QUEENSLAND.

BUREAU OF SUGAR EXPERIMENT STATIONS.

DIVISION OF ENTOMOLOGY.
BULLETIN No. 16.

# Australian Sugar-cane Beetles and their Allies.

BY

J. F. ILLINGWORTH and ALAN P. DODD.

1921.



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Bureau of Sugar Experiment Stations,
Brisbane, 1st September, 1921.

The Under Secretary,
Department of Agriculture, Brisbane.

SIR,—I have the honour to submit for publication, as Bulletin No. 16 of the Division of Entomology, "Australian Sugar-cane Beetles and their Allies," by Messrs. J. F. Illingworth and Alan P. Dodd.

I have, &c.,
H. T. EASTERBY, General Superintendent.

Approved: E. G. E. SCRIVEN, Under Secretary.

# FOREWORD.

The title of this paper indicates a tremendous subject, a fact all the more patent when one realises that the grubs of fully 50 species of Scarabæids have been taken in the canefields of Australia. Fortunately, the great majority of these are held in check by natural controls, only a few species becoming so abundant as to menace the sugar industry.

The writer undertook an investigation of these pests, in June 1917, being located at Meringa in the Cairns district, North Queensland. Already, during the preceding six years, considerable life-history work had been carried on by the Division of Entomology of the Bureau of Sugar Experiment Stations, the results of which had been recorded in the first six bulletins. Hence with this substantial groundwork it was possible to begin field experimentation at once.

Primarily, our attention has been given to the most serious of all cane-pests, *Lepidoderma albohirtum*, a species extending right up and down the coast of Queensland. Therefore, except where otherwise mentioned, the following notes and descriptions refer only to this species.

It gives me pleasure to express my appreciation of the tremendous amount of tedious, painstaking life-history work which was done before I took up the investigation, by A. A. Girault, A. P. Dodd, and E. Jarvis. Furthermore, I wish to render an especial acknowledgment to Mr. Dodd, who has assisted me loyally in every possible way, often working early and late in order to accomplish results. He has also collaborated in this paper, writing the sections under his name. Then, too, all of the drawings, except where otherwise stated, have been made by Mr. Jarvis. And, finally, I must note the cordial assistance of both the millers and growers, who have spared no efforts to facilitate the investigation.

Plate I.—Stages in the Development of *Lepidoderma albohirtum* Waterhouse; all Natural Size and Colour.

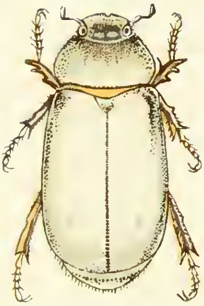
Fig. 1. The newly emerged beetle.

Fig. 2. The egg-chamber in the soil, with eggs; just laid.

Fig. 3. The full-grown grub.

Fig. 4. The pupa.

# Plate I



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Del. E.Jarvis

# Australian Sugar-cane Beetles and their Allies.

By J. F. Illingworth.

## THE GREYBACK CANE BEETLE, LEPIDODERMA ALBOHIRTUM WATERHOUSE.

### THE NAME.

The type locality of this species is Bowen, North Queensland, the species having been named by C. O. Waterhouse in 1875.* Nevertheless, subsequently there appears to have been considerable confusion, especially in Queensland, as to the correct terminology for this insect.

Reviewing the literature on the subject, I found that R. E. Turner (6),† speaking at the Agricultural Conference held at Mackay on 23rd and 24th September, 1892, used the name *Lepidoderma albo-hirta*. And, a year later, Sydney Olliff (8) mentioned *Lepidoderma albo-hirtum* among the beetles infesting sugar-cane in New South Wales. The next reference that I was able to locate was the excellent bulletin by H. Tryon (19) on the Grub Pest, published in 1895. He referred to this species as *Lepidiota albohirta*, and, further along on the same page, he used the name *L. squamulata* for it, as he likewise did on the title-page. In his subsequent writings, however, I found that Mr. Tryon used the name *L. albohirta*; and later changed the form of the specific name, in his annual reports for 1907, 1908, 1909, to *albo-hirtum*. In Australian Insects, 1907, on page 157, W. W. Froggatt used the correct terminology, as did also Rev. T. Blackburn, in his paper published in the Transactions of the Royal Society of South Australia, 1912, p. 52-3. On 30th January, 1912, A. A. Girault wrote to the United States National Museum for advice on the name of this species, and Dr. E. A. Schwarz, the eminent custodian of Coleoptera, replied, 29th March, 1912, as follows:—

"*Lepidiota albohirta* is no doubt the beetle described as *Lepidoderma albohirtum* by Waterhouse in Tr. Ent. Soc. Lond. 1875, p. 202. The genus *Lepidoderma* being closely allied to *Lepidiota* is probably not recognised as valid by the present Australian Coleopterists, but I have no means of speaking definitely about the subject, because the literature on Australian Coleoptera is at present not at hand. Moreover we do not have the above species in the collection of the U. S. Nat. Museum and should be glad to get specimens. The type locality is given by Waterhouse as Port Bowen and no other locality is mentioned by him. The type or type specimens are in the British Museum. I regret very much that I cannot give further information on this beetle."

Subsequently, nevertheless, Girault continued to designate the species as *Lepidiota albohirta*; furthermore, it was so determined for

* Trans. Ent. Soc. Lond. 1875, pp. 201-2.

† The numbers in parentheses refer to the bibliography.

him by Mr. A. M. Lea, Entomologist of the South Australian Museum, 14th May, 1914, except that Mr. Lea used the original ending, *um*, for the species. Hence, in the later writings from this station the misnomer continued to appear. On 21st December, 1920, I wrote to the South Australian Museum for Mr. Lea's further assistance in clearing the matter up. In reply, 7th January, 1921, Mr. Lea supplied a copy of the original description, leaving no doubt in my mind that our common greyback beetle is *Lepidoderma albohirtum* Waterhouse.

## HISTORY OF THE PEST.

A review of the history of almost any pest is both interesting and profitable; furthermore, it lends perspective. Unfortunately, isolated as we are, it has been difficult to locate many of the earliest records of grubs damaging sugar-cane. Tryon (19), however, in his excellent bulletin on the "Grub Pest of Sugar-Cane" throws considerable light on the subject, especially for the northern districts of Queensland. His earliest records are from the Mackay district, as follows:—

"During 1872-4, at Branscombe Plantation, the cane growing just outside the scrub land, and between it and the forest land, died off, and in ploughing out the stools the roots were found to have been gnawn through, and cockchafer grubs were found under the stools—from five to twenty in each case (W. E. Davidson). They also occurred then on the Pioneer Plantation, of which Mr. Spiller was the proprietor. In 1874-5 some acres of cane at Miclere Plantation succumbed in a manner similar to that which occurs when grubs are present (W. T. Paget), and at Richmond Plantation, a field of seventy-five acres in extent was wholly injured by them. In 1885 they were prevalent on the Cedars Plantation, for at that time some forty or fifty acres of sugar-cane had, in consequence of their ravages, to be ploughed out, and the land occupied by it had to be replanted three or four times before they were ultimately got rid of. They were also at that time met with on the alluvial forest lands at Farleigh. That it was still a generally recognised sugar-cane pest in the Mackay district in 1885 appears from the fact that H. Ling Roth, in his article 'On the Animal Parasites of the Sugar-cane,' referred to it as being 'one of the most destructive creatures' with which planters had to deal, and as effecting the destruction of 'whole fields of cane.' At Dumbleton Plantation grubs were very prevalent prior to 1887 (H. H. Lloyd), and at Inverness Plantation it had already proved destructive, especially in dry seasons (J. McBryde). In 1888 we learn of its occurrence at Cortweed, where it destroyed at that time a quarter of a plantation of 150 acres (Z. W. Christensen); and again at Homebush, during the same year, 400 acres of cane had to be ploughed out by reason of its presence (R. G. Smith), and at Te Kowai at the same time the crop was also very much affected, the roots of the sugar-cane covering a good many acres being eaten by it (J. E. Davidson)."

That the grubs continued their destructive work in the Mackay district during the next two decades is evidenced by the numerous comments on that subject appearing in the Sugar Journals as well as other publications. Of special interest are the remarks of W. T. Paget (17, 18), that the grubs had made their presence felt at Mackay in 1893, and in 1894 they were very serious. Again (29), in 1899, he remarked at the Agricultural Conference, at Mackay, even after destroying four tons of beetles on their estate in 1894, the cane was ruined the next year just the same. Many of the principal feeding-trees had been removed subsequently, but Mr. Paget did not consider that this was responsible for the disappearance of the beetles in his section. He considered the district free from the grub-pest in June, 1899. At the same meeting, E. Swayne (31) said that it had been twenty-five years since the grubs first appeared in Mackay, and in 1891-2 their numbers were so great that they threatened the stoppage of the industry. During 1895 the Agricultural Department voted £1,500 to assist in their destruction. From 1896 to 1899, 50¼ tons of beetles were collected at an expense of £2,649 19s. 7d. Even as late as 1909 the *Mackay Mercury* (44) stated that receivers had destroyed 22 tons of grubs in that district; and in 1911 (47) they again collected 22 tons. They give the interesting figures that a ton of beetles is equal to 560,000, since there are about 250 to the pound.

Moreover, the grubs had become troublesome in a number of other sugar-growing districts, both north and south of Mackay. In January, 1891, Albert Koebele (1) found several species of grubs damaging the cane-roots in the Clarence and Tweed River districts of New South Wales. He says:—

"Of these a species of *Anoplognathus*, commonly called 'Christmas Beetle,' was most numerous, and is often ploughed up both in the larva and imago state. Two other species of large Scarabæid larvæ were found behind the plough, as well as a species of *Heteronyx*, together with larvæ and pupæ, no doubt of the same species."

As a control measure Koebele recommended shaking the beetles from the trees early in the morning, when they could easily be picked up and destroyed. He also says:—

"They are readily attracted by lights, and may be collected with traps consisting of a bright light placed over a tin or other vessel about a foot deep by two feet wide, with perpendicular sides and with about two inches of water in the bottom. Many such simple traps could be placed over the fields in December and January, when the beetles are on the wing. Dark nights are best for attracting insects. Without doubt the presence of toads, if these were introduced, would have a remarkable effect in diminishing the numbers of these as well as many other injurious insects."

In June, 1892, Professor E. M. Shelton (4), of the Agricultural Department, at the suggestion of some of the afflicted growers, wrote Dr. C. V. Riley, Chief of the Division of Entomology, Washington, D.C., as follows:—

"It has been in my mind for some time to write to you concerning an insect which interests Queensland planters in a very practical way and about which I hope to interest you. Our plantations, particularly those devoted to the growth of sugar-cane, are just now suffering from the ravages of a dreadful scourge in the shape of a grub, very like the larva of the *Lachnosterna fusca* of your country. This grub literally swarms in nearly all the canefields the whole length of the Queensland coast. I can give you many facts to show the extraordinary voracity of this pest and the extent of its ravages. One planter assured me that upon an estate of 1,000 acres he has 400 acres of cane. Another figures his loss during the past at between £4,000 and £5,000 sterling. Cases of this kind might be multiplied almost indefinitely.

"I may say that the insect itself is known as *Lepidiota squamulata*. So far planters are powerless in its presence. The only attempt at circumventing it is made by hand-picking. In the South Sea Islands a boy* follows every plow with a four-quart tin pail, and very frequently he is able to fill this pail in going across a small field. The travelling inspector of the Colonial Sugar Refining Company tells me that upon one of their plantations they have during the past season picked of these grubs no less than 700 pounds weight from a single acre. You do things in a large way in America, but can you beat this?

"I have recommended the planters to try kainit, which I see referred to in Insect Life as having been useful in the case of cutworms and other underground larvæ, but so far the kainit has not the slightest influence in checking the ravages of this grub. Can you suggest anything in the way of a remedy? If you can only give us a hint in this direction that is at all workable I can promise you that your reputation in Australia, great as it now is, would be made so far as we could make it. I notice in one of the American papers a statement to the effect that a French company is sending out hermetically sealed vials containing a fungus which is said to be most destructive to larvæ like the one under consideration. Do you know anything about it?"

In reply Dr. Riley wrote: —

"The insect which you report as so seriously affecting sugar-cane plantations on the Queensland coast is, from the very nature of the case, as you will readily see, a most difficult one to counteract. The occurrence of this insect and its work have never been brought to my attention and its habits in the imago state are altogether unknown to me, though I doubt not similar to various American Lachnosternas. In this country, particularly here in Washington, we have very successfully treated lawns infested with white grub by soaking the ground with kerosene emulsion, as described in the first volume of Insect Life on page 48, and I believe that this will perhaps prove to be the only practical remedy against your insect. The emulsion of kerosene could be distributed by means of some of the injecting devices manufactured in France for use in disinfecting vineyards of the Phylloxera with bisulphide of carbon, and this latter substance, too, would be an effective remedy against the grub were it not for the expense of applying it on so large a scale. The expense of the application would also be a great obstacle to the use of kerosene emulsion, though this last would be much cheaper than the bisulphide. At this distance and in entire ignorance of the habits of the adult insect, I can give you no further advice as to the best remedies. It is possible that the food-habits of the adult insect will furnish a more easy and practical, not to say cheaper, method of controlling it. This would be the case if the beetle is known to feed on any plant which could be sprayed with Paris green or London purple. I should be glad to get specimens of the insect in all stages, and also, if you can furnish it, a full account of its habits in other than the larva state.

