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SOUTHWESTERN CORN BORER IN KANSAS

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SOUTHWESTERN CORN BORER IN KANSAS [1]

By D. A. WILBUR, H. R. BRYSON, and R. H. PAINTER [2]

INTRODUCTION

While the attention of the corn growers of Kansas and the other mid-western states had been focused on the widely publicized European corn borers moving into the heart of the Corn Belt from the East, a relatively unheralded corn pest from Mexico, known as the Southwestern corn borer, *(Diatraea grandiosella* Dyar) invaded central and western Kansas from the South. During the brief period of 1940-1942 this insect became established in about one-half of the counties of the state and even reached counties bordering Nebraska.

In 1941, 533,300 acres of corn representing 23 percent of the Kansas corn acreage were located in these infested counties. By 1942, the Southwestern corn borer had increased in population sufficiently to infest nearly all of the cornstalks in an area covering several counties in southcentral Kansas and had caused such damage that in certain fields the crops were not worth harvesting. In other fields in which an excellent crop was produced, the borers by girdling the lower part of the stalks cause up to 75 percent of the stalks to lodge shortly before harvest time.

The Southwestern corn borer crossed the Mexican border into Arizona, New Mexico and Texas in or before 1913. By November of 1931, it had established itself in the Panhandle of Oklahoma, in southeastern Colorado, and in the southern part of Morton and Stevens counties in Kansas.

During this period, 1913 to 1931, the distribution, life history, habits and control of the insect were under investigation by representatives of the Bureau of Entomology and Plant Quarantine and their report was published in Technical Bulletin 388.[3] In this report the authors indicated the potential seriousness of the Southwestern corn borer by the following statement:

"The insect is gradually increasing its range to the north and to the east toward the main corn-growing section of the United States. Although, its general advance appears to take place by spurts at irregular intervals, the occurrence of a favorable year may cause one of these sporadic advances to establish the borer permanently in the main Corn Belt."

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1. Contribution No. 527 from the Department of Entomology.

2. The authors are Associate Entomologists, Kansas Agricultural Experiment Station. The authors gratefully acknowledge the assistance of their associates and the willing coöperation of county agents, branch station workers, and farmers in obtaining information regarding the seasonal activity of the Southwestern corn borer.

Acknowledgments are also due Paul Dittemore, former experiment station editor, for reproducing the maps and charts; Floyd Hanna, college photographer, for making certain of the photographs; and Roy Fritz, former associate in the Department of Entomology, for securing various data.

3. Davis, E. G., Horton, J. R., Noble, C. H., Walter, E. V., and Blanchard, R. A. The Southwestern Corn Borer. U. S. D. A. Tech. Bul. 388. 62 pp., December, 1933.

The 10 years that followed appeared to belie this warning since no further advance was made by the borer toward the northeast. In fact, during the years, 1933 through 1938, when there was little corn harvested in much of the southwestern quarter of Kansas, the borer disappeared from the state. However, during the mid-summer of 1941 there were reports of renewed activity of the borer in Oklahoma and in September it was learned that the insect had again invaded Kansas. The insect is now firmly established in the southwestern portion of the Corn Belt, and there is little possibility of its eradication. It would appear that an annual toll of the corn crop will be taken by the borer, the amount depending on the weather and other natural agencies and the extent to which control measures are applied by the growers.

This bulletin has been prepared from limited observations made during the first one and one-half years of the Kansas invasion. It is intended for use in answering queries of farmers, county agents, and others within Kansas who have observed the ravages of the pest and desire such information as is available on the subject. Technical Bulletin 388 of the United States Department of Agriculture provides an excellent discussion of the insect, but most of the data were obtained in Arizona and may not be applicable under Kansas conditions.

FOOD PLANTS

In Kansas the only crops found to be infested by the Southwestern corn borer are corn, including field corn, popcorn and sweet corn, and sorghums, including both the forage and grain types. In Texas, Arizona, and New Mexico, infestations have been observed in sugar cane, broomcorn, Sudan grass, and Johnson grass in addition to corn and the sorghums. Only minor infestations of sorghums have been found in Kansas and these have not resulted in as much injury to the sorghums as occurs in corn. Because of the light infestation relatively few sorghum stalks are girdled.

DISTRIBUTION

In the most recent account, Technical Bulletin 388, United States Department of Agriculture, the distribution of the Southwestern corn borer was recorded as follows:

"The Southwestern corn borer is believed to be quite generally distributed throughout Mexico, having been reported from the States of Sonora, Chihuahua, Sinaloa, Nayarit, Jalisco, Colima, Peubls, and Vera Cruz. Proceeding northward, the known area of distribution in the United States as of November, 1931, includes the southeastern corner of Arizona, the southeastern two-thirds of New Mexico, most of the Panhandle and Big Bend districts of Texas, and about two-thirds of the Oklahoma Panhandle. In 1931, it appeared in the extreme southwestern corner of Kansas and the extreme southeastern corner of Colorado."

The publication also noted that the distribution in Kansas was limited in 1931 to the extreme southern parts of Morton and Stevens counties. The excessively dry conditions of the several years that followed checked the spread of the borer temporarily by eliminating its food plants. The center of this dry area developed directly across the northeasterly-advancing front of this insect's migratory path.

The next report of the insect's presence in the state came to the attention of Kansas entomologists in September, 1941. In December of that year some old cornstalks were found in southern Reno

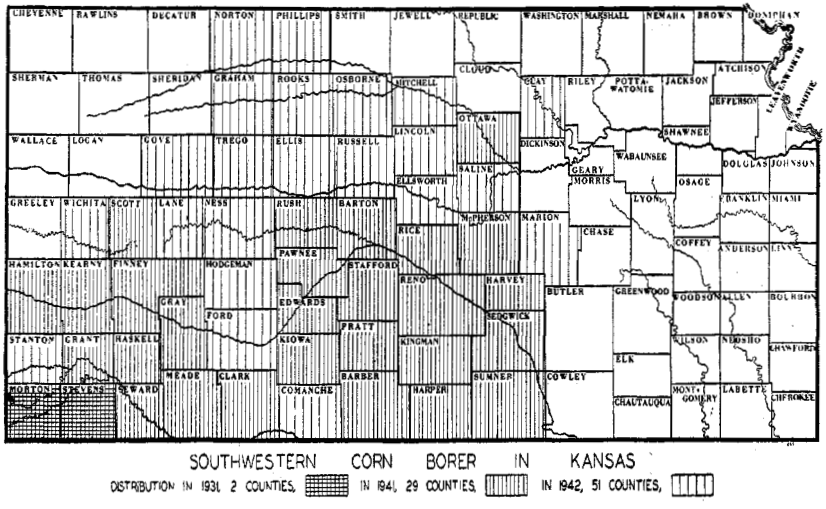

FIG. 1. Southwestern corn borer in Kansas

county which had holes in them similar to those made by this insect. Hence, it seems probable that a light infestation was present in the state in 1940.

During the fall and early winter of 1941-'42, the borer was reported or identified from the following additional 27 counties: Barber, Barton, Clark, Edwards, Finney, Grant, Gray, Hamilton, Harper, Harvey, Haskell, Kearny, Kingman, Kiowa, McPherson, Meade, Ottawa, Pawnee, Pratt, Reno, Rice, Rush, Scott, Sedgwick, Seward, Stafford, and Sumner. The spread during the succeeding season reached the important corn-growing counties adjoining Nebraska. The borer was recorded by entomologists in 1942 in the following additional 22 counties: Clay, Comanche, Ellis, Ellsworth, Ford, Gove, Graham, Hodgeman, Lane, Lincoln, Marion, Mitchell, Ness, Norton, Osborne, Phillips, Rooks, Russell, Saline, Stanton, Trego, and Wichita.

