ENTOMOLOGICAL SERIES—BULLETIN No. 6

DEPARTMENT OF AGRICULTURE

MYSORE STATE

PULSE BEETLES

(STORE FORMS)

BY

K. KUNHI KANNAN, M.A., F.E.S.,

Senior Assistant Entomologist

BANGALORE:
PRINTED AT THE GOVERNMENT PRESS
1919

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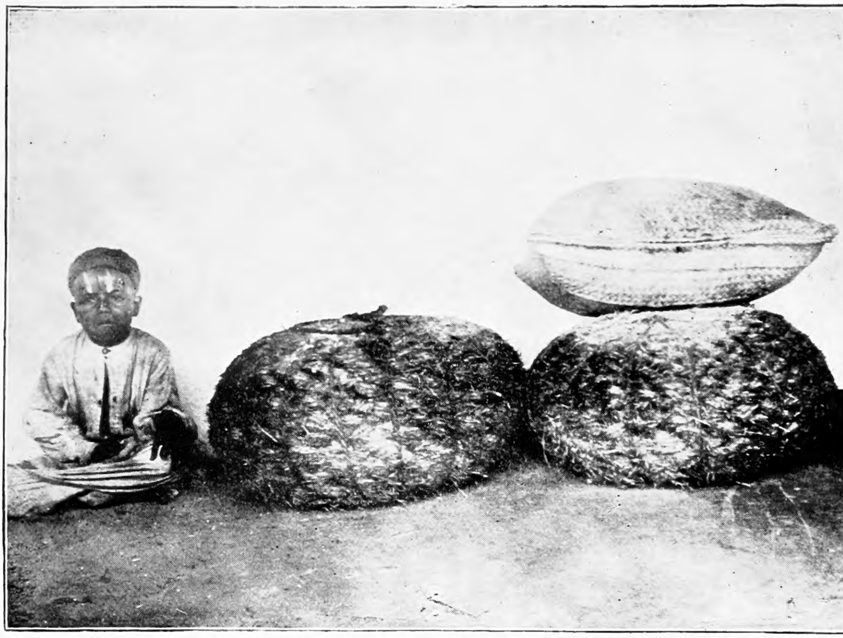

FIG. 1.—Two 'moodais' with bag made of matting on top of one.

FIG. 2.—Two bamboo bins used for storing cereals. The hut of the owner is seen to the right.

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FOREWORD.

THE study of Pulse Beetles was commenced by Dr. Coleman and myself more than eight years ago and was undertaken mainly with the idea of finding a simpler remedy than fumigation. Whatever success has been achieved in this attempt is chiefly due to the investigation of the local methods of storing pulses some of which were found to be highly ingenious and suggestive.

Before the investigation proceeded far, Dr. Coleman was drawn off to more responsible duties. But I have always had his sympathy and encouragement for which I am deeply grateful. A good part of the experiments described were carried out under my direction by Mr. B. C. Shantappa, Junior Assistant Entomologist.

K. KUNHI KANNAN,
Senior Assistant Entomologist.

PULSE BEETLES.

The Store Forms.

Almost all pulses such as gram, lablab, peas and beans are liable to attack by species of tiny beetles which develop inside the seeds and gradually render them unfit for human consumption. A number of these confine their depredations to the field and cease to attack when the crop is harvested and stored. Other species, however, do the greater

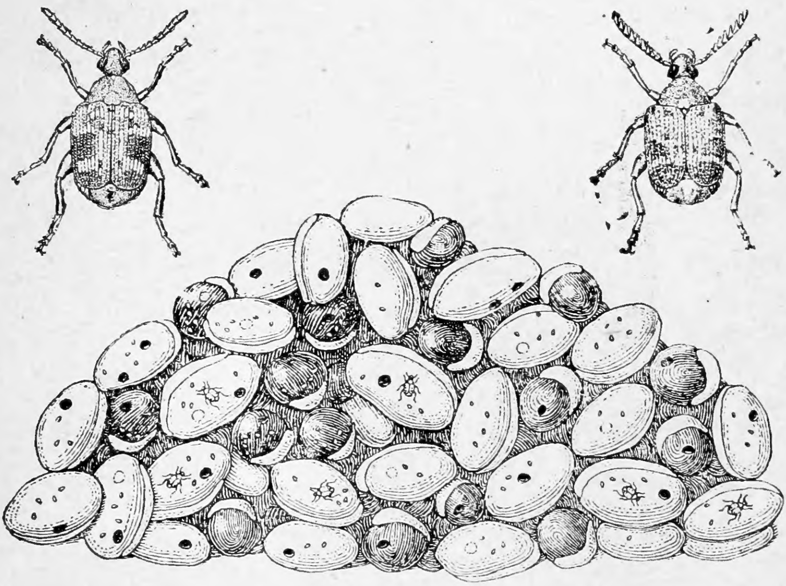
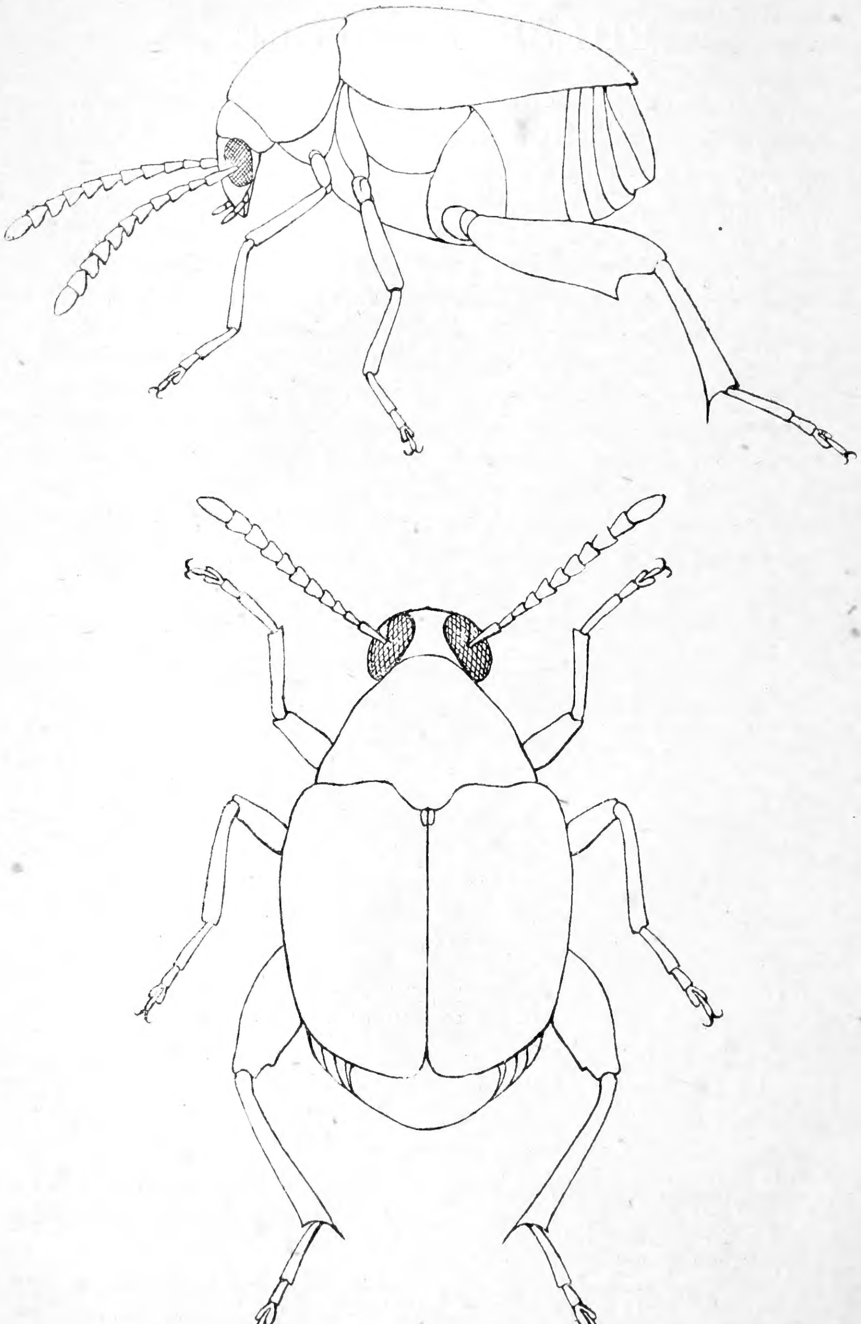


Fig. 1.—Damaged seeds showing beetles, their eggs, and the holes through which they came out. At the corners above are shown enlarged the two species concerned.

part of the injury while the seed is in the store although they may get their start while the crop is in the field. The seeds in either case are damaged by the excavations of the larvæ which complete their development inside them. Those that are so injured, show usually one or more round holes through which the adult beetles have emerged and small shining ivory specks which are eggs or egg shells from which the larvæ have hatched out (Fig. 1). The infested seeds will rapidly accumulate among them a mass of dead beetles and discs cut by them out of the seed coats as they emerged. In cases of severe damage, the presence of these decaying



FIGS. 2 & 3.—Outlines of a pulse beetle. Above, side view. Below, top view.

insects and riddled emptied seeds imparts an unpleasant odour which renders it unsuitable for human food. Where pulses are stored for seed, the damage may have more serious consequences; for, so much of the food material necessary for development is destroyed that the seeds may not sprout, or, if they do, the seedlings may not thrive.