"With regard to the White Grub fungus which the French firms are advertising, I have no confidence whatever in it. I have experimented with it and believe that the results have been generally overstated and that the fungus is being pushed merely as a speculation."

During the Agricultural Conference held at Mackay on the 23rd and 24th September, 1892, Mr. R. E. Turner (6) delivered a most instructive address on the subject of "Insect Pests," dealing primarily

* Obviously there is a mistake here, and what is probably meant is that "a South Sea Island boy follows the plow" in Queensland.

with the cane-grub. He mentions two species as being most destructive. *Lepidoderma albohirtum* and *Anoplognathus lineatus*, which is now known as *A. boisduvali*. Further, he remarks:—

"As these insects are native and only attack the cane incidentally, their natural food being the roots of grasses, it is impossible to exterminate them, for even if we succeeded in clearing the canefields of them at one time beetles would soon find their way from the uncleared land and deposit more eggs. It is, however, very unlikely that any considerable increase will take place in their numbers if we protect their natural enemies, insectivorous birds. At present, I am sorry to say, we are doing just the opposite. Some laws indeed do exist on the subject, but such laws are useless unless backed up by public opinion. Very few even of those directly interested in agriculture think of discouraging the slaughter of birds and the destruction of eggs by their own children, hence it is seldom that birds are seen in any number in the neighbourhood of a homestead. . . . Many birds prey on the insects, both in their grub and perfect stages; some are able to detect the presence of a grub underground. I believe that the bandicoots, although usually as we all know not far from vegetarians, have no objection to the grubs as a variation in their diet. I will not go so far as to recommend the protection of bandicoots. Frogs and lizards destroy a great number of beetles themselves; the former are not much interfered with, but a good many of the larger lizards are destroyed, owing to the peculiar and mistaken but very prevalent idea that they are venomous."

15th November, 1892, a correspondent (3) of the Sugar Journal wrote that the grub-pest was unusually severe during the preceding two seasons on the Herbert and Johnstone Rivers, and stated that most of the injury was undoubtedly due to the larvæ of *Lepidoderma albohirtum*.

In a report on a visit to the Clarence River district, N.S.W., March 1893, Sydney Olliff (8) recorded several species of beetle larvæ found at the roots of sugar-cane. Among these he recognised *Anoplognathus concolor* Burm., *Lepidoderma albohirtum* Waterh., *Lepidiota squamulata* Waterh., and a *Heteronyx* species, but in no case did he find them numerous or destructive.

A report (10) published in the Sugar Journal, July, 1894, said that the grubs had done most serious damage for years on the Johnstone River; and further on in this same report is Mr. Swallow's most interesting account of their status in the Cairns district. (It must be noted that this report was originally published in 1893 for private circulation among the officers of the Colonial Sugar Refining Company.)

"We first noticed the grub-pest seriously between three and four years ago (i.e. 1889), and it was all over the estate and right up to the Pyramid Plantation; in fact, around the place generally things looked very serious for us, so we came to the conclusion that something must be done at once to check the pest. That year one-third of the estate was ploughed out after the cane had been taken off; 40 acres of cane gave but 10 tons sugar, through the grubs being so bad. All wood lying on the ground was either sent to the mill as firewood or burnt; all trash, and in fact anything that would burn, was burnt.

"We, at the same time, started a travelling fowl-house on wheels, holding about 100 fowls. These fowls were taken to the field and turned out loose behind the ploughs. In the early morning they answered well, but as their appetites became satisfied they would come back to the house and rest, going out again as they became hungry. One kanaka boy had charge of them, and had to see that they were shut up safely at night-time. It is wonderful the amount of good that these fowls did, as in many cases just by a little scratching they often turned up grubs which had been missed by the boys following the ploughs (boys with tins were behind each plough, harrow, &c.) ; and, again, when the grubs were very small, there being more chance of them being missed by the boys. As regards the eggs, we have never discovered the eggs in the ground, but have noticed them in beetles which have been killed. Besides fowls we have at times a large number of black magpies, though they do not seem to remain all the year round with us. While here they are, as a rule, very busy behind the ploughs and newly ploughed land, killing and eating the grubs. Ibises come here in large numbers, and they also attack and eat the grubs; we seldom see them on grass land, but as a rule on newly ploughed land.

"We now have the greater part of our estate cleared of timber lying on the ground, and partly stumped. There are still a few stumps left in the ground, but these are being gradually burnt away when burning the trash off; the ploughs in consequence can go over the whole of the ground except a very small portion around the stumps. I am quite sure that it is having been able to get at all the old land, I may say, with the plough, turning it up, having boys and birds on the lookout for grubs and beetles, that we have been fortunate enough to get rid entirely of the grubs. At the present time (1893) there is not a piece of grub-eaten cane on the place that one can see. Besides looking out for the grubs great attention has been paid to the catching and trapping of the beetle. Casks were placed in and around fields, the cask was partly filled with water, a tallow lamp was made fast to a board nailed on and across the top of the cask, tar or molasses was smeared all over the outside of the cask. Thousands of beetles were caught in this manner, besides those turned up by the plough."

In 1895 the grubs continued so destructive that legislative measures were set on foot, in both the Mackay and Herbert River districts, in order that funds might be collected for the suppression of the pest. This matter was outlined by Mr. Paget (17), of Mackay, and later the growers, by a direct tax upon themselves which was finally augmented by a Government subsidy, expended many thousands of pounds in collecting the pest by hand, as has been indicated above.

At the Agricultural Conference held in Mackay in June 1899, Wm. Beal (28) said that during the preceding ten or twelve years 30,000 acres of scrub had been felled in the Childers district, with a marked decrease in the pest. He considered that thorough cultivation was an important factor in the control of the pest.

The Colonial Sugar Refining Company's Annual Report for the season of 1907 (36) states that the Hambledon district lost fully 20,000 tons of cane from grubs during 1906-7, and that this loss had a net valuation of £20,000. Then, in their report for the season of 1908 (38), they estimate the loss due to grubs for their five Northern mills at 40,000 tons for the year. £2,800 was spent for the destruction of 31·73 tons of beetles, and Mulgrave spent an additional £1,000. And, again, in the report for 1909 (39), they estimate the loss for the Cairns district at £50,000. £1,500 was spent for collecting 14 tons of beetles and 2 tons of grubs.

In 1911, G. H. Pritchard, Secretary of the A.S.P.A. (49), while speaking on the subject of an entomologist for the sugar industry, remarked that during the season of 1910-11 over £3,000 was spent in the eradication of grubs in the Cairns district. They had destroyed 22 tons of beetles and 9 tons of grubs. It was estimated that there was an annual loss of 25,000 to 30,000 tons of cane in that one district. And, later, while on a deputation to the Minister for Agriculture in 1912, Mr. Pritchard (53) estimated that the annual losses from grubs on cane in Queensland were fully £100,000.

## NATURE OF THE INJURY.

Grubs are most destructive on well-drained land; consequently, in Northern Queensland, crops on the red volcanic soils are usually the worst affected. These soils are very porous, often extending to a great depth, and underlaid with gravelly subsoils. As a matter of fact, they are so friable that they may be cultivated at almost any time, even during the rainy season when it would be disastrous to go on to the fields of heavier clay. Then, too, because of the loose nature of the red soils, especially in districts with heavy rainfalls, they are usually poor in both humus and lime, which, we shall see later, are of considerable importance for the growing of successful crops.

As is well known, the grubs of the greyback beetle, *Lepidoderma albohirtum*—the principal cane-pest of Northern Queensland—are only destructive during a few months out of the year, from about February to May. During this time, however, they attack sugar-cane in any stage of its growth.

Ordinarily the cane is well advanced at this season, but it makes little difference in what stage it is, for as soon as the weather turns dry the leaves begin to yellow and wither as if suffering from extreme drought. In badly affected areas, like the Greenhills estate, this is a most heartrending sight, especially when one considers all the effort that has gone into the crop; yet, year after year, hundreds of acres succumb in this way on the above estate, the leaves finally becoming as dry as if a fire had been through the fields. This drought-stricken appearance is due to the fact that the roots have all been eaten off and often the root-stocks, too, badly gnawed, so that one can easily pull the stools right out of the ground. In fact, I have sometimes seen the cutters jerk out the individual stalks, when harvesting grubby cane, because it was easier than cutting them off. Of course, under such conditions the ratoons are worthless, but in any case they are likely to be after such devastation by the grubs.

Furthermore, in the case of mature cane the damage often occurs several months before the mills open up for crushing, and there is inevitably considerable loss through deterioration, for the lateral eyes on grubby cane grow out at the expense of the sugar content. Nevertheless, if there is no wind this cane does not usually fall down, and a partial return is secured from the crop. On the other hand, with a cyclone such as that of 10th March, 1918, or the one of 2nd February, 1920, all of the mature cane that has been badly injured by grubs is tipped right out of the ground, and many thousands of tons rot before it can be milled.

With late-planted (i.e. September-October) cane, the procedure is somewhat different, for the crop usually grows well until about February, when it is ready to "lay by," then suddenly, if there are many grubs present in the soil, it ceases to develop, and the leaves soon have the same drought-stricken appearance described above. Under such conditions no cane develops, hence the final result is much the same: the crop is a total loss.

With early planting (i.e. March-April) of grubby fields, unless they have been thoroughly worked for several months, the numerous full-grown grubs which are normally in the soil at that season at once attack the sets, which either do not grow at all, or if they do start the shoots are pale and attenuated, so that they often die out altogether. Examination then shows that not only have the roots been mostly eaten off, but both the sets and the shoots also are often considerably gnawed into (Plate 2), especially at the cut ends of the former, the grubs themselves being often located in the cavities they have made. Under such conditions it is practically useless to replant the field until these grubs have hibernated.

Moreover, the young plant cane is frequently injured by grubs at other seasons than that noted in the last paragraph, especially the late planted crop, in certain areas. This, however, is the work of grubs of other species, notably those requiring two years for the life-cycle. In forest areas about Gordonvale the large third-stage grubs of *Lepidiota frenchi*, which come up out of their deep hibernating chambers about September, are capable of doing as severe damage, especially to young cane, as the grubs of the greybacks do at other seasons. In the scrub areas here this species is replaced by two others, *L. caudata* and *L. froggatti*, both of which may do as much damage.

In the Cairns district the grubs of *L. frenchi* have proved a serious pest, since the third-stage grubs last for a full year in the soil, and are destructive to cane-roots for several months before the season for the greybacks begins. The general result of their work on the plant is the same; but the appearance of the field is usually quite different, for they work more in patches; there will be here and there an area a chain or so across where the cane is almost dead, while the surrounding cane is thrifty and green.

As I have indicated above, the change in appearance of grubby cane may be very sudden, especially following a considerable rainy period, if the weather turns dry; for then the few roots still remaining, which sufficed to supply the needs of the plant while evaporation was slight, suddenly prove quite inadequate, as indicated by a piping of the leaves even before they begin to yellow. This rolling of the leaves while there is still sufficient moisture in the soil is thus the earliest sign that the plants are suffering from root injury and lack sufficient moisture. Hence the general impression that the grubs are worse in dry weather is undoubtedly incorrect, for investigation demonstrates that most of the damage was done before, even during the rainy season, at which time the grubs work principally near the surface. This leads me to speak of the value of deep-rooting varieties of cane.

On several occasions I have called attention to the grub resistance of D 1135, which is undoubtedly due both to its habit of deep rooting and its superior vigour. The roots are numerous and extend to a depth of 16 to 20 inches—far below the normal activities of the grub. Then, too, with this variety new roots are developed rapidly, hence the stool maintains its grip on the soil even in the face of severe hardship, and does not uproot. It is most instructive to see stools of this variety green and upright, in the midst of a field of Badila that has entirely succumbed to the attack of grubs.

That grubs are most destructive on well-drained soils does not mean that they do not exist in other soils, for quite the opposite is often the case. Even on the river-flats, where the soils are normally well supplied with water, and the cane seldom shows any injury from grubs, I have found them to be very numerous, by digging; in one case as many as 16 per stool. Naturally we might conclude that this apparent immunity is solely due to the fact that the land has more abundant humus; yet I think a better explanation is that in the event of roots being eaten new ones are more quickly produced in this moist soil to replace them, hence the leaves show none of the withering effect.

Most of these remarks have reference to plant cane, since on badly infested land it is seldom possible to secure ratoon crops. Nevertheless, in some instances the injury to the first crop is slight and the following ratoons are wiped right out. In fact, it is usually considered that the grubs are more destructive to ratoon cane than they are to the plant. My experience is that in the latter case cultivation can be carried close up to the plants, and is continued for a much longer period than with ratoons. Therefore, in most instances, if the plant crop is severely injured, there is little hope of securing a profitable ratoon crop the next season.

Fortunately, if the grubs are with us, it does not signify that they will always be with us. In some districts they have disappeared as if by magic—possibly by disease or other natural cause; still there is no question that they leave the older areas as the timber is gradually cleared away and the country opened up; but they usually continue their depredations in the newer fields, which border the feeding-trees, in which case the "firing line" appears to be only moved back.

I have neglected to mention that some of the beetles feed for a brief period upon the leaves of the sugar-cane, producing scars similar to those made by cutworms or grasshoppers (Plate 3). They have often been noticed taking their first meal on the cane before flying away to the feeding-trees, but whether this is a customary performance has not yet been demonstrated; in any event I have never observed any serious injury resulting from it. However, it has been recorded by W. T. Paget (18) that when the natural feeding-trees of the chafers were destroyed at Mackay they ate the cane-leaves; but the reference does not state whether the injury was extensive enough to be serious or not.

