STUDIES ON THE IDENTIFICATION, FEEDING HABITS, AND CONTROL OF THE FLAT GRAIN BEETLE, *LAEMOPHLOEUS PUSILLUS* (SCHONH.) (COLEOP. CUCUJIDAE)

by

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INTRODUCTION

The work here presented was intended to determine if there might be a way of identifying the flat grain beetle *Laemophloeus pusillus* (Schonh), which is a common pest of stored grain in Kansas.

It was desired to determine the quantity of a new Pyrenone Wheat Protectant necessary to kill flat grain beetles.

It was also desired to determine the per cent moisture and kind of grain required by the flat grain beetle for maximum reproduction.

Further it was desired to determine whether the flat grain beetle could penetrate and use for food grains that had no breaks in their seedcoats.

It was realized at the beginning of this study that little had been published concerning the various aspects of the flat grain beetle. It was known that the available keys to the species in the genus *Laemophloeus* were difficult to use.

The flat grain beetle is referred to by some writers as *L. minutus* (Oliv) but it is designated as *L. pusillus* in the Common Names of Insects by the American Association of Economic Entomologists.

REVIEW OF LITERATURE

The flat grain beetle *L. pusillus* (Schonh) is one of the most common insect pests found in stored grain. It is of cosmopolitan distribution and has been reported from most of the states of the U. S. A. and from such places as Mexico, Puerto Rico, Philippines, China, Great Britain, Finland, Japan and India. (Davies 1949). A grain bin survey in North Dakota (Munro and Telford, 1941) shows the flat grain beetle to be the predominating species. A similar survey in Oklahoma made by Fenton (1941) shows that the flat grain beetle was by far the most numerous species. Tests were conducted at Hutchinson, Kansas by Schwitzgebel and Walkden (1944) to determine the flight and abundance of grain pests. Flight screens coated with tanglefoot and erected between wheat bins and revolving insect nets showed the beetles of the genus _Laemophloeus_ to be the most numerous of the grain insects. An examination of the mill streams in flour mills in Missouri, Kansas, and Oklahoma, made by Good (1937) showed that _Triboliums_ occurred in the greatest numbers followed by the flat grain beetle. Shepard (1939) found the flat grain beetle to be the second most numerous stored grain insect pest in Minnesota flour mills.

Cotton (1950) considers the flat grain beetle to be a secondary pest which follows the attack of more destructive grain insects. He stated that the flat grain beetle is a scavenger by nature and prefers grain and meal that is out of condition. This is not in complete agreement with Payne (1946), who maintains that the flat grain beetle may live as a scavenger but does equally well on sound grain that is not out of condition. However, in order to reproduce, the flat grain beetle must have a high relative humidity. Davies (1949) also found that flat grain beetles cannot penetrate completely undamaged wheat. However, due to the normal processes of handling, when the wheat is finally stored many of the wheat kernels are damaged enough to permit an infestation of flat grain beetles to occur. He says that a completely sound grain must have no abrasions or cracks whatever in its seedcoat if it is to be immune to the attack of flat grain beetles. Any small blemish in the seedcoat can be enlarged by the small mandibles of the larvae or the adults. The seedcoat is most apt to be broken, cracked or entirely gone at the germ end. The germ is usually eaten by the larvae and if there is no other place of entry, the adult can penetrate the endosperm through the membrane which separates the endosperm from the germ.

Cotton (1950) stated that the flat grain beetle is one of the most common of the stored grain insect pests. In the past, this species has been considered of little economic importance. It is quite possible however, that the destructiveness of the flat grain beetle has been underestimated.

Davies (1949) observed on the basis of small cultures that a pure infestation of the flat grain beetle alone can result in serious heating of bulk grain. Schwitzgebel and Walkden (1944) stated that the flat grain beetle is often responsible for heating of stored grain and for increasing or translocating moisture which resulted in caking the surface of the grain.

According to Davies (1949) it is the habit of the flat grain beetle to attack and eat out the germ of the grain. He found that a certain amount of the endosperm is also consumed. Whether such an infestation would be sufficiently extensive or develop with sufficient rapidity to result in large scale deterioration of the wheat is a matter which can be settled only by further investigations, Davies (1949). Fenton (1941) pointed out that regardless of the actual damage done much wheat was condemned in Oklahoma for purposes of securing loans as a result of flat grain beetle infestations. Infestations of any consequence in grain or flour by the flat grain beetle would most probably result in a reduction of its original sale price as five live insects per 1,000 grams would cause the grain to be classified as weevily. (Official grain standards)

LIFE HISTORY, HABITS AND BIOLOGY OF THE FLAT GRAIN BEETLE

A review of the literature shows that very little has been published on the life history, biology or habits of the flat grain beetle although there are many references to its presence. Apparently the internal anatomy has never been worked out. The egg, larval instars, pupa and life history have been studied by Davies (1949).