Although, as stated, there are a number of different species of these pulse beetles, they all resemble one another greatly in appearance, (Figs. 2 & 3). They are usually about an eighth of an inch long, but some may measure as much as a quarter of an inch. The body is short and stout and considerably swollen below. The prothorax is curved down so that the small head is scarcely visible from above. The antennæ are more or less toothed in the male. The elytra or wing-covers have parallel grooves in them. They usually stop short of the abdomen of which the hinder portion is therefore more or less conspicuous. The third pair of legs is much enlarged somewhat as in a flea. The abdomen below and wing-covers above are more or less hairy. There are various markings on the wing-covers, which, however, vary both with species and individuals.

PACHYMERUS (BRUCHUS) CHINENSIS.

Of the species found in Mysore attacking stored pulses, *P. chinensis* is among the commonest. Fig. 4 shows an individual of this species. The markings seen are not, however,

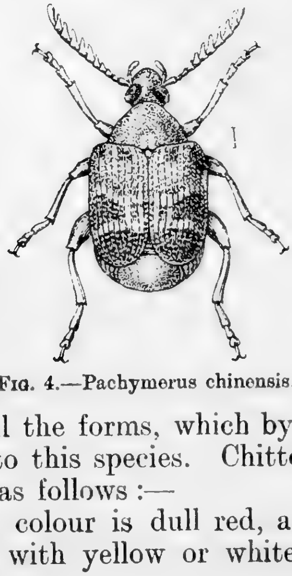


FIG. 4.—Pachymerus chinensis.

characteristic of all the forms, which by rearing have been proved to belong to this species. Chittenden in describing the species writes as follows :—

" The ground colour is dull red, and sometimes more or less variegated with yellow or white pubescence. The pattern of the elytra varies, that shown in the illustration being the prevailing form of specimens reared in the District of Columbia. The darkest spots at the sides are not round and conspicuous as in the four-spotted bean weevil and the special spots are wanting while often black is the prevailing colour of the dorsal surface[1]."

The description shows quite clearly the variability of the markings but not either the range or extent it has in Mysore. The progeny reared from common parents show so wide a range that, without the knowledge of their parentage, the individuals are likely to be regarded as not belonging to the same species. The extremes are represented on the one side by the entire absence of markings and hairs on the elytra and on the other by a blackening which involves more than half their length. Chittenden's description is therefore that of an intermediate form. The variation is not confined to the markings alone. The male antennæ are not always pectinate but may also be serrate and the serrations may not be conspicuous.

What these variations are due to, it is impossible to say in the present state of our investigation. They are not, however, the result of a difference in seed as cow-pea (*Vigna catiang*); black-gram, green-gram (*Phaseolus mungo*), etc., made no difference in progeny. A large moisture content appears to produce a darker coloration but not sufficient to alter or obscure the markings. From the results obtained, it does not appear likely that forms now regarded as distinct species can successfully cross, but it is too early to say whether this possibility can be altogether excluded. It is certain, however, that the limits of the species are much wider than have been hitherto indicated in the description by Fabricius and others.

Life History.

The life history of all the forms attacking stored pulses is more or less identical, the differences being confined to details. There are, however, interesting points which have to be gone into at some considerable length to enable the reader to understand the remedies tried and recommended and to follow the discussion which has to be raised hereafter of the habits of some of the species.

The egg is oval-shaped, but unlike most eggs is drawn

[1]. The Year Book of the Department of Agriculture of the United States for 1898. Page 243, Footnote No. 1.

almost to a point at the narrow end. It is about ·3 mm. in length and about half of that in breadth (Fig. 5). Immediately before extrusion, the contents lie a little loose in the shell. When laid, the egg, therefore, is able to adjust itself to the surface of the seed so that it loses its convexity on one side and becomes flat. With this flattening, the egg also becomes fuller. The egg comes out of the body bathed in a gummy secretion which, besides fixing firmly the flattened side of the egg to the seed, forms a broad rim around the edge which further strengthens the attachment. When the egg is first laid, it is clear and almost transparent; but later on, the protoplasm becomes granular and opaque except at the broad end which remains clear for

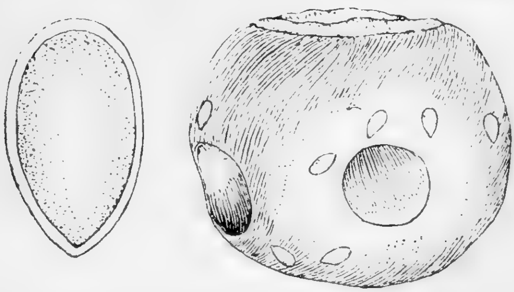


Fig. 5.—Seed of Cajanus indicus showing eggs, disc cut by a larva, and hole through which a beetle emerged. To the left an egg is figured much enlarged to show the rim around.

some time longer. In this latter region the black head of the larva appears later. The larva takes from four to seven days to hatch, the time varying with the season. When hatched, it lies on its back and the brown mandibles are seen at the most convex region, standing out conspicuously against the shining black head.

The larva is a thick-set grub about ½ mm. long (Fig. 6). It is pale and opaque and shows clearly thirteen divisions besides the head. There are three pairs of legs which are all reduced to conical stumps except the first pair which shows signs of division and appears under the high power of a microscope to be terminated by a number of very small spines. The mouth parts are adapted for boring. The mandibles are capacious and prominent with a very broad hinge above and narrowing down to a point at the tip below. The labrum is drawn out in the shape of a tongue and lies close above the mandibles. The maxillæ are reduced to bristly stumps which are situated just behind the mandibles. The labium is absent as is to be expected, for its presence would interfere with the working back of the excavated powder or meal.

The chitinous plate from which it springs is prolonged into a triangular process so that the meal will be worked along its sloping sides.

The most remarkable feature of the larva is the presence of a curved H-shaped chitinous plate (Fig. 6) which is situated far forward dorsally on the first thoracic segment. The

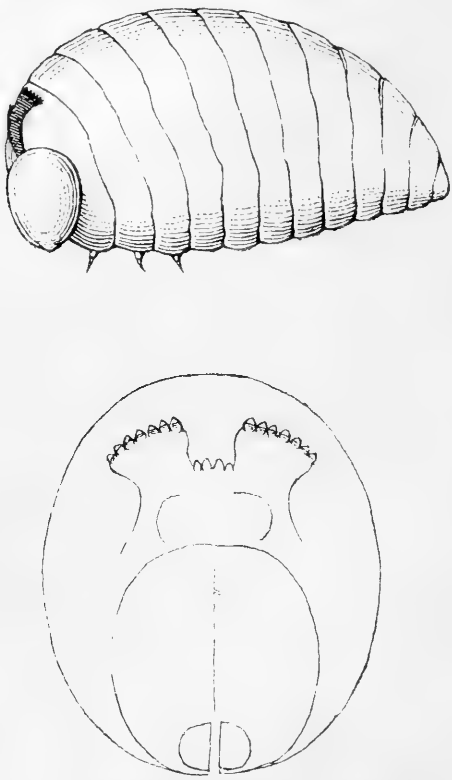


Fig. 6.—Above, larva of Pachymerus chinensis, showing the chitinous process. Below, the chitinous process as it stands on the prothorax. (Front view.)

upper limbs of the H have seven teeth gradually diminishing in size towards the outer extremity and bent on themselves so that they are all blunt. At the place of the cross piece in the H there are four teeth similarly curved and blunt. The whole structure is curved backwards so as to follow the curvature of the segment, but it can be erected at an angle to the body which may be very obtuse.