Finally, as Tryon (19) has pointed out—

"Failure in the crop, for which the grub-pest has been held responsible, has been partly due to the co-operation of the gumming disease. It must not be inferred, however, that this has always been so, for such an inference would be quite contrary to what is actually the case; much less is it true that the grub-pest manifests a preference for 'gummed cane,' or, indeed, for such as is not in a condition of perfect health."

## HABITS AND LIFE HISTORY.

The greyback beetles, although usually designated as cane-beetles, are by no means addicted to this crop, for, as investigation has demonstrated, they are apparently indigenous to the country. Hence they naturally exist in the uncultivated grass land; and from this, under some circumstances, they eventually spread into the cultivated areas, especially where these lie in proximity to suitable trees on which the beetles may feed.

That the beetles flourish in wild grass land is evidenced by Stockton paddock, near Innisfail. This grass area of 240 acres is a most interesting spot, since most of the money from their Cane Pest Destruction Fund is spent for beetles collected there. Furthermore, strange to say, the surrounding canefields have not suffered from grub injury. While the writer was there in June, 1919, it was easily demonstrated by digging that grubs were abundant in this grass land; hence it would appear that that great mass of beetles was developed right here, year after year, alongside of the cultivated cane areas, without injuring that crop. Moreover, digging almost anywhere in grass land, at the proper season, especially where there is much of the so-called blady grass, discloses the grubs, even when far removed from cane areas; in fact, I have been told that they are abundant during their flight even up on the Atherton Tableland. Then, too, we now know that these beetles have an extensive range both up and down the coast; and they certainly are by no means limited to those sections that produce sugar-cane.

Since grubs under natural conditions in uncultivated areas are seldom injurious to grasses, it would appear that man, by his serious interference with the balance of nature, is mainly responsible for much of the devastation that is now resulting to his crop. This opens up an important subject, which will be treated in detail in a later section.

## Emergence of Beetles.

The beetles appear any time from October to February, depending entirely upon meteorological conditions. In fact they are frequently ready for months, waiting in their pupation chambers several feet below the surface for the soil to become sufficiently moist for them to escape. Thus, on 4th July, 1917, the writer found beetles fully 3 feet below the surface, in red volcanic soil so dry and hard that there was no hope of their escape under such conditions. That year the penetrating rains set in at the end of October, and the beetles came out in great numbers on 4th November. Hence the wait in the mature stage, without food, was just four months in this instance. And again, on 5th July, 1918, Girault found similar conditions at Greenhills; that year the beetles did not emerge until 25th November.

After close observations for several years, it has been our experience that the beetles never appear in noticeable numbers until a few days after the first soaking rains, occurring any time between October and February. For instance, in the humid belts, such as the Babinda area, the beetles emerge fully a month before they do in the drier sections of the Cairns district. And, again, an extremely late emergence was that at Meringa during the season 1919-20; the rains did not begin until 15th January, 1920, and the beetles were not out in force until the 23rd of that month.

Just after emergence the exit-holes of the beetles are very noticeable in the badly infested fields. These are about half-an-inch in diameter, and the tube is fairly clean. It is a problem what they do with the soil; the only explanation that occurs to me is that it is compressed into the surrounding walls as the beetles push their way to the surface. In November, 1911, Girault traced these tubes right down to the chambers, in each of which he found a cast pupal skin.

After emerging the beetles usually climb up on to the cane, where they frequently take their first meal, as has been indicated above

(Plate 3, fig. 1). Evidently they often remain right there for several hours—even until the next evening—for during the first few days of the flight it is not uncommon to find newly emerged beetles rather abundantly feeding on the cane-leaves during the daytime.

## Evening Flight and Mating Habits.

All of our observations go to show that the principal flight of the greybacks from the cane to the feeding-trees takes place at dusk, usually between 7 and 8 p.m., and during this hour they do their mating. Just about 8 p.m. they all congregate and settle on the foliage of their favourite feeding-trees, where they remain very quietly until dawn.

During the 1919-20 season Mr. Dodd was stationed at Greenhills, where he was able to keep the emerging beetles under constant observation. He found that on leaving the cane they usually flew directly to the nearest feeding-trees, regardless of the direction of the wind: in that particular locality the forest feeding-trees were to the east and south-east with a small area of scrub further back. And again, during the past season (1920-21) we both spent most of our time early and late in the fields, so were able to verify former observations.

It was not until this last season that we had made any definite observations on the mating habits of the greybacks. This was chiefly due to the fact that we had not gone after them properly, for we now know that copulation takes place repeatedly as long as the beetles are on the wing, and that they are polygamous. In other words, it appears that the beetles mate repeatedly, evening after evening, beginning as soon as dusk comes on, during the whole of their aerial existence, the males going from one female to another. Most peculiar is the fact that they continue copulating even when the females are packed full of ripe eggs which are ready to lay.

The reason that very little has previously been known of their mating habits is chiefly because these beetles favour large, tall trees, and often select those with thick foliage, especially for mating, even trees on which they do not feed, such as the mango, bamboo, milky pine, &c.; a fact which explains the clusters of beetles that may often be shaken out of these trees especially where located in the farmyards. The mating habits of *Lepidiota frenchi* and *L. rothei*, on the other hand, are easily observed, for they mate openly on low bushes, and even copulate while hanging on wire fences where other objects are not at hand. As is well known, the males in these species invariably slide backward and hang head downward, as soon as connection is secured, and they hang perfectly motionless and rigid for a considerable period, after which they separate and either fly away or, if food is at hand, begin feeding.

This year we were fortunate in finding greybacks, also, on low trees near the laboratory, and observations between 7 and 8 p.m. disclosed the fact that their mating habits did not differ materially from the species of *Lepidiota*, other than has been explained above. Since the beetles of this species remain on the trees during the day it is not uncommon to find the pairs sitting together at that time, but in no instance have I found them copulating except in the early evening; yet during cloudy weather they may begin somewhat earlier—indeed, on one dark afternoon I observed pairs mating as early as 5.50 p.m.—but in any case the evening activities last for only about an hour. During this time, however, there is a continual loud hum about the feeding-trees, due to the fact that all the beetles move, either in search of mates or for exercise and better foliage on which to feed during the night.

### Morning Flight.

I have been informed by observant growers on several occasions that the beetles flew into the cane at daybreak, supposedly to oviposit, and, furthermore, I also found the following note by Girault in our file :—

"Gordonvale, December 23rd, 1911. At half-past one this morning I took up a position at the edge of a canefield adjoining a forest; the night was clear but moonless and pleasant. While darkness lasted I saw no beetles, nor heard any. At 5 o'clock, however, a single beetle was observed flying into the cane from the forest; five minutes later a half-dozen more were observed to do this, in an irregular manner exactly similar to their flight from the cane to the forest at dusk. All of these beetles alighted in the cane after about fifty yards, but none could be followed, and this flight lasted but for a very short time; it was not light until about twelve minutes later. I could find no beetles in the forest from whence they came. Were these ovipositing females, leaving the cane to feed in the night or on a night when this is convenient to them?"

Fortunately, Mr. Dodd was able to practically clear this matter up while at Greenhills during the fortnight 23rd January to 4th February, 1920. On clear mornings he found that the flight started about 4.45 a.m., the beetles moving from the forest over the cane; at first the flight was clearly defined, but toward its conclusion the beetles began whirling low over the cane, and many were seen to settle on the leaves where they remained quiet for some time; but they had disappeared by noon, supposedly into the soil, for in one instance he observed a beetle drop to the ground and commence to dig at 9 a.m.

The writer was able to verify these observations during the 1920-21 season. Morning after morning I went into a field of cane near the laboratory between 4 and 5 o'clock. The sky was clear, with bright moonlight. Each time the beetles began to come from the feeding-trees to the east and south-east as soon as the sky lightened a little. At exactly 5 o'clock I saw the first one coming from the direction of the place where the sun was soon to appear, a little to the south of east. In a few minutes dozens were coming, all from the same quarter. Their flight was rather steady and regular, about 10 to 12 feet over the cane, and they went as far as the eye could see against the skyline to the west and north-west, right to the back of the farm, which had invariably been an infested area, though located fully half-a-mile from these feeding-trees to the east. Going to the part of the field where the beetles were settling I found them circling downward rather erratically, each one finally landing with head up on a cane-leaf, which swung down with its weight. I watched many of them and this was invariably the case. The morning flight constantly ended before 5.30, and the air became noticeably quiet, especially after the incessant hum that the beetles made when moving in such numbers.

Just after the flight one morning I watched six of the beetles that had settled near together on the cane-leaves.

No. 1 fell to the ground at 6.30 and dug in under the stool.

No. 2 fell off at 6.45 and crawled under the stool before digging in.

No. 3 fell at 6.50 and went under a bit of trash about a foot from the stool.

No. 4 dropped at 6.55 and dug under a lump of earth about a foot from the stool.

*Note.*—These four were all on cane-leaves in the sun; the other two were in the shade.

No. 5 did not drop until 7.06, and it chanced to fall into a nest of ants where it was soon covered with myriads of them, clinging to the various appendages; by their combined activities they soon gave the beetle a bad time. Each ant clung to bits of trash, lumps of soil, &c., so that the struggling beetle was soon weighted down, and it was with the greatest difficulty that she could move. After an extra effort, by violently kicking her feet together, she knocked off many of the foe, and at once made off as fast as she could go, impeded as she still was with many of the ants hanging to her. About 10 feet away she accidentally fell on her back and her tiny tormentors quickly renewed the attack. For a while she kept the numbers down by violent kicking, and rubbing her feet together. Soon, however, she became weary, for the struggle had gone on for three-quarters of an hour, and she ceased to kick. The ants then piled on her in overwhelming hordes, and it looked as if she were doomed. Nevertheless, after resting motionless for fifteen minutes, she started with renewed strength, and by a fortunate chance the tip of a cane-leaf was pushed near her by the wind, so that she was able to regain her feet; she then made off a second time, and after going about 3 feet dug in under a bit of trash, about a foot from the stool of cane, and escaped at 8.15. The struggle lasted an hour and nine minutes.

No. 6 fell off the leaf at 8.30; hence she had remained thus suspended for three hours.

It is of particular interest that all of the hundreds of beetles that I collected from the cane-leaves after the morning flight were gravid females packed full of ripe eggs, which is certainly conclusive evidence that they were there to lay. Furthermore, those that were collected thus, alive, and placed in tins of moist soil, oviposited at once—from 20 to 35 eggs, with an average of 28.

It is a well-known fact among collectors of this pest, that the beetles while inhabiting the feeding-trees also have a definite morning flight, which takes place at the same time that the gravid females depart to oviposit. For instance, at 5 a.m.—about daybreak on a clear morning—the beetles began moving and feeding, and soon they commenced to fly around the trees in great numbers; the commotion lasted for about a quarter of an hour, when they settled in the denser foliage and began quietly feeding again. Evidently this flight is simply to secure exercise and a fresh location with better protection for the day; at any rate no sex attraction is apparent at that time.

## Midday Flight.

During particularly hot days a noon flight has also often been observed. Under these conditions the beetles leave the exposed positions where they have been feeding, and fly to cover in any available tree or shrub that offers denser foliage for shade, regardless as to its attractiveness as a food plant. A most interesting case was noted by Mr. Dodd (91) in which, on an extremely hot day, he saw hordes of beetles fly and take shelter on the shady side of the trunks of large trees, lining them from 3 to 50 feet.

### Ovipositing.

Prior to the season of 1920-21 we had little direct evidence as to the ovipositing of these beetles in the field, for most of the observations had been made in pots of soil in the insectary, where the beetles were naturally limited as to depth. These observations, however, coincided with those made by Tryon (19) in which he states:—

"When about to lay its eggs the beetle enters the ground to a depth of about 6 inches, or even sometimes to a less depth. This habit is displayed when the beetle is confined under experimental conditions, but it seems that it is highly probable that it is also manifested in the field, since what appears to be the eggs of the beetle have been turned up whilst hoeing the sugar-cane in December. The beetle then executes a rotary movement of its body, and so, by forcibly compacting the soil surrounding it, produces an oblong cavity measuring about 1½ inches long and 1¼ inches wide. This has smooth walls internally, but the latter are not specially lined, as is the case with the chamber wherein the chrysalis or pupa lies. The latter is also of a much more regular and symmetrical shape than is the egg-chamber. In this cavity the eggs are laid one on the other to the number of twenty-five or sometimes less. These are usually compacted together like those of a carpet-snake, the yielding envelopes of individual eggs often showing evidences of having undergone pressure from those that have surrounded them. The eggs usually fill the egg-chamber, and, if this does not happen, fine earth that falls in from above assists in doing so. Beetles when confined in breeding-cages have also been noticed to deposit their eggs singly in the earth, and they may therefore be expected to display this habit sometimes also whilst living under natural conditions."

I have been able to locate only two definite published observations of the finding of egg-chambers under natural conditions in the field. Girault and Dodd (66) found a cluster of 11 eggs in a rude cavity in dry clay loam of natural forest, at a depth of 7 inches; and some time later Dodd (91) located a single set of 13 eggs directly under a cane-plant in red volcanic soil, at a depth of 5 inches.

