

but this is more difficult and less satisfactory with insect damage by such as the Hessian fly and joint worm. In the latter cases we can compare with previous years, but we have no basis to estimate accurately the injury in individual fields since there is no reliable comparison between infestation and injury. In the case of the fall injury by Hessian fly, the damage can be estimated only when the infestation is severe and the plants killed outright and in the case of spring injury by fly and by the wheat joint worm we do not know just how much or even the approximate damage by the insects. It is planned to get positive data on these facts another year for the joint worm and Hessian fly by enclosing large areas during the oviposition period of the fly and joint worm, two to be kept free from infestation and two to be infested by the introduction of joint worm adults and Hessian fly, respectively. It is to be hoped that others may be in a position to repeat these experiments and to make similar tests with other insects.

CONTINUITY OF INVESTIGATIONS

In order to secure reliable results it is important, and in the cases of such insects as the Hessian fly and corn root aphid, absolutely necessary, to continue the experiments over a period of years. This is well illustrated in the 1918 Hessian fly sowing experiments. Should we base our conclusions on this single season's results, our recommendation for fall sowing of wheat would be inaccurate since the fly-free date in 1918 was earlier than normal.

Continuity of observation is also very necessary in assisting the entomologist to predict the likelihood of an insect outbreak a following year and to determine the seriousness of such a possible outbreak. Thus a study of the likely hibernating quarters of the chinch bug in a certain section of the country extending over a comparatively large area and for several consecutive years is necessary to enable the entomologist by surveys from fall to fall, to determine with reasonable accuracy, the probabilities of a chinch bug outbreak and the extent and degree of the likely infestation the following season.

ELEODES OPACA SAY, AN IMPORTANT ENEMY OF WHEAT IN THE GREAT PLAINS AREA¹

By JAMES W. McCOLLOCH, *Associate Entomologist, Kansas State Agricultural Experiment Station*

Although the false wireworm, *Eleodes opaca* Say, was described in 1823 (Say, 1823, p. 263) it was not recognized as an insect of economic

¹ Contribution from the Entomological Laboratory, Kansas State Agricultural College, No. 38. This paper embodies some of the results obtained in the prosecution of project No. 100 of the Kansas Experiment Station.

importance until 1908. In the fall of that year several instances of injury were noted in western Kansas and considerable injury occurred in southwestern Nebraska (Swenk, 1909). Since the first recognized outbreak in 1908 there have been three well-marked outbreaks and reports of minor injury have been received every year. With the increasing importance of this insect it was deemed advisable to undertake a study of its life economy and accordingly in 1915 it was incorporated in one of the experiment station projects. The life-history has been thoroughly worked out, and insofar as time would permit, field studies have been made.

DISTRIBUTION

Eleodes opaca has a wide distribution throughout the Great Plains area. Blaisdell (1909, pp. 177-178) records it from Texas, Oklahoma, Kansas, Nebraska, Colorado, and South Dakota. Wickham (1899, p. 60) reports it from Lyon County, Iowa. Fall and Cockerell (1907, p. 204) list it from Coolidge, New Mexico, and Evans (1903, p. 318) says it was taken in the Northwest Territories in 1879-80. Prof. R. A. Cooley recently furnished the writer with a single female taken at Culbertson, Montana.

In Kansas, this species is generally distributed over the western two-thirds of the state. Popenoe (1877, p. 36) says it occurs from Louisville westward. In the vicinity of Manhattan it is found in rather limited numbers and increases in numbers as one progresses westward across the state.

HISTORY AND IMPORTANCE

Previous to 1908, *Eleodes opaca* was not recognized as an insect of economic importance. It was known to occur in large numbers in the native grass lands throughout the Great Plains area but had never been mentioned as injurious. In the fall of 1908, a large number of worms, reported to be seriously injuring germinating wheat in western Kansas, were received by the Department of Entomology and determined as tenebrionid larvæ. According to Swenk (1909) severe damage also occurred in several Nebraska counties. He determined the larvæ as *Eleodes opaca*.