He found that the egg is small and translucent without external sculpturing. The eggs are laid singly in flour or in farinaceous material and are sticky when first deposited so that small bits of food stuff cling to them. Davies concluded that the flat grain beetle has four instars with the latter part of the fourth instar serving as the prepupal stage. The fourth instar larva has a pair of silk glands on the ventral side of the prothorax. This seems to be unique among Coleoptera as all other forms produce silk in modified malpighian tubules and extrude it through the anus. After a short time, the larva passes through the pupal stage and emerges as a light colored adult which later changes to a dark reddish brown.

The length of the life cycle varies greatly and is affected more by temperature than by humidity. At 17° C. and 75 per cent relative humidity, the time required is 137 days and at 30° C. with the same humidity, the time is 29 days. The females of the flat grain beetle lay eggs continuously throughout their life and their egg laying is stimulated by the presence of the male. Payne (1946) stated that the length of life of adults averaged from six months to a year. According to Davies (1949), when food is insufficient, cannibalism takes place, in which case the pupa is most often attacked. Payne (1946) did not find evidence of cannibalism.

The flat grain beetle is a good flier if the temperature is favorable. Seventy-five degrees F. is approximately the minimum temperature for sustained flight although attempts to fly are made below this temperature. The flat grain beetles will readily fly at 85° F. and 90° F. and are strongly attracted to light. Thousands of flat grain beetles that escaped from rearing containers, have been found dead about the base of electric light bulbs in the entomology rearing room.

IDENTIFICATION

The species in the genus Laemophloeus are difficult to identify. This is particularly true when the identification has to be made from uncleared specimens.

An attempt was made to find quick and relatively simple methods to distinguish between the flat grain beetle and the rusty grain beetle. These are the two species which are found most commonly in Kansas.

Two keys to the identification of the species of Laemophloeus have been found, Reid (1942) and Hereford (unpublished thesis 1931). A comparative study of the genitalia of the three common species, L. pusillus, L. ferrugineus and L. turcicus, complete with drawings was also made by Reid (1942). Identification can be made by the use of genital characteristics, but it is quite comparative. Also, it is necessary to clear and mount the specimens. Specimens of Laemophloeus should be boiled vigorously for fifteen minutes in a 10 per cent KOH solution to obtain good clear specimens. Vigorous boiling tends to lift the elytra and wings and to turn them out away from the abdomen. This prevents their obstructing the view of the internal organs. The flat grain beetle is only one-sixteenth of an inch long and is difficult to manipulate if the wing covers have not already been spread. Specimens of both the flat grain beetle and the rusty grain beetle were cleared in this way and then run through 30, 50 and 95 per cent alcohol and xylene before being mounted in balsam.

The keys prepared by Reid and Herford are based on similar key characters. Most of the characters are of a comparative nature and if all the species are not available at the time of comparison, it is difficult with the keys to ascertain an identity with certainty. Further it is necessary to be well acquainted with the amount of variation within the species and with each character that is used.

Tarsal Formula

The males of the genus Laemophloeus may be separated from the females on the basis of a tarsal formula. The tarsal formula is written as three hyphenated numbers and indicates the number of tarsal segments in tarsi of the pro, meso, and meta thoracic legs respectively. The males have a formula of 5-5-4 whereas the females have 5-5-5. The segments next to the tibia are sometimes difficult to see because they may be partially covered by the end of the tibia.

Antennae

The approximate lengths of the antennae of the two species are summarized in Table 1.

Table 1. Approximate lengths of the antennae of L. pusillus and L. ferrugineus.

	pusillus	ferrugineus
Male	2/3 body length	1/2 body length
Female	2/5 body length	2/5 body length

Drawings of the antennae have been made by Reid (1942). However, due to their small size and to variations, these differences are not prominent except in the males of the flat grain beetle. The male flat grain beetle has longer antennae than the female or the rusty grain beetle. The segments of its antennae are three to five times longer than broad, while the antennal segments of the female and the rusty grain beetle are about as long as broad. It may be noted from Table 1 that the antennae of the females of both species are approximately the same length.

Size

On the average, the males of both species are slightly longer than their females.

Head Ridge

A ridge was found in these studies which positively distinguishes the flat grain beetle from the rusty grain beetle. The flat grain beetle has a ridge which runs horizontally across the posterior portion of the vertex and forward on either side to the dorsal side of the eyes (Fig. 1). This ridge is not found in the rusty grain beetle (Fig. 2). It is necessary to bend the head downward or pull it forward because the most prominent part of the ridge is normally covered by the anterior margin of the thorax. This ridge looks like a suture when viewed through a microscope.