The above formed slender evidence on which to base a conclusion; yet the general inference has been that the eggs, in fields of sugar-cane, are normally deposited in chambers directly under the cane-stools and at a depth of approximately 6 inches or less.

In order to clear up this matter once for all, I started a series of experiments during this past season (1920-21), placing gravid beetles in cages both in the insectary and under natural conditions in the field. Observations in the insectary agreed in the main with what Mr. Tryon has recorded, but in every case the egg-chambers were located right at the bottom of the flower-pots; so the beetles were evidently limited as to the depth that they might have gone. This was strongly demonstrated in the large field-cage, from which I got most instructive results.

This cage was made of wire gauze and located in the garden, where the soil had been well ploughed. On 31st December, 1920, it was supplied with 21 gravid female beetles that had been collected from the cane-leaves immediately following the morning flight. The soil was well watered.

On 3rd January emergence holes were observed in the soil outside the cage where some of the beetles had tunnelled up and escaped, and five beetles were resting on the gauze inside. Dissection showed that these had already laid. The next day I found another hole outside, and though no more beetles had come up in the cage I decided to excavate and examine for the egg-chambers. The first egg-chamber was located 10 inches outside the wall of the cage, 6 inches deep, and was full of loose earth among the 26 eggs. We then carefully dug down to a depth of about 2 feet, and gradually worked toward the area that had been covered by the cage. When we got right under the wall of this, at a depth of 12 inches, in hard subsoil, we discovered a great cluster of eggs which was apparently four sets, very close together as if in definite cells—98 eggs in all; apparently the beetles had disturbed one another's egg-chambers. The sixth set was also 12 inches deep, in the subsoil, with 28 eggs; the cell was filled with loose earth as usual. The seventh set was 13 inches deep, against a solid piece of root, 26 eggs, the cell full of earth. The eighth chamber was 15 inches deep, beside a hard root, 27 eggs. The ninth was 14 inches deep, in hard subsoil, 27 eggs. These were all the eggs that we were able to locate; the other beetles evidently escaped or burrowed outside of the area that we dug. The average number of eggs of the nine sets thus located was about 26.

With this information we were able to work more intelligently in the field. In an abandoned grub-infested field at Greenhills we dug two trenches; each trench was about 4 feet wide by 6 feet long and 2 feet deep, two stools of cane being in each of these excavated areas. The results were most surprising; we found many tiny grubs of various sizes up to a fortnight old, and twelve egg-chambers of the greyback beetles.

No. 1, 10 inches deep and 2 feet from the stool, had 31 newly hatched grubs; they were just starting to dig out of the chamber.

No. 2, 8 inches deep, had 24 eggs in a well-formed cell, but filled with loose earth; this was also 2 feet from the stool, on the other side of the row.

No. 3, a well-formed chamber, 18 inches deep and directly under the stool; this cell was oval in form, 1 inch by $1\frac{1}{4}$ inch in size, and fairly smooth inside; the 32 eggs were very large, evidently just ready to hatch, and, with the loose soil, comfortably filled the chamber.

No. 4 was also under the stool, 13 inches deep, and had 28 eggs; the cell as usual was filled with loose earth around the eggs.

No. 5 was 12 inches deep, under the stool, and had 32 eggs evidently about a week old.

No. 6, 12 inches deep, right under the stool, 23 eggs; they were packed in with the loose soil, and were about a week old.

No. 7, 8 inches deep, right under the stool, with 31 newly laid eggs.

No. 8, 9 inches deep, under the stool, with 33 eggs.

No. 9 was 18 inches below the surface, under the stool, and had 27 newly hatched grubs.

No. 10, 16 inches deep, under the stool, with 32 eggs, about a week old.

No. 11, 18 inches deep, one foot from the stool, with 23 eggs.

No. 12, 9 inches deep, one foot from the stool, with 23 eggs.

These twelve egg-chambers had an average depth of 12½ inches, and averaged 28·2 eggs each. Hence, with the numerous young grubs that we found near the surface, these four stools would average well over 100 grubs per stool. The year before, the cane in this field was badly injured by grubs, and I found as high as 134 grubs per stool.

As mentioned above, it has been observed that these beetles in confinement do not always place their eggs in chambers. Our observations on this point, however, indicate that such finds are chiefly due to the soil being unfavourable for the beetles to construct a proper cell, usually because it is too dry. If there is not sufficient moisture for the particles to pack as the beetle compresses the walls of the chamber, they fall in upon the eggs, and as she moves about in laying they become scattered, giving the appearance that they were so placed intentionally.

Furthermore, it has been repeatedly observed that the eggs will not withstand dryness, for whenever they are exposed to the air, for even a brief period, they burst open on one side and a part of the contents is forced out. Hence instinct apparently teaches the beetle that her eggs must be placed deep enough in the soil so that there will be no possiblity of their becoming dry before hatching; otherwise she would not go to all the trouble of placing her egg-chamber at such depths.

Particular attention to this phase of the problem was called by Girault and Dodd (66), who found by experiment that the eggs soon shrivelled and dried up when placed in either dry soil or simply exposed to the air. The eggs exposed in the sunlight naturally shrivelled more quickly than those in the shade; and they found, too, that even when the eggs were covered with a shallow layer of moist soil they failed to hatch, because the soil dried out too quickly and they became shrivelled.

### Effect of Desiccation on Ovipositing.

To note the instincts of the beetles in this matter, an experiment was started by the writer on 5th January, 1921, using four small cages, with dust-dry soil from Greenhills. These were marked A, B, C, D, and a gravid female beetle was placed in each. The soil in A was then watered, so that it was very similar to that of the field, since this cage was to be used as a check.

On 6th January, A had laid in a chamber 1 inch by 1¼ inches, at the bottom of the pot 5 inches deep; the 28 eggs appeared to be normal. C had also laid; 36 very small, white-looking eggs were loose in the dry dust, near the centre of the pot, and the beetle was still buried; dissection showed that she still had several small undeveloped eggs in the ovaries. B and D had no eggs, and both beetles were on the surface of the dry soil.

On 7th January, B was buried in the dust but had not laid. D was on the surface in the act of laying, so I watched her for some time; after laying an egg she turned to the right a couple of times before settling down to deposit another. This was preceded by a movement of the pygidium and a forcing out of the vagina for about ¼-inch, so that the cement glands, which are dark in colour, could be seen on the outside. The whole process required about five minutes for each egg. She invariably turned round and round to the right, before laying the next egg. The eggs were very sticky when first extruded, so that they clung to particles of soil as well as to each other, wherever they happened to touch. After laying 20 eggs the beetle left the soil and climbed up on the side of the gauze cage. After a few minutes the exposed eggs began to burst; about one-fourth of the contents ran out and dried in a droplet at one side.

On 8th January the beetle in B was on the top of the soil turning round and round to the right, as if anxious to lay. She appeared to be tired out, for she frequently fell over on her back and had considerable difficulty in righting herself. D was still on top of the soil, but had laid no more eggs.

On 11th January B was dead; on dissection I found only 6 ripe eggs; she was evidently an old specimen, and had probably already laid one or more sets in the field. No eggs were laid after her capture.

On 12th January D was dead, lying on top of the soil. On dissection I found the ovaries empty and very little food in the intestine, though she had been supplied with fresh leaves daily. In the soil, which was still dry as dust, I found that she had laid 30 more eggs, near the bottom of the pot, 5 inches deep. In a few cases the eggs were sticking together in twos and threes, and also so covered with the soil particles that they were hard to find. This was a remarkable beetle, for she laid 50 eggs during a week's confinement, 20 in the first set and 30 more after a rest of five days.

On 14th January I found A dying; the ovaries were empty. The eggs from D were small and dry. On the other hand I was surprised to find the eggs of C increasing in size, but this was due to the fact that the pot had absorbed water through the bottom from the shelf during a rain, and the lower soil was fairly moist.

On 22nd January the eggs of A had hatched, and the grubs appeared to be about a day old; hence the incubation period was almost normal—15 or 16 days. The eggs in both C and D finally dried so that they did not hatch.

This experiment indicates that under unfavourable climatic conditions the ovipositing of the beetles is seriously interfered with, for not only is the act delayed or the beetle itself destroyed, but even if accomplished the eggs may succumb to desiccation.

## Re-emergence of the Beetles.

It has been generally supposed that once the beetles laid their eggs they died; in fact, this has been so stated in practically all the publications on the subject. Nevertheless, during the past season (1920-21) we have been able to demonstrate that quite the opposite is the case, for undoubtedly cane-beetles are repeaters. That is to say, after laying a set of eggs, instead of dying in the soil the female goes through the performance of emerging all over again. Just as in the first instance, she frequently feeds upon the cane-leaves before flying away to the trees to develop a second set of eggs. Moreover, we now know that this procedure is continued as long as the beetles live; hence, three or more sets of eggs are probably deposited, for they are on the wing from two to three months. Mr. J. Clark (35), formerly in charge of the nursery for the Colonial Sugar Refining Company at Hambledon, long ago considered this probable; and it gives me pleasure to now be able to verify the statements of such a keen observer, in this and other matters dealing with the life-history of the pest.

The demonstration that the beetles do not stop at one set of eggs was only made possible by a continued study of the reproductive organs of the female, covering the whole period that they were on the wing. Hundreds of specimens collected both from cane-leaves and from feeding-trees were dissected day after day, noting the changes that took place in the ovaries; and, finally, I sketched these structures (Plate 4) with the *camera lucida* so as to get exact detail.

A brief description of the female reproductive organs may be of value here, especially to assist the reader in an understanding of the following matter:—

The two ovaries, each composed of six egg-tubes (*Et*) are the principal part of the female reproductive system. These, while the eggs are undeveloped, lie in the ventral part of the abdomen and are closely surrounded with air-tubes, the latter not shown in this illustration. Later, however, when the eggs are nearly ripe—two or more in each tube (Plate 5. Fig. 3)— their mass practically fills the whole abdominal cavity. Furthermore, in this drawing it will be noted that each egg-tube has a series of ova (i.e. undeveloped eggs), and that these are of gradually increasing size. These originate one after another from the long oval body at the upper end, which is called the germarium. This structure contains innumerable nuclei, each of which is capable of developing into an egg if the insect lives long enough. Hence it will be seen that the number of eggs that one of these beetles may produce is only limited by the time that it remains alive and active. And, finally, attached to each germarium is a terminal filament (*Tf*), which attaches it to the body-wall at the back, and thus acts as a support for these organs. The six egg-tubes on each side open into an oviduct (*O*), and these again unite to form a common duct, the vagina (*V*), which opens to the exterior. The vagina is expanded near its outlet into a large muscular pouch, the *bursa copulatrix* (*Bc*), which is a structure to accommodate the intromittent organ of the male when mating. There is also a prolonged, tube-like structure, the spermatheca (*S*), opening from the vagina; and a pair of dark-coloured, disc-shaped, cement glands (*Cg*). The spermatheca, as its name indicates, is a receptacle for the sperm; the two glands form the sticky secretion which covers the eggs when laid.

The egg-tubes when the beetle first emerges are very small, usually showing hardly more than a single tiny ovum in each (Plate 5, fig. 1). Hence, as has been previously demonstrated, the beetles must feed for approximately a fortnight after emergence before eggs are ready to lay. Therefore, following upon this event, when I began to find great numbers of the beetles with empty ovaries on the feeding-trees, I at once suspected that they had laid and had returned to start all over again. That this was a fact I was soon able to show, for I found that in a few instances a single ripe egg had been left behind in one of the oviducts after the set had been deposited (Plate 6, fig. 1). In this sketch it will also be noticed that the egg-tubes themselves were considerably distorted and wrinkled immediately after passing the eggs. This, however, is only natural, and they become normal again very soon after laying, as will be seen in figs. 2, 3, and 4 of this same plate.

How many sets the beetles normally lay we have so far not been able to determine. This indeed is a difficult matter, for they do not do well in confinement, usually dying soon after laying; and in the field, of course, it is impossible to determine the life of any individual. Hence we can only judge by the time that the main body of the beetles are in evidence, for, as stated above, there is no question that the eggs continue to develop as long as the adults live. Moreover, on this point it is interesting to note that the last beetles captured on the feeding-trees, 8th February, 1921—almost three months after the first emergence—still had eggs in all stages of development; in two the ovaries were empty, showing that they had just laid, probably their third or fourth set, and were back on the trees to try it over again, even at this late date; eight had new sets of eggs well under way, more than half-formed; the remaining six had fully developed eggs, ready to lay again, as follows:—21, 24, 24, 24, 25, 24, hence an average of 23·66. From this we see that the number of eggs in these late sets does not fall much below those for the earlier ones, which averaged about 26 to 28.

To show the continued reproductive ability of these aged beetles, I have sketched egg-tubes from specimens collected on 8th February. Plate 6, fig. 3, is from a beetle taken on the feeding-tree, and fig. 4 of this same plate, from one taken on a cane-leaf where she was resting after depositing her eggs preparatory to taking flight back to the feeding-trees. In each case it will be seen that there were sufficient ova already in the tubes to form new sets.

