A PRELIMINARY INVESTIGATION INTO THE LIFE HISTORY AND HABITS OF THE SIAMESE GRAIN BEETLE (*LOPHOCATERES PUSILLUS* KLUG)

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SECTION I. INTRODUCTION

The numbers of Lophocateres pusillus Klug. occurring in badly infested paddy in Trinidad and British Guiana are sufficient to raise the question as to whether the damage they cause is insignificant, and to suggest a more detailed study of the life history than was undertaken by Chittenden in 1916.

Although L.pussillus has been known for over half a century, the literature on it is limited to short notices in connection with its technical description or records of its occurrence in new localities.

According to Chittenden (1905), L. pusillus made its first appearance in the New World in 1893 when it was first observed in rice and other exihibits from Siam, Ceylon and Liberia at the Worlds Columbian Exposition in Chicago. It was not until 1905 that it became established on the North American continent. Chittenden (1916) reports its occurrence firstly in 1903 in corn in Peru, then in 1904, in rice from Java, and in 1906 in rice from Guatemala, where it also occurred on black beans and is of the opinion that L. pusillus arrived in North America via Charlestown, S.C., where millers had for some years been importing rice from Siam and other points in the Orient.

In 1909, states Chittenden (1916), it was reported on eggplant and gourd seeds, and beans from Siam; in rye and flour in Texas, and in paddy imported into the U.S.A. from India and traced to Demarara.

Reyne (1924) found L. pusillus on Sesamum seed in Surinam. In 1926 Roepke reported that he had observed the insect attacking stored shelled rice in Java, but doing little harm. Zacher (1926) found L. pusillus in macaroni in Germany. In Malaya Corbett and Padgen (1941) noticed that rice in the bush was only suitable to the insect if the husks were damaged. Larvae of L. pusillus were discovered feeding on damaged tissues of dried bananas from the Ivory Coast, examined at Marseilles by Clement in

1945.

1945. Landani and Swank (1954) used L. pusillus in tests of Pyrethrum in wheat in Georgia. Lastly, Baeta Neves (1954) reports its presence in Portugal in stored products.

L. pusillus is worldwide in its distribution and apart from the original description, no work has been done in the investigation of the life history and habits of this insect.

SECTION II. DESCRIPTION

The Adult. (See Fig.1.)

The genus Lophocateres was characterised in 1883 by Olliff who referred it to the sub-family Peltuii of the family Trogositridae, a group of beetles having flattened or more or less oval, bodies with much flattened thoracic and elytral margins. Olliff's description, as given by Chittenden (1916) is as follows.

Genus Lophocateres Olliff.

Head nearly quadrate. Eyes small, lateral, not prominent. Antennae 11-jointed, basal joint large, with inner angle much produced, 2nd joint short, 3rd rather longer, 4th to 7th transverse and very short, last four forming a gradually elongated club, of which the joints increase in breadth as they approach the apex. Mandibles robust, inner margins straight, apex slightly incurved. Maxillae with both lobes narrow and sharply jointed, the inner much shorter. Maxillary palpi three-jointed, the basal very small, the 2nd rather longer, the 3rd longer than the 1st and 2nd together, rounded at apex. Labium with anterior margin rounded. Labial palpi 2-jointed, of which apical is somewhat the longer. Prothorax transversely quadrate, rather strongly margined laterally. Elytra about the same width as the thorax, depressed, covering the abdomen, sub-parallel, with fine costae. Legs short and slender; tibiae armed on outer margins with short, sharp spines, the posterior tibiae with a row of blunt teeth at the base, slightly projecting over the first joint of the tarsus, tibial spurs short, tarsae 5-jointed, the basal very short, the second and third rather longer, the fourth shorter, and the fifth nearly as long as the other four together; claws simple.

The fine but distinct costae on the elytra, the gradual four-jointed club of the antennae, and the peculiar structure of the posterior tibiae, are characters which will serve at once to distinguish this genus.

The antennae of the species present in Trinidad have the basal joint much enlarged and produced on the inner surface, the terminal joints forming a three-jointed club instead of a four-jointed one. (See Fig. 4) The strongly produced apices of the thoracic margin are a marked character of the group, but not found in other forms of stored grain pests.

The species may be further recognised from Klug's original description.

Losphocateres pusillus Klug.

Elongate, flattened; dorsal surfaces glabrous, ferruginous brown, with elytral margins paler ferruginous, strongly punctate. Head deeply, closely, and coarsely punctate. Thorax transverse, finely and distinctly punctate like the head. Sides sub-parallel, narrowed anteriorally. Elytrae parallel, each presenting seven costae, which bear on each side a row of close and deep punctures. Apices of elytra rounded. Legs ferruginous. Length 2.7 to 3 mm., Width 1 to 1.2 mm.

The Egg.