During 1909 and 1910 a few specimens of false wireworms were received with the information that they were doing a slight amount of damage to fall sown wheat. In the fall of 1911 a well-marked outbreak of this insect occurred in western Kansas, resulting in the destruction of several thousands of acres of wheat.

Again in the fall of 1914 and the spring of 1915, considerable injury was reported in several localities. The last and most severe outbreak

began in the fall of 1917, and is still in progress. In Kansas, west of the 98th meridian, the infestation has been general and entire fields have been destroyed. Reports of serious injury have also been received from Oklahoma and northwestern Texas. During the present outbreak the injury has not been confined to wheat, but has included oats and barley and occasionally corn and sorghums.

In all probability this insect has been responsible for much injury to wheat previous to 1908, but has been confused with the true wireworms and other insects. Many of the letters in the files of the Department of Entomology prior to this time refer to wireworms damaging fall sown wheat. From the text of these letters it would seem now that the insect in question was *Eleodes opaca*. In the field investigations the writer has often found the farmers confusing false wireworm injury with that caused by true wireworms, white grubs, fall army worms, Hessian fly, and winter killing.

NATURE OF INJURY AND FOOD

The principal injury by *Eleodes opaca* is done by the larvæ during the fall. At this time they attack the wheat seed immediately after planting and destroy it before germination. During dry years when the grain may lie in the ground several weeks before sprouting, the injury becomes most severe. After the seed germinates the injury becomes less noticeable and often ceases altogether. In some cases, however, considerable damage may occur after the wheat is several inches high. This was especially true in 1911 when the larvæ destroyed many fields by cutting the plants off just above the seed. Occasionally some damage occurs in the spring, due to the larvæ burrowing through the stalks or even cutting them off. The original food of the larvæ was apparently the roots and seeds of native grasses and weeds, but within recent years, due to the breaking out of the native sod, wheat has apparently supplemented this food. In the rearing work the best results have been had by feeding the larvæ wheat seed and bran. Other foods have been used, but in all cases the larvæ either died or made a very slow growth. Aside from wheat it has been possible to rear the worms on sprouting corn, foxtail seeds, and crab grass roots. In one instance larvæ were found feeding on the roots of bindweed in the field. During the present outbreak, serious damage has occurred in the spring to oats, barley, sorghums, and corn. In every case these crops were planted early on land where the worms had destroyed the wheat the previous fall. Wheat is subject to the greatest injury because it is planted at the time when the larvæ are reaching maturity and are voracious in their feeding. Swenk (1909, p. 334) reports larvæ found in ears of corn that had probably fallen on the ground.

Little is known concerning the amount of injury done by the adults. Swenk (1909, p. 336) states that the beetles fed voraciously on corn leaves in the breeding cages. When the experimental work was started, the adults were supplied with various weeds found in the wheat field, but in no case did they feed to any extent and the mortality was high. A few of the beetles fed sparingly on smart weed, dried wheat leaves, and fresh wheat leaves. Wheat heads that were not yet mature were then introduced into the cages and the beetles began to feed on them at once. Later soaked wheat kernels and bran were supplied and they fed on these readily. Mating and oviposition began soon after the change to this food. The fact that the beetles fed on the wheat heads and grain suggests the possibility that they may feed on them in the field, and in fact, recent investigations bear this out since typical injury has been found on wheat in the shock. It is not unusual to find large numbers of beetles about the shocks and stacks of wheat, and in many cases the fall infestation has radiated from such places.