Abdominal Apodemes

It has also been found in these studies that the two species have differently shaped apodemes situated in the anterior part of their abdomen. Figures 3, 4, and 5. The flat grain beetle has a very thin suture, (Fig. 4), which runs through the center of the apodemes, lengthwise of the body. The posterior margin of the apodemes in the flat grain beetle is more cleft than that of the rusty grain beetle. It is difficult to see this suture in some specimens and a careful adjustment of the prepared slide and illumination may be necessary to make it evident. This suture is visible only in cleared specimens. Directly beneath this suture and on the ventral side as observed from the dorsal side is another very pronounced suture much larger and darker than the one described. It is usually necessay to tip the slide on an incline plane so that the large predominant suture which is present in both species is not in a direct line of view with the suture in question.

Thorax

The flat grain beetle and the rusty grain beetle may be separated by the shape of their thoraxes. As may be seen from Figs. 6, 7, and 8, the thorax of the flat grain beetle is more rectangular than that of the rusty grain beetle. Further, the thorax of the male flat grain beetle is more narrowed posteriorly than that of the female. However, the sexes of the flat grain beetle are best separated by the characteristic male antennae. The thoraxes of the male and female of the rusty grain beetle are very similar and they could not be separated on their shape.

Several beetles were chilled in the refrigerator until they had become inactive, after which identifications were made using the shape of the thoraxes. The specimens were later cleared and mounted on slides and the identification checked using the genital characters. Each identification of the uncleared specimens was found to be correct.

It was concluded that the shape of the thorax was a good identification character.

Table 2 is a summarization and comparison of the identifying characters of L. pusillus and L. ferrugineus.

Table 2. Summary of distinguishing characteristics which can be used to separate pusillus and ferrugineus.

		pusillus	ferrugineus
Antennae	male	2/3 body length	1/2 body length
	female	2/5 body length	2/5 body length
Thorax	male	rectangular, slightly narrowed posteriorly	prominently narrowed posteriorly
	female	rectangular, not narrowed posteriorly	prominently narrowed posteriorly
Head ridge		present	absent
Abdominal apodemes		prominently cleft in center, median suture present	slightly cleft in center, median suture absent

The following key is by Reid 1942:

A Key to the Species of Laemophloeus Recorded from Stored Products in the British Isles.

1a. Hind angles of the thorax blunt. Species somewhat resembling ferrugineus but thorax more slender. Species indeterminable, near ater Erickson.

1b. Hind angles of the thorax sharp pointed 2

2a. Scutellum triangular. Thorax more shining with strong side keels, and the hind angles produced into fine points. Elytra relatively smooth and shining . . . . janeti Grouvelle.

2b. Scutellum strongly transverse. Thorax less shining, the side keels less developed and the hind angles less sharply produced. Elytra duller 3

3a. Thorax strongly to moderately contracted behind. Antennae not more than half the body-length, the terminal segment not more than twice as long as broad, almost parallel sided. Head and thorax finely and usually sparsely punctured. Males with a blunt tooth on the ventral side of each mandible near the base . . . . ferrugineus Stephens.

3b. Thorax only slightly contracted behind. Antennae from a half to more than three-quarters the body-length; length of terminal segment varying accordingly, if only twice as long as broad ( ), not parallel-sided but widening distally. Head and thorax nearly always more strongly and closely punctured. Males without a tooth on the ventral side of the mandibles near the base 4

4a. Thorax distinctly transverse, without a small median longitudinal impunctate area, the punctures small to moderate sized. Front angles of the thorax slightly more rounded, hind angles slightly less acute. Eyes less convex. Terminal segment of the antennae in the males a little less expanded distally. . . . . minutus Oliver.

4b. Thorax not distinctly transverse, often with a small median longitudinal impunctate area, the punctures usually large and shallow. Front angles of the thorax less rounded, hind angles more acute. Eyes more convex. Terminal segment of the antennae in the males a little more expanded distally . . . . turcicus Grouvelle.

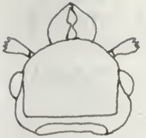

Fig. 1. *L. pusillus*
Ridge on sides and back of head.

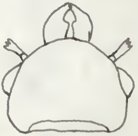

Fig. 2. *L. ferrugineus*
No ridge on head.

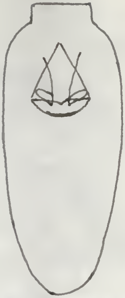

Fig. 3. Outline of abdomen of Laemophloeus
showing relative location of apodemes.

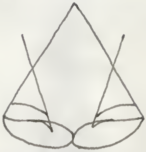

Fig. 4. L. pusillus
Suture uniting upper and lower apodemes.

Fig. 5. L. ferrugineus
Note absence of suture and wider space
between apodemes.