## Duration of Aerial Life.

As has been suggested above, it is a difficult matter to know how long the beetles live under natural conditions, since they do not take kindly to confinement. Mr. Dodd (91) found that the greatest length of life of adults taken from the forest, when supplied with food in cages, was thirty days, and that the females lived longer than the males. Furthermore, these results have been borne out by our subsequent observations. Nevertheless, we know that the beetles live much longer under natural conditions—probably two months or more, as indicated above. Early in the season the two sexes are almost equal in numbers on the feeding-trees, but later, during brief periods while many of the females are away ovipositing, the males may be found greatly in excess. For example, on 4th January, 1921, in a lot of beetles from the feeding-trees I found that 85 per cent. were males, and most of the remainder (females) had empty egg-tubes, showing that they had just laid. These conditions suggested that most of the females were away ovipositing at the time, which supposition was apparently correct, for a few days later the numbers of the two sexes were approximately equal again. Toward the end of the season, however, the males evidently begin to die off first, as is indicated by their lessening numbers in the feeding-trees—in fact, the last lot that we collected, on 2nd February, had only 15 per cent. males. As to the habits of this sex, it appears that they spend their whole aerial life among the feeding-trees, never returning, as do the females, to the soil.

## Stages in Development.

*The Egg.*—Considerable has already been said in regard to the egg stage above, but I have hardly more than suggested the remarkable increase in size which takes place as the incubation period advances. To illustrate this feature I have sketched the eggs at various stages of their development, using the *camera lucida* to get the comparative sizes exact (Plate 5). As indicated, they are all magnified five diameters. Fig. 4

shows an egg just laid; fig. 5, one week after; and fig. 6, when a fortnight old, ready to hatch. A better notion perhaps of the fresh egg, in natural size and colour, is shown on Plate 1, fig. 2.

The incubation period, as indicated above, is evidently considerably affected by unfavourable conditions, such as extremes of temperature, moisture, &c. We have seen, however, that the parent beetle seeks to avoid such extremes by placing the eggs very deep in the soil. Yet it is hardly possible to follow their development closely in these natural conditions.

Nevertheless, with experiments carried on in the open-air insectary, under conditions as nearly normal as possible, we found the duration of this stage to be fourteen to sixteen days, which probably is not very different from results in the field. At any rate I think we are not far out of the way in estimating a fortnight for the egg stage under field conditions.

*The Grub or Larva.*—On 15th January, 1921, I was fortunate in observing the hatching of the eggs. When I tipped them out of the pot most of the grubs had already escaped, but several were still in the act of eating their way out. One had evidently just escaped, for its head was white and soft, and it had already eaten half of its shell. Moreover, since there were no other eggshells in the soil, it would appear that the grubs invariably make their first meal upon this waste material, immediately after hatching, as is often the case with other insects.

The grubs pass through three distinct larval stages, direct evidence of which was obtained by Girault and Dodd (66) by rearing. I understand that the first author published minute technical descriptions of these stages in "Societas Entomologica," Germany, 1913, but I have not been able to refer to it.

The newly hatched grubs at once begin to work their way upward, and shortly they are found near the surface among the cane-roots, where they remain during the whole of the growing period if the weather remains favourable. Under dry conditions, however, they burrow deeper; but during an over-supply of moisture, on the other hand, they work nearer the surface, in fact coming right out of the soil, where trash and other vegetable matter is available for them to feed upon and hide under. Particular attention was called to this latter habit by Mr. J. Clark (35) at Hambledon, where it was made use of extensively for the collection of the grubs during rainy weather. He mentions one grower, Mr. W. C. Abbott, who collected about 100 gallons of grubs during the season from two acres of Badila, by simply picking them from under the piles of trash during the wet weather.

To determine the duration of each of the stages through which the grubs pass, Girault and Dodd (66) reared them in soil planted to corn at the laboratory, and successfully carried a few of them through all of the stages. From their results it would appear that the first and second stages require about five to six weeks each, and the third stage three to four months.

Under the splendid growing conditions in the soil at Greenhills, our field observations indicate that the grubs are much more rapid in their development. The season of 1920-21, being a normal one, may be used for purpose of illustration. On 31st December, 1920, we dug up the first stage I grubs in the field, and they appeared to be a fortnight old. On 11th January, 1921, all the grubs were still in stage I; but on 18th January 12 per cent. of them had changed to stage II; and by the 25th of that month 27 per cent.

As has been noted, the beetles were still on the feeding-trees on 8th February, hence newly hatched grubs continued to be in evidence when digging. Of those collected on that date, 26 per cent. were in the first stage, 73 per cent. in the second, and 1 per cent. had already changed to the third stage.

On 24th February, however, no beetles were in evidence, though 23·5 per cent. of the grubs were in stage I, and only 54·2 per cent. in stage II, because 22·3 per cent. had changed to stage III. A week later, 2nd March, 14 per cent. were in stage I, 43 per cent. in stage II, and 41 per cent. in stage III.

And finally, on 11th March, scarcely 1 per cent. of the grubs were left in the first stage, a fact which is interesting since this was only about a month after the last straggling beetles were seen on the feeding-trees, for it goes to show how brief is the first stage; 26 per cent. were in the second stage, and 73 per cent. had already developed into the third, the really destructive stage.

From these data it would apparently only require approximately a month for each of the first two stages. The third or final stage of the grub, however, remains active among the roots of the plant right up to the time that the cold nights of May or June set in, before descending to hibernate; hence the duration of this stage is fully three to four months, or considerably more if we take into account the time spent in the hibernating chamber before pupation takes place.

These grubs, like those of all related species in various parts of the world, are not primarily addicted to feeding upon living roots, but normally depend upon the decaying organic matter in the soil for their food. As Girault and Dodd (66) have well stated—

"They are continually passing large quantities of soil through their bodies, altering to a certain extent, no doubt, its chemical nature and considerably changing its physical texture. This alteration is brought about by the fact that the organic matter of the ingested soil is partially digested and used as food while the soil is expelled from the anus in the form of a pellet. This constant movement of soil through their bodies, combined with the loosening effect on the soil of locomotory movements of the legs and mandibles, must have in the long run an important effect on the character of soils in a grub-infested area. But, unlike earthworms, grubs do not to any extent transport soil from beneath to the surface.

"The following evidence has been collected to show that the grubs subsist largely upon organic matter in the soil, attacking living vegetation at the same time but not constantly and habitually. Habitually and constantly, they are swallowing soil, extracting partially its organic content, yet a supply of living vegetation seems necessary for their normal development:—

(1) Young larvæ when hatched are wholly white, and remain so until placed into bare soil, after which, in the course of a day or so, they become coloured—the colour due to soil which has been ingested. That they are not starved is shown by their growth and appearance.

(2) Larvæ kept in bare soil pass, for days at a time, large amounts of excrement. This would not be possible unless food was being obtained.

(3) Larvæ kept in bare soil mixed with paris green invariably die after about three days.

(4) Starved grubs have never been found in nature, though coming from bare soil or from some depth beneath the roots of grasses. Larvæ obtained from a piece of land maintained for three months in a state of barrenness were as plump as usual, their food canals full of organic matter mixed with soil.

(5) Grubs are healthy for several months in bare soil without access to living vegetation.

(6) In cultivated canefields, the larvæ are often found in bare parts some distance away from living plants and apparently unable to reach same for several days at least.

(7) Larvæ kept in pure sand or in empty glasses commence to shrivel after several days and to die after a week.

(8) Grubs are not habitually and constantly attendant upon plants.

(9) Examination of the food canals shows considerable variation in the nature of the contents, which always is a mixture of soil and organic matter of vegetable origin, the organic matter sometimes predominating, often the soil doing so.

(10) Forbes (1907) states that Stiles has shown that a certain intestinal parasite of swine passes an intermediate stage in the intestines of white grubs (North American). These parasites must be ingested with soil containing the excrement of swine probably, or by direct ingestion of the excrement. If the ingestion of the soil by these grubs was purely accidental and of small amount, it is most likely that the parasites would be unable to survive, yet they are abundant. It is most likely, then, that they must be habitual soil-swallowers."

In my experience the grubs do not necessarily require living roots for healthy development; in fact, I have found them of maximum size under piles of old, decayed cane-stubble, many of them living right in the old stalks in holes which they have excavated while feeding. Organic matter, however, is certainly necessary for their development. Hence, if they cannot find this in the soil, they naturally attack the living roots and even the rootstocks for their supply.

My observations have been that the grubs are only excessively destructive to sugar-cane when it is growing on land which is deficient in organic matter. Hence, as I have indicated above, the young grubs work as near the surface as the supply of moisture will permit, for there they find the greatest amount of organic matter, i.e. rubbish from the crop, such as old leaves, &c., which are decaying on the surface of the soil.

Usually the young grubs find sufficient organic nourishment in this way, and do not appear to damage the living roots. But as they increase in size, particularly where grubs are numerous in fields, the available supply of decomposing organic matter is soon used up; hence the living tissues of the plant are gnawed to such an extent that it suffers seriously.

As further evidence in this matter, it is well known that grubs do not usually damage the cane planted on newly opened-up scrub land, which is probably due to the fact that this land is rich in a supply of humus accumulated from its rank growth of vegetation. And, again, the same may be said of the soil on river-flats. The crops on new forest land, on the other hand, frequently suffer right from the start, for such soil is poorer in organic matter, which is largely due to the annual fires that pass through these lands.

Normally there is little lateral movement of the grubs in the soil, as long as they are able to find sufficient nourishment right under the stools of cane, a fact which is especially true during dry weather. I refer to this matter because growers have frequently told me that as soon as the rains ceased they could notice the advance of the grubs across the fields, by the yellowing of the tops. This apparent advance, however, is not due to a migration of the grubs, but may be explained by relative infestation. That is to say, the parts of the fields near the feeding-trees are usually more heavily infested, and hence become yellow soonest: while, as we have demonstrated, as the number of grubs per stool varies inversely with the distance from the feeding-trees we would naturally find that the cane planted farther away would be slower to succumb to drought, being less injured by the grubs.

There is no question, however, that the grubs have ability to move about in the soil, where they have occasion to do so, that being their natural element. Nevertheless, when taken out of the soil, progress is almost out of the question. They squirm about, lying on their sides, and try to get back into the soil as soon as possible. Hence there is no reason to believe that they voluntarily come out on the surface, even in wet weather, in order to move from one place to another.

To learn something of the movement of the third-stage grubs in very moist, red volcanic soil, I experimented somewhat during January, 1918, at Meringa. Single grubs were placed at different points on the surface in a part of the field that was not infested, and the places where they entered the soil was marked. After twenty-four hours I dug until I located each of them, finding that in no instance had they moved more than 12 inches laterally, though one had descended to a depth of 9 inches. This soil was without roots, with little organic matter, so there was every incentive to travel in search of food.

Toward the end of their feeding period, in May or June, the third-stage grubs become very yellow, especially on the thorax, because of the great amount of fat they have stored up to last them over the several months which they pass in the resting stage in the pupation chamber.

*The Pupa.*—When the cold nights begin, therefore, if they have reached this stage in their development, they begin their descent, going perpendicularly deeper and deeper; and if the soil is not too hard there is apparently no limit. Girault (57) found them as deep as 4 feet; and on several occasions growers have reported to me that they found them considerably deeper—in one instance 6 feet. In none of our excavations have we gone deeper than 4 feet; yet, in the loose, red volcanic soils, we frequently located the pupating grubs at a depth of 3 feet to 3 feet 6 inches. In fields with heavy clay subsoil, on the other hand, the grubs do not go down so far; in fact, it is not uncommon to find them pupating almost at the surface. This is undoubtedly largely due to the moisture content in such poorly drained situations. While it has been found that the grubs can exist in super-saturated soil, and even withstand immersion for a considerable period—two or three days—they are evidently uncomfortable under such conditions. Hence, as has been noted, they move toward the surface when the soil becomes saturated, and I have even found them coming right out of the ground when the surface became flooded. Along the river-flats it is not uncommon to find the grubs pupating very near the surface, in fact so close to the top that most of the pupæ may be turned out by ploughing.

The pupal cell is oval in form, and measures about 1 by 2 inches inside, the walls inside being smooth and compact. The black internal lining of the cavity is evidently formed from the soil contents of the alimentary canal, which the grub expels shortly before changing to the pupa. I have frequently dug up grubs just after they had expelled this waste matter when they were on the point of pupating. In this condition they are semi-torpid, and the hinder part of the body, which is normally plump when filled with soil, is much shrivelled, so that the skin is considerably wrinkled. As is the case with most beetles, the pupa lies on its back in the cavity.

Our field observations would indicate that there is no regularity as to the time that pupation takes place, for it evidently may occur any time during a period of fully six months. Our earliest record was on 16th May, 1918, at Greenhills; and the latest, 8th December, mentioned by Girault and Dodd (66). Moreover, available data would indicate that the grubs pupate sooner in well-drained, porous soils than in those containing more clay and moisture. For instance, during June, 1917, I found that approximately one-third of the grubs had pupated by the 29th of that month, and, as mentioned above, fully formed beetles were in the chambers by 4th July. And, on the other hand, it was the latter part of August before the pupæ began to be found in numbers in the heavier clay soils near the Mulgrave River.

As to the duration of the pupal stage, we have little direct evidence. This is due to the fact that specimens removed from their chambers do not develop in a normal manner. Even if they do not succumb to dryness, as is frequently the case, the length of this period is considerably increased. And on the other hand it is a difficult matter to keep them under observation in their natural habitat. I think we may naturally conclude, however, from the above observations, that this period does not last much if at all over a month.

In order to forcibly bring out the known facts in the relation of this species to sugar-cane, we have made use of the valuable suggestions which we obtained from a recent publication by John J. Davis (107). Hence, in Plate 7, we have a pictorial story of the life-history of the pest, month by month, showing both its activities in the soil and air, as well as the effects upon the growth of the cane-plants. Then too, in Plate 8, these facts have been recorded diagrammatically to cover all of the data that we have accumulated on this species.