How the Larva Bores.

We are now in a position to follow the procedure of the larva in effecting entry into the seed. The larva which is on its back when hatched turns over so that the ventral side is below. The head, as already stated, is at the broader end of the egg where the hole is made. Before making the excavation, the H-shaped chitinous plate is brought at a convenient angle and fixed against the egg shell in which process the re-curved teeth of the upper limbs are of considerable help (Fig. 7). Once the teeth of the plate are fixed, the larva begins operation by working the mandibles alternately or together according as the work is for excavation or for

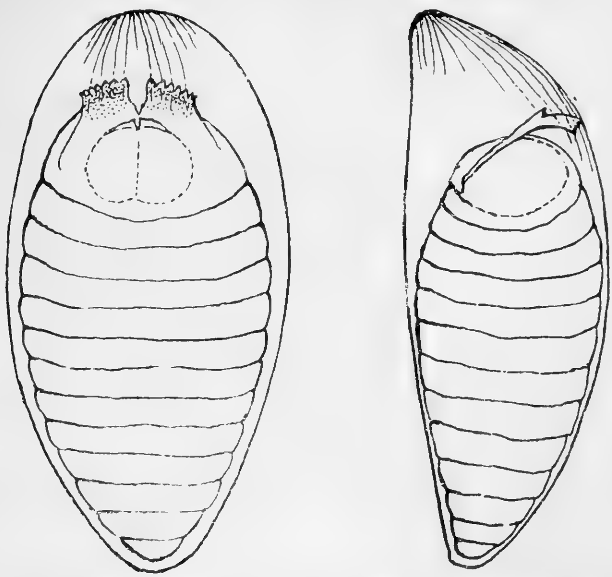


Fig. 7.—Larva showing how the chitinous process is fixed against the egg shell. Left side, top view. Right side, side view. Note the radiating grooves made in the egg shell.

collecting the powder excavated. The chitinous process apparently serves a two-fold object. It stands on a small movable fold of skin which can be rapidly moved backwards and forwards so that the head may be nearly covered or completely free. When the teeth are fixed against the egg shell far behind, *i.e.*, near its greatest convexity in the thoracic region, the head is freer and the mandibles are engaged in the anterior half of the hole; when, on the other hand, the posterior half of the hole has to be made, the chitinous structure is adjusted further forwards. In either case, the angle at which the chitinous process is fixed against the egg shell, appears to determine the inclination of the head and consequently the part of the hole that the larva works on at a particular moment.

To understand clearly why the larva does not actually bend its head downwards as one might expect it to do in these circumstances, it has to be remembered that its body is very short and thick. It seems certain, therefore, that any active bending of the body would have to take place in the middle so as to form a semi-circular shape which, in fact, the larva does take in later stages of the growth. In these earliest stages, while the larva is still practically restricted to the narrow confines of the egg shell, there is no room for such a bending process. Moreover, as the legs are atrophied, they cannot function in gripping the surface of the seed. The posterior end of the egg is also narrow and is fully occupied by the abdomen of the larva.

The procedure which the larva follows in boring into the seed is therefore very different from what one might expect. The forces exerted in the prócess of boring into the seed seem to be of two kinds. Firstly, the chitinous process being fixed against the egg shell in the region of its greatest convexity, forms a firm base for the action of the mandibular muscles. Secondly, there is a thrust forward from the abdominal end which, as already stated, is closely applied to the egg shell. This forward movement is, by reason of the attachment of the H-shaped process to the egg shell, converted into a vertical force thrusting the mandibles against the surface of the seed.

As the larva is working, the chitinous process sways forward and backward with the teeth as fulcra, and the lower limbs of the H expand and contract as the head is pushed downward out of the hood or withdrawn. When the sides of the hole have to be excavated, the larva turns a little to the right or to the left. In the process of turning from one side to the other, the larva may turn completely over. The meal excavated is worked back to the pointed end of the egg by a peristaltic movement of the ventral surface. A little is also worked on the sides of the egg shell. When the hole is sufficiently large, the head with the chitinous process closely pressed against the first segment is first inserted. For obvious reasons the operations inside cannot be followed, but larvæ which have penetrated thus far, when exposed, show a much attenuated neck and a swollen abdomen into which apparently the viscera have been pushed back. The advantages of a narrow neck in enabling the head to work all round the hole with ease, are obvious. There are reasons to believe from observations made on penetration by the larvæ of free living forms that the chitinous process is fixed along the side of the hole during further excavations deeper into the seed. From the above description it will be seen that the chitinous process is not used as an excavating organ.

Occasionally, larvæ may be found turning over to lie on their backs and nibbling the egg shell with the mandibles so as to produce a transverse marking on it. What the object of this operation is, is not clear. It is possible, however, that it roughens that part of the interior of the egg shell and is intended to get for the teeth of the chitinous process a better grip.

The tension on the egg shell exerted by the larva soon reveals itself in minute folds radiating from the anterior and posterior extremities of the egg shell (Fig. 7). There are also shallow grooves produced by the teeth of the chitinous process as they are moved forward or backward during the course of larval adjustments. The force so exerted by the chitinous process may be so great as to rupture the egg shell. This break is usually observed in the region of the greatest convexity of the egg and through it meal from the excavation may also be seen to come out.

There has been some obscurity in the past in regard to the function of the chitinous process. Riley[1] was the first to draw attention to this structure in the post-embryonic larva of *B. fabœ*. After describing the larva at length he proceeds :—

"We are not aware that similar structural peculiarities in the first larval stages of Bruchus have been pointed out before. They seem to indicate, perhaps, affinities with Chrysomelidæ and are evidently of advantage in aiding the young creature in the work it has to do. This stage is very evanescent. Immediately after finding the proper spot for entering the bean, the larva *gnaws* its way in and moults."

The description, while it does not disclose the function of the chitinous process, attributes the actual excavation to the jaws.

Chittenden[2] is even less clear in regard to the allocation of functions. Apparently following Riley, in describing the same larva, he states "that both plates and legs are evanescent but they assist the larva in obtaining the entrance into the seed." Chittenden figures the chitinous plates for each of the other species he describes but has not made any statement in regard to it in these either. There is, however, little

. Riley. Insect Life, Vol. IV, Page 300.

. Chittenden. Year Book of the Department of Agriculture, 1898, Page 236, Footnote No. 2.

reason to believe that he looked upon them as having functions different from those attributed to it in *B. pisorum*. In any case Lefroy[1], apparently on Chittenden's authority, has stated in regard to Bruchid larvæ generally that "the larva is provided with three pairs of incomplete but functional legs as well as a series of thoracic plates which enable the larva to bore into the seed and establish itself." Fletcher[2] also appears to attribute a share in the excavation to the chitinous process of a free living form *P. chinensis* as he calls it. He states "that the young newly hatched grub is slender, darkish-coloured and hairy with long slender thoracic legs and a well-developed prothoracic plate which is armed with peculiarly sharp toothed edges which help the grub to bore into the shell of the pod which the grub at once proceeds to do and then eats its way into the seed."

The quotations given above are with reference mainly to the free-living forms. We have not yet had an opportunity to study fully the process of penetration in the various free-living forms; but if we may judge from the analogy of the forms examined, any share in excavation, as is suggested by the quotations given above, for the chitinous process in the former, is highly problematical. The apparatus is situated immediately behind the head before the thoracic prominence begins. In case the larva is supposed to work with the chitinous process in the normal way, *i.e.*, ventrally, the hood in which the process is situated has to travel over the head down below, so far indeed that it will pass over the mandibles. On the other hand, if the larva works on its back, which is what one is likely to be led to expect from the inverted position in hatching, the chitinous process will, in its work, encounter the thoracic prominence which will prove thus a serious obstacle. Furthermore, the mandibles are far more powerful than the chitinous process which is very slender. It appears to us, therefore, that the function of the chitinous process in Bruchid larva cannot be very different in the various species from what has been described, at least in those species in which the eggs are laid flat on the surface of the seed and are attached to it.