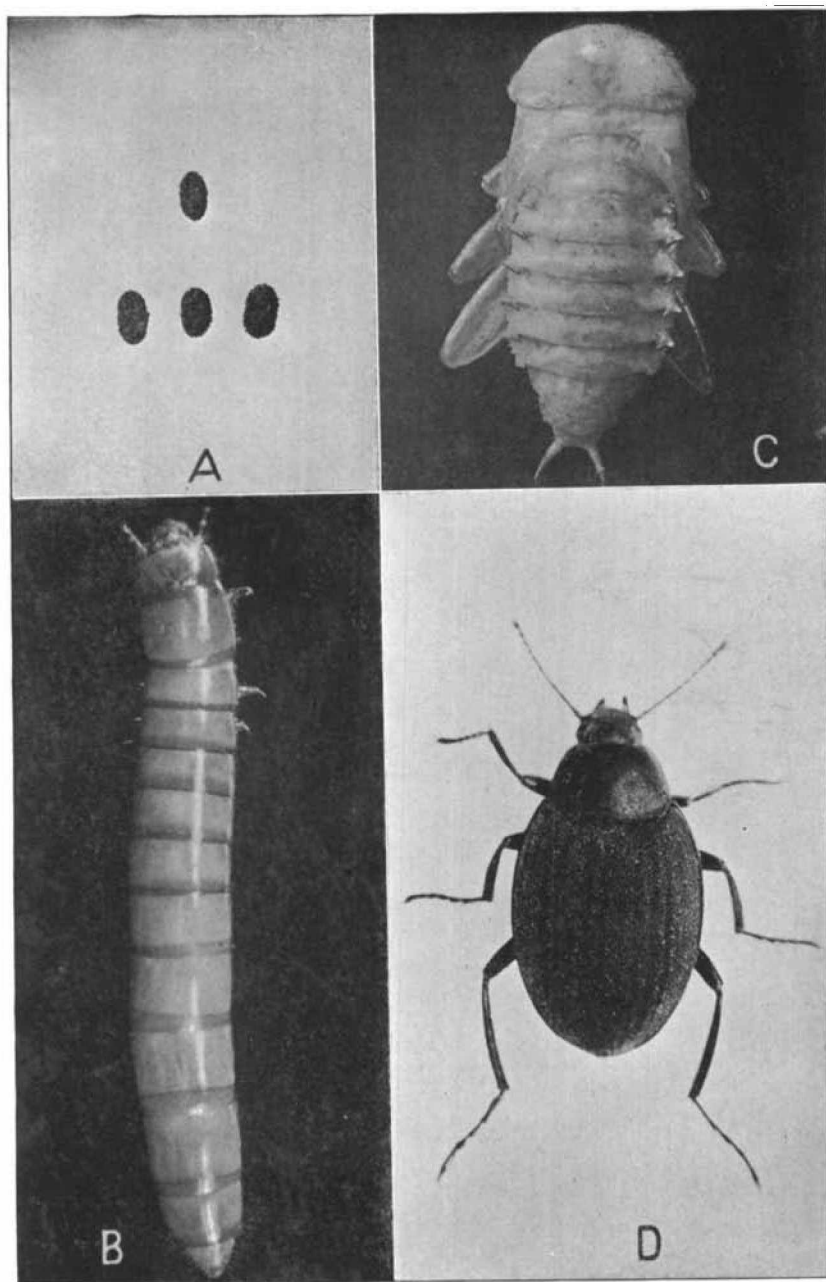
DESCRIPTION AND LIFE ECONOMY

METHOD OF REARING.—The same methods were followed in the rearing of *Eleodes opaca* as were described by the writer (1918, pp. 214–215) for the life-history work with *E. tricolorata*. The eggs were kept in the field insectary while the other stages were kept in a cement cave.

EGG.—The eggs of *Eleodes opaca* (Plate 8, A) closely resemble those described for other members of the genus, being oval in shape longitudinally, and circular in diameter. They show some variation in size, being from 1.1 to 1.4 mm. in length and from 0.50 to 0.65 mm. in width. They are white in color when deposited and change to a creamy yellow before hatching. A sticky secretion covers the egg, causing particles of soil to adhere to it. In the breeding cages the eggs were deposited in cavities in the soil ranging from one inch to five inches in depth.

The length of the egg stage varies with the temperature, and the season of the year. Eggs deposited during midsummer hatched in from 6 to 10 days, while later in the fall the stage was prolonged to 19 days. The first oviposition recorded occurred on July 5, and the last on October 4. The exact length of the egg stage was determined for 993 eggs, as shown in the following table:

LENGTH OF EGG STAGE				
Year	No. of Eggs	Min. Days	Max. Days	Average Days
1915	685	7	15	10.0
1916	144	6	19	11.3
1918	164	6	15	7.2
Average				9.7



Elrodia opaca Say: A, Eggs showing soil particles adhering; B, Larva; C, Pupa; D, Adult, female.