The egg varies slightly in length from 0.85 mm. to 1.15 mm. and the width from 0.10 mm. to 0.15 mm. It is elongate, approximately cylindrical, obtusely pointed at each end, colour milky white, to slightly grey, opaque. The surface is slightly sticky, the cementing material being added at oviposition. The egg is frequently sickle-shaped. There is a tendency for the egg to vary in shape according to where it is laid.

The Larva. (Fig. 2.)

1st Stage.

The young larva, upon hatching, is slender, elongate, and flattened in form, white, almost transparent, with eyes and mouthparts darker. Before the second instar, the head capsule, the thoracic and anal shields and cerci turn a light brown colour, then a dark brown. Length 0.9 mm. to 1.1 mm. Width 0.15 mm. to 0.2 mm.

2nd Stage.

Similar to first stage, larger, with chitinised parts darker.

The subsequent stages differ only in size from the second stage.

The description of the mature larva is that of Willem Claudius Rey, translated by Chittenden (1916).

Body subelongate or oblong, somewhat attenuate at the extremeties, subdepressed or a little convex, absolutely pilose at edges; dirty white, somewhat shiny, with head and last abdominal segment glabrous, the latter armed at the apex with an angular median tooth, and with two strong hooks curved upwards and slightly towards each other.

Head nearly round, a little narrower than the prothorax, somewhat divided by a median channel into two smooth and somewhat convex discs, flattened, bi-impressed and subrugulose in front, decided fulvous yellow provided on side with four or five long pale bristles. Labrum transverse, ruddy. Mandibles ferruginous with black points, bidentate. Palpi small, testaceous; eyes rather distinct; antennae slightly projecting, testaceous, the joints narrowing gradually.

Prothorax in shape of a transverse rectangle somewhat out of proportion, pale and shiny. Mesothorax and metathorax transverse, wider than prothorax, but both together hardly exceeding its length. Pale, more or less unequal, the sides somewhat curved.

Abdomen more or less enlarged, somewhat rounded at sides of the segments, and narrowing to the rear. Of the nine segments, the first eight are shiny dirty white, short, more or less uneven, folded transversely and surmounted by four longitudinal rows of swellings or scars, the lateral rows of which are less pronounced. The ninth is a little narrower, provided on the back with a large flattened plate, which is received in a broad hollow on the eighth segment, fulvous, rugulose or folded transversely for about the

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first third, and broadly hollowed upon the summit, the deepest part of the hollow armed with a median angular or conical tooth and limited by two strong hooks, darker in colour with the points recurved upward and inward.

Beneath the body is pale, subdepressed, sparsely hairy, more or less uneven, with the underside of the head and the last ventral arch fulvous.

Feet short pale and terminating in short hard hooks, almost straight, brownish. Length 5.34 mm., width 1.08 mms.

These measurements are from 12 fully mature larvae, freshly killed and extended full length.

The pupa. (Fig. 3.)

The pupa has not been described previously. It is about the same size as the adult. Pinkish to light brown in colour, length 2.8 mm. to 3.1 mm., width, 1.0 mm. to 1.3 mm.

Head subquadrate, clypeus and labrum free from setae. Prothorax subquadrate, seven pairs of setae, 2 pairs anteromarginal, three pairs lateromarginal, two pairs lateroposteromarginal.

Mesonotum and metanotum usually with one to three pairs of fine setae.

Abdomen with nine distinct dorsal tergites, the ninth bearing two long pleural spines.

Ventrally the ninth segment bears two fleshy processes. Tenth abdominal segment reduced and ventral. Pleural area of each abdominal segment with two or three pairs of setae.

Tips of wing pads extended to fourth abdominal segment. Tips of metathoracic tarsi sometimes extending just past the tips of the wing pads.

SECTION III. LIFE HISTORY

Methods and Materials.

The paddy used in the investigation into the life history of L. pusillus was D.110, harvested in November 1955 and S.100, harvested in 1956.

Precautions against the introduction of any other stored grain insects were taken by sterilising the paddy in sealed jars in an oven at 75°F to 80°F for 2 hours. The paddy was then tempered by slow cooling, and placed in gauze covered Kilner jars. The adults of L. pusillus were then introduced, 15 adults in each of 5 Kilner jars.

The adults were obtained from jars of paddy containing a mixed population of stored grain insects namely Rhyzopertha sp., Calandra sp., and Lophocateres. 24 larvae of L. pusillus were recovered from these varied populations and introduced into a Kilner jar containing crushed rice, and on emergence, the adults of these larvae were added to the Kilner jars containing the other adults.

Unsorted grain was used in the initial experiments. Observations were made at frequent intervals on the life history and the habits of the grain beetle. Much difficulty was experienced in recovering the eggs, observing of oviposition sites, injury to the grain and the general behavior of the beetles, due to the presence of a large number of damaged and otherwise unsound grains. It was then decided to work with sound grain only, as far as was possible, by floating off the unsound grain and reinfesting the selected sound grain.