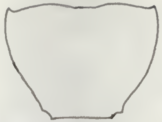

Fig. 6. *L. ferrugineus*
Thorax narrowed posteriorly and pointed corners anteriorly.

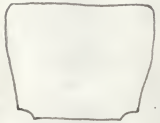

Fig. 7. *L. pusillus* - male
Thorax slightly narrowed posteriorly and rather square corners anteriorly.

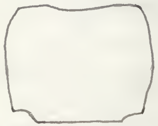

Fig. 8. *L. pusillus* - female
Thorax almost rectangular.

OCCURRENCE AND DISTRIBUTION OF BEETLES OF THE GENUS *LAEMOPHLOEUS* IN KANSAS

It is generally believed that beetles of the genus *Laemophloeus* are widely distributed in Kansas.

From the insect collection records of screenings made from probe samples of wheat from farm bins by the Production and Marketing Administration inspectors, the following data were obtained to support this assumption. All the records referring to insects of the genus *Laemophloeus* were examined for the months of August, September, October and November, 1952. One hundred and twenty-one references were found and the numbers and distribution throughout 50 counties were recorded on the map, (Fig. 9). It may be seen that the genus *Laemophloeus* is widely distributed throughout Kansas. Many of the probe samples contained insects in this genus only. The grain from which the samples were taken was unusually low in moisture and definitely not favorable to the presence of the beetles.

Samples that contained three or more specimens averaged 0.63 per cent higher in moisture content than the average for all the samples.

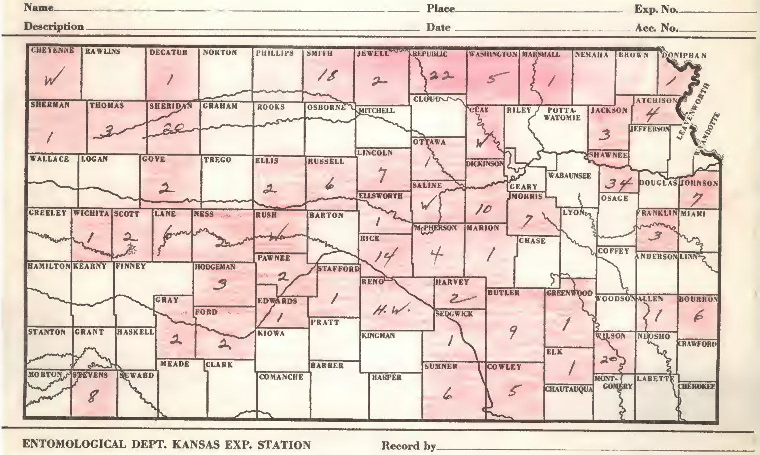

Fig. 9. Map showing the counties in Kansas from which beetles of the genus Laemophloeus have been recorded.

Counties with numbers - Number of insects recorded from P.M.A. collections August, September, October and November, 1952.

H.W. - Records of Walkden and Schwitzgebel

W. - Additional records of D. A. Wilbur

REPRODUCTION OF FLAT GRAIN BEETLES IN SORGHUM VARIETIES

The object of this experiment was to determine the extent of reproduction of flat grain beetles in various varieties of sorghums.

Materials

Twenty varieties of newly harvested sorghums (Table 3) were secured from A. L. Clapp of the Department of Agronomy, Kansas State College, in November, 1951. The test beetles were obtained from stock cultures. Sixty wide mouthed pint mason jars and lids were cleaned and marked with manila tags.

Procedure

The moisture content of each variety was adjusted to 14 per cent. There was cracked sorghum in each variety varying up to two per cent. Three 100 gram samples of each variety were placed in wide mouth mason jars. Thirty-five beetles were added to each jar and self-sealing lids were inverted so that the jars were only partially sealed. This was thought necessary because the test was designed to continue more than 100 days. The jars were placed in five cartons holding twelve jars each. The cartons were placed in a rearing room May 17, 1952, where a constant temperature of 80° F. was maintained for 127 days. The jars were opened September 21, 1952, and the number of live and dead beetles were counted. A final moisture reading of each variety was made at this time.

Results

The results of this experiment are shown in Table 3. It is readily seen that the moisture content of the grain dropped from 14 per cent to an average of 11 per cent but the 11 per cent average is quite uniform in that none of the 60 samples deviate more than 0.5 per cent.

The various varieties of sorghums showed a marked difference as

Table 3. Determination of the rate of reproduction of L. pusillus in three replicas each of twenty sorghum varieties with an initial moisture content of 14 per cent for 127 days.