The area known to be infested by the Southwestern corn borer is indicated on the map (Fig. 1.) In the counties along the edge of

the area the borer usually is not abundant, and because of this fact it may occur in several nearby counties such as Cowley, Butler, Smith, Sheridan, Logan, and Greeley without having been discovered.

The heaviest infestation at present occurs in a strip about 100 miles wide and extending between Barber and Ellis counties. In this area, all fields examined were infested and all except early-planted fields showed from 80 to 100 percent of the stalks infested. The infested area north of the center of the state was occupied in 1942 almost exclusively by larvae of the second generation. This would indicate that the moths that laid the eggs producing these borers at the northern edge of the infested area probably flew at least 100 miles. All available observations indicate that moth flight is the chief means of distribution of the Southwestern corn borer.

GENERAL DESCRIPTION OF THE INSECT

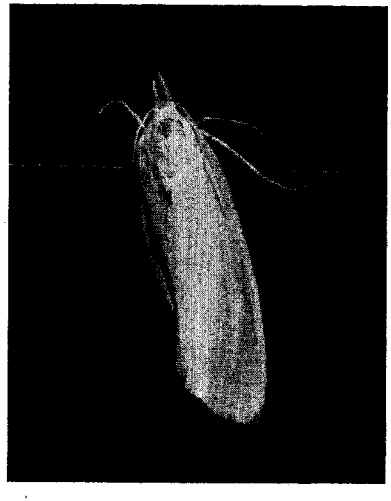

FIG. 2. Adult female moth. (Enlarged 1½ times.)

Moths. The females are approximately three-fifths to three-fourths of an inch long and are of a soiled white to pale yellow color (Fig. 2). The hind wings of both sexes are broader and lighter in color than the fore wings and are somewhat semicircular. The wings are folded about the body when not in use, thus giving the moths a cylindrical appearance. The males are slightly smaller than the females and are somewhat darker. During the day the moths are likely to be hidden in the corn plant and, unless disturbed, are active only at night. Even in heavily infested fields these moths would escape the notice of anyone not familiar with them.

Eggs. The eggs are elliptical to oval in shape and decidedly flattened with a slightly convex upper surface. The eggs (Fig. 3) were obtained from moths confined in the laboratory. The eggs were translucent, white in color and did not develop the three transverse, pink or orange-red markings characteristic of most of the eggs observed in the field. Eggs were found on both the upper and lower surfaces of leaves, either singly or overlapping one another in chains or masses of several eggs. In the field the eggs were scattered from the tip to the base on the leaves below the whorl.

Larvae (borers). With the exception of the overwintering forms, the larvae are of a dull white color and are covered with a regular pattern of conspicuous dark brown or black spots (Fig. 4, left). These larvae are not likely to be confused with the larvae of any other insect in cornstalks in central and western Kansas but in southeastern Kansas it would be impossible to distinguish them from larvae of the Southern cornstalk borer which occurs in that area.

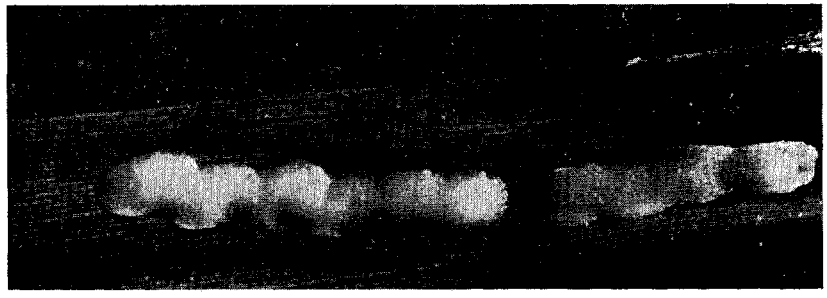

FIG. 3. Flat elliptical eggs on corn leaf. (Enlarged about 5 times.)

The mature borers of the second generation lose their spots, becoming white over the entire body (Fig. 4, right). Occasionally, some faint evidence of the spots remains. These all-white larvae are the ones that girdle the cornstalks in the fall, and remain unchanged from September or October until time for the short prepupal form in late May or June. Full-grown borers average between one, and one and one-fourth inches in length.

FIG. 4. (Left)—Above, live spotted summer larva. Below, dead larva. Seldom more than one larva survives in the same tunnel. (Right)—White hibernating larva.

Pupae. The pupae are slightly shorter than the mature larvae and have the typical brown color of many other moth pupae. They are found within the tunnels made by the larvae (Fig. 5). Empty pupal cases are frequently seen protruding from emergence holes in the stalks. Full technical descriptions of all stages of the insect are to be found in Technical Bulletin 388, United States Department of Agriculture.

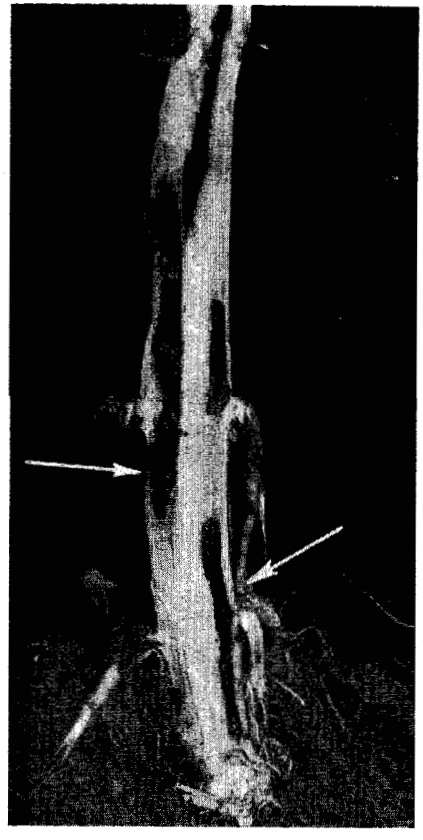

FIG. 5. Split stalk showing first generation pupae in tunnels.

SEASONAL HISTORY AND HABITS

Seasonal Cycle. The mature larvae of the second generation are present throughout the winter in the base of the stalks. During the season of 1942, those overwintering larvae that were observed did not pupate until in June. On June 15, approximately four-fifths of the insects observed were pupae and the other one-fifth were larvae. Pupae collected on this date emerged as moths within a few days.