LARVA.—As pointed out by Swenk (1909, p. 335) the larva of *Eleodes opaca* (Plate 8, B) closely agrees with the description of *E. dentipes* as given by Blaisdell (1909, pp. 497–499). The minor differences have already been discussed by Swenk, and need no further treatment. On hatching, the larvæ are about 2.8 mm. in length. Growth is comparatively rapid and by fall the worms are about full grown, being from 21 to 23 mm. in length.

The larvæ moult eleven times, including the moult when pupating, between hatching and pupation, the time between moults varying to some extent. An average of the length of each stadium, as determined for six larvæ, is as follows: first stadium, 4 days; second stadium, 3 days; third stadium, 4 days; fourth stadium, 6 days; fifth stadium, 8 days; sixth stadium, 13 days; seventh stadium, 15 days; eighth stadium, 12 days; ninth stadium, 18 days; tenth stadium, 199 days; eleventh stadium, 20 days. In moulting the skin is split on the dorsal side from the vertex back to the first or second abdominal segment, and the old skin is shed by the larva arching the back and drawing the body out, the posterior end emerging last.

The larvæ are subterranean in their habits, and thus far the writer has never observed them on the surface of the ground. Swenk (1909, p. 333), however, cites a case where they were found in large numbers on the surface following a heavy rain. They show a preference for rather dry soil, and usually the majority of the worms are found at the junction of the loose drier soil with the compact moist soil. In the fall they are found at the bottom of the drill rows where they are feeding on the seed wheat. In the spring they are more often located just beneath the surface of the ground, under clods and wind-blown soil. The principal food of the larvæ appears to be wheat kernels, but they also feed on the roots and seeds of native grasses and weeds, and on decaying matter. In the rearing work, the worms thrived best on soaked wheat and bran. During the spring of 1918, considerable injury was also done to germinating oats, barley, corn, and sorghums, where these crops had been planted on infested wheat land. The larvæ also feed on their cast-off skins and on larvæ that are dead or in a weakened condition.

Most of the larvæ become practically full grown by October, and thus pass the winter. Early in the spring they become active, and usually moult once during April. Pupation occurs during the last of April and throughout the month of May. The transformation to the pupal stage is preceded by a semipupal or quiescent state lasting about a week. The length of the larval stage as determined for the several years that the work has been in progress is shown in the following table:

LENGTH OF THE LARVAL STAGE

Years	No. Larvæ	Min. Days	Max. Days	Average Days
1915-16	3	329	355	338.3
1916-17	25	292	329	305.2
1917-18	22	311	346	329.1
Average				317.7

PUPA.—The pupæ of *Eleodes opaca* (Plate 8, C) vary from 13 to 15.5 mm. in length, and from 3.5 to 5.5 mm. in width. They are white in color with semitranslucent appendages. This color changes as development takes place, the body becoming creamy yellow and the appendages reddish brown. In general, the pupæ resemble those of *E. clavicornis* described by Blaisdell (1909, pp. 500-501), with certain modifications noted by Swenk (1909, p. 335).

Pupation occurs in the field during April, May, and June. In 1915, pupation began about April 20, reached its maximum May 4, and was practically over by June 1. The spring of 1918 was cold, and pupation did not begin until May 7. The maximum was reached about May 20, and pupæ were to be found until the last of June. Before pupating, the larva constructs a spherical cell from one-half to two inches below the surface of the ground. Here it remains in a quiescent state for about a week before transforming to the pupa. The length of the pupal stage has been determined for 149 pupæ, the pertinent data being shown in the following table:

LENGTH OF THE PUPAL STAGE

Year	No. Pupæ	Min. Days	Max. Days	Average Days
1915	50	13	25	20.6
1916	4	9	13	11.5
1917	19	8	11	9.6
1918	76	8	23	11.1
Average				14.1

ADULT.—The adult beetles (Plate 8, D) are fusiform oval in shape, black in color, and sparsely covered with whitish hair. The dorsum of the elytra is quite flat. The female is more or less broadly oval in shape and the abdomen is rather strongly convex. The anterior tarsi are unmodified. The male differs from the female in that the body is narrow and the abdomen is but slightly convex. The first two segments of the anterior tarsi are slightly widened and clothed with two dense pads of spongy pubescence. The males are 10 to 12 mm. in length, and about 5 mm. in width. The females are somewhat larger in size, being 11 to 14 mm. in length, and 5 to 7 mm. in width.