The floatation technique used was that using a 26% solution of Magnesium Sulphate in which the unsound grains will float while the sound grains will sink. The sound grain was well air-dried before reinfesting in the way described. Some information was, however, obtained before sound grain only was used.

A moisture content determination too, was done at the commencement of the investigation, in order to obtain an estimate of the moisture content at which the beetles were developing in the paddy. The method used was the standard two-stage air oven method specified for the United Kingdom and Colonial territories. The mean moisture content of the paddy used in the investigation was 12.3%.

In addition to cultures on paddy, both adults and larvae were kept and allowed to increase naturally on a very fine type of Hydak's formula, mixed as follows:

Corn flour	16 parts.
Baking flour	2 parts.
Skimmed milk	2 parts.
Yeast	1 part.

A little honey was added, and mould prevented by the addition of glycerine.

Oviposition.

An attempt was made to determine the preferred oviposition site or sites. Several hundred grains were examined under a hand lens in an attempt to determine whether the adult females preferred laying their eggs over the germ or at the end further from the germ, or somewhere in between. The grains examined were from the first Kilner jars before the unsound grains were floated off. The jars, at this point, still contained a mixture of sound and unsound grains.

Out of 320 grains examined, 47 were found to contain eggs in varying numbers. Rice grains appear to have a slight ridge over the germ which may or may not split open. This may be a point of weakness in the palea. Where the lemma or palea were cracked or split, the eggs were deposited inside the split wherever it occurred on the grain. Where the eggs were laid in such splits and cracks, they appeared to have been thrust in as far as the ovipositor could reach, the ovipositor being extremely long, almost half the length of the adult female.

In an experiment to determine the preferred oviposition site, hulls of selected sound grains were purposely damaged in one of three different places:

(a) over the germ,

(b) at the end furthest from the germ, and

(c) half way along the grain.

Four grains split in each way were placed in each of 3 jars with 88 sound grains (making 100 grains per jar). Twelve adults were placed in each jar, and the grains examined at 2 day intervals. Grains in which eggs were found were removed and replaced with new split ones of the same kind. (Table 1)

Results.

Table I. Total No. eggs in 3 Jars oviposited on 3 types of grain.

	Split over Germ.	Split at Other end	Split ½ Way
24.1.57	22	6	8
26.1.57	14	10	8
28.1.57	12	7	9
	48	23	25

In all three jars the grains split above the germ appeared most attractive to the ovipositing females and contained more eggs that the grains split in the other ways. The paddy used in this experiment was the S.100 variety, which appears to have a much harder hull than D.110. The adults fed on the grains damaged along the hull and at the ends further from the germ. This may account for the fewer eggs in these grains. Undamaged grains were untouched generally and only 4 eggs in all were found adhering to the surface of these grains.

When this experiment was first started the damaged grains were stained with methyl green for easy identification, but this was discontinued as the damaged grains could easily be picked out from the undamaged ones.

It appears from the above 2 experiments that the

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females have a preference for ovipositing on or near the germ of the grain but are restricted to a certain extent by the hardness of the lemma and palea, and the condition (soundness) of the grain. Their ability to exist on wholly sound or comparatively sound grain will be discussed later.

As regards the number of eggs laid in one grain, this varied from three to fourteen. On Hydak's formula, eggs were laid in small cracks near the surface of the lumps of food. There the number of eggs laid in one location varied from five to twelve.

Regardless of the number of eggs laid in one grain, never was more than one larva in any instar found in one rice hull. The hatchability of the eggs appears to be good. No really reliable egg mortality tests were carried out, but when eggs from one grain were isolated in small bottles, there was 83% viability. On Haydak's, a number of eggs laid together in one crack were observed, and there emerged from seven eggs, six larvae.

Eight grains containing 4 to 9 larvae were isolated in small bottles and in each bottle only one larva developed. It appears from this that, in infested paddy, one of the larvae emerging from a batch of eggs destroyed or ate the unhatched eggs in the hull. Another indication of this habit is that in spite of a large number of eggs being laid in the first Kilner jars great difficulty was experienced in maintaining enough beetles on rice throughout the whole period of the investigation. This is, however, by no means conclusive evidence that the first larva emerging destroyed the others in the same grain.

<u>The larva.</u>

The larva, on emerging from one end of the egg capsule is almost transparent and can only just be seen with the unaided eye. It does not leave the grain but begins to feed at once on the endosperm, or germ. If it emerges at the germ end of the grain, it will first eat the germ, following which it will proceed to scarify the top of the grain, that is, the area lying immediately inside the lemma. (Fig. 5 (c) and (d)).