It is probable that these moths deposited eggs during the latter part of June and the first part of July in the region of southcentral Kansas. The larvae that hatched from these eggs were known as first generation borers. When observed on July 15, most of the larvae were less than half-grown and were still present around the central bud or whorl of the plants. However, many were larger and had already bored into the stalks. By July 25, some borers still remained around the central bud. Several pupae were found at this time. In Figure 5, the pupa in the tunnel on the left is of the first generation. At this time the borer pupates at the base of its tunnel wherever it may occur along the stalk. The following generation

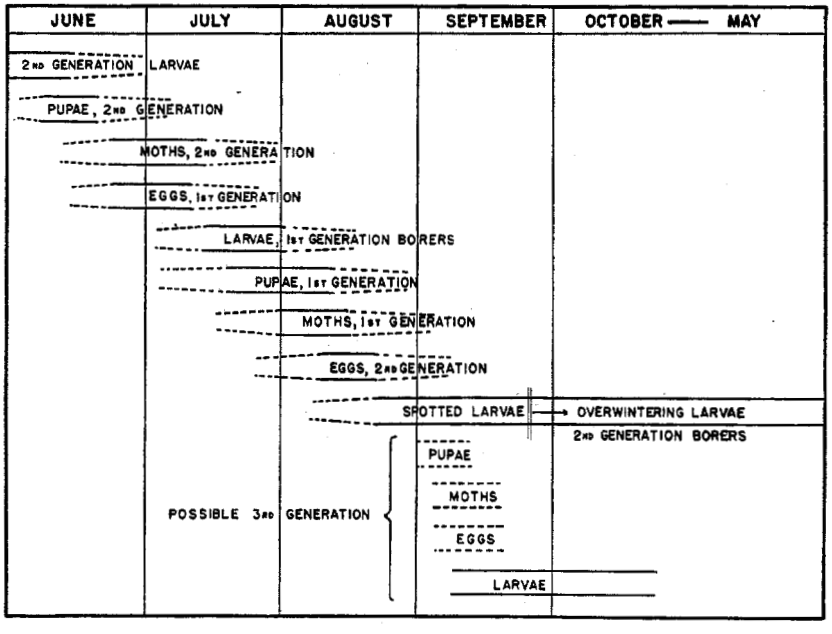

FIG. 6. Showing diagrammatic representation of the seasonal cycle of the Southwestern corn borer in Kansas. Solid lines represent known dates. Broken lines represent probable extremes.

pupates only below ground at the base of the stalk. One empty pupal case was observed in corn in Barber county on July 25.

Thus by the first of August most of the first generation larvae had pupated and moths had emerged (Fig. 6). Eggs were deposited during the first half of the month. By mid-September, second generation borers were from two-thirds mature to mature. Some of them had assumed their overwintering coloration and were girdling stalks and preparing cells in which to hibernate. At this time numerous small larvae were observed feeding on the side buds in the axils of the lower leaves, the only succulent parts remaining on the plant.

These may represent the third generation of borers. It is not likely that they matured.

Overwintering Larvae. All first generation larvae and all but the last instar larvae of the second generation are white with numerous dark-brown or black spots (Fig. 4 left). These dark spots are lost at the final molt of the second generation larvae so that most of the borers observed in the field during the 8- to 10-month period from late September until mid-June are uniformly white in color (Fig. 4, right). A faint pattern of the summer spots can be found

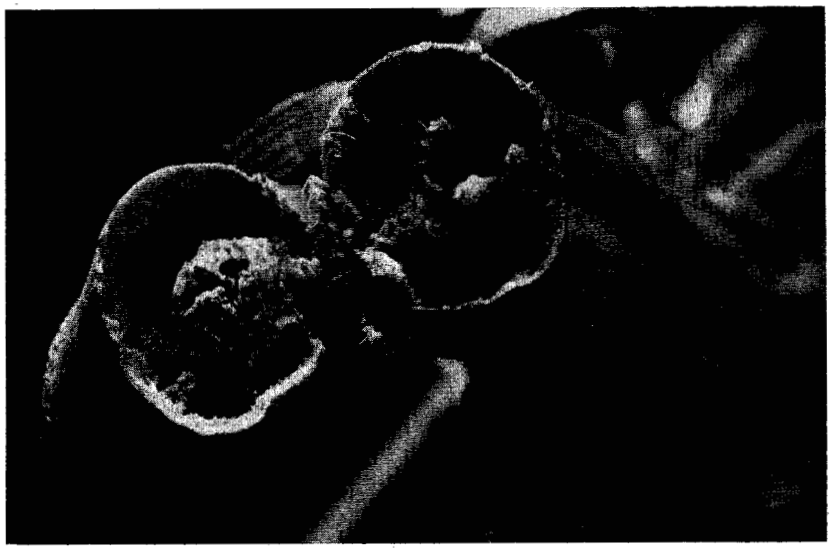

FIG. 7. Severed stalk showing details of internal girdling or reaming. Note thin, knife-like edges.

on some of the white larvae during the winter period. Occasionally, spotted larvae were found alive in mid-January. It is not known whether these spotted larvae are able to survive the full hibernation period. The presence of more than one overwintering larva in a stalk is not common. In Figure 4, left, the fate of the second larva is shown.

Construction of Hibernation Cell. The mature borers of the second generation tunnel down the stalks well below the soil surface and usually go to the extreme base of the stalk in preparation for hibernation. In the lower portion of this tunnel, a long cell is hollowed out and prepared by lining the walls with a thin layer of silk and by closing the upper part of the tunnel with a tough, silken plug. The completed cells vary from two and one-half inches to nine inches in length, averaging about four and one-fourth inches and are slightly over one-fourth of an inch in diameter. The cells are smooth and clean throughout their entire lengths.

Before the hibernation cells are capped or even before their construction is started, certain of the mature larvae move back up the stalk to a place above the soil-surface and ream the inside of the stalk until only a very thin outer shell remains (Fig. 7). This reaming, which is a form of internal girdling, may completely sever the stalk so that it falls to the ground immediately or it may partially cut the stalk so that it will remain standing for an indefinite period. The time required for partially-girdled stalks to fall depends on the proportion of the circumference of the stalk reamed, the amount of sap remaining in the base of the stalk, the weight of the upper part of the plant and the severity of winds. Some partially

FIG. 8. Cornfield showing "down" stalks as a result of the girdling activities of second generation larvae in preparation for hibernation.

girdled stalks do not fall until after the ears have been harvested. Usually, there is no external evidence that internal girdling has been done within a stalk until the stalk falls. A fine hairline occasionally is visible at the point where the reaming has been done and with slight pressure such stalks break readily.

Girdling was observed on various internodes of the stalk up to the seventh internode. On 95 percent of the stalks, girdling was done on the first three internodes above the soil surface, with 49 percent on the second internode, The height on the stalk where reaming or gridling took place averaged about three and three-fourths inches above the ground. Occasional stalks were observed which had been girdled in two places, usually in different internodes.

When the reaming process was once started on a stalk, the larvae usually kept at work until at least half of the circumference of the stalk was reamed. Eighty percent of the girdled stalks examined had been grooved for over half of the circumference. Most of the reamed stalks lodged, even though they were not completely severed (Fig. 8).

When the reaming has been accomplished, the cell completed, and the larva transformed to its hibernating form, the insect is prepared for wintering. At this time it may be found, head directed upwards, in the lower part of the cell, usually within a half-inch of the base of the stalk. In certain fields the hibernating larvae were found higher in the stalk. In a field in Barber county the average location of the borers was 2.4 inches from the base of the stalk; an extreme case was six inches.

Winter Mortality. When the Southwestern corn borer was first found in Kansas in numbers, a question frequently asked was, "Will an insect from Mexico be able to live through the Kansas winters?" The insect survived the winters of 1941-'42 and 1942-'43. Examinations of infested stalks in early April, 1942, showed that as high as 28 percent of the hibernating borers had successfully passed through the winter. At a corresponding date in 1943, the survival varied from 2 to 32 percent.

The extent to which borers were able to overwinter successfully varied markedly in neighboring fields and in different parts of the same field. In the fields examined in sandy areas there was a greater survival in the heavier soils as compared with the lighter, sandy soil. The greatest survival observed in the spring of 1943 (32 percent) was near Garden City. A 2 percent survival was found in a field in northern Ellis county which indicates that the species is able to overwinter in the corn-growing areas of northern Kansas.