Emergence begins about the middle of May, and continues through

June. From this time on until the middle of October the adults are to be found in the field, the greatest number being present during July and early August. The normal length of life for the adult is from two to four months. Most of the beetles under observation lived from 60 to 90 days, while one male lived 130 days. Unlike *Eleodes tricostata* none of the beetles of this species hibernate over winter, and thus far the writer has never found adults later than October 18. While most of the adults emerged during June in the life-history studies, no mating was observed previous to July 3. During the four years that these studies have been under way, copulation has occurred the first week in July, and oviposition usually follows in two or three days. The first oviposition was noted July 5, and the last on October 4. The period of oviposition, together with the number of eggs per female was determined for seven mated females in 1915, this data being summarized in the accompanying table. Similar studies made the following years gave essentially the same results.

OVIPOSITION RECORD FOR SEVEN FEMALES, 1915

Female No.	Period Oviposition, Days	No. Days on Which Eggs Were Laid	Total No. of Eggs	Ave. No. Eggs Per Day for Period of Egg-Laying	Ave. Per Day for Days on Which Eggs Were Laid	Max. No. of Eggs Laid in 24 Hours
1	59	48	373	6.3	7.7	31
2	46	39	389	8.4	10.0	34
3	11	3	23	2.0	7.6	6
4	27	17	93	3.4	5.4	9
5	18	12	44	2.4	3.6	11
6	35	32	241	7.0	7.5	25
7	14	12	105	7.5	8.8	23
Average	30	23.3	181.1	5.3	7.2	19.8

While matings were observed frequently in all cages, the presence of the male was not necessary after fertilization once took place. In the case of female No. 1, the male died July 18, but she continued to deposit fertile eggs until September 6. The proportion of sexes as determined from reared and collected adults indicate that the females are slightly in excess of the males. Fifty-six per cent of the beetles taken in the field have been females, while 54 per cent of the reared beetles were females.

The adults of *Eleodes opaca*, like many of the other members of the genus *Eleodes*, are more or less nocturnal or crepuscular in their habits. In the field they are generally most active early in the morning, and about dusk in the evening, while during the hotter parts of the day they are to be found hiding under any suitable covering. In the prairie lands, rocks, manure, piles of weeds, and clumps of grass offer ideal hiding places, while in the wheat fields they are to be found under shocks and around stacks of wheat, under Russian thistles, in clumps of volunteer

wheat, and, in fact, any place where there is protection. It is not unusual to find them in large number under piles of Russian thistle that have collected along a fence. They also probably make use of the burrows of the various insects, and animals common to their locality. Snow (1877, p. 19) found twenty adults under bones near Colorado Springs, Colorado.

The adults apparently have a wide range of food habits. In the field they have been found feeding on evening primrose, Russian thistle, and alfalfa. In the rearing cages they fed sparingly on smart weed and on wheat leaves, while they showed a great preference for heads of wheat, soaked wheat and bran. Examinations made in the field indicate that they may feed on the wheat in the stack and shock, especially if it becomes damp. When confined on a small plot of young wheat they destroyed it in a few days. In one case a beetle was found feeding on a nymph of *Melanoplus differentialis*, but it was impossible to determine whether it had killed the grasshopper or not. It is not unusual for them to feed on the dead or weakened members of their own kind.