In any case, in the light now thrown on the process of excavation in *P. chinensis*, the behaviour of the post-embryonic larvæ of other species has to be examined, more especially of the free-living forms. The chitinous structure appears to vary a great deal. For each one of the species

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1. Lefroy. Indian Insect Life, Page 350.
2. Fletcher. Some South Indian Insects, Page 307.

studied by Chittenden the chitinous process figured differs considerably. It has peculiarly sharp teeth in *B. pisorum* in which the larva has got three "apparent joints" in each leg. In *B. obtectus* which is said to deposit eggs on the outside of the pods as well as inside, the teeth of the chitinous process are blunter, but the legs are better developed. The plate and legs in *P. chinensis* have already been described. In *B. quadrimaculatus,* Chittenden says "the teeth are sharper and the thorax is armed on the lower portion of the plate with three acutely pointed teeth on each side[1]." If by this is implied the lower teeth are absent in *P. chinensis,* Chittenden has failed to observe them in the latter species. In any case there can be no doubt that there is a remarkable variety in strength and form of the structure so peculiar to Bruchid larvæ which may help in explaining such apparently small differences in the habit of egg-laying as oviposition on green pods, dry pods, inside the pods, etc. It is proposed to discuss these in greater detail in the bulletin on free-living forms.

The Subsequent History of the Larva.

Soon after effecting entry into the seed, the larva casts its skin. Before it does so it swells considerably, nearly twice its size when hatched. The thoracic region is considerably arched at the time and there is a kind of jerking movement affecting the whole body, probably in order to split the skin. The skin ruptures usually along the thorax, but extends to the head as far as the triangular piece above the labrum. The larva emerging from the skin is no longer provided with the chitinous process. The legs are still further reduced and appear only as conical prominences. The mouth parts do not alter appreciably. The shape assumed by the larva in the second instar, it continues to have until pupation. The larva usually lies in a doubled up condition. This enables it to move about in the chamber with greater ease than if it lay along its full length. The pupating chamber has as its boundary on one side, the seed coat in which the larva cuts a ring. The chamber is smoothened with a secretion from the larva, apparently similar to that out of which a cocoon is formed in Cary-borus gonagra. The period of pupation varies from seven to twelve days. The adult after emergence remains in the chamber for about two days until the integument hardens. Afterwards it

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1. Chittenden, loc. cit. footnote page 247.

bites through the ring so that the disc falls off, and then emerges from the seed. The ring, though it is made by the larva, does not appear to be necessary for the emergence of the beetle. Beetles emerged successfully from cow-pea seeds in which the position of the pupæ was reversed and which were glued on to the glass at the disc end of the pupal chamber. There is also reason to believe that the larvæ, which later on turn into the beetles that hibernate, do not cut a ring. The larvæ pupate just near the seed coat as usual and the rings cut by the beetles in these chambers are as neat as those cut by the larvæ. The absence of the ring makes the insect inside less subject to the changes of weather and this is probably the reason why no rings are cut by such larvæ. When seeds with such pupal chambers are sown, the beetles make their escape as soon as the seed coats burst.

The total period required to complete the life history varies from nineteen days to as much as one month and twenty-one days. The shortest period is during the warm weather and the longest, during the cold weather.

The life history described above is different in important details from that described by Fletcher. The figure of the larva given by him is acknowledged to be after Chittenden. But he states that it *has long slender thoracic legs* "and the prothoracic plate is armed with peculiarly sharp teeth[1]." Chittenden, on the other hand, says in regard to the larva that it is, of course, smaller than that of the pea weevil, *the minute temporary legs* are apparently not jointed and the prothoracic plate bears *blunt rounded teeth* instead of acute spines. There appears, therefore, to have been a mistake which is in all probability one of identification. From the description given later, Fletcher clearly looks upon the species as a serious pest in the field; for, he recommends that "the insects may be caught with hand nets in the evening when they are abundant." It is clear, therefore, that he regards the species as free-living. On the other hand, Chittenden[2] says "that eggs are laid both on the outside of the pod in the field and upon dried seeds and notes that beetles continue to develop in the dried and stored seed for several generations until the seed becomes completely ruined for any practical purpose and unfit for the sustenance of this insect." That is to say, the insect is more important as a pest of stored grain. We have obtained eggs laid on the

1. Fletcher loc. cit. Page 307.
2. Chittenden loc. cit. Page 244.

seeds in the open pods before harvest but have failed to get the beetles to oviposit on the growing pods. The life history described by Fletcher is, therefore, not that of a free-living form. There is a free-living Bruchid which is common in Mysore on red gram in the field and whose larvæ are provided with legs and thoracic armature of the description given by Fletcher. The life history described by him, in all probability, is of this species. This form is, however, unable to multiply in the store as has been found by experiment.

Habits of Beetles.

The adults appear to take no food during their life. Beetles emerged on the same date died nearly about the same time whether they were provided with seeds or not. Nor were any markings visible on the seeds even though a fine powder was found deposited in the dishes in which beetles were kept along with seeds. Dissection showed the alimentary canal empty, except for a little white stuff near the origin of the malphigian tubes, evidently the excretion from the latter.

Beetles may copulate and lay eggs soon after emergence. The eggs are usually laid in the upper layer of seeds only. When the topmost layer of seed is so riddled and excavated that there is no more food for the larva, the beetles proceed to the layer next below which is less injured, so that, on examining a lot of infested pulses long kept in store, the percentage of injured seeds is found to diminish gradually the further they are below the top surface. It is clear, therefore, that beetles always come up to the top, wherever they happen to emerge in the receptacle. They generally remain there without flying away if they are not disturbed. Usually, however, when the store is opened they appear to be disturbed and a number escape. This disturbance results apparently from the difference in temperature, for it is higher in an infested store than outside. When no lid is provided for the receptacle, most of the emerging beetles may remain on the top without flying away.

The instinct of the beetles to seek the top surface on emergence is of great advantage. The initial infestation at the time of storing is only of a few seeds. It follows that the few beetles emerging in different places in the receptacle separated by several hundreds of seeds, cannot find one another for purposes of copulation unless they all reach a common place. Secondly, even if they happen to meet layers beneath the top surface, there cannot be any freedom of movement required for the female beetles to travel over a large number of seeds and deposit their eggs; for eggs cannot be crowded on a few seeds without the risk of hampering the development of several, which, distributed over a larger number of seeds, might have a better chance of completing their development. On the top surface, there is no pressure of surrounding seeds but on the other hand complete freedom of movement.

To ascertain what exactly induces the beetles to come to the top, the following experiment was conducted. A tin box was filled with infested gram so as to leave no space above the top surface for beetles to move freely and lay their eggs. Into the tin six large holes were bored, four at the sides at right angles, one in the middle on the lid above and one on the bottom below. Into each of these holes a glass cylinder six inches long was fixed. All the cylinders were filled with uninfested gram for about half their length, the seeds in the cylinder at the bottom being prevented from falling by a paper disc fixed into it, with holes sufficiently big for the beetles to pass through but too small for the seeds (Fig. 8). This arrangement prevented the possibility of any beetles emerging from the seeds inside the cylinders themselves, but to make it absolutely certain, the uninfested seeds were made to extend inwards into the tin for a little way from the cylinders. The cylinders were then corked to prevent beetles from escaping. When the arrangements were complete, the gram from the cylinders above and below A and D had a straight level but in the four cylinders at the sides it sloped towards the cork B, C, E and F. It is clear that pressure is greatest on seeds in the bottom cylinder D, less in the cylinder on top A and least in cylinders B, C, E and F. On emergence of beetles inside, by far the larger number worked their way into the top cylinder, a few were found in each of the four cylinders at the sides, but none at all in the cylinder below. The beetles in two of the side cylinders B and E. were now allowed to escape, the grain was pressed back and kept at that level by means of a paper disc with holes as in cylinder D. The result was that into these two beetles ceased to come up while in the other two C and F which were left as in the first experiment, they continued to appear. When the paper discs were removed from the cylinders C and F and inserted in B and E instead, the beetles put in their appearance in the former but not in the latter.