Observations during the winter of 1941-'42 suggested that the mortality was severe during the early part of the winter. In mid-January of 1943, however, there was a survival of from 45 to 85 percent. Casual observations by some farmers and county agents suggested that the mortality occurred during the severe cold spell in January and February. When observed in the early spring, some of the dead larvae were so badly decomposed that they were classed by the observers as missing, others were soft and rotted, while the remaining larvae were heavily coated by a fluffy mold.

A 2 percent survival of borers in the spring is not a negligible number in view of the fact that virtually 100 percent of the stalks were infested in several counties in Kansas. Taking as an average 5,000 infested stalks per acre, a 2 percent survival would leave 100 moths to emerge in June, half of which would be ovipositing females. In a quarter section of corn with a 2 percent survival there is, therefore, the threat to next season's crop of 8,000 ovipositing females, each capable of laying approximately 250 eggs, which is more than enough to restore the original fall population to 100 percent infestation.

From observations made early in April, 1943, it was found that the borer will overwinter successfully in sorghum stubble. There was as great or greater survival on April 1 among overwintering borers in infested sorghum stubble as compared with infested corn stubble in the same and in adjoining fields.

Summer Activities. Larvae of the first generation feed within the whorl until they are about half-grown. Then they move down the stalk and attempt to enter at any internode. Entrance holes are usually made near the base of the leaf blade or within the protective covering of the leaf sheath. A coil of frass (Fig. 9) may be

FIG. 9. Protrusion of frass from an entrance hole. This is evidence that the stalk is being tunneled by a borer.

found protruding from each entrance hole until it becomes dislodged and accumulates at the base of the leaf beneath the hole. Difficulty is frequently experienced by the larvae in entering the stalks, as is indicated by the numerous attempts at entrance found along the stalks.

During this period the borers appear restless and may be found wandering up and down the stalk. Some of the borers may construct a cell out of frass and borings between the leaf sheath and stalk. Frass accumulates in quantities inside the leaf sheath as a result of groovings made on the outside of the stalk, and on the inside of the leaf sheath. The borers have not been observed migrating across the ground to neighboring corn or sorghum plants. In some cases, they appeared to have moved to other tillers on the same plant or to other stalks in the hill. This was particularly true of sorghum plants.

Tunnels in the stalk occurred anywhere from the base to the tassel. Each larva cut an exit hole and then pupated in the lower part of its tunnel. When the pupae were mature they moved towards the exit to permit the escape of the adult. Empty pupal cases were observed protruding from the exist holes.

PLANT INJURY

The Southwestern corn borer may feed on almost any part of the corn plant. Feeding starts with the hatching of the eggs into first generation larvae in late June and may continue until the borers are

FIG. 10. Typical "dead heart" injury caused by young larvae of the first generation feeding within the whorl. The white leaves are evidence of a severed bud. The ragged leaves also represent earlier injury to the leaves caused by the young larvae.

settled for the winter in hibernation cells. The injury caused by the borer to the corn plant is usually the result of one or more of the following activities:

(1) Feeding on the leaves; (2) feeding on or about the terminal bud within the whorl; (3) boring within the stalk; (4) boring into the shanks and ears; and (5) internal girdling of stalks.

Feeding on the Leaves. Injury to the leaves is caused by the feeding activities of newly-hatched larvae as they move down the

unfurled leaves toward the bud and by older larvae working on the tender leaves within the whorl. When the feeding is done horizontally through the furled leaves, it results in a series of holes which extend across the leaf and resemble the feeding injuries caused by the corn billbug. Much of the feeding, however, is parallel to the midrib of a single leaf. The larvae may not cut holes entirely through the leaf, but may consume only the green portion of it leaving a thin translucent membrane, which gives the leaf a partially skeletonized appearance. This type of injury is evident on the leaf blades of the plant pictured in Figure 10.

The injury to corn leaves caused by the feeding activities of the Southwestern corn borer closely resembles the "ragworm" injury characteristic of the first generation of the corn earworm. Rarely is more than a small portion of the total leaf surface injured, although, the affected area may be conspicuous for some distance. This leaf injury can be observed in the corn field while driving along the highway. Distinction between this injury and that done by corn earworm can be made with certainty only by finding the larvae.

Feeding on or about the Terminal Bud within the Leaf Whorl. The feeding activity around the terminal bud is frequently much more serious in its effects than the feeding on the open leaves. The leaf whorl provides shelter and protection for the young worms which will remain on this portion of the plant until they are about half grown. Todd and Thomas[4] observed as many as 13 young larvae in the whorl of a single plant in Texas.

The feeding activities of the borers in the whorls are likely to sever the buds, thus bringing about a condition known as "dead heart" (Fig. 10). Within a cornfield these severed whorls assume a bleached or blasted appearance and stand out prominently among the green foliage. Stalks with severed buds do not develop normally and may produce lateral branches giving the plants a bushy appearance. This type of injury is caused principally by first generation larvae, although if there is corn available in the pre-tasselling stage at the time of the attack of the second generation borers, similar injury can occur. In numerous fields of medium- to late-planted corn in the southcentral part of Kansas during the early summer of 1942, the "dead heart" injury might be ranked as abundant, though probably not severe. Early-planted corn is likely to be in full tassel when the moths from the overwintering larvae are depositing eggs and consequently escapes the "dead heart" injury.

Boring Within the Stalk. After the larvae are approximately half grown, they leave the leaf whorl, move down the stalk and enter one of the internodes above the soil surface. In Figure 9, there may be seen a mass of yellowish curled excreta protruding from an entrance hole. The excreta remains in this position for a time and later drops and accumulates at the base of the leaves. While moving down the stalk, borers may tunnel in the midrib of a leaf or

4. Todd, C. J., and Thomas, F. L. Notes on the Southwestern Corn Borer, *Diatraea grandiosella* Dyar. Jour. Econ. Ent. 23:118-121; 1930.

gouge a half-tunnel along the outside of the stalk where it is protected by the base of the leaf. Many larvae have been found living in a small cell constructed within an accumulation of frass which resulted when an entrance hole was being made into the stalk. As many as eight tunnels of first generation borers have been found in a single stalk. In Figure 5 are shown four distinct tunnels made by

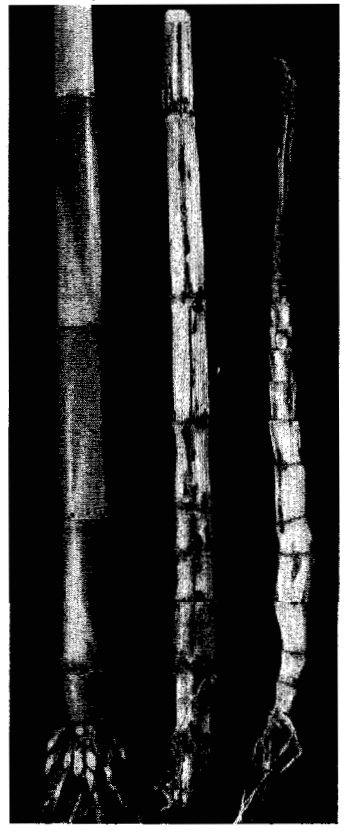

FIG. 11. Stunted stalks resulting from severe borer attacks. Note the shortened internodes as compared with those of uninfested stalk on the left.

the first generation larvae. There were three other tunnels in the same stalk. Generally each borer sought an unoccupied internode, but occasionally two borers have been observed in the same internode.