LENGTH OF LIFE-CYCLE

Three generations of this insect have now been reared from adults collected in the field in 1915. Each generation has occupied about one year and the data secured in this study coincides very closely with the field observations. Taking the average length of the various stages, each brood required 341 days from the time the eggs were laid until the adults emerged. The essential data showing the length of the life-cycle are summarized in the following table:

SUMMARY OF THE LENGTH OF THE LIFE-CYCLE

Stage	Minimum Days	Maximum Days	Average Days
Egg	6	19	9.7
Larva	292	355	317.7
Pupa	8	25	14.1
Life-cycle	306	399	341.5

ENEMIES AND PARASITES

Very few natural enemies are known to attack *Eleodes opaca*. Bruner (1892, p. 12) records finding the eggs of a tachinid on the elytra. Each year that these studies have been carried on a few beetles have been collected in the field from which have been reared specimens of the hymenopterous parasite, *Perilitus eleodis* Viereck. In no case has the percentage of parasitism been high, and the relation of this parasite to *opaca* has been given but little attention. From the notes at hand, the behavior appears to be the same as in the case of *Eleodes*

tricostata (McColloch, 1918, pp. 221-222). A gregarine (*Stylocephalus giganteus* Ellis) has frequently been found in the alimentary tract of the adults.

Swenk (1909, pp. 335-336) encountered considerable difficulty in his rearing work, due to the presence of what was apparently a bacterial disease. This disease usually began as a small dark red spot on the thoracic segments, or on the terminal abdominal segments, and spread rapidly, soon encircling the body, resulting in the death of the larva. Where several larvæ were confined in the same cage, the disease often spread to the others. The writer has often encountered this same disease, but since the larvæ were reared in separate boxes, it never spread to any extent. Two species of fungi have been found attacking the larvæ, namely, *Sporotrichum globuliferum* and *Metarrhizium* sp.

PHYSIOLOGICAL RELATIONS

Eleodes opaca is a typical species of the Great Plains, an area of low rainfall and rather high temperatures. While it has been recorded as far east as Iowa, it does not occur in large numbers east of the 98th meridian. It is not common to the vicinity of Manhattan, being found only on the high, grassy uplands. The years of greatest injury in western Kansas have been characterized by excessive temperatures and low rainfall. In the life-history studies, eggs, kept in cages where the maximum temperature during the day was 112°, and the relative humidity 25 per cent, hatched in six days. The adults were not affected by a daily temperature of from 105° to 112° when the humidity was low. In ovipositing, the adults showed a preference for dry soil, and the rate of egg-laying decreased when the beetles were placed in cages containing moist dirt. Some moisture, however, is required by the adults, and this was supplied by feeding wet bran once a week. The larvæ thrived best in a slightly moist soil. When the soil was too wet to crumble nicely, the mortality increased rapidly. High temperatures, such as experienced by the eggs and adults, were fatal to the larvæ and the best results were had by keeping them in a cave where the temperature remained constant at about 80° during the summer, falling slowly to 39° in midwinter. There is some evidence that the larvæ can withstand low temperatures, and Swenk (1909, p. 334) cites a case where they survived a twelve-hour exposure to a sweeping wind of from 59 to 72 miles an hour velocity, with the temperature about zero.

Like most of the species of the genus, the adults of *opaca* are negatively phototropic to strong light. During the day they are usually to be found hiding under various types of shelter, confining most of their activities to the early morning, evening, and night. The larvæ

are subterranean in their habits, and when placed on the surface of the ground they immediately burrow into the dirt.

CONTROL

Thus far it has not been possible to carry out any extensive experiments on the control of *Eleodes opaca* in the field. The measures advocated are based on a study of the history of over 200 infested fields obtained through personal visits, and from questionnaires furnished to the farmers. In most cases the history of the field has been obtained for the preceding two or three years. A study of the data thus secured suggests several promising methods of procedure which have proved beneficial in controlling or reducing the amount of injury.