The larva will continue to feed on the endosperm and will moult in the hull. Frass and exuviae remain inside the hull and are not extruded, being packed into the space where the endosperm has been eaten away.

If the larva emerges from the egg at the end of the grain away from the germ, it is capable of feeding on the hard endosperm, working its way along the "top" (and occasionally along the "bottom") of the endosperm to the germ.

It appears that there is enough food in the germ and endosperm of one grain to suffice for the development of the larva until it pupates. If, however, the larva consumes all the food in one hull, it will leave that empty hull and enter another grain, usually an unsound one.

The number of larval instars.

From the measurement of 88 last abdominal segments, and a grouping of the measurements, there appear to be four instars. When, however, these are tested by the application of Dyar's Law it appears that one instar has been missed and that there are in actual fact five instars.

Average width.

	No. measured per "step"	Divisns of eyepiece micrometer	mm.	Ratio between "steps"
(1)	7	5.57	0.07	
				2.29
(2)	10	12.30	0.16	
				1.44
(3)	23	21.39	0.23	av. 1.46
				1.48
(4)	48	27.60	0.34	

It will be seen that the ratios $^{(3)}/_{(2)}$ and $^{(4)}/_{(3)}$ are almost identical, but that the ratio $^{(2)}/_{(1)}$ is much greater. If the smallest observed width (0.07 mm.) is multiplied by the average of ratios $^{(3)}/_{(2)}$ and $^{(4)}/_{(3)}$ (i.e. 1.46) the value obtained is 0.10 mm. If this value is in turn multiplied by the same factor and multiplication continued to produce a geometric progression, the successive steps in the progression will be seen to approximate closely to those actually obtained by measurement.

		Observed width (mm.)
Width observed in 1st instar	0.07	0.07
Calculated width in 2nd "	0.10	none
" " " 3rd "	0.16	0.15
" " " 4th "	0.22	0.23
" " " 5th "	0.32	0.34

A further confirmation of the fact that there are five instars is obtained by plotting $\log_{10}$ widths against the number of instars minus one. A straight line is only obtained on the basis of 5 instars. (Fig.6.)

A possible explanation for this apparent missing instar is that, while the first instar segment can be easily measured by killing the hatching larva and the third is the smallest one which can be found in the cultures, the second instar segment is so small that it is easily missed.

In order to determine the length of the larval stage of L. pusillus, fourteen newly laid eggs were placed individually in small bottles containing Haydak's formula and plugged with cotton wool. The eggs were stuck on the sides of the bottles, just above the nutrient and kept under observation.

On emerging after an incubation period of six to eight days the larva, which are light sensitve, commenced feeding and very quickly burrowed into the food and disappeared from view.

The Hydak's was then periodically removed and carefully crumbled so that the larva could be observed. Three of the larvae remained near the side of the bottles, and eventually constructed their pupal cells next to the glass, and could be observed without disturbing them.

TABLE II.

Egg No.	Date of Ovip.	Date Hatched	Date Prepupa	Date Pupated	Length Days	Date Adult Emerged	Length Days
1	22.1.57	28.1.57	21.2.57	26.2.57	29	10.3.57*	41
2	22.1.57	28.1.57	19.2.57	24.2.57	27	8.3.57*	39
3	22.1.57	29.1.57	23.2.57	28.2.57	30	13.3.57	43
4	22.1.57	28.1.57	24.2.57	28.2.57	31	10.3.57	41
5	23.1.57	30.1.57	20.2.57	25.2.57	26	11.3.57*	40
6	23.1.57	28.1.57	Died	-	-	-	-
7	24.1.57	29.1.57	Died	-	-	-	-
8	24.1.57	28.1.57	28.2.57	4.3.57	35	17.3.57	45
9	24.1.57	30.1.57	Died	-	-	-	-
10	24.1.57	31.1.57	24.2.57	28.2.57	28	12.3.57	40
11	25.1.57	29.1.57	27.2.57	3.3.57	33	13.3.57	44
12	25.1.57	29.1.57	Died	-	-	-	-
13	25.1.57	31.1.57	1.3.57	6.3.57	34	16.3.57	44
14	26.1.57	1.2.57	2.3.57	7.3.57	34	21.3.57	48

* Approximate dates of emergence.

Average 32 days.

Larval life appeared to be fairly long, varying from 26 to 35 days, with an average of 32 days.

The 5th instar larva is quiescent and may be considered as a prepupa. The 4th instar larva constructs (in Hydak's) a cell in which the pupa will eventually be formed. After the completion of this cell the 4th instar larva moults, and the last skin is ejected from the cell together with any frass. The quiescent stage lasts from 4 to 5 days.

During the prepupal stage, the larva loses its dirty white colour, and becomes a pinkish brown colour.