# A Study of some of the Common Trees in their relation to the Aerial Life of the Beetles.

By Alan P. Dodd.

A botanical survey of the area surrounding canefields with regard to the aerial life of *Lepidoderma albohirtum* is both interesting and instructive. Two features are outstanding and at once impress themselves on the mind: firstly the number and variety of the trees used for food by these beetles, and secondly the frequent close relationships between food plants and those immune from attack. Tryon (19) was the first to make the former observation; the list of feeding-trees given by him contained twelve species, representing four families; he thought that only scrub trees were attacked. Girault and Dodd (66) included about twenty trees in their list, compiled from direct observation, and, moreover, expressed their belief in the immunity of certain trees from assault by the beetles; and as they summarised existing data briefly and suitably we cannot do better than quote from their bulletin:—

"Trees on the edges of canefields are usually chosen for feeding purposes but all through the forest and often a mile or two from canefields beetles can be found. . . . Sometimes hundreds of beetles will congregate on one tree to feed, especially if the tree be large, but as a general rule only a small number collects on one tree. Special situations are often chosen, and numbers may be gathered day after day in one small area, where none can be found elsewhere in the neighbourhood. Trees of any size may be selected, but small shrubs and saplings (from 8 to 25 feet high) appear to be preferred; however, a large tree will often attract scores of beetles, while rarely is a small one crowded. That certain food plants are favoured is evident; observations, however, have been restricted to seasons when the beetles were comparatively few, and in abundant seasons trees may be attacked indiscriminately. Food plants may belong to almost any order, whereas trees in the same genus, and obviously closely related, may or may not suffer defoliation. Jungle (*i.e.* scrub) or forest trees are attacked without difference. Around Gordonvale the country is mostly forest, which may account for the preponderance of forest trees given in the food list. Tryon (1896, p.19) remarks as follows:—'Since their (*i.e.* the beetles') food is yielded almost wholly by the leaves of so-called scrub trees, they are almost exclusively found within or in the vicinity of scrubs, or along the course of creeks that are fringed by scrub vegetation.' Our experience at Gordonvale shows that the beetles feed throughout the forest land as well as on the fringes of jungle vegetation. This may be accounted for by the prevalence of forest (*i.e.*, open bush with typical Australian *Eucalyptus* and other flora) lands."

The great majority of our observations has been made around Gordonvale, where open forest country predominates; scrub only occurs in isolated patches, or in fringes along streams or gullies. We have paid spasmodic visits to other districts, noting feeding-trees there; but no comprehensive study of this phase of the subject has been undertaken outside the locality stated. Hence, probably many food plants have been overlooked, especially in scrub districts.

Our list of feeding-trees, compiled from personal observation, embodies 34 different kinds, typifying twelve separate families, which are given herewith:—Burseraceæ (1), Meliaceæ (1), Ampelideæ (1), Anacardiaceæ (2), Leguminosæ (4), Combretaceæ (1), Myrtaceæ (7), Euphorbiaceæ (3), Urticaceæ (11), Scitamineæ (1), Palmæ (1), and Gramineæ (1). At various times beetles have been collected from trees that were not positively recognised as feeding-trees; they may have been there primarily for shade; and where any doubt existed such trees have been placed in this category. In the following compilation we have divided the trees into four classes; the first includes those that are constantly and habitually attacked; the second those that are occasionally or rarely eaten; the third those in which the beetles sometimes congregate to shelter during the day, usually trees with dense foliage; and the fourth, common trees which are not known as feeding-trees. These convenient divisions are observed right through the list, the number 1, 2, 3, or 4 appearing in parentheses, referring respectively to the classes discriminated above. Thus "(4) *Wormia alata*" signifies that that particular tree is not known to be attacked.

## List of the Feeding and other Trees in relation to Lepidoderma albohirtum Waterhouse.

### Family DILLENIACEÆ.

(4) *Wormia alata* R. Br.

An upright tree, rarely attaining a height of 25 ft., growing along lowland or swampy streams; bark brownish red and flaky. Leaves oval, rounded at both ends, 4-8 in. long, broad, shining, stiff. Flowers usually 2 or 3 together, open, over an inch across, bright yellow, the stamens, &c., red.

This handsome tree fringes many of the creeks in the swampy or low-lying areas near Cairns.

### Family RUTACEÆ.

(3) *Citris aurantium.* Orange.

### Family BURSERACEÆ.

(2) *Canarium australicum* F.v.M.

A small to medium-sized erect tree, growing on forest land near scrub; bark light-coloured, rough, and tightly clinging; branches thick, marked with broad scars left by fallen leaves. Leaves pinnate, composed of 5 to 9 leaflets united to the central leaf-stem by short stalks, oval, the lower ones sometimes nearly circular, 2-4 in. long, ashy-green, greyish beneath, smooth, leathery, with prominent veins. Flowers small, whitish, in clusters mostly on upper portion of a stalk 3-5 in. long. Fruit olive-like, oval, dark or purplish, $\frac{3}{4}$ in. long.

This tree is scattered throughout the forest land; the compound or pinnate leaves, with their large leaflets, which are greyish beneath, ought to be recognisable characters.

## Family MELIACEÆ.

(2) *Dysoxylon cerebriforme* Bailey.

A tall erect tree growing in second-growth scrub; bark rather smooth and light-coloured, the trunk with conspicuous leaf-scars. Leaves compound, very long; leaflets 7 to 9 or more, large, up to 8 in. long by 3 in. wide. Flowers small, in loose clusters, near the summit of the branchlets. Fruit globular, $1\frac{1}{2}$ in. long by $1\frac{1}{4}$ in. diameter.

A common tree on edges of scrub at Babinda and other scrub portions of the Cairns district.

(4) *Melia composita* Willd. White Cedar.

A medium-sized erect tree, with rather smooth, mottled grey bark. Leaves compound, the branchlets slender and inclined to droop; leaflets 5 to 7, ovate, pointed at apex, 1-2 in. long by $\frac{1}{2}$-1 in. broad, coarsely toothed, sometimes lobed at base. Flowers in loose clusters, purple, small. Fruit oval, $\frac{1}{2}$-$\frac{3}{4}$ in. long.

This graceful tree is found on the edges of farms in the volcanic lands near Gordonvale.

## Family AMPELIDEÆ.

(2) *Vitis trifolia* Linn. Wild Grape Vine.

A woody climber, very common in forest land. Leaflets 3, ovate, 1-2 in. long, notched or toothed on the sides, with soft fine silky hairs. Flowers small, inconspicuous. Berries small, dark, globular.

This creeper is frequently met with, clinging round the trunks of forest trees.

## Family ANACARDIACEÆ.

(1) *Semecarpus australiensis* Engl. Tar-tree.

A medium to large spreading tree, growing on lower scrub lands; branches thick; bark grey and containing a very caustic sap that blackens upon exposure to the air. Leaves up to 12 in. long by 3 in. wide, elongate, narrowed at base, pointed at apex, green above, grey or whitish beneath. Flowers very small, clustered. Fruit 1 in. diameter, about $\frac{1}{2}$ in. thick, supported upon a large fleshy succulent stalk.

The tar-tree is well known on account of the caustic action of the sap.

(2) *Buchanania muelleri* Engl.

A bushy and spreading tree of medium height, scrub land. Leaves 4 to 6 in. long, $1\frac{1}{2}$ in. broad, narrowed at base, rounded at apex. Flowers usually below the terminal leaves; small, whitish, in loose clusters on a stalk 2 in. long. Berries small, round, purple, $\frac{1}{4}$ in. diameter.

Resembles the cultivated mango very much in appearance; the leaves are very much like those of its relation the tar-tree, but are smaller and more rounded at the apex.

(3) *Mangifera indica* Linn. Mango.

## Family LEGUMINOSÆ.

(4) *Acacia aulacocarpa* A. Cunn. Black Wattle.

An erect tree of varied size, sometimes attaining a large height, in either forest or scrub land. Leaves ashy-green, 3-4 in. long by 1 in. broad, tapering at each end. Bark rough, thick, tightly clinging, dark. Flower-spikes 2 or more inches long, narrow, bright yellow. Pod long, narrow, irregularly or spirally twisted, about $\frac{1}{8}$ in. broad.

The common Black Wattle.

(1) *Acacia polystachya* A. Cunn. Grey Wattle.

A spreading forest tree of medium height, the bark tightly clinging, rough, greyish. Young branches angular at first but soon becoming rounded and tapering. Leaves somewhat sickle-shaped, narrowed at each end, 6-10 in. long, 1-1$\frac{1}{2}$ in. broad, dark ashy-green. Flower-spikes 1-2 in. long, solitary or two or three together; flowers yellow, not very close. Pod flexible, not spiral, several inches long, about $\frac{1}{2}$ in. broad.

This tree grows on the low-lying lands at Highleigh, near Gordonvale, and is locally known as the Grey Wattle. In general appearance it closely resembles *A. aulacocarpa*, but the bark is much lighter in colour.

(1) *Acacia holosericea* A. Cunn. White Wattle.

A small erect tree, growing on marshy forest land. Leaves closely covered with minute silky white hairs, 4-6 in. long, 1-3 in. broad, or the lower ones much larger. Twigs with three angles. Flower-spikes often 2 or more in. long, yellow. Pod long, narrow, irregularly or spirally twisted, about $\frac{1}{8}$ in. broad.

A conspicuous tree on account of the whitish appearance of the foliage, from whence it receives its local name.

(1) *Acacia mangium* Willd. Broad-leaved Scrub Wattle.

Erect tree, sometimes attaining a good height (60 ft.), and growing in scrub land. Bark light brown; twigs with three sharp angles. Leaves rather bright green, not pubescent, with four prominent veins. 5-10 in. long, 2-4 in. broad, ovate. Pod long, narrow, spirally twisted, about $\frac{1}{8}$ in. broad.

This wattle will be at once distinguished by the large, broad leaves.

(4) *Acacia* sp. Narrow-leaved Wattle.

A tall graceful tree, about 40 ft. high, on edge of scrub; bark light grey, rather smooth. Twigs very slender. Leaves dark green, more or less curved, 6-8 in. long, $\frac{1}{4}$ in. wide, tapering. Flowers and pods unknown.

Known to us only from the Greenhills area.

(1) *Acacia flavescens* A. Cunn. Cream-flowered Wattle.

A small erect tree, attaining a height of 30 ft.; bark dark brown, strongly roughened. Young shoots clothed with grey or yellowish hairs; terminal twigs angular. Leaves broadly sickle-shaped, 4-8 in. long, 1-3 in. broad, with 3 prominent veins. Flowers in small globular heads, creamy or pale yellowish, borne in great clusters. Pod straight or curved, very flat, 3-5 in. long, $\frac{3}{4}$ in. broad, leathery.

A common tree in the vicinity of Cairns; it is never found in swampy land, and does not attain a large size. At a casual glance it might be mistaken for *A. aulacocarpa*, but the bark is much more ribbed or roughened. When in flower the masses of creamy blossoms are very noticeable.

(4) *Pongamia glabra* Vent.

A small tree with widely spreading head, the bark rather smooth and light brown. Leaves compound or pinnate, each leaf containing 5-9 smooth, glossy green leaflets, pointed ovate, 2-4 in. long by 1-1½ in. wide. Flowers in pairs, grouped together on stalks 3-5 in. long; flowers ½ in. long, lilac-coloured. Pods 1½-2 in. long by 1 in. broad, woody, containing one or two brown flat seeds about $\frac{3}{4}$ in. long.

A graceful tree. The foliage has been found of value as fodder for stock.

(3) *Poinciana regia*. Poinciana.

Food plant of *Xylotrupes australicus*.

(4) *Pithecolobium saman*. Rain-tree.

(3) *Castanospermum australe* A. Cunn. Moreton Bay Chestnut or Bean-tree.

A large to very tall tree, with dense glossy foliage. Leaves compound, 1-1½ ft. long; leaflets 11 to 15, oval or broadly oblong, pointed at apex, 3-5 in. long. Flowers usually on the branches or old wood, bright red and orange, 1-1½ in. long and 1 in. wide. Pod 8-9 in. long by 2 in. broad, curved and pointed at apex, spongy inside and divided into 3-5 cells, each containing a large chestnut-like seed.

This fine scrub tree is too well known to require much description.

## Family COMBRETACEÆ.

(2) *Terminalia catappa* Linn. Fiji Almond.

A deciduous tree, with wide spreading branches, sometimes attaining a large size, cultivated in parks, gardens, &c., but also found wild; branches in horizontal circles round the trunk. Leaves clustered at end of branches, very large, up to 16 in. long by 8 in. broad. Flowers on solitary terminal spikes, very small, dull-coloured, and strongly scented. Fruit yellowish, 1-2 in. long, compressed and showing two distinct ridges.

The horizontal branches and large leaves make this tree very noticeable; the kernel of the fruit is edible.

## Family MYRTACEÆ.

(4) *Melaleuca leucadendron* Linn., var. *viridiflora* Gærtn. Swamp Tea-tree.

A tree attaining a great height, growing in swamps or swampy ground, with a thick whitish bark peeling off in thin layers. Leaves 1-4 in. long, ½-¾ in. broad, the young terminal leaves covered with fine silvery hairs, usually with three prominent longitudinal veins. Flower-spikes solitary or 2 or 3 together, the flowers yellow.