When small plants are attacked the activity of the borers in feeding about the buds, and in tunneling within the stalks frequently

causes a shortening of the internodes, resulting in stunted plants. Figure 11 shows two stunted corn plants and an uninfested plant. The short plant on the right had 20 borer holes distributed along its entire length. This stunting may be accompanied by excessive suckering or lateral branching causing the plant to have a bushy appearance similar to that caused by "dead heart."

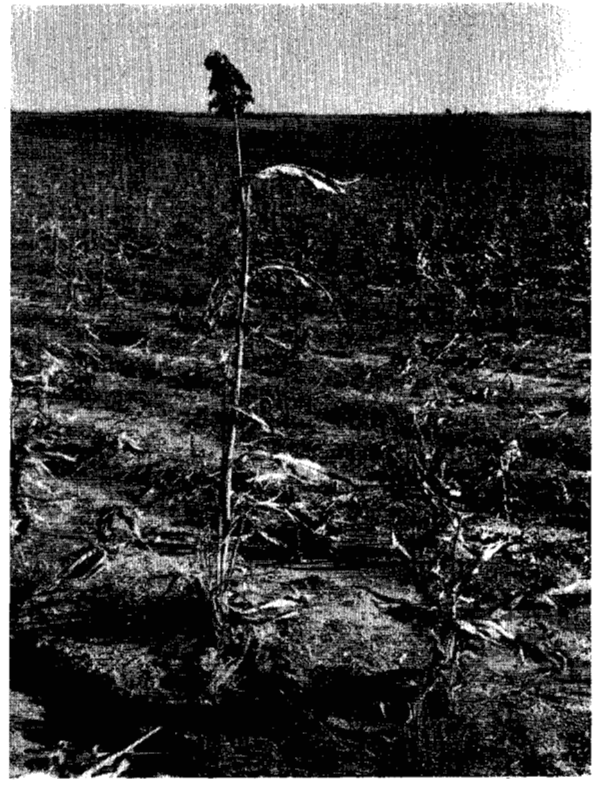

FIG. 12. A field of corn severely stunted as a result of a borer attack. The sorghum plant in the foreground, although infested, attained normal development and emphasizes the resistance of sorghums to the borer.

In southcentral Kansas where the attack of the first generation borers was severe during the 1942-growing season, there were fields in which few stalks exceeded three or three and one-half feet in height (Fig. 12). Every stalk in these fields had been entered repeatedly by borers while the corn was young. Stalks less than two and one-half feet high contained as many as 30 borer holes.

In spite of such an attack some plants tasseled and produced ears, One plant about 18 inches in height, which had been riddled by 26

borer holes, still produced a tassel and two "nubbins," one of which made three or four kernels. These fields of stunted corn occurred even though the summer of 1942 was one of the most favorable growing seasons on record as indicated by the tall sorghum plant in the field of stunted corn (Fig. 12). Stunting caused by the attacks of the Southwestern corn borer should not be confused with stunting that frequently results from unthrifty growth as a result of early planting, unfavorable weather or other conditions.

In the fields where the corn had already attained its more normal height before the stalks were excessively tunneled, the effects of tunneling were less marked. In these cases substantial ears were produced though the kernels did not fill out as well as they might otherwise have filled. It is not known how serious this type of injury may be, but estimates of from one-tenth to one-fourth reduction in yield have been made. Borers of the second generation may enter nearly mature stalks. If this is the only attack upon the stalk, the development of the ear is not likely to be affected to an appreciable amount. The extent of the injury caused by borers tunneling into the stalks is dependent upon the development of the stalk at the time of attack. This in turn, is affected by the time of planting and by the generation of borers making the attack.

Occasional stalks in which tunneling had occurred were found broken over early in the season. These weakened stalks were felled by their own weight, had been blown down by the wind, or were pushed over during cultivation.

The number of borer holes, either entrance or exit, in a stalk should provide a reliable index of the extent to which that stalk has been subjected to borer attack. In January, 1943, an examination was made of 238 infested stalks taken from 17 fields in five counties in Kansas. The borer holes in the first eight internodes above the ground were counted; the greatest number found in one stalk was 35. As many as 11 holes were found in a single internode. An examination made of 1,884 internodes revealed 80 percent of them either uninfested or contained but one hole to the internode, 18 percent had two or three holes, while the number of holes in the remaining 2 percent of the internodes varied in number from four to 11. Borer holes occasionally occur above the eighth internode and rarely may be found in the stalk of the tassel.

When the infested stalks were arranged according to the time of planting and the generation of the attacking borers, differences were noted in the average number of holes in a stalk as indicated in Table 1.

The early-planted corn had the fewest borer holes per stalk while medium-planted corn had over three times as many holes. Stalks attacked only by the second generation larvae had but a third as many holes per stalk as did medium-planted corn which had been subjected to the attacks of both generations of borers.

TABLE 1. *Number of borer holes in infested corn stalks. Central Kansas, 1942 crop.*

	Number of stalks.	Number borer holes.	Average number holes per stalk.
Early-planted: Attacked by both generations	25	131	5.2
Medium-planted: Attacked by both generations	98	1,725	17.6
Medium to late-planted: Attacked by second generation only	115	672	5.8
Totals	238	2,528	10.6

Boring into the Shanks and Ears. As the ears developed there was much evidence of borers working into the shanks and ears. Occasionally, the shanks were entered through the stalk, (Fig. 13),

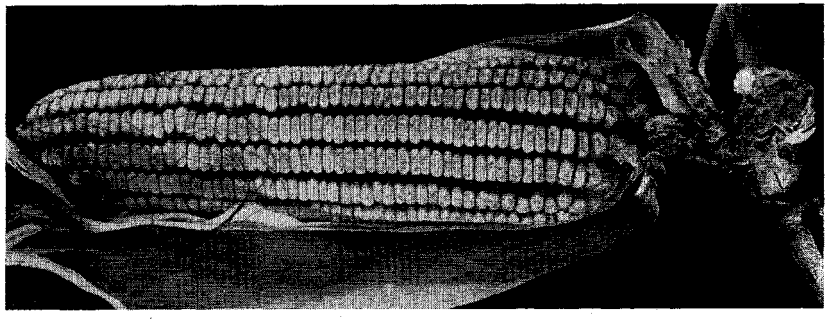

FIG. 13. Ear showing late-infested shank. Such injury may cause the ears to break off and fall to the ground before they can be harvested.

but more often they were entered from the outside (Fig. 14). The interior of the shank frequently was tunneled its entire length and three or four entrance or emergence holes were found in many shanks. Generally, when the borers reached the ear they would feed about the base of the shucks and not enter the ear. Some ears were observed, however, in which the borers penetrated the cob after the manner of the European corn borer, as shown at the base of the ear in Figure 14. The tip of this ear was damaged by the corn earworm. Where heavy feeding had been done at the base of the ear, the corn near the base of the cob tended to ferment and rot.

Farmers generally are unaware of this shank and ear injury. One farmer in speaking of the injury by the borers, said that he was thankful that the borers did not work around the ear. Upon examining his own corn, which had made an excellent growth despite borer attack, it was found that the first 10 ears examined were infested in the shanks, or ears, or in both.

Early infestations in both stalks and ears may cause the development of the ear to be so retarded that no grain is formed. With later infestations the grain production may be normal even though the shank is entered. Occasionally, the shanks are so badly riddled that the ears drop.