These experiments appear to us to prove that beetles work their way upwards on emergence; secondly, that it is to get relief from the weight of the seeds on top of them that beetles move upwards. The presence of beetles in the cylinders at the sides, B, C, E and F may appear to contradict

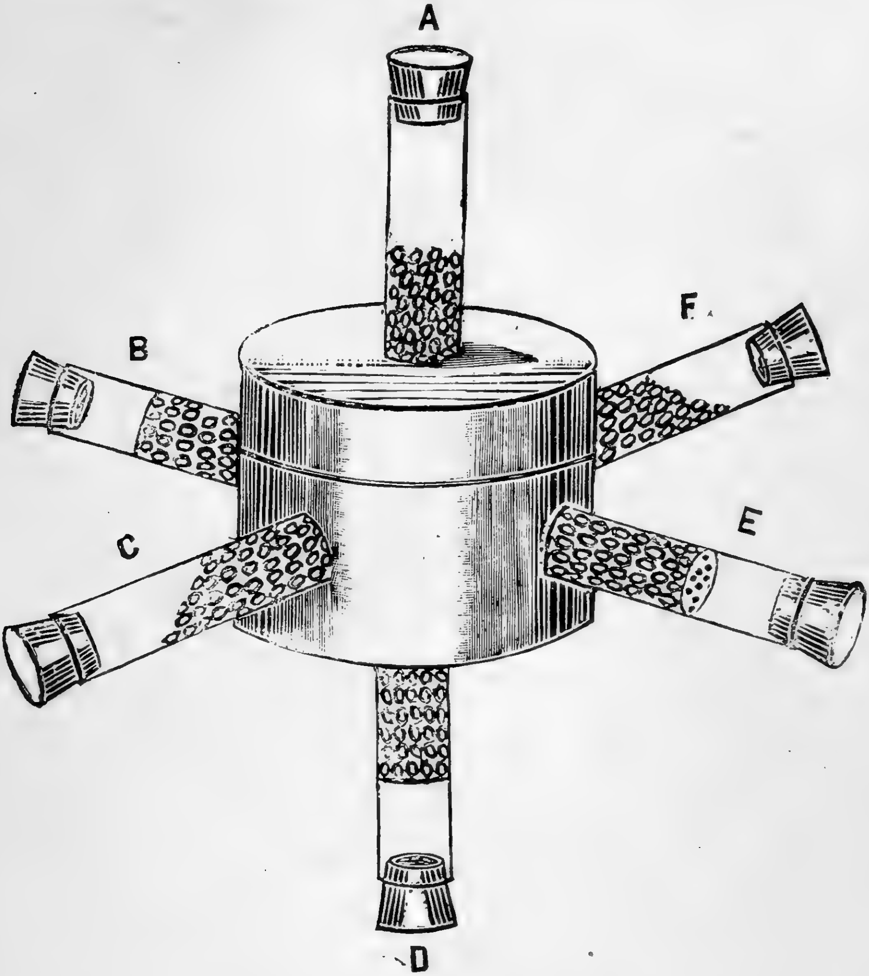

Fig. 8.—Cylindrical tin box containing infested gram and having tubes inserted as described on page 14.

the conclusion drawn. The few beetles found in these are, however, those that have been deflected from their upward movement by the diminished pressure among seeds in the neighbourhood of the insertion of the cylinders. It will be recalled that, at the commencement of the experiment, the seeds in these cylinders sloped and that therefore there could not be the same pressure in them or in their neighbourhood inside the tin, as in cylinders A and D. The beetles working their way upwards to the top surface in the tin are certain to feel the difference as soon as they come within the area and make for the direction where pressure is less. That it is so is proved by the fact that no beetles appeared in those cylinders where the seeds were pressed back by paper discs. The negative geotropism exhibited by the insects appears thus to be directly caused by the weight of the seeds above them which they feel when they emerge. As they move upwards this weight becomes less and less until it disappears completely when they reach the top surface.

The pest appears to be carried over from year to year by the adults. Adults have been taken from situations near which pulses were stored. They have also been taken in the field in seasons of the year when the crops which they attack are not yet ripe. At the time of harvest, a number of pods are dry and open. The beetles get at the exposed seeds in these pods and lay eggs on them. Infestation may also take place during the interval between harvest and storage or in the store itself. In one instance where multiplication had ceased for over a year in a quantity of infested seeds kept in a bottle, a fresh attack ensued in spite of the fact that the jar was never opened during the interval.

Three species of parasites have been reared out, of which two are black-bodied species, one large and the other small. These do not multiply in large numbers proportionate to the number of beetles until the infestation has advanced far. They are, therefore, of little use as checks. As many as six have been reared out from one larva but the number varies and probably depends on the size of the larva at the time of oviposition. Boring has been observed to take place through the egg shells and through the other parts of the seed far removed from them. The following is an account of observations made by Dr. Coleman and kindly furnished for this bulletin :—

"Female parasite explored surface of seed with feelers bent down. Then she raised herself and brought tip of abdomen down between the hind legs in almost vertical position. The tip of the abdomen was then moved away posteriorly leaving the tips of ovipositors in a vertical position. Boring did not immediately take place, but tips of ovipositors were moved about on the surface of egg as if seeking the most favourable point for penetration.

Frequently the process stopped here and parasite moved again as if not satisfied with the position. This was observed to happen in one case as often as five times.

"When the position was finally found, satisfactory boring commenced (Fig. 9). This consisted practically of a vertical drilling motion consisting of raising and depressing of abdomen. Small quantities of meal (borings) could be seen about the ovipositors. The boring lasted in the two cases observed about 15 minutes and at the end, the ovipositors were sunk into the seed right up to the sheath and the top of the abdomen was then pulled out and the parasite walked away. During the act of drilling, the insect keeps up a jerky movement of the outer antennæ.

FIG. 9.—Bruchocida orientalis ovipositing through seed of Cajanus indicus. Note ovipositor between middle and hind legs. (From photograph.)

"Oviposition has been observed to take place in the centre of the hilum also. The following are the descriptions of the two species:—

BRUCHOCIDA ORIENTALIS, (CRAWFORD.) (Fig. 10.)

"*Female.*—Length about 4 mm.; sheaths of ovipositor exposed 1 mm.; bronzy, with tints of green, the scape of antennæ reddish, pedicel green, rest of antennæ dark brown; first joint of funicle about one and one-half times as long as the pedicel, the following joints successively decreasing in length, the last somewhat longer than broad; very similar in sculpture to *B. vuilleti*; wings with white hair as far out as the apex of submarginal vein; beyond this the hairs dark, longer and more numerous than in *vuilleti* and the wings somewhat infuscated; front and hind coxæ bronzy; front and middle legs and middle coxæ reddish ; hind legs darker with bronzy tints ; tarsi white.

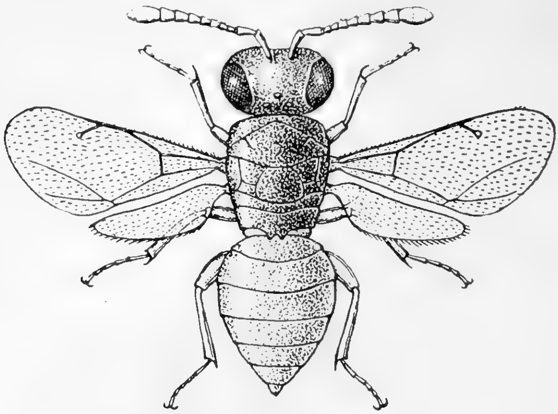

FIG. 10.—Bruchocida orientalis.

" Three females, Bangalore, India, reared from Bruchus chinensis. (L. C. Coleman, Collector.)

BRUCHOBIUS COLEMANI, (CRAWFORD). (FIG. 11.)

" *Female.*—Length about 2·5 mm. Similar in color and sculpture to *B. laticeps*, Ashmead, but the third ring joint transverse ; marginal vein over half as long as the submarginal ; postmarginal shorter than the marginal (about

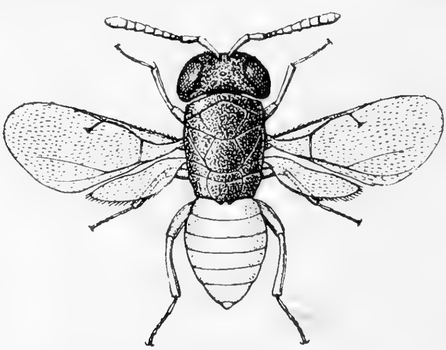

FIG. 11.—Bruchobius colemani.

as 12:17) ; stigmal shorter than postmarginal (about as 8:12) ; stigmal knob enlarged ; femora dark, the hind femora mostly greenish anteriorly.

" *Male.*—Length about 2 mm. Similar to the female, the antennæ with two ring joints, the scape and pedicel reddish-honey color, funicle somewhat lighter, club darker ;

first joint of funicle as long as the second; legs reddish-honey color; hind femora somewhat darkened and with a small spot with metallic reflections; abdomen no longer than propodeum.