Variety	Final % Moisture	Sample No. 1		Sample No. 2		Sample No. 3		Average number of insects	
		live	dead	live	dead	live	dead	live	dead
Double Dwarf 38	10.61	103	10	44	22	96	34	81	22
D.D. White Sooner	10.72	158	28	98	34	148	40	134.6	34
Waxy D.D. Sooner	10.91	44	32	22	13	63	26	43	28.6
Midland	10.93	51	30	68	25	76	33	65	29.3
Norghum	11.52	70	20	46	31	49	21	53	24
Martin	11.40	67	40	53	36	39	39	53	38.3
Wheatland	10.71	126	34	80	28	159	32	121.6	31.3
D.D. Yellow Sooner	10.87	47	31	29	33	21	29	32.3	31
Redlan	11.05	19	55	31	28	13	37	21	40
Gurno	10.97	5	30	11	24	23	12	13	22
Blackenship	10.92	53	33	21	16	53	35	42.3	28
Midland X Wonder Club	11.03	40	22	21	14	66	16	42.3	17.3
Combine Kafir 60	10.89	63	21	71	20	58	15	64	18.6
Day	11.53	12	35	25	28	35	40	24	34.3
Early Kalo	11.32	15	22	39	7	17	18	23.6	15.6
Westland	11.00	17	20	36	16	33	31	28.6	22.3
Combine White Kafir	10.80	48	25	56	22	59	24	54.3	23.6
White Martin	11.10	24	35	28	25	22	47	24.6	35.6
Colby	10.82	62	22	85	18	61	20	69.3	20
Plainsman	11.02	92	22	42	24	23	19	52.3	21.6

foods for the flat grain beetle as indicated by the rate of reproduction. Gurno was the only variety which showed no reproduction at all. The varieties which showed 50 or less live beetles upon examination are Redlan, Waxy Double Dwarf Sooner, Double Dwarf Yellow Sooner, Gurno, Blackenslip, Day, Early Kalo, Westland and White Martin. The varieties which showed eighty or more live beetles were Double Dwarf 38, Double Dwarf White Sooner and Wheatland. The most reproduction occurred on Double Dwarf White Sooner.

EFFECTS OF FEEDING BY THE FLAT GRAIN BEETLE ON THE GERMINATION OF WHEAT, CORN AND RYE

The object of this test was to determine the effect of flat grain beetles on the germination of wheat, corn and rye after exposure for two, four and six week intervals.

Materials

Nine hundred flat grain beetles were taken from stock cultures reared on wheat. Corn was secured from the Agronomy Department, wheat from the Milling Department, and rye from the Central Feed Store. Eighteen two-ounce bottles with screw-top lids were used.

Procedure

The grain was examined under the widefield microscope so that the imperfect kernels, particularly those with broken seed coats could be eliminated. Rye grain as ordinarily stored contains only a small percentage of kernels with unbroken seed coats so no attempt was made to select perfect kernels of rye. The grain used was adjusted to 12 per cent moisture. After examination each sample was tied in a small cheese cloth sack and returned to the moisture adjusting jar from which it was originally taken. By this procedure the small amount of moisture which might have been lost during the examination would be regained from the large quantity of grain present in the jar. Three days after examination of the last quantity of grain, 20 grams were added to each bottle along with 50 beetles. It was originally intended that the experiment should run for 12 weeks and that every two weeks a sample would be sent to the Seed Testing Laboratory for a germination analysis. However, as may be seen from Table 4, the immediate mortality rate was too high to warrant continuation of the experiment. Counts of the live beetles were made every two weeks until all were dead.

Results

At the end of three weeks, all beetles were dead, (Table 4). The beetles survived longer when confined to rye than when confined to corn or wheat. Sixteen per cent of the beetles were alive after two weeks on rye as compared with 3.6 per cent on corn and 1.6 per cent on wheat. Two beetles were alive on rye after four weeks while all were dead on corn and wheat. As before stated, no attempt was made to select perfect kernels of rye. Apparently the beetles were able to penetrate the rye grains.

Table 4. Number of live flat grain beetles remaining when 50 beetles were confined to samples in closed bottles of relatively unblemished grains of wheat, corn and rye at 12 per cent moisture at intervals of two, four and six weeks to determine their effect on germination.

Sample No.	2nd Week			4th Week			6th Week		
	Rye	Corn	Wheat	Rye	Corn	Wheat	Rye	Corn	Wheat
1	1	2	0	0	0	0	0	0	0
2	15	0	5	1	0	0	0	0	0
3	15	7	0	1	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	5	0	0	0	0	0	0	0	0
6	0	2	0	0	0	0	0	0	0
Total number of live insects	36	11	5	2	0	0	0	0	0
% of live insects	16	3.6	1.6	.6	0	0	0	0	0

UTILIZATION OF UNDAMAGED GRAIN AS FOOD BY THE FLAT GRAIN BEETLE

The object of the following test was to determine whether the flat grain beetle could utilize for food grains that have no breaks or blemishes in the seed coats. This test was prompted by the poor results secured from the germination tests in which low survival resulted when beetles were confined to rye, wheat and corn kernels relatively unblemished.