<u>The Pupal Stage</u>.

The pupal cell is approximately 4 mm. long and .15 mm. wide. The pupa lies on its back at the bottom of the cell. In rice the pupa remains in the now empty hull.

A few days prior to the emergence of the adult, the eyes of the pupa become dark and the mouthparts and the segments of the tarsi begin to colour.

The first adult emerged on the 10th day after pupation and others took 12, 13 and 14 days, with an average of 12 days.

The newly emerged adult is light in colour, soft in texture and feeble. It remains in the pupal cell for about one week after emergence, slowly turning from light brown to very dark brown, and then emerges from this cell.

Mating begins soon after emergence, and the first eggs are laid about two weeks after emergence.

A complete life cycle from adult to adult, therefore, takes about 6 to 7 weeks.

The adults of L. pusillus are very sluggish in their movements, more so than most stored grain pests, and cling closely to the rice grains on which they are feeding or resting. They have, too, a habit of congregating or crowding into small groups, thus showing, according to Chittenden (1916) the gregarious habit common to most herbivorous insects found in stored material.

They appear to prefer darkness to light and are seldom seen on the surface of the grain. As the population which was worked with was obtained from a mixed population of Calandra sp., Rhyzopertha sp. and Lophocateres pusillus, no evidence was present of a possibly predaceous habit.

SECTION IV. DAMAGE (Fig. 5 c & d)

Damage to the paddy is caused by both the adult and the larva. On the D.110 variety, the adult will, when feeding, begin by making a hole in the lemma or palea, if the hull is sound, or enlarging a crack or split in the hull if the grain is already damaged; and then feed on the endosperm, preferring the germ to the remainder of the grain. The adult will begin feeding at one end of the grain and consume the entire germ and endosperm before moving on to the next grain.

Frass is voided outside the grain and it is only when a larva has developed inside a hull that frass will be found inside the hull.

The larva will eat the germ first if it hatches from the egg near the germ and will work its way along the top of the endosperm below the lemma (See Fig. 5). The grain is consumed from the top until there is none of the endosperm remaining. If the amount of endosperm inside the hull is small the larva will leave the hull partially filled with frass and exuviae and enter another grain.

When adults were introduced into a jar of carefully selected sound paddy of the S.100 variety, they made very poor progress, and several complete introductions of adults were lost in this way. They appeared to be incapable of penetrating the sound lemmas and paleas of this variety. The S.100 variety used had no cracks or splits in the paleas and the lemmas, or gaps between these, allowing no access to the endosperm. The water content of the grain also appeared to be of some importance. During the dry season the grain appeared considerably drier than during the wet season, and <u>L. pusillus</u> had considerable difficulty during this period.

There are two main methods of recognition of damage caused by <u>L. pusillus</u>. The first is the peculiar way in which the endosperm is scarified, with no obvious sign of entry of an

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insect, and the second is the characteristic shape of the faeces of this insect. (See Fig. 5.)

The faecal pellet is voided in a sausage shaped form with fairly even constrictions, the pieces being of varying lengths. Faeces of all colours occur, namely, white, pale yellow, darker yellow or fawn, pinkish, brown, dark brown and black. In a jar of paddy infested with L. pusillus the bottom of a jar was covered to a considerable depth with frass voided by the adults.

Hulls may be found almost completely filled with frass voided by the larvae.

SECTION V. SUMMARY AND CONCLUSION

Owing to its close association with the grain on which it feeds, its inconspicuous habits and the fact that the larvae are usually inside the grains, infestations of L. pusillus may easily be overlooked by the casual observer.

In Trinidad L. pusillus usually occurs in association with other pests of stored grain.

The habit of the larvae of crawling into an inconspicuous place to undergo its development and to pupate makes detection difficult.

L. pusillus appears to take a shorter time for development from egg to adult if kept on Hydak's formula. They are fairly longlived, and appear to have no hibernation period in the West Indies.

The eggs are tucked into crevices which will afford protection. Incubation period for eggs is approximately 6 - 7 days. When about to transform, the larvae form pupal chambers into which they seal themselves. This pupal stage lasts for approximately 12 days. The larval stage lasts for approximately 30 days.

Nowhere in the world has L. pusillus reached the stage where it is a serious pest of stored foodstuffs. This does not, however, mean that it could not become so. Although it is comparatively unknown in many countries, it does cause some loss of foodstuffs, and also reduces germination, therefore, warranting control measures to prevent its development in stored foodstuffs.

In Trinidad it does not appear to be well known amongst local rice growers. The writer showed some specimens to local growers to determine whether they were familiar with the insect, and in almost all cases the reply was in the negative. This may, however, be due to an outright denial of any insects in their stored grain, or ignorance on the part of the people interviewed.