"*Habitat.*—Bangalore, Mysore, India."

A minute egg parasite less than ·3 mm has been noticed recently in very large numbers. It has a yellow body and red eyes. The eggs attacked by this hymenopteran turn blackish in a couple of days after oviposition and the development is completed in about ten days, the adult coming out through a neat hole made at the broad end of the egg shell. The species has not yet been identified.

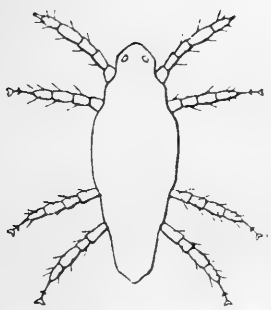

Fig. 12.—Pediculoides ventricosus ? in an early stage.

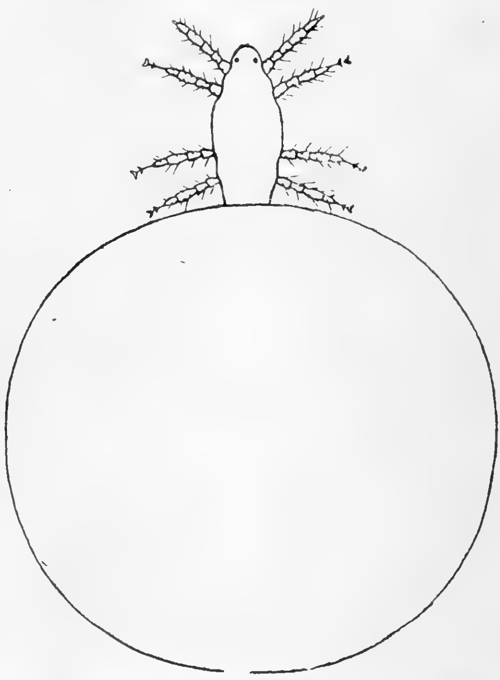

Fig. 13.—Pediculoides ventricosus ? a gravid female.

A fourth enemy is a species of mite, probably Pediculoides ventricosus, described as a pest on the broad bean weevil[1], (Fig. 12) which attacks the larva, pupa and the adult inside the pupal chamber. The enormously swollen abdomen of the gravid female (Fig. 13) all but conceals the rest of the body. Before this advanced stage of maturity, the female resembles the male mite which is very minute and both may be found at times moving among the seeds in large numbers. The body is about thrice as long as broad and is

1. Chittenden. The Broad Bean Weevil. U. S. Department of Agriculture. Bulletin No. 96, Part V, 1912.

slightly swollen in the middle. The posterior three legs end in suckers. There are a pair of eyes. Some of these may be found in the empty egg shells. Probably they effect an entry through these and keep track of the larva. This enemy is not found at all times and is by no means a serious check on the pest.

Control Measures.

The remedy universally suggested by Entomologists is fumigation of the seed before storage or whenever the seeds are found to be infested. This consists in exposing the seeds to the fumes of carbon bisulphide or hydrocyanic acid in an air-tight receptacle until the insects are dead. A fumigation chamber can be made at a low cost out of a tin-lined dealwood box. It is provided with a rim in which runs a groove into which the lid fits. Water is run round the channel after the lid is put on. The infested seed is put into the receptacle and carbon bisulphide is placed on the top of the seed in a shallow dish. The fumes of the chemical are heavier than air and descend to the bottom. In doing so the insects and their various stages get killed. The dose is at the rate of 2 lbs. per thousand cubic feet of space but in small chambers of a few cubic feet, it is usually doubled. The seed is removed after two days and stored in a larger receptacle which should also be air-tight to prevent the beetles getting in. Large quantities may be fumigated in rooms; provided these can be made air-tight. Great care has to be taken in the case of the chemical as it is highly inflammable. No light of any kind, not even that of a lighted cigar, should be brought anywhere near the chemical, nor should bottles containing it be placed in the sun or in any other warm place. Otherwise there is danger of serious explosion. Hydrocyanic acid gas is also an efficient fumigant but is even more dangerous to human life. It is prepared by dropping crystals of potassium cyanide into dilute sulphuric acid, the crystals being previously enclosed in thin paper to avoid a too rapid evolution of the gas. This gas is one of the most violent poisons known and immediately the crystals are dropped, the lid should be put on and the operator should withdraw. The dose for a 100 cubic feet of space is the gas produced by dropping one ounce of potassium cyanide (98 per cent grade) into an ounce of sulphuric acid diluted with 3 fluid ounces of water. For fumigating seeds hydrocyanic acid gas is, however, not usually employed.

Both the chemicals mentioned are fatal to human life. This does not, perhaps, detract from their value as fumigants where the seed to be treated is a very large quantity and fumigation done under intelligent supervision. But the problem in Mysore is different where there are a multitude of small producers who store their pulses for the greater part of the year both for purposes of consumption and for seed and who, moreover, live in houses in which fumigation cannot be conducted under reasonable safeguards. (Frontispiece Fig. 2) Their illiteracy is an even more serious obstacle in the way of recommending the use of dangerous and highly explosive chemicals.

Means, therefore had to be devised other than fumigation to keep the stores of the raiyat from the beetles. From the very beginning of the investigation the aim was kept steadily in view of finding a remedy which was inexpensive and at the same time adapted to conditions in which the raiyats lived and worked. It was necessary for the realisation of this object to study the methods already in practice among the raiyat population.

The results of the enquiry have been very encouraging and are briefly summarised. It is an essential preliminary to all storage that the seeds should be dried in the sun for three days. After thorough drying the seed is stored in large earthen pots, bins made of split bamboo or in bags made of gunny or matting. The capacity of the pots may vary from a few seers[1] to as many as a hundred or more. The bin is made of split bamboo having a large bulging base with a narrow neck. The seed is taken, when wanted, out of a small hole large enough for the hand near the bottom. This is closed by a cocoanut shell brought close against it by a string passing through the eye (Fig. 14). This arrangement obviates the necessity of disturbing the top layers. The disc put on once remains closed except when the whole basket has to be emptied. Bins may be made with interlaced bamboo smeared over with clay. Bamboo bins may be also cylindrical, but pulses are not generally stored in such. The more usual practice is to store them in bags, gunny or matting, which are always kept one on top of another. A most interesting method is to store in what are called "moodais," which are made out of pelted straw and which when completed are spherical (Frontispiece Fig. 1). These "moodais" are tightened further by means of ropes

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1. A 'seer' is a local measure equivalent to about 1250 C.Cs.

all round. It takes as much as a day to make one so that raiyats are tempted to abandon the method even though they have a great deal of faith in it. The seeds may be mixed with sand, ashes, ragi husk, etc., before storage. In baskets they are not so mixed, but the top layer may be smeared over with castor oil. A practice which evidently prevailed among the people but is no longer so, is the use of a small quantity of mercury—little more than a few drops—which is placed in-

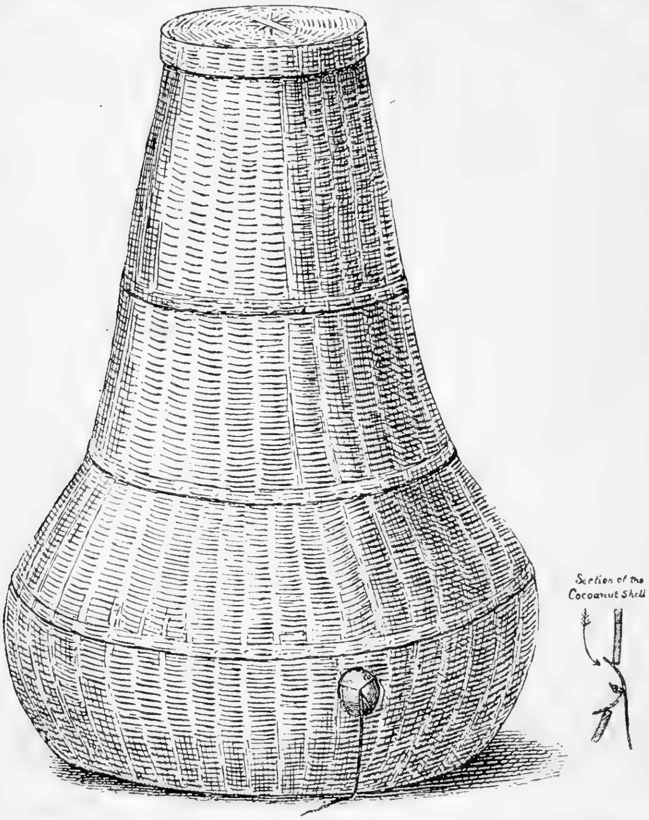

FIG 14.—Bamboo bin with narrow mouth shewing arrangement for withdrawing seed from below.