Materials

Seven-hundred and fifty beetles from stock cultures were used. Corn was obtained from the Agronomy Department, rye from the Central Feed Store, and wheat from the Milling Department. Fifteen two-ounce bottles with screw type lids were used.

Procedure

The moisture content of each grain was adjusted to 11, 12.5 and 14 per cent. A 20 gram sample of corn and wheat at each of the above three moistures was examined under a microscope and only those grains with seed coats that were completely free from blemishes were selected. The above process was duplicated selecting rye, wheat and corn with definite cracks in the seed coats. Undamaged rye was not used because rye as it is ordinarily stored, contains very few perfect grains. Following the examinations, the grain was returned to the original jars to maintain adequate moisture. Twenty grams of grain and 50 flat grain beetles were added to each of the 15 test bottles and the lids were sealed. One hundred and twelve days later, the jars were opened and the number of live beetles was determined.

Results

The results of this experiment are shown in Table 5. It is readily seen that there was 100 per cent mortality in both wheat and corn with undamaged seed coats at all moisture levels. There was survival at 14 per cent moisture in cracked corn, wheat and rye. It was concluded that flat grain beetles cannot penetrate perfect grains. This conclusion agrees with the results found by Davies (1949) in a similar experiment. Of the grains tested, rye was the most favorable for reproduction at the 14 per cent moisture level. However, at 11 and 12.5 per cent moisture, rye was no better than corn and not as favorable as wheat. It may also be seen from Table 5 that the flat grain beetle survives best in grain containing cracked kernels at a high moisture content.

Table 5. The number of live flat grain beetles surviving after 50 beetles were exposed for 112 days to perfect kernels of corn and wheat at 11, 12.5 and 14 per cent moisture and in kernels of wheat, corn and rye with blemishes in the seed coats at the same moistures.

Type of Grain	Numbers of live beetles		
	11%	12.5%	14%
Wheat with uncracked seedcoats	0	0	0
Corn with uncracked seedcoats	0	0	0
Wheat with cracked seedcoats	2	88	132
Corn with cracked seedcoats	0	0	67
Rye with cracked seedcoats	0	0	254

TOXICITY OF PYRENONE WHEAT PROTECTANT, FORMULA T_{460}, TO FLAT GRAIN BEETLES

The following tests were devised to determine the quantity of Pyrenone Wheat Protectant T460 (P.W.P.) necessary to kill flat grain beetles when they are confined to treated wheat at 11, 12.5 and 14 per cent moisture for 14 days.

Materials

Pyrenone Wheat Protectant T460 containing 1.1 per cent piperonyl butoxide and 0.05 per cent pyrethrins was secured from the U. S. Industrial Chemical Co., Baltimore, Maryland. Fifty-eight pounds of newly harvested wheat and 58 wide mouthed quart mason jars with lids were used. Twenty-nine hundred flat grain beetles from stock cultures were used.

Procedure

It was first desired to determine the approximate quantity of protectant necessary to kill flat grain beetles when confined to treated wheat at 14 per cent moisture. Ten pounds of wheat was adjusted to 14 per cent moisture. The rates of 50, 100, 150 and 200 pounds per thousand bushels of wheat were arbitrarily chosen because it was thought that quantity of protectant required to kill would be within this range. The quantity of protectant used per pound of wheat at the above rates are as follows:

50 lb./1,000 bu. = 0.3760 gms./lb.
100 lb./1,000 bu. = 0.7521 gms./lb.
150 lb./1,000 bu. = 1.1283 gms./lb.
200 lb./1,000 bu. = 1.5044 gms./lb.

Ten pounds of wheat was added in one pound lots to each of 10 wide mouthed quart jars. Two of the samples were left untreated as checks and 50 beetles were added to each of the other jars. Self sealing metal covers were inverted so as not to seal the lids. Two replications at each of the above rates were made. Two one pound lots were placed in a gallon jar and the protectant was weighed out and added to the contents of the jar. The jar was sealed and shaken 100 times with a rotary twisting motion to secure uniform mixing. The contents were equally divided and returned to the respective quart jars. Fifty beetles were added to each jar. This process was repeated for each of the four rates. The samples were then placed in the rearing room at approximately 80° F. and 75 per cent relative humidity. The jars were examined 14 days later.