Even if L. pusillus is present in only small numbers

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and isolated populations, it does make grain rather unsightly and detracts from its marketable value. These should be good enough reason for preventing its occurrence in paddy.

As it is very similar in its habits to many of the other insects infesting stored grain, in that its development is retarded in sound grain and in dry grain, the control measures applying to these other pests may in all probability be applied to the control of <u>L. pusillus</u> with equal success. Once again, cleanliness is a big step in keeping populations of this and other pests in check.

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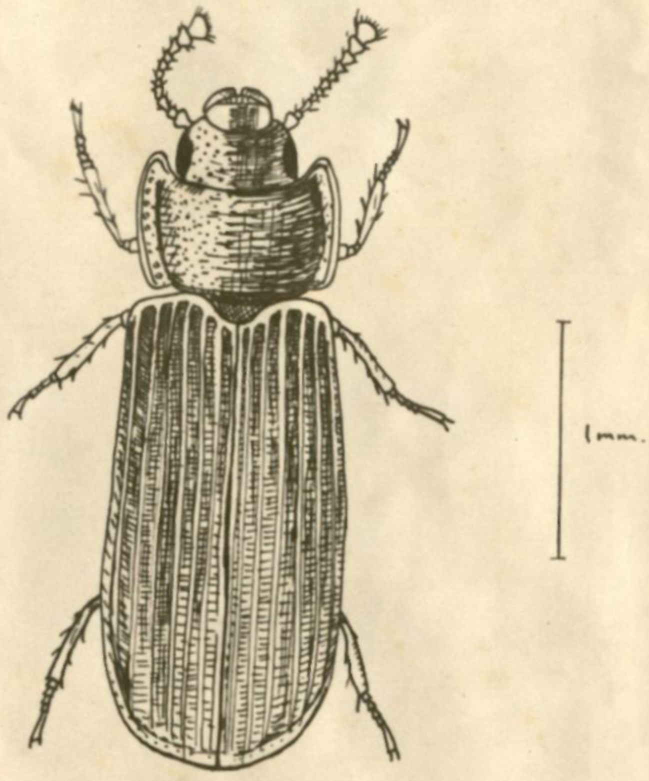


FIG. 1 — ADULT.

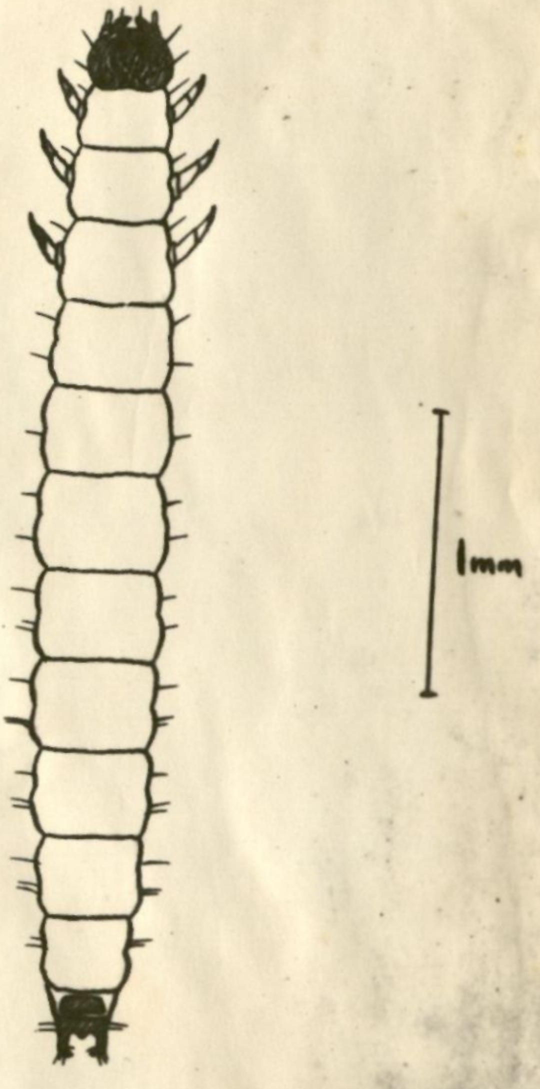


FIG. 2 – 5th INSTAR LARVA.