side the excavated shell of a soapnut in the store. With the exception of storage in "moodais," all these methods have been tried in the Insectary. The admixture of sand, ashes, ragi husk, etc., was found entirely useless. The layer of seeds smeared over with castor oil was found, on the other hand, quite effective though emergence was by no means absolutely prevented. Similar results were obtained with mercury which were quite unexpected. In small jars of a capacity of a few seers, the presence of the metal placed in a dish absolutely prevented emergence while the check teemed with beetles. It made no difference whether light had access to the jar or not. In large receptacles containing 100 seers and more, the effect was not so marked even though emergence was reduced by about three-fourths. To decide in which stage of life of the beetles the mercury acted as a poison, the following experiment was tried. Four lots of seeds one in which the beetles had just laid eggs, second in which the larvæ were about half grown, third in which the larvæ had pupated, and fourth in which the beetles had emerged, were all exposed to the action of mercury with corresponding check in each case. It was found that the effect was on eggs in which the protoplasm was apparently disintegrated and the shells became empty. It is possible that no effect was produced on either the larvæ or pupæ because these stages are wholly spent inside the seed. A fresh series of experiments was carried out which appears to show that the mercury has no action on the eggs once the larvæ are fully formed. Detailed results of these experiments which are of scientific rather than of practical interest will be published elsewhere. For the present it is enough to state that, to preserve small quantities from attack, a little mercury placed in the receptacle which need not be air-tight will be quite effective. The treatment does not affect germination.

With regard to castor oil, the secret of its undoubted efficacy was not revealed until the investigation had continued for some time and the method of penetration by the larvæ was discovered.

It will have become clear from the method of larval penetration described, that the larva would be quite helpless if the eggs were not firmly attached to the seed as its main hold is on the egg shell. Larvæ carefully dissected out of the egg shell invariably fail to effect an entry into the seed. Now we find that the smearing of the seeds with oil prevents the close adherence of the egg to the seed. Eggs deposited on seeds so treated fail to assume their normal form, and even if they do hatch, fail to furnish the larva with the support that it requires for boring into the seed. For, immediately it starts the boring, the egg shell begins to move.

Observations on the effect of castor oil when smeared on the upper surface led to the discovery of the instinct of the beetles to seek the top surface. As has already been stated, there was hardly any emergence in seeds which had the top layer treated with the oil. In this case the beetles had been introduced after the top layer was treated. There was therefore reasonable ground to believe that the beetles laid eggs on the treated seeds as being the first they met with. In a subsequent experiment a quantity of infested seeds was placed at the bottom of the pot, uninfested seed about four times the quantity was placed on top of it and then the layer of oiled seeds was introduced. In spite of it, the results were the same. It appeared, therefore, certain that in this experiment too, beetles had sought the top surface for egg laying even though they must have emerged far below the surface. It was this fact coupled with the observation that the percentage of infested seeds diminished directly with their depth from the surface that established beyond a doubt the instinct of the beetles to seek always the top surface.

Once the discovery was made, the wisdom of some of the methods adopted by the raiyats became clear at once. The bamboo bin with a narrow neck and a hole at the side appeared admirably suited to prevent serious damage by the beetles; for, in this arrangement, the top surface is very much reduced and is left undisturbed. In the "moodais" there is no level surface on top at all and the seeds are packed so close together that there is little space afforded to the beetles to proceed far from the place of emergence to find a male or to lay their eggs. When the seeds are mixed with husk in these, the interspaces between the seeds are still further reduced. The practice of keeping these "moodais," bags, etc., one on top of another is also to be recommended as the pressure so exerted tends to reduce further the space between the seeds, required by the beetles and hinder their multiplication. With regard to oiling the top layer of seeds, the method, though effective, does not entirely prevent beetles from getting into the untreated layer below and laying their eggs on the seeds there.

Another method that deserves notice is the storage of pulses under ragi (*Eleusine coracana*) or savai (*Panicum frumentaceum*). These grains are not attacked by pulse beetles. When they are used as a top layer several inches deep, the beetles, on emergence to the surface, do not generally get back to the pulses below and the latter are usually saved from attack.

There can be no question that these methods reduce damage to a great extent. At the same time, without considerable care, the few that manage to emerge may successfully reproduce and there is the chance of injury extending to a considerable percentage of the seeds. To effect improvements, it was necessary to prevent the beetles that came to the surface from getting back to the seed for oviposition. The device first thought of was what may be called a paper trap (Fig. 15). A number of semi-circular rings are cut into the paper. The paper is closely adjusted to the surface of the seeds, so that there is no space between them and the paper. The beetles, on emergence, will get through the holes

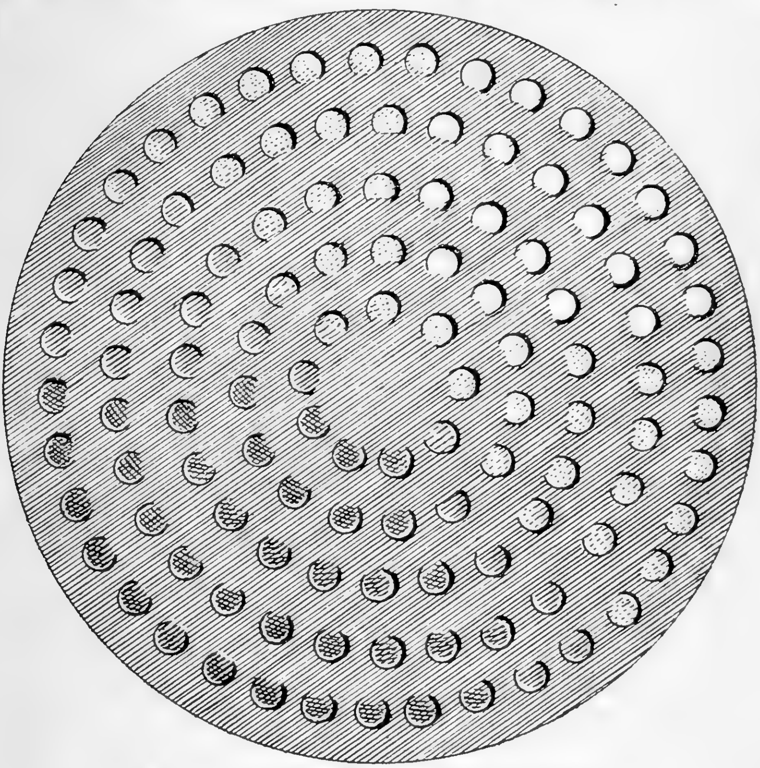

FIG. 15 —Paper trap shewing discs cut into it.

on to the top of the paper, but fail to get back as the semi-circular disc comes in contact against the seeds directly they try to do so and unless the disc is lifted up or drawn a good way, there is no hole sufficiently large for the beetles to pass through. Properly adjusted, the paper trap was absolutely effective. There were drawbacks, however, to an extensive adoption of this device. In the first place, unless the bins are standardised, the size of the paper will have to be varied according to the size of the neck, or, if the bin is not full, to the size required to completely cover the top layer at whatever level this happens to be. Secondly, any careless adjustment may afford sufficient room for the beetles below the paper to move about as they please, and consequently to reproduce. The idea was thus abandoned. The next idea that occurred was to have a layer of seeds of castor, (*Ricinus communis*) or of *Abrus precatorius* on the top of the pulses. Castor has got a very thick shell too hard for the larva to penetrate and develop and *Abrus precatorius* has a very smooth seed coat. When beetles were compelled to lay eggs on these, no progeny followed even though a number of larvæ successfully penetrated. Unfortunately, however, when these seeds were spread as a top layer, the insects while they came above them on emergence, got back to the pulses below instead of depositing the eggs on the seeds above. The last idea was to spread a layer of sand. This had been tried previously mixed with pulses and had proved useless because, as was found later, the beetles could work their way through to the top where some of the seeds were lying exposed uncovered by it. When used as a top layer it was found quite effective, but the layer should be at least half an inch thick. In thinner layers the insects displayed the remarkable habit of bringing up the seed. Two or three of these joined and brought up seeds in which eggs were subsequently deposited. Eggs were not laid, however, on the seed below the sand.