It was next desired to make a more precise determination using the same moisture levels. The above procedure was duplicated using the protectant at the rates of 20, 30, 40, 50, 60, 70 and 80 pounds per 1,000 bushels of wheat. These quantities were chosen because Table 6 shows that the effective dosage is between 50 and 100 pounds per 1,000 bushels of wheat. The quantities used were as follows:

20 lbs./1,000 bu. = 0.1504 gms./lb.
30 lbs./1,000 bu. = 0.2256 gms./lb.
40 lbs./1,000 bu. = 0.3008 gms./lb.
50 lbs./1,000 bu. = 0.3760 gms./lb.
60 lbs./1,000 bu. = 0.4512 gms./lb.
70 lbs./1,000 bu. = 0.5264 gms./lb.
80 lbs./1,000 bu. = 0.6016 gms./lb.

Results

The results of the first part of this experiment are shown in Table 6. It is readily seen that the effective dosage is between 50 pounds and 100 pounds per 1,000 bushels. The results of the second part of the experiment are shown in Table 7. It may be seen that the protectant is more effective at 11 and 12.5 per cent moisture than at 14 per cent moisture. Also that the protectant is more effecient at 11 per cent than at 12.5 per cent. The quantity of protectant T460 necessary to produce a median lethal dosage at each of the above moisture levels is 20 pounds per 1,000 bushels. It may be observed that as the moisture levels decrease, the number of surviving insects decreases. Also it may be seen that lower dosages of the protectant were required at the lower moisture levels. The recommended dosage of 75 pounds per 1,000 bushels is far above the quantity necessary to control flat grain beetles.

Table 6. The number of flat grain beetles that survived exposure to Pyrenone Wheat Protectant T460 at the following rates at 14 per cent moisture content with 50 beetles per sample.

Lbs. per 1,000 bu.	Sample No. 1	Sample No. 2
50	1	27
100	0	0
150	0	0
200	0	0
CHECK	48	49

Table 7. The number of flat grain beetles that survived exposure to Pyrenone Wheat Protectant T460 at the following rates and moistures with 50 beetles per sample.

Lbs. per 1,000 bu.	11%		12.5%		14%	
	Sample No. 1	Sample No. 2	Sample No. 1	Sample No. 2	Sample No. 1	Sample No. 2
20	3	6	13	12	13	28
30	0	0	3	6	9	6
40	1	0	0	3	2	1
50	0	1	0	1	2	2
60	0	0	0	0	2	0
70	0	0	0	1	1	1
80	0	0	0	0	0	1
CHECK	13	10	14	24	42	39

SUMMARY AND CONCLUSIONS

The flat grain beetle is able to live on whole grain that has cracks in the seedcoats and is unable to live on grain without cracks in the seedcoat. Most grain as it is stored, has varying quantities of grains with cracked seedcoats sufficient to support populations of flat grain beetles. In general, the species may be considered a primary pest.

The flat grain beetle is cosmopolitan in distribution and may be present in large numbers. The flat grain beetle may be of greater economic importance than has been supposed previously.

The life history requires about 30 days under optimum conditions.

A ridge was found on the head of the flat grain beetle which positively distinguishes it from the rusty grain beetle. The tarsal formula of the males in the genus Laemophloeus is 5-5-4 and in the females 5-5-5.

The antennae of the males are longer than the antennae of the females. This long antennae of the male flat grain beetle is very characteristic for the species. The bodies of the males in general are slightly larger than the females.

The sexes of the flat grain beetles may be separated also on the shape of the thorax and on genital structures. Also, the flat grain beetle and the rusty grain beetle may be separated on the shape of their thoraxes.

The flat grain beetle and the rusty grain beetle may be distinguished by the characteristic shape of their abdominal apodemes.

It has been shown that various varieties of sorghums show marked differences as foods for the flat grain beetle as indicated by the rate of reproduction. Gurno was the only variety that did not show any reproduction.

The varieties Double Dwarf White Sooner and Wheatland were most favorable for reproduction.

Rye is a more suitable food for the flat grain beetle than either corn or wheat.

Optimum conditions for reproduction of the flat grain beetle requires food with a high moisture content.

The flat grain beetle cannot penetrate grain without cracks in the seedcoats. However, most stored grain contains enough damaged kernels to support large populations.

Genus Laemophloeus is widely distributed throughout the state of Kansas. Collection records are included from 50 different counties.

Pyrenone Wheat Protectant T460 was more efficient in killing flat grain beetles at low moisture contents than at high moisture levels. The M.L.D. at 14 per cent moisture was found to be 20 pounds per 1,000 bushels. The protectant is highly efficient at all moisture levels. The recommended dosage of 75 pounds per 1,000 bushels is far above the quantity necessary to control the flat grain beetle.

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STUDIES ON THE IDENTIFICATION, FEEDING HABITS, AND CONTROL OF THE FLAT GRAIN BEETLE, *LAEMOPHLOEUS PUSILLUS* (SCHONH.) (COLEOP. CUCUJIDAE)

by

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The flat grain beetle *L. pusillus* is one of the most common insect pests found in stored grain and is of cosmopolitan distribution. It has previously been considered to be of little economic importance but it is becoming increasingly apparent that its presence has been underestimated from an economic standpoint.