(1) *Melaleuca leucadendron* Linn., var. *cunninghami* Bail. Thick-leaved Tea-tree.

A small tree growing in swampy land. Leaves thick and stiff, 4-7 in. long, 2-4 in. broad. Flowers yellow.

This variety never attains a great height.

(4) *Melaleuca leucadendron* Linn., var. *sanguinea* Cheel. Red-flowered Tea-tree.

A small tree growing in swampy land. Leaves rather stiff, 3-5 in. long, 1-2 in. broad. Flowers red.

In growth and appearance this form is very similar to the preceding.

(4) *Melaleuca leucadendron* Linn., var. *mimosoides*. River Tea-tree.

A graceful tree with bushy folige, growing along or in river-beds. Leaves not stiff, slender, 4-6 in. long, ½-¾ in. broad. Flowers creamy-white, borne in profusion.

A very distinct variety from the other three.

(1) *Eucalyptus tesselaris* F.v.M. Moreton Bay Ash.

A medium to large erect tree, common on forest land; bark on lower stem black and persistent and marked out in separate pieces by longitudinal and cross grooves, the branches and upper trunk smooth and whitish. Leaves lance-shaped to almost straight or sword-shaped, 3-6 in. long. Flowers in clusters of 1-2 or 3-6 on short slender stalks. Fruit oval or oblong, about ¼ in. long, the capsule deeply sunk.

The Moreton Bay Ash may at once be known by the dark lower trunk and smooth branches.

(1) *Eucalyptus corymbosa* Sm. Bloodwood.

A small to very large tree, smaller on the lowland than on the ridges; bark tightly clinging, thick, dark brown. Leaves lance-shaped, about 3-6 in. long, with numerous fine transverse parallel veins. Flowers rather large, in clusters of several. Fruit ½-¾ in. long, pitcher-like; seeds large, oval, narrow.

The commonest tree of the forest lands of the Cairns district.

(2) *Eucalpytus leptophleba* F.v.M. Box.

A slender tree of small to medium height, on the lower-lying forest land; bark tightly clinging, dark but more or less mottled with grey. Older leaves about 6 in. long by $2\frac{1}{2}$ in. broad, bluish green; young leaves near the flowers much narrower. Flowers whitish, about $\frac{1}{2}$ in. across. Fruit about $\frac{1}{4}$ in. diameter.

Common on the low-lying forest lands around Gordonvale, in company with *E. corymbosa*, which it resembles very closely, but the somewhat mottled bark will serve to separate it.

(2) *Eucalyptus crebra* F.v.M. Ironbark.

A medium-sized to large tree on forest land; bark hard, dark grey, rough and furrowed. Leaves lance-shaped, straight or sword-shaped, 4-6 in. long, rather thick. Flowers in clusters of 3-6, small, on short stalks. Seed capsules about $\frac{1}{8}$ in. diameter.

The ironbark keeps to the hills or ridgy country. In general appearance it resembles the bloodwood, but the bark is much rougher and more furrowed.

(2) *Eucalyptus tereticornis* Sm. Blue Gum.

Tall handsome tree, common on forest land; bark smooth, whitish or ash-coloured, shedding in thin layers. Leaves lance-like, curved, pointed, 6 in. or more in length. Flowers in clusters of 1-8 on stalks about $\frac{1}{8}$ in. long, united to a footstalk. Fruit almost globular, about $\frac{1}{3}$ in. diameter; capsule not sunk, the valves protruding beyond the rim.

Everyone is probably familiar with this graceful tree.

(4) *Eucalyptus platyphylla* F.v.M. Poplar Gum.

Large, handsome, somewhat straggly trees, on low-lying forest land; bark smooth, white. Leaves light green, broadly oval or roundish, the large ones 8-10 in. long by 6-8 in. wide, broadest at the base. Flowers in clusters of 3-6 on very short stalks united to short footstalks. Fruit somewhat conical, about $\frac{1}{3}$ in. diameter, not contracted at orifice.

Easily known by the large broad leaves.

(3) *Tristania suaveolens* Sm. Swamp Mahogany.

Small to medium-sized bushy tree, on low-lying forest land; bark thick, brown, peeling off in thin stringy flakes or splinters. Twigs, leafstalks, &c., hoary grey. Leaves broadly oval, about $3\frac{1}{2}$ in. long, $2\text{-}2\frac{1}{2}$ in. broad, green above, silvery grey and velvety beneath. Flowers very small, scented, yellow, clustered on last few inches of terminal twigs, in groups of about 8, shortly stalked, united to a stem about 1 in. long.

A very common tree in swampy or low-lying forest; the brown stringy bark makes it easily noticed or distinguished.

(3) *Eugenia tierneyana* F.v.M. River Cherry.

A bushy tree, rarely attaining a height of 60 ft., growing on banks of streams; bark smooth, ashy grey; branches spreading. Leaves narrow-oblong, 3-6 in. long, glossy green.

Flowers whitish, large, in loose clusters on old wood or at base of leafstalks. Fruit globular, ½ in. diameter, bright red, borne in large numbers.

The glossy green dense foliage of the River Cherry is well known; the fruit is dry and acid and makes very good jam. Feeding-tree of *Repsimus aneus.*

(3) *Careya australis* F.v.M. Cockatoo Apple.

A small rather straggly tree, rarely over 20 ft. in height, the bark thick and tightly clinging and pink inside. Leaves oval, or more broadly rounded at apex than base, light green, about 4 in. long. Flowers large, 2 in. across, white, the stamens red and very numerous; a few flowers together at ends of short leafy shoots. Fruit apple-shaped or ovoid, green, 1½ in. or more in diameter.

One of the common trees of the low-lying grounds.

(2) *Barringtonia calyptrata* R. Br.

A tall erect tree, attaining a great height, with a bushy head, the branches not spreading; bark dark grey, rough and tightly clinging. Leaves clustered together at ends of branches, 10-16 in. long by 4-6 in. broad, tapering toward base, rounded at apex. Fruit pear-shaped, green, 3 in. long by 1½ in. in diameter.

A conspicuous tree, growing in low-lying scrubs.

## Family PASSIFLOREÆ.

(4) *Carica papaya* Linn. Papaw.

## Family RUBIACEÆ.

(3) *Sarcocephalus cordatus* Miq. Leichhardt-tree.

An erect handsome tree, attaining a great height, growing in swampy land near scrubs, or in beds of streams; bark coarse, thick, and furrowed. Leaves large, broadly oval, up to 10 in. in length, rounded at base, pointed at apex. Flowers small, yellow, sweet-scented, but borne in dense, globular, fluffy heads 1 in. diameter. Fruits united in a hard round or oval mass of more than 1 in. long, pitted and rough.

(4) *Timonius rumphii* DC.

A tall erect shrub or slender tree, with hard blackish bark. Leaves pointed, narrowed at base, 3-5 in. long by 1-1½ in. wide. Flowers small, yellowish white, clustered at ends of terminal twigs. Berry globular, of about ½ in. diameter, hard, green.

## Family OLEACEÆ.

(3) *Linociera ramiflora* DC.

A bushy shrub or tree of considerable size, on scrub land, the bark grey and rather smooth. Leaves 4-9 in. long, 1½-4 in. broad, narrowed at base, rounded or pointed at apex. Flowers very small, in clusters on stalks 1-2 in. long. Berry round, green, hard, under ½ in. in diameter.

## Family BORAGINEÆ.

(3) *Cordia myxa* Linn.

A handsome tree with dense foliage. Leaves shining green, ovate, 2-4 in. long. Flowers small, in close clusters. Fruit borne in great bunches, like grapes, round, whitish to pink, $\frac{1}{2}$ in. diameter, soft and fleshy.

This tree is met with in scrub lands, and is sometimes found cultivated. The masses of fruit remain on the tree for a considerable period.

## Family LAURINEÆ.

(4) *Litsea ferruginea* Benth. & Hook.

An upright tree attaining a height of 30 ft., in scrub, the branches with fine reddish hairs. Foliage dense, the leaves glossy dark green, stiff, ovate, pointed at apex, rounded at base, 3-6 in. long, brownish beneath and with fine hairs. Flowers small, inconspicuous. Fruit small, oval.

A common tree in the scrubs, and food plant of *Anoplognathus punctulatus*.

## Family PROTEACEÆ.

(4) *Grevillea gibbosa* R. Br.

A small tree or tall shrub in open forest, ridgy country. Leaves long, slender, lanceolate, 3-5 in. long, $\frac{3}{4}$ in. broad; foliage somewhat silvery, caused by a white dusting on the leaves, the young foliage rusty or reddish. Flowers small, in dense spikes 3-6 in. long. Fruit a hard woody nut, round, compressed, fully $1\frac{1}{2}$ in. in diameter, splitting when ripe lengthways, and enclosing two flat, broadly winged seeds.

(4) *Persoonia falcata* R. Br.

A small upright tree growing in open forest, ridgy country, with brown scaly bark. Leaves long, slender, blade-shaped, 4-10 in. long, $\frac{1}{4}$-1 in. wide, dull dark green. Fruit rounded, $\frac{1}{2}$ in. long.

Related to the Grevilleas and not unlike them in appearance.

## Family EUPHORBIACEÆ.

(1) *Glochidion ferdinandi* Muell. Arg.

A tree sometimes attaining medium height, in or in the neighbourhood of scrubs, the bark brown and inclined to be splintery. Leaves glossy and smooth, on short leafstalks, ovate, from $1\frac{1}{2}$ to 6 in. long by $\frac{1}{2}$-2 in. broad. Flowers small, yellow, situated on terminal branches between the leaves. Seed capsule 5- to 7-celled, rounded, flattened, furrowed between the cells; dark green.

A common scrub tree.

(4) *Glochidion lobocarpus* Benth.

A small, erect, slender tree or tall shrub, the bark light grey and rather smooth. Leaves ovate, green above, pale or whitish beneath, $1\frac{1}{2}$-$2\frac{1}{2}$ in. long. Flowers small, inconspicuous. Seed capsules deeply 3-celled.

Growing in small clusters throughout the forest. It differs widely in appearance from the preceding species.

(2) *Breynia cernua* Muell. Arg.

A small, upright, slender tree or tall shrub, growing in second-growth scrub. Leaves very glossy, broadly ovate, 1-$2\frac{1}{2}$ in. long. Flowers very small, inconspicuous. Berries red or purple, small, borne singly at the base of the leafstalks.

Common in the vicinity of Babinda; in general appearance it closely resembles the species of *Glochidion*, especially *G. lobocarpus*. A feeding-tree of *Lepidiota caudata* and *Anoplognathus smaragdinus*.

(1) *Aleurites moluccana* Willd. Candle Nut.

A handsome erect tree, attaining great height, 100 ft., on scrub land, with smooth light-grey bark. Leaves crowded at ends of branches, broadly ovate, up to 8 in. long by 5 in. broad. Flowers small, numerous, in terminal masses. Fruit large, somewhat fleshy, round, fully 2 in. diameter.

A well-known and conspicuous tree.

## Family URTICACEÆ.

(1) *Ficus infectoria* Roxb. Strangle Fig.

A large, deciduous, spreading tree, parasitic on Eucalypts or scrub trees, frequently met with on edges of scrubs, and sometimes attaining a very large size. Leaves smooth, from $3\frac{1}{2}$ to 5 in. long, on long leafstalks, oval or oblong-oval, the young foliage often pinkish. Fruit in pairs, globose when ripe, $\frac{1}{4}$ in. diameter, whitish flushed with red and dotted.

The most common Strangle Fig in the vicinity of Gordonvale; it very closely resembles *F. nesophila*, but the leaves are rather larger, the fruit is smaller and uniformly rounded. A very fine example of this tree occupies a prominent position in Abbott street, Cairns.

(1) *Ficus nesophila* Miq. Allied Strangle Fig.

A spreading and often large tree, parasitic on Eucalypts near borders of scrubs. Leaves smooth, 2-4 in. long, oval, pointed at ends and toward base. Fruit subglobular or somewhat turbinate, solitary or in pairs against base of leafstalks or on leafless wood of previous year's shoots, about $\frac{3}{8}$ in. diameter, yellowish green when ripe.

A rarer tree than the foregoing. A very large specimen ornamented the grounds of the Court-house, Cairns, but is now being demolished.

(1) *Ficus pilosa* Reinw.

A large widely spreading tree, parasitic on Eucalypts bordering scrub land. Leaves smooth, about 6 in. long, oval. Fruit usually in pairs and close against twigs and base of leafstalks; red with yellow spots, orange-coloured inside when ripe, about $\frac{3}{4}$ in. long, somewhat oval.

Allied to both *F. infectoria* and *F. nesophila*. The leaves are larger and rather coarser; the sessile, larger red fruit easily distinguished it. In the neighbourhood of Gordonvale it is found growing on *Eucalyptus platyphylla*.

(2) *Ficus decaisneana* Miq. Glossy Fig.

A small, graceful, parasitic tree. Leaves smooth and glossy, with very prominent veins, ovate, and longly acuminate, up to 6 in. long by 2 in. broad, on rather short flattened leafstalks. Fruit solitary or in pairs at the base of the leafstalks on very short stalks, globular, $\frac{3}{8}$ in. diameter, yellow.

We are aware of only one tree, which is near Meringa: the smooth leaves with their prominent veins should serve to distinguish it from the other parasitic figs.

(4) *Ficus thynneana* Bailey. Cairns Banyan.