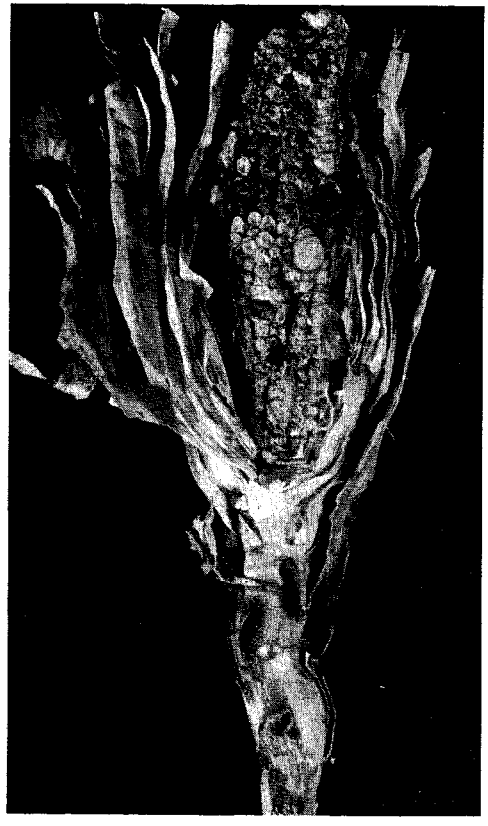

FIG. 14. Severe injury to both shank and cob which renders the ear valueless. This injury is typical in fields badly infested by first generation borers. Corn earworm injury at top.

Internal Girdling of Stalks. The activities of the larvae in the girdling process have been discussed under seasonal history and habits. Girdling of the stalks constitutes the chief borer injury to corn and sorghums observed in Kansas. As a result of girdling a single borer late in the season may fell a large, mature stalk with fully developed ears (Fig. 15). For the most part farmers have been unaware of the Southwestern corn borer infestations in their fields until the stalks were seen lying on the ground.

Not all of the infested stalks are girdled. Observations made in several counties at the end of the 1942-growing season revealed that an average of nearly one-half of the infested stalks were girdled. The extreme ranged from 4 percent girdling in an early-planted field in Barton county to 84 percent in a small field of popcorn in Ellis county.

FIG. 15. Heavy stalk, with typical borer holes, which has broken over as a result of partial girdling.

Not all of the girdled stalks fall. The extent to which the stalks lodge depends on several factors: The circumference of the girdled stalk; the weight of the upper part of the stalk and ears; and the prevalence of heavy winds. In general, about three-fourths or more of the girdled stalks fall.

An estimate of the down corn as a result of borer attack was made in a 160-acre cornfield in northeastern Stafford county in January, 1943. The ears of corn on the ground left by the me-

chanical corn picker were collected from a representative area of one-eighth acre (Fig. 16), and was found to approximate 22.5 bushels per acre. This particular field had been under observation throughout the growing season and was known to have been infested only by the second generation borers. While inspecting the field in early November, stalks could be heard breaking and falling because of a wind blowing at the time. Corn falling to the ground is largely lost because of the difficulty in harvesting, spoilage, and destruction by animals.

In Figure 16, the pile of cobs at the right of the corn represents corn destroyed by the kangaroo rat *(Dipodomys ordii richardsoni*

FIG. 16. The pile of ear corn, weighing 148 pounds, and the 38 cobs, stripped of their kernels by rodents (equivalent to 22.5 bushels per acre), gathered from the ground on one-eighth acre in a cornfield severely infested by second generation borers.

Allen), which is prevalent over much of the sandy, corn-growing region in central and western Kansas. Mice and birds likewise destroyed many ears that had fallen to the ground. Some ears on the ground were molded while most of them were dirty or even covered with soil.

The chief complaint of the farmers, however, was due to the back-breaking labor required to salvage the ears lying on the ground. The mechanical corn pickers, which are coming into general use in the more extensive corn-growing areas in the state, lose much of their effectiveness as a labor-saving device when percentages of from 15 to 50 percent of the ears are on the ground.

CONTROL

Information on which to base control recommendations for the borer under Kansas conditions is scant, being obtained from observations limited to the winter of 1941 and the growing season and winter of 1942. From available data, certain of the following practices may be feasible and should result in reduced damage by borers:

(1) Substitution of sorghums for corn; (2) early planting; (3) late fall treatment applied to stalks and stubble; (4) deep plowing of stubble; (5) low cutting of stalks; (6) planting of resistant varieties.

FIG. 17. Sorghum stalks infested by the borer.

Since the Southwestern corn borer has demonstrated its ability to migrate considerable distances within a single season, beneficial results are certain to be more marked if community action can be obtained. Furthermore, reliance should not be placed in any one control procedure, but should embrace as many recommendations as can be put into effect.

Substitution of Sorghums for Corn. The heaviest infestation of borers observed in planted fields of sorghums in Kansas was one having 7 percent of the stalks infested. When volunteer sorghum plants were present in heavily-infested cornfields, the infestation in sorghums ran as high as 54 percent. Where volunteer corn plants occurred in a sorghum field, not only were the corn plants infested but a few sorghum plants around the corn were likewise infested.

The observations suggest that after the corn plants have attracted the moths, the moths will oviposit on sorghums as well as on corn, but that sorghums are not in themselves particularly attractive to the moths. The infestations observed on sorghum have been largely in the most heavily infested areas in the state and have consisted of second generation borers (Fig. 17).

Sorghum plants, in comparison with corn, are unattractive for oviposition by the Southwestern corn borer moths, and the stalks do not appear to provide a habitat as suitable for the borers. This is evident from the fact that borer tunnels in sorghums are usually short and are confined to the lower part of the stalks. Examinations of infested corn and sorghum plants in January, 1943, revealed only 35 percent of the borers in the sorghums were yet alive as compared with approximately 70 percent of those in corn stalks. Larvae taken from sorghums were observed to be much smaller than those which fed on corn as indicated in Table 2.

TABLE 2. *Comparison of weights of hibernating borers taken from stalks of corn and sorghums. January, 1943*

	Corn.		Sorghums.
	Rice and Stafford counties.	Kiowa county.	*Kiowa county.
Number of borers	24	27	27
Average weight	255 mg.	260 mg.	176 mg.
Average weight of five largest	281 mg.	406 mg.	256 mg.
Average weight of five smallest	132 mg.	118 mg.	109 mg.

* Kiowa county data obtained from same field.

The data show that mature larvae from sorghums weighed 32 percent less than those taken from corn stalks, a difference highly significant statistically. It would appear from the evidence that while a small percentage of sorghums may become infested by borers there is little likelihood that such infestations will become serious and that sorghums safely can be substituted for corn. Infested sorghum plants may be girdled internally in the same manner as corn.

It has been demonstrated that over much of central, southern, and western Kansas sorghums produced a larger yield of both grain and forage and will withstand conditions of heat, drouth, and grasshoppers better than will corn. Figure 18[5] prepared by the Department of Agronomy, Kansas Agricultural Experiment Station, indicates the corn and sorghum areas in the state.