The species in the genus *Laemophloeus* are difficult to identify and the available keys are difficult to use.

An attempt was made to locate structural characters which would enable the two common species present in Kansas, the flat grain beetle and the rusty grain beetle, *L. ferrugineus*, to be separated. A ridge was found on the flat grain beetle which extends along the sides and across the back of the vertex. This ridge is not found on the rusty grain beetle and provides a character for separating the two species.

The two species may also be separated on the shape of their thoraxes. The thorax of the flat grain beetle is more rectangular and less narrowed posteriorly than the rusty grain beetle. Specimens of both species were separated in this way and the identifications checked by examinations of the genitalia. Separation by means of the shape of thoraxes was found to be an accurate method.

The flat grain beetle and the rusty grain beetle were found to have characteristic apodemes located in the anterior part of the abdomen. The apodeme in the flat grain beetle had a faint suture running between the apodemes and lengthwise of the body that was not present in the rusty grain beetle. Also, the posterior margin of the apodemes in the flat grain beetle is cleft deeper at the center than in the apodemes of the rusty grain beetle.

An experiment was conducted to determine the extent of reproduction of flat grain beetles in 20 varieties of sorghum. Thirty-five beetles were added to each jar. The jars were partially sealed and the samples were examined 127 days later. The varieties showed a marked difference as foods for the flat grain beetle as indicated by the rate of reproduction. The variety Gurno did not show any reproduction. The varieties which showed 50 or less live beetles upon examination were Redlan, Waxy Double Dwarf Sooner, Double Dwarf Yellow Sooner, Gurno, Blackenslip, Day, Early Kalo, Westland and White Martin. The varieties which showed eighty or more live beetles were Double Dwarf 38, Double Dwarf White Sooner, and Wheatland. Double Dwarf White Sooner was most favorable for reproduction.

A determination of the affect of flat grain beetles on the germination of wheat, corn and rye upon exposure for two, four and six week intervals was made. Whole grain was used and adjusted to 12 per cent moisture. Twenty-gram samples were examined and placed in two-ounce bottles along with 50 beetles. It was intended that the experiment should continue for 12 weeks and that a germination analysis would be made every two weeks. However, all beetles were dead at the end of six weeks. No attempt was made to select unblemished rye because most of the rye as stored contains cracks in the seed coats. Sixteen per cent of the beetles were alive after two weeks on rye as compared with 3.6 per cent on corn and 1.6 per cent on wheat.

An experiment was conducted to determine whether the flat grain beetle could penetrate and use for food whole grains which had no breaks or blemishes in the seed coats. Whole grains of wheat and corn were examined under a microscope and only grains free from blemishes were selected.

Slightly cracked grains of rye, corn and wheat were used as checks. Samples of each kind of grain were tested at 11, 12.5 and 14 per cent moisture. Twenty grams of grain and 50 beetles were added to each two-ounce bottle and examined 35 days later.

There was 100 per cent mortality at all moisture levels of beetles exposed to perfect grains and it was concluded that the flat grain beetle cannot penetrate grains which do not have blemishes in the seed coat. In the cracked grain the largest number of live beetles were found in the samples with 14 per cent moisture. Rye grain at 14 per cent moisture was found to be the most favorable for reproduction, followed by wheat and corn respectively.

Insect collection records from various sources including screenings made from probe samples of wheat from farm bins by the Production and Marketing Administration inspectors were examined. Beetles of the genus Laemophloeus were found to be present in 50 widely distributed counties in Kansas.

It was desired to determine the quantity of Pyrenone Wheat Protectant T460 necessary to kill flat grain beetles when confined to treated wheat with moisture levels of 11, 12.5 and 14 per cent for 14 days. The approximate quantity of protectant necessary to kill flat grain beetles was found by treating wheat at 14 per cent moisture at the rates of 50, 100, 150 and 200 pounds per 1,000 bushels of grain and exposing 50 beetles to one pound samples for 14 days. The amount necessary was found to be between 50 and 100 pounds per 1,000 bushels. A similar experiment was conducted using wheat at 11, 12.5 and 14 per cent moisture at the rates of 20, 30, 40, 50, 60, 70 and 80 pounds per 1,000 bushels. It was found that the quantity of protectant necessary to produce an M.L.D. at 14 per cent moisture was 20 pounds per 1,000 bushels of wheat. It was also found that lower dosages of the protectant were required at the lower moisture levels. The recommended dosage of 75 pounds per 1,000 bushels of wheat is far above the quantity necessary to control flat grain beetles.