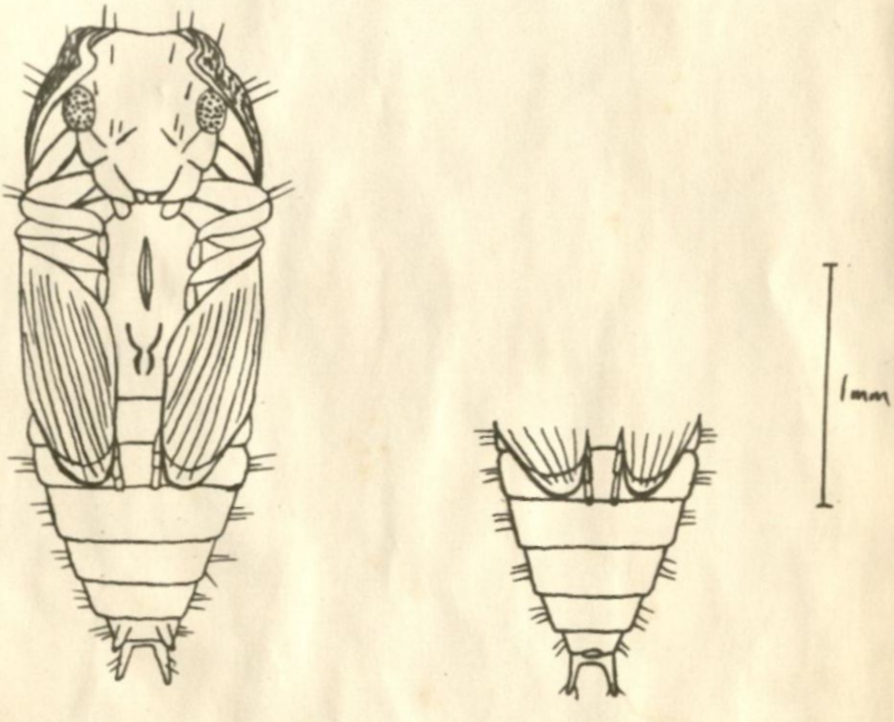
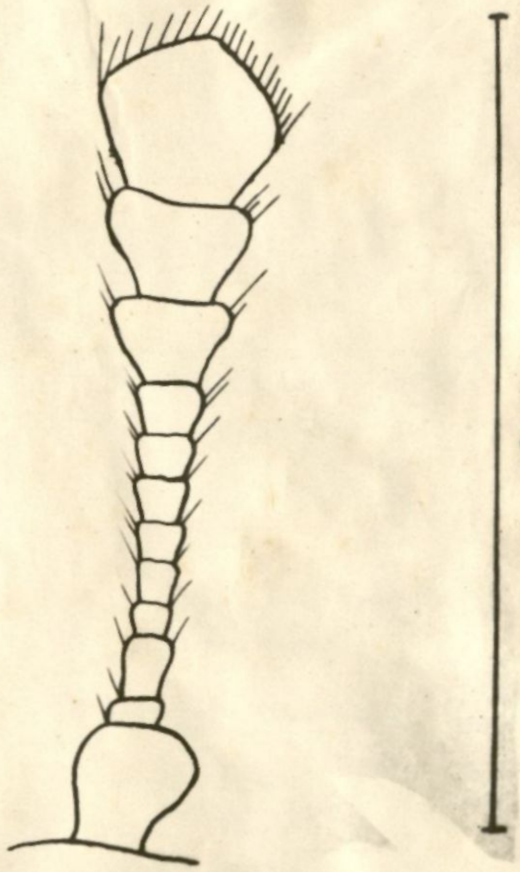
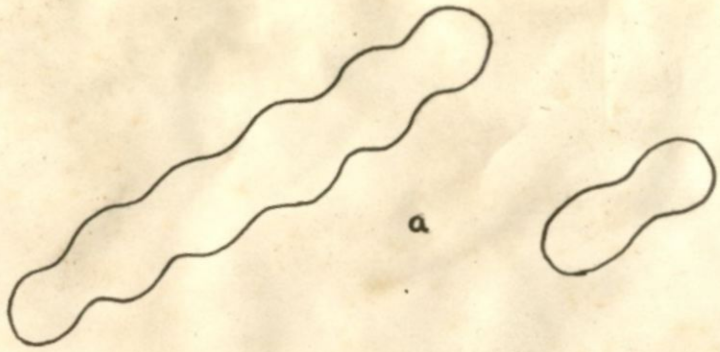


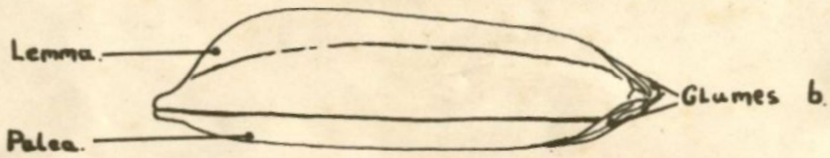
FIG. 3. — PUPA.



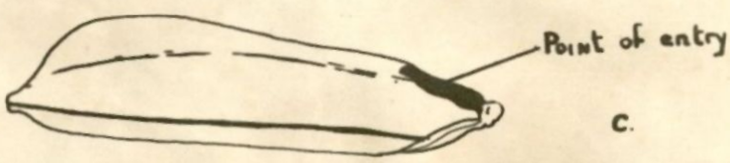
ANTENNA. FIG. 4.