ROTATION.—The investigations in many fields infested by false wireworms show that in nearly all cases the greatest injury has occurred on land continuously cropped to wheat, while fields that have been in a row crop or fallowed previous to wheat have suffered little damage. The beetles are wingless, and migration from field to field must take place on foot. These facts indicate that a careful rotation of crops, combined with certain other practices to be mentioned later, would eliminate much of the damage and the writer has seen many fields where this has been the case. In following a system of rotation in western Kansas, it must be remembered that the number of crops that can be alternated with wheat is limited principally to feed crops such as sweet sorghums, kafir, milo, and feterita, and, under certain conditions, corn. Occasionally oats and barley are included, and many farmers practice a rotation whereby a small grain crop is planted early in the spring on land where the worms have destroyed the wheat crop the previous fall. Such a system usually increases the injury since it provides additional food at a time when the larvæ are maturing. Where the fall wheat has been destroyed, the land should be worked about the first of May and planted to a row crop. If the field is kept cultivated and free from weeds and grasses, it is often possible to return the land to wheat in the fall. This is not always feasible, since the feed crops are late maturing, and in this case oats or barley should be planted in the spring to be followed by wheat in the fall. Call and Salmon (1918, pp. 42-43) suggest the following rotation for western Kansas: wheat two years; kafir or other sorghums, one year; and summer fallow, one year. By this system, one-half of the farm is in wheat each year, one-fourth in a feed crop, and one-fourth is fallowed for the next wheat crop. Such a system, if carefully followed, would reduce the false wireworm injury and at the same time increase the yield.

SUMMER FALLOW.—The practice of summer fallow whereby the land lies idle for a year, being worked sufficiently to keep down the plant

growth, is practiced to a limited extent in western Kansas. Where this method is followed there has been little or no injury from false wireworms. Summer fallowing deprives the beetles and larvæ of food, and destroys many eggs. The beetles are also deprived of shelter during the day. This method of handling the wheat land is somewhat more expensive than the usual methods, but the yields are generally ample to encourage its use.

WEEDS AND VOLUNTEER CROPS.—During the summer months, large numbers of adults are to be found hiding under Russian thistles and in clumps of volunteer wheat and oats in the fields. The keeping down of these plants will deprive the beetles of shelter, and cause them to seek protection elsewhere, and will also serve to deprive the larvæ and adults of food. Heavy growths of weeds and grasses along the roadsides and fence rows should also be kept down during the summer.

TIME OF PLANTING.—Some injury can be avoided by delaying the planting of wheat in the fall, although as a rule late planting does not yield as well as early sowing. The larvæ usually ceased their activities during the latter part of October, and wheat planted after the middle of this month will be less subject to injury. With regard to the time of planting, it might be stated that with favorable conditions, such as a well-prepared seedbed, good seed, and plenty of moisture, seeding may be made moderately early. On the other hand, if the season is dry and the seed may lie for some time in the ground before germinating, it is advisable to delay the planting. The larvæ are most active in a dry, loose soil, and the greatest injury has occurred in those years when the summer and fall have been dry.

In the case of spring crops, planting should be delayed until about the first of May, at which time most of the larvæ have reached maturity and are transforming to pupæ. This is especially to be recommended when the crop is to be planted on land where the wheat has been destroyed by the worms.

SPRING PLOWING.—The practice of plowing or listing infested fields early in May will destroy large numbers of pupæ by breaking up the pupal cells, and crushing the pupæ or by exposing them to natural enemies and climatic conditions. The writer has been in many fields where this has been done, and in every case from 80 to 95 per cent of the pupæ were destroyed. This method can be followed where the larvæ have destroyed the wheat and it is planned to plant sorghums or corn.

STACKING VS. SHOCKING.—Examinations made in fields where the previous wheat crop was shocked often show more injury than where the crop was stacked. In other words, the shocks provide shelter for the beetles in all parts of the field, and instead of the outbreak being

confined to one part of the field, it is general over the entire area. When the grain is stacked at harvest, the infestation often radiates out from the stack, indicating that the beetles have congregated there.

POISON BRAN MASH.—The use of the poison bran mash as prepared for use against grasshoppers may prove beneficial in some cases in the control of *Eleodes opaca*. Under laboratory conditions the beetles ate it voraciously, and were attracted to it from a distance of two or three feet. The possibility of its use under certain conditions where the adults are congregated in large numbers around wheat shocks and stacks, and piles of Russian thistles may prove practical. Experiments in poisoning the larvæ have thus far given negative results.

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EXPERIMENTS WITH POISON BAITS AGAINST GRASSHOPPERS¹

By D. A. RICKER, *W. LaFayette, Indiana*

During the past season grasshoppers were abundant and caused considerable damage to clover, alfalfa, tobacco and other crops in the vicinity of southern Wisconsin. Especially were they abundant in

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