5. Salmon, S. C., Corn Production in Kansas. Kansas Agricultural Experiment Station, Bul. 238, pp. 1-42, 1926.

In district 1, corn is more profitable than grain sorghum nearly every year. In district 2, corn is usually more profitable than grain sorghums on the bottom lands and on the better uplands. On the less fertile soils in this district, however, the sorghums are usually more certain and more profitable. In district 3, grain sorghums almost always outyield corn on medium to poor soils while on the best lands the season is the determining factor. In district 5, corn is the more dependable crop. In district 4, corn seldom produces as large yields as grain sorghums and it is almost always a less profitable crop.

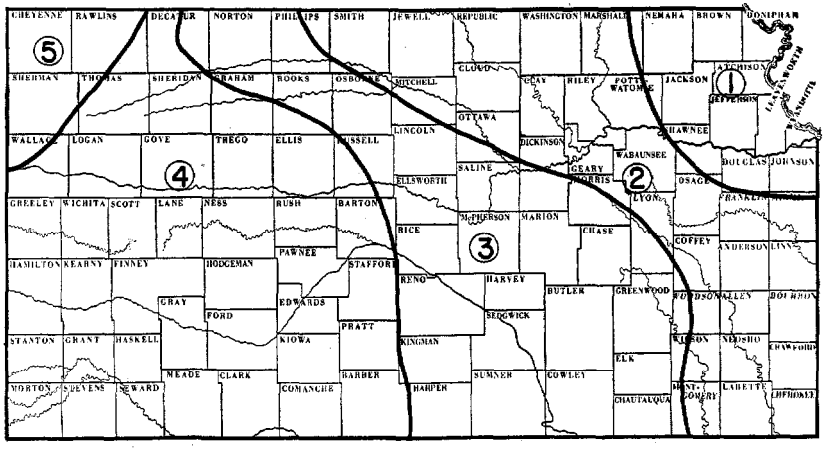

FIG. 18. Corn and sorghum areas in Kansas.

Tests on the feeding value of grain sorghums as compared with corn have been conducted by the Department of Animal Husbandry, Kansas Agricultural Experiment Station. Their published results indicate that grain sorghums are equal to or better than corn for fattening hogs [6] and cattle.[7]

A substitution of grain sorghums for corn wherever practicable is then not only good procedure for the control of the Southwestern corn borer but is also a sound agronomic and economic practice.

Early Planting. From observations of borer infestations in the fall of 1941 and during the 1942 growing season, and from reports of farmers and county agents over the same period, it was apparent that early-planted corn suffered considerably less damage from both generations of borers than did medium- and late-planted corn.

6. Aubel, C. E. The comparative value of Colby milo, Wheatland milo, Westland milo, Blackhull kafir, and corn as swine-fattening feeds. Kansas Agricultural Experiment Station, Circular 43-H-1, 1943. (Progress report on project 110.)

7. Weber, A. D. The comparative value of Wheatland milo, Blackhull kafir, Westland milo, and corn as cattle-fattening feeds. Kansas Agricultural Experiment Station, Circular 43-13-2, 1943. (Preliminary report on project 78, sub-project 29.)

A wide range of corn-planting dates is practiced by farmers in Kansas, both within the same locality and between localities. For example, in Barber county in southcentral Kansas, some corn is planted during the last week of March while other fields may not be planted until early June. The average planting date in this locality is around May 1. In Ellis county, approximately 100 miles to the north of Barber county May 1-15 is considered early planting. June 15 is recommended and some corn is not seeded until mid-July. This wide range in planting dates offers an opportunity to take advantage of the later emergence of moths from the overwintering borers, which, in 1942, did not occur until the latter half of June.

Young larvae of the first generation borers normally remain in the bud until they are about half-grown. By late June of 1942, early-planted corn was already tasseled and silking had started so that it was impossible for that corn to be injured by "dead heart" or stunting of the plant. Some borers could enter the stalk but stocky stalks can survive an infestation with only minor effects on the yield. Medium and late-planted corn, particularly the latter, are of a size which may be affected by both "dead heart" and stunting and in 1942 much late corn in southcentral Kansas was still in the whorl stage when the eggs were deposited for the second generation of borers. In early-planted corn, the crop was nearly mature by the time of the appearance of the second generation worms and consequently escaped serious injury.

The extent of the infestations in early-planted corn as compared with that planted later is indicated in Table 3 which data were obtained in Barber and Barton counties. Not only has the infestation increased with the later-planting date but the extent to which the stalks were girdled was increased as well. From Table 1 it may be noted that there are three times as many holes in medium-planted corn attacked by both generations of borers as in early-planted corn. In medium-planted corn attacked only by second generation borers

TABLE 3. *Relation of planting date to extent of infestation among neighboring fields of corn.*

LOCATION.	Planting date.	Number stalks examined.	Percentage uninfested.	Percentage infested.	Condition of infested stalks.	
					Percentage not girdled.	Percentage girdled.
Barber county	April 15	100	21	79	63	37
	May 1	100	0	100	37	63
Barton county	April 20	25	84	16	75	25
	Early May	50	60	40	40	60
	Mid-June	50	16	84	33	66

the average number of borer holes was approximately the same as with early-planted corn.

Contrary to Kansas experience, late planting proved to be more feasible in Arizona and New Mexico, according to the United States Department of Agriculture, Technical Bulletin 388. Late planting likewise is a part of the control program for the European corn borer.

In the event of considerable delay in the germination or development of early-planted corn, or of an exceptionally early emergence of the moths from the overwintering borers, early planting may not be as effective as it was under the conditions of the 1941 and 1942 seasons. Also it should be noted that the yield of early-planted corn is not as good as in the case of medium- to late-planted corn.

Late Fall Treatment Applied to Stalks and Stubble. Since the mature borers cease feeding in the early part of October and remain in their hibernation cells until late spring, they are vulnerable to cultural practices which will expose them to the rigors of winter. The overwintering larva is in a cell at the base of the plant from two to six inches below the surface of the soil. Available evidence indicates that any treatment which dislodges and throws the stubble to the surface will expose the bases of the stalks to the fluctuations of atmospheric conditions. On the surface of the soil these conditions are more sudden and of a wider range than are the fluctuations of temperature at the depth where the insect hibernates. In this situation they are also more exposed to natural enemies than when undisturbed.

Listing. Listing out the corn stubble shows promise as a method of destroying the overwintering larvae. This practice disturbs the stubble and stalks by breaking and throwing them to the surface in a horizontal position thus exposing the larvae tothe rigors of winter.

A check on the survival of the larvae in experimental fields listed early in the winter showed that 100 percent of the larvae were dead when the stalks were examined in early spring. The only live larvae found were in the stubble which had been missed by the lister. Listing also leaves the surface of the soil in such a condition as to reduce soil blowing and prepares the surface for the reception of winter precipitation.

One-way Disc Cultivator. The one-way disc cultivator throws the stubble to the surface and at the same time cuts and splits many of the stalks. No borers survived where fields under observation had been one-wayed. In areas where soil blowing is a menace, one-waying may not be as advisable as listing since the surface of the soil is exposed to the action of the wind.

Deep Plowing of Stubble. Plowing under the stalks and stubble to a depth of at least four inches before June 1 prevents the escape of the moths from their overwintering cells and thus greatly reduces the number of moths for the deposition of eggs of the first generation borers. Harrowing after plowing seals the surface of the soil and makes escape of the moths more difficult. Plowing usually is not

advisable where soil blowing occurs. Listing or one-waying to prevent the survival of the overwintering larvae may be a better practice from the agronomic point of view than deep plowing under these circumstances.

