than 14 percent moisture it is not advisable to attempt to store it on the farm.

It is very important to see that the grain is stored in a bin that is free of insect infestation. Any small amount of grain left in the bin from the previous year is almost sure to be infested Before storing another year's crop, bins should be cleaned by sweeping very thoroughly, being particularly careful to clean out the refuse in the corners and all cracks. Since it frequently is not practical to clean out all refuse completely and since certain species of insects, particularly cadelle beetles and their larvæ, remain in wooden walls, it is recommended that, after sweeping as thoroughly as possible, the bin be sprayed to destroy any remaining insects. Any good type of household spray is effective, though a cheaper and yet effective spray may be prepared by thoroughly mixing 1 gallon of winter spray oil, nine gallons of water, and six ounces of lye. This should be sprayed over the walls and floors, taking particular care to see that all cracks and corners are adequately sprayed.

Avoid storing wheat near infested grain such as chicken feed, since this may be a source of infestation.

FUMIGATION

When stored grain is found to be infested, the best method of control is by fumigation. For fumigation to be effective, the wheat must be stored in a tight bin. Any cracks should be stopped with wet newspapers or some other material that will prevent the leakage of gas. Fumigation is most effective when the temperature of the grain is between 65° F. and 75° F.

The fumigants recommended, together with the amount needed to fumigate 1000 bushels of wheat, are as follows:

1. Six gallons of a mixture containing 3 parts of ethylene dichloride and 1 part of carbon tetrachloride by volume.

2. Three gallons of carbon disulphide.

The first named mixture has been found best suited for farm fumigations. It is effective, non-inflammable, does not injure germination of the grain, and is less hazardous to use than many other fumigants.

The carbon disulphide is the cheaper of these materials, is non-injurious to grain and is very effective, but has the disadvantage of being highly inflammable and explosive. On account of its inflammability it is recommended that it be used only where wheat bins are separate from barns or other farm buildings.

The fumigant should be applied from the outside of the bin by means of a bucket type sprayer (Fig. 24). The proper amount of fumigant is placed in a bucket and one operator does the pumping while the other directs the spray into the bin. This means that the hose of the sprayer must be sufficiently long to reach from the ground to the top of the bin. A coarse stream should be sprayed evenly over the entire surface of the grain. In spraying carbon disulphide by this method, both the nozzle and the pump should be grounded by attaching a small copper wire to the nozzle and another to the pump. The other ends of each of these wires are then attached to some metallic object imbedded in the ground. The purpose of this is to prevent the building up of any static electricity that might result in a spark, capable of igniting the explosive material.

Do not enter the bin and apply with a sprinkling can unless wearing an approved gas mask. In case neither a mask or sprayer is available, the carbon disulphide may be applied by pouring it through small funnels which have been thrust into the wheat at approximately 48 points evenly spaced over the surface of the wheat. In a 1000-bushel bin, ½ pint of the material is then poured into each funnel. The use of 10 to 12 funnels will greatly facilitate the procedure when this method is used.

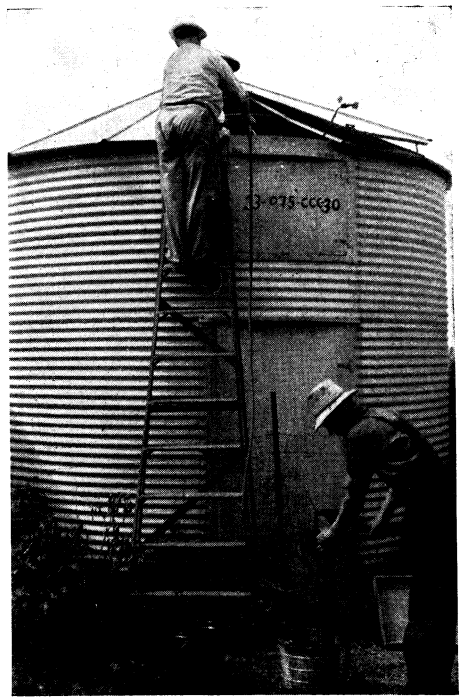

Fig. 24.—Fumigating a Wheat Bin.
Infested wheat in farm bins must be fumigated to prevent continued damage. The work should be done on a still, warm day. The bin should be tight to confine the fumigant. The best combination is three parts by volume of ethylene dichloride and one part of carbon tetrachloride. (See page 43.)

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