This is then the remedy that has occurred to us as equally efficient, simple and within the means of the poorest raiyats. The bin best suited for storage is the one already described, having a narrow neck with a large base. The sand is put as a top layer. The lid remains closed as a rule, the quantity required being withdrawn from the hole at the side near the base. The brood from the initial infestation will work their way to the top of the sand layer and will die there without being able to lay eggs. And since the lid remains closed until the whole basket has to be emptied, chances of infestation during storage are reduced to a minimum.

Before covering the top layer with sand, it is necessary to see that the seeds are pressed down well in the basket. Otherwise the gradual settling after storage may so disturb the sand layer that gaps in it may be formed especially along the sides of the basket exposing the seeds and allowing the beetles to come up. It is further necessary that no seeds should be withdrawn for at least a month after storage for the removal may have much the same effect on the sand layer. Assuming the seeds are infested at the time of storage at least a month must elapse before the adults arising from the infestation emerge and come to the top and die. Any disturbance of the sand layer during this period may expose the seeds and so enable these beetles to reproduce. A third precaution is to have the sand layer at least a couple of inches thick to ensure that slight disturbances do not expose the seeds in any way. It is also necessary to see at frequent intervals that the sand layer is intact.

There is reason to believe that this remedy has a wider application than to pulse beetles, for the instinct on which it is based must be the means by which other stored grain insects as well secure copulation and reproduction unhampered. The same instinct has been found to direct to the top surface such widely differing species as *Tribolium castaneum, Lasioderma serricorne, Calandra oryzæ, Gibbium scotias, Rhizopertha dominica.* Experiments have, however, not progressed far enough, nor is this bulletin the appropriate place, to record whether the sand layer would be effective

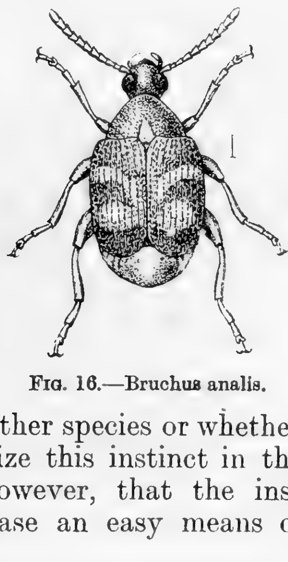

FIG. 16.—Bruchus analis.

against these and other species or whether other devices have to be made to utilize this instinct in their destruction. It may be stated, however, that the instinct is likely to furnish in every case an easy means of controlling these pests.

Since the discovery of the method described above, the announcement has been made that it has been discovered in Pusa also. We have not yet had any detailed description of experiments which resulted in the discovery there. It would be interesting to know the line of investigation carried out there which has yielded the same result.

OTHER FORMS IN STORED PULSES.

There are at least three other forms to be found in stored pulses in the State. The more common one is *B. analis,*

(Fig. 16). The form in Mysore answers to the description given by Fabricius but there are variations as great in this species as in *P. chinensis*. In the typical form as described by Fabricius the elytra are shorter than in *P. chinensis*, the portion of the abdomen exposed is greater and has a black suffusion only interrupted by a median white line. On each elytron there is a black spot in the middle which is tipped behind more or less conspicuously with white. The scutellum is white. All the markings, white as well as black, may be absent or the black may be present in varying depths. So too with the black coloration of the pygidium and the median white line, both of which may be wanting. Even the white spot on the scutellum may be inconspicuous. Owing to the absence of these markings, some of the forms are with difficulty identified as *B. analis*. There can be no doubt, however, of the range in variation in the forms as most of these have been noted in the progeny from the same parents.

The form attacks cow-pea by preference but may attack other pulses also. There is little to be noted in the life history which is practically identical with that of *P. chinensis*.

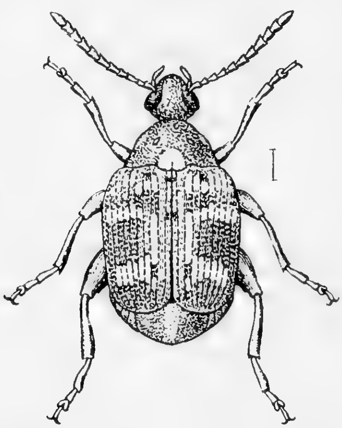

FIG. 17.—Bruchus quadrimaculatus.

B. quadrimaculatus, (Fig. 17).—This form is easily distinguished by the markings on the elytra which together assume the shape of X in white and by its slightly larger size. The space enclosed by each of the limbs of the X is dark brown. Chittenden describes the species as follows :—

" The ground colour is black, with black, grey and white pubescence. The antennæ are serrate and not pectinate in the male. The basal lobe of the thorax is marked with white pubescence only. The elytra are longer and the grey and white pubescence is so arranged as to leave four large black spots whence the species derives its name. These markings are often variable and lacking."

Little need be added to the description save that the four spots on which the name is based are more often absent than present, and when present, always inconspicuous in Mysore.

The species was taken in the field in seeds of lablab in open pods. Multiplication continues in the store, but it appears to require a greater degree of moisture in the seeds so that the infestation tends to diminish rather than increase in the store. The life history does not differ in material particulars, from those of the species already described.

An unidentified species, (Fig. 18).—This form multiplies in the store in seeds of lablab. It is much more common than B. quadrimaculatus. The beetle is smaller being never longer than 2·25 mm. The markings on the elytra are somewhat similar to those in quadrimaculatus but the colour

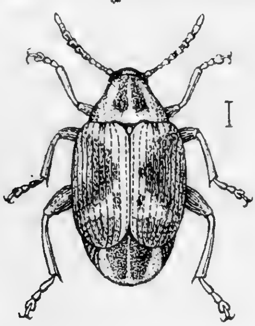

FIG. 18.—An unidentified species.

is dull grey. The limbs of the X are, however, less curved and more like those of the alphabet. The portion enclosed by each limb varies from black to brown. The limbs themselves are light brownish-grey and this is the ground colour of the elytra. In very dark forms the elytra may be tipped with black, but usually, there are only a few scattered spots. The prothorax is much curved, the margin has a slight rounded prominence. There is a faint double ridge along the median line and a large black spot in the middle. The antennæ are serrate. The terminal segments excepting the last are usually dark. The coxæ of the last pair of legs is black. The pygidium has also a large black marking. The range in variation is as great in this form as in others and the markings may be well defined and very conspicuous or more or less absent.

The life history is much the same as that of other store forms.

The forms described above are identified as species in accordance with the description given by either Fabricius or Chittenden. With regard to each, as has already been stated, there is a very wide range in variation so that forms undoubtedly allied to the typical representative of the species may nevertheless be regarded as not belonging to it unless proved to be so by actual rearing. There is little reason to believe that the different species in the store are able to cross and successfully reproduce; but nothing on this point can be definitely stated until more experiments are carried out than has been done in the past. Until this work is done—and it is being attempted in Mysore—the identification of the species described above should be regarded as only provisional.

Summary.

1. There are no less than four species of Bruchids which are responsible for damage to pulses in store.

2. Though varying in appearance and size, they have more or less, the same life history.

3. The pulses are infested either in the field when exposed in dry open pods or in the store itself by the adult beetles which alone appear to be responsible for carrying the infestation over from one year to another.

4. Eggs are deposited on the surface of the seed. The larvæ bore into the seed, inside which the further development is completed, the adult beetles emerging out through neat holes cut out of the seed coat.

5. The life history takes from three to six weeks, the actual period depending on the season.

6. The beetles are directed by a remarkable instinct to come to the top surface where alone eggs are deposited.

7. Advantage may be taken of this instinct by spreading a layer of sand, a couple of inches thick on the top surface which prevents the beetles which come to the top for copulation from getting back to the seed.

8. Some of the methods practised by the raiyats are to be commended though they do not completely prevent injury. Among these, the practice of "moodai" tying and smearing the top layer of seeds with castor oil are the most efficient.

9. The closer together the seeds are packed in the

receptacle, the greater the difficulty for the beetles to come to the top for oviposition.

10. There are few enemies. There are three hymenopterous parasites and one acarid which are not efficient checks.

11. The range in variation of the species is enormous. The identification of the species described should be regarded as provisional.

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