Low Cutting of Stalks. Cutting the corn at or near the surface of the soil with a low-cutting binder by early September will remove a large number of borers from the field, and will prevent their establishment in hibernation cells. This treatment is particularly adaptable where early-maturing corn is grown.

Planting of Resistant Varieties. Some differences have been observed in amount of infestation and degree of injury done by the Southwestern corn borer to various hybrids and varieties. It is uncertain whether these differences are the result of inherent resistance to the borer or whether they merely result from differences in environment, maturity, or other features of adaptation. In 1942, certain hybrids appeared able to stand for a longer time under borer attack than others. There appears to be, however, no relationship between size of stalk and amount of girdling.

The success in breeding for resistance to the European corn borer, to the related sugar cane moth borer *(Diatraea saccharalis* Fab.), and to other insects suggests that resistance to the Southwestern corn borer merits investigation. Experience with other insects indicates that hybrids resistant to the European corn borer cannot necessarily be expected to be resistant to the Southwestern corn borer. Some of the hybrids also may not be adapted to Kansas conditions.

In several places in Kansas in 1943, planting of adapted corn hybrids and varieties have been made for the purpose of studying resistance to Southwestern corn borer. These same tests will be used to determine whether some hybrids of known resistance to the European corn borer may be also resistant to the Southwestern invader.

PARASITES, PREDATORS AND DISEASES

No parasites have been reared during the investigation in Kansas, but in the studies of this insect made in New Mexico and Arizona several insect parasites were reared that are not known to occur in this state. There is a possibility that some of these may spread into this area or that they could be introduced to aid in the control of the borer.

Several cornstalks were found which had been opened by birds such as woodpeckers. Ants have been seen to feed upon dead borers and several insects that are probably scavengers have been reared from infested cornstalks.

During examination of infested stalks, both before and after hibernation of the larvae, a number of these insects were seen which were evidently infected with bacteria or fungi. It is not known whether these species were parasitic or whether they feed upon dead organic matter.

INSECTS THAT MAY BE MISTAKEN FOR THE SOUTHWESTERN CORN BORER

Southern Cornstalk Borer *(Diatraea crambidoides* Grote). The Southern cornstalk borer is one of the most injurious insects to corn over much of the southeastern United States. In the larval stage the Southwestern corn borer and the Southern cornstalk borer cannot be distinguished even by the specialists on this family of moths. However, there are minute structural differences in the moths which make their identification possible. During the fall of the year, an outbreak of the Southwestern corn borer can be distinquished by its internal-girdling habit since the type of injury has not been recorded for the Southern cornstalk borer. At the present time, the Kansas distribution of the Southern cornstalk borer is limited to the eastern quarter of the state where it rarely causes appreciable damage. The Southwestern corn borer has not yet advanced to that area. With the exception of the internal girdling injury, the activities of the two species of borers are quite similar.

Corn Earworm *(Heliothis armigera* Hbn.). The corn earworm is well known to Kansas corn growers when found on the corn ear. However, when found on other parts of the corn plant, the corn earworms are not as easily distinguished since there are so many variations in their color pattern. The first generation of the corn earworm usually attacks the corn plant a little earlier than the first generation of the Southwestern corn borer. With both insects, eggs are laid on the upper leaves near the bud and the larvae move to the bud to feed within the whorl. The effect of this feeding is apparent after the leaves have pushed out of the whorl.

The characteristic injury is generally known to farmers as "ragworm injury." In typical specimens the holes caused by the Southwestern corn borer are smaller, more regular, and frequently progressively larger from the tip of the leaf to the base than are those made by the corn earworm. There are so many exceptions to this rule, however, that, one cannot be certain without examining the larvae.

Larvae of both species may be found within the whorl of a single plant. The larvae of the Southwestern corn borer may be identified by their pattern of shiny black or brown spots against a background of white, while corn earworm larvae become much larger and have an entirely different color pattern. Both species may be found on or within the ears, the corn earworm usually attacking from the silk end of the ear and the Southwestern corn borer from the shank end. Accumulations of frass from the corn earworm are much larger and coarser than from the borer. Corn earworms occassionally cut out shallow pits along the stalk and may even tunnel into the stalk, but their tunnelings are much larger in diameter and shorter than are those of the Southwestern corn borer.

Fall Armyworm ***(Laphygma frugiperda*** **A and S).** The fall armyworm resembles the corn earworm in size and in its striped pattern, may be found working on the ears of corn. This species is likewise responsible for a type of "ragworm" injury to the leaves before the plant has tasseled. The fall armyworm is likely to do more tunneling into the stalks than the corn earworm, its tunnel occurring almost anywhere along the stalk except below the ground. These tunnels are larger in diameter and shorter while the walls are smoother than the tunnels caused by the Southwestern corn borer.

Common Stalk Borer, ***(Papaipema nebris nitela*** **Guenee).** This insect frequently enters the stalks of corn in Kansas. The young stalk borers work within the stems of grasses and smaller weeds within the cornfield until these smaller-stemmed plants are outgrown. Then they move on to corn and burrow within the lower part of the stalks. Their entrance holes are much larger than are those of the Southwestern corn borer. Most stalk borer larvae may be distinguished by their white stripes which are interrupted by a dark band just behind the true legs. Full-grown larvae lose these stripes.

Corn Billbugs ***(Calendra*** **Spp.).** The plump, legless larvae of the corn billbug may be found boring in cornstalks, usually just above the soil surface. Here again the entrance holes and the tunnels are readily distinguishable from those of the Southwestern corn borer. Both billbugs and their grubs make short, shallow excavations while the tunnels of the Southwestern corn borer are longer and extend longitudinally within the cornstalk. The adult corn billbugs are large-snouted beetles. These beetles frequently feed on the leaves of corn before they have unfurled and leave a regular pattern of holes across the leaf that is very conspicuous after the leaves push out of the whorl. This damage occurs before the Southwestern corn borer has left its winter quarters.

SUMMARY

1. The Southwestern corn borer, *(Diatraea grandiosella* Dyar) is known to be present in 51 counties in the western two-thirds of Kansas.

2. Its range extends north to the Nebraska border, south to the Oklahoma line, east to the eastern boundary of Sedgwick, Marion, and Clay counties.

3. The life cycle of the borer includes at least two generations each year. Larvae of the second generation overwinter at the bases of stalks and stubble within cells constructed by the larvae.

4. If undisturbed, a sufficient number of borers survive the winter to reinfest an area the following spring.

5. The moths from the overwintering larvae emerge and lay eggs on the leaves of young corn plants to start the spring generation.

6. By the first of August most of the first generation larvae have pupated and emerged as moths. By mid-September, second generation borers are two-thirds matured to fully matured.

7. The borers injure the plant by feeding on the leaves, feeding on or about the main bud within the whorl, boring within the stalk, boring into the shanks and ears, and by girdling or reaming the stalks from within causing them to break over or fall to the ground.

8. Fallen stalks result in considerable loss to the farmer, because the ears are difficult to harvest, spoil readily and are exposed to destruction by rodents. Observations show that in one field 22.5 bushels per acre were missed by the mechanical picker used to harvest the crop.

9. Observations show that corn suffers more injury than sorghum. The borers have not been found attacking other plants in Kansas.

10. While effective control measures have not been worked out, limited experimental data and observations indicate that substitution of sorghums for corn, early planting of corn, late fall treatment of stalks and stubble to expose the overwintering larvae to the rigors of winter, deep plowing of stubble, and low cutting of stalks, are all practices which should contribute much to the control of the Southwestern corn borer in Kansas.

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