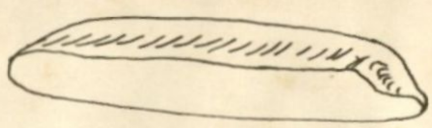
FAECES.



Sound Grain.



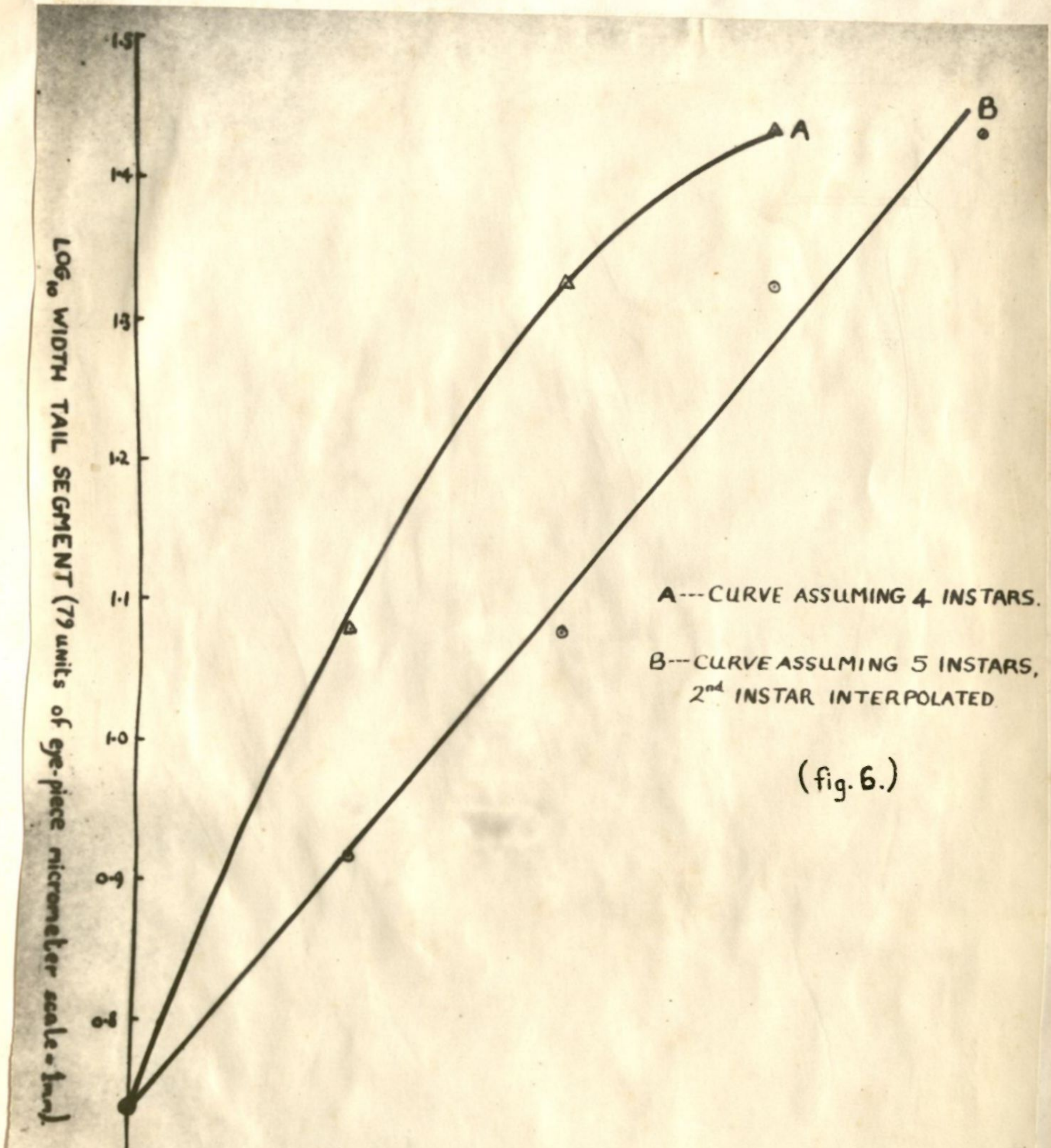
Damaged Grain.



d.

Damaged Endosperm with hull removed.

Fig. 5.



1·5
1·4
1·3
1·2
1·1
1·0
0·9
0·8
0·7
LOG₁₀ WIDTH TAIL SEGMENT (79 units of eye-piece micrometer scale = 1mm)
0
1
2
3
4
INSTARS MINUS ONE. (n-1)
A
B
A---CURVE ASSUMING 4 INSTARS.
B---CURVE ASSUMING 5 INSTARS, 2nd INSTAR INTERPOLATED

(fig. 6.)