A dwarfed tree with a densely spreading head, the branches more or less horizontal and emitting numerous roots. Leaves short and broad, rather thick, up to 4 in. long by $2\frac{1}{2}$ in. broad, broadly rounded at apex, on short, rather flattened leafstalks. Fruit borne singly or in pairs, at base of leafstalks, sessile, pear-shaped, the apex rather flattened, $\frac{1}{2}$-$\frac{3}{4}$ in. long, yellow.

The only specimen known to us is growing against the seawall on the Cairns Esplanade, and this is the tree from which the original description was made.

(1) *Ficus benjamina Linn.* Weeping Fig.

A medium-sized tree, cultivated in parks, gardens, &c.: often found wild as a parasite on scrub trees. Foliage drooping, of a rich green, and very dense; leaves shining, about 3 in. long. Fruit globular, flushed with red, or often bright red, about $\frac{3}{8}$ in. diameter, on the young twigs.

The common cultivated Weeping Fig.

(2) *Ficus platypoda* A. Cunn. Rusty Fig.

An erect tree of robust growth with widely spreading head, on forest land, sometimes parasitic on Eucalypts. Leaves on broad, flattened leafstalks, smooth, rather thick, green above, whitish and rusty-looking beneath, about 6 in. long by $1\frac{1}{2}$ in. broad, tapering to a point toward each end. Fruit mostly in pairs, on the young twigs, globular, umbonate at apex, less than $\frac{1}{2}$ in. diameter, reddish yellow.

A conspicuous tree; although sometimes parasitic this species is not a true Strangle Fig.

(1) *Ficus elastica* Roxb. Rubber-tree.

A very large, spreading tree, cultivated, one of those yielding the rubber of commerce. Leaves leathery, dark green above, rusty red beneath, broadly oval in outline, 3-9 in. long; terminal shoots enclosed in large, red, conspicuous bracts.

Occurring only in parks, gardens, &c.

(4) *Ficus magnifolia* F.v.M. Red-leaved Fig.

A bush or small tree in or on edge of scrubs. Leaves broad, slightly scabrous, tapering to a point, usually about 6 in. but sometimes $1\frac{1}{2}$ ft. long, the young foliage reddish to bright red. Fruit mostly in pairs, on the old wood or previous year's growth, sometimes on the young growth, or in clusters at the base of the plant, pear-shaped, $\frac{1}{2}$-$\frac{3}{4}$ in. diameter, dull yellowish or reddish.

Very plentiful on scrub land; conspicuous on account of the colour of the new growth.

(4) *Ficus cascaria* F.v.M. Ribbed Fig.

A small tree in or on edges of scrubs. Leaves smooth, shining, pale beneath, 3-5 in. long, $1\frac{1}{2}$-$2\frac{1}{2}$ in. broad. Fruit on the young growth, single or in pairs, pear-shaped, $\frac{1}{2}$ in. diameter with six longitudinal raised ribs outside, very hollow inside.

A common tree around Babinda; the rather pale foliage and ribbed fruit will serve to distinguish it.

(2) *Ficus opposita* Miq. Rough-leaved Fig.

A tall shrub or small tree, common on forest land. Leaves very variable in size and shape, usually 2-3 in. long, more or less oval, rough above, hairy beneath. Fruit solitary or in pairs, nearly globular when ripe, dull reddish, about $\frac{1}{2}$ in. diameter.

A very common tree on forest land. It never attains large size or height. The rough or scabrous foliage is a distinguishing factor.

(4) *Ficus hispida* Linn. Hairy Fig.

A shrub or small tree on scrub land, the young twigs hollow and pipe-like. Leaves broadly oblong or almost oval, mostly 6-10 in. long, variable in size and shape, rough above, soft beneath. Fruit either in pairs or more often in leafless clusters on older wood, round or somewhat top-shaped, $\frac{3}{4}$-1 in. diameter, whitish or yellowish, more or less hairy.

Plentiful in scrub areas; the large rough leaves and clustered fruit are conspicuous characters.

(1) *Ficus glomerata* Willd. Cluster Fig.

A tall erect tree bordering creeks and scrub land. Leaves ovate, smooth, 3-5 in. long. Fruit in clusters on the principal stems, globular, 1-$1\frac{1}{2}$ in. diameter, red or pinkish when ripe.

The common Cluster Fig, well known in most districts.

(1) *Ficus chretoides* F.v.M. Light-barked Fig.

A tall erect tree, growing in scrubs, and attaining a height of 60 ft. Leaves smooth, broadly ovate, 6-10 in. long and 4-6 in. broad. Fruit on the old wood or principal stems, dark greenish when ripe, depressed-globular, 1-1½ in. diameter.

A fine tree; it resembles *F. glomerata* in its growing habits, but the leaves are very much larger. It is very common in the lower scrubs of the Cairns range.

(1) *Artocarpus integrifolia* Linn. Jack-fruit.

A handsome tree, with dense dark-green foliage, attaining a height of 20 ft. Leaves large, broad, rounded at apex, up to 7 in. long by 5 in. broad, shining. Fruit of the bread-fruit type, borne on the stems and branches, weighing several pounds, oval, green, its surface roughened and divided into numerous sections.

An introduced tree found in gardens.

### Family SCITAMINEÆ.

(1) *Musa chinensis.* Banana.

### Family PALMEÆ.

(1) *Cocos nucifera* Linn. Coconut.

### Family GRAMINEÆ.

(2) *Saccharum officinale.* Sugar-cane.

(3) *Bambusa* sp. Bamboo.

## Observations and Comments on the List.

A glance through the list will reveal the fact that twenty different trees are included in the favoured food plants, while fourteen are given as occasionally attacked; eleven are classed as harbourers; and nineteen common trees are regarded as immune.

Some notes on those plants in the first class may prove of interest. We come first of all to the Tar-tree (*Semecarpus australiensis*), which in the vicinity of Gordonvale grows rather freely in scrub fringes, and often attains a considerable size; in the beetle season practically every example is badly invaded, and we have seen a tree 70 feet high almost wholly defoliated. The Grey Wattle (*Acacia polystachya*) appears to flourish solely in one locality, at Highleigh, Gordonvale, where its leaves are eaten to some extent. The White Wattle (*A. holosericea*) is another tree of limited areas; a clump of these small trees borders the edge of a swampy tract of land near Gordonvale, and we are aware of a similar cluster at Mossman; in both situations the foliage was extensively consumed. The Cream-flowered Wattle (*A. flavescens*) is a very general species round Cairns, one of its centres of distribution being the Greenhills estate, on the eastern side of which it forms semi-dense forests; however, the low-lying and swampy ground does not sustain it, except in solitary cases. At Greenhills it follows next in importance as a feeding-tree to the Moreton Bay Ash; moreover, it grows in much greater abundance; the trees are often crowded, and the foliage frequently bears a very ragged appearance. The leaves of the Thick-leaved Tea-tree (*Melaleuca leucadendron* var. *cunninghami*) are eaten to an appreciable extent, but we have not yet observed a tree severely defoliated. This now brings us to the Moreton Bay Ash (*Eucalyptus tessellaris*), for which tree the beetles show a partiality above all others; it grows throughout the forest areas and is exceedingly plentiful everywhere around Gordonvale. In the beetle season it harbours the pest earliest, possibly because it is so common on the edges of canefields; the trees are quickly denuded, soon presenting a very bare aspect, and even when separated from cultivated fields by a mile or more of natural bush they are still found loaded with beetles. At Greenhills young Moreton Bay Ashes, reaching a height of 35 feet, fringe the eastern side of the worst-affected fields; for the first few days after emergence the greybacks were almost wholly on these trees, straightway devouring the young foliage and then the older leaves; after a week or so, scarcely any greenery was left, and they then sought the Wattles, Bloodwoods, &c.; subsequently, whenever the afflicted Moreton Bay Ashes put forth a few new shoots, they were rapidly revisited, until the end of the aerial existence of the scourge. Probably the Bloodwood (*E. corymbosa*) is the commonest tree of the Cairns district; its leaves are favoured to a considerable extent, but usually only the younger ones. *Glochidion ferdinandi* is the scrub tree, referred to by Tryon (19) as "*Phyllanthus* (*? ferdinandi*) or Wild Nutmeg," where he states that "it was found during the season of 1894, to be more frequently resorted to by the beetle for food requirements than was, perhaps, any other tree; and, in fact, one of those plants was seldom observed in a district where the grub pest prevailed that did not contain a greater or less number of these insects." Girault and Dodd (66) also mentioned it under the name of "*Philanthus* sp." Where it occurs on the edges of scrubs at Gordonvale it is usually sought after; around Macknade Mill, in the Herbert River district, it is known as "the Beetle-tree," which would serve to show its importance as a feeding-tree. The Candle Nut (*Aleurites moluccana*) is found sparingly in scrub areas, where it may attain a great height; both at Mossman and Cairns it was noticed to be attractive to the beetles; a very tall example near Meringa was drastically treated by them. Now follow the Figs; the three closely related Strangle Figs (*Ficus infectoria*, *F. nesophila*, and *F. pilosa*) are taken conjunctly, since they are equally infested; of these the first-named is most frequently met with. A large spreading tree of this species growing near Meringa, and separated from canefields by several hundred yards of bush, was completely stripped. In a patch of scrub a mile from the eastern border of the Greenhills estate there is a huge specimen of this parasitic fig; its aerial roots have enclosed several trees, forming a buttressed trunk many feet through, while the spreading head towers over its surroundings; in January, 1921, the branches of this giant were almost bare, while the ground beneath was covered with the excreta of the beetles. The ornamental Weeping Fig (*F. benjamina*) and the Rubber-tree (*F. elastica*), which are cultivated in parks and gardens, are also highly favoured. The Cluster Fig (*F. glomerata*) occurs near scrubs or along streams, and is a favourite food plant, being swiftly almost entirely denuded. Its ally, *F. ehretioides*, is a rare plant around Gordonvale, but has been recorded as a feeding-tree wherever it was recognised, and has been observed strongly attacked. The foliage of another cultivated tree, the Jack-fruit (*Artocarpus integrifolia*), readily entices the beetles. Bananas, too, are greatly damaged, and Coconut Palms are almost invariably stripped bare.

Little need be said of trees in the second class, but a few words on those of the third category may be worth while. The Mango has been recorded (66) as a food plant, and though this may happen occasionally our evidence is negative; trees have been watched where the beetles swarmed and mated night after night, yet it could not be discovered that the foliage had been at all consumed; on account of its dense leafage it yields splendid shelter for the beetles during the day. Girault and Dodd gave the River Cherry (*Eugenia tierneyana*), Leichhardt-tree (*Sarcocephalus cordatus*), and the Cockatoo Apple (*Careya australis*) as being occasionally attacked, but in our experience they can only be classed as harbouring trees. The Bamboo is often regarded as an important food plant; we are mindful of clumps of these in canefields, where the beetles swarmed in vast numbers each night, and yet investigation failed to show that the foliage had in any way been eaten.

The third and fourth classes in the list are interesting in view of the fact that they show what common trees may be planted or let grow around homesteads, canefields, &c., with a reasonable degree of impunity. Of course, it is quite feasible that, with the absence of the usual feeding-trees, the beetles will turn their attention to those that are now considered immune. One that we can commend highly as an ornamental and shade tree is the River Cherry (*Eugenia tierneyana*); the glossy green foliage is very distinctive and gives splendid shade, and the prolific crops of cherry-like fruit can be used for making very good jam.

Perhaps the most interesting feature in a study of the feeding-trees is the obvious discrimination in the choice of food that the beetles exhibit, even between trees that are closely related. A striking example of this power of discernment is observed in the Wattles; among others, two species occur in great profusion in the Cairns district—namely, the Black Wattle (*Acacia aulacocarpa*) and the Cream-flowered Wattle (*A. flavescens*); the former has not under any circumstances been recorded as being eaten, while the latter is one of the most important feeding-trees. A yet more forcible case is instanced in the various forms of the Paper-barked Tea-tree (*Melaleuca leucadendron*), one variety of which is highly favoured by the beetles, the other three apparently being immune. Six members of the genus *Eucalyptus* thrive in the neighbourhood of Gordonvale; one, the Moreton Bay Ash, is more readily attacked than any other tree; four are more or less preferred; and one, the Poplar Gum (*E. platyphylla*), is palpably distasteful. In this family (Myrtaceæ) there are two exceedingly common trees in this same district, the Swamp Mahogany (*Tristania suaveolens*) and Cockatoo Apple (*Careya australis*); both of these are everywhere to be noticed in the forest areas, but neither suffers invasion. Then, too, in the genus *Glochidion*, one species is much fancied, the other, to our knowledge, not being appreciated (of this second species, *G. lobocarpus*, Tryon records that "it is also attacked by the beetles," although we have not found such to be the case). Finally there are the various Figs; no discrimination seemingly is made between the several Strangle Figs; the rough-leaved variety (*F. opposita*) is eaten intermittently, but some of the smaller kinds that are rarely more than shrubs, as *F. magnifolia*, *F. casearia*, and *F. hispida*, would seem to escape aggression.

The knowledge that cane-leaves are sometimes eaten leads to the interesting surmise that if the forests were cleared away it might be possible for the beetles to subsist entirely on this foliage. However, considering the myriads that breed in canefields and the immense number of females that return to deposit their eggs, it is not surprising that a few individuals have acquired the habit of dawdling there for a day or so to eat; it has been found that these stragglers were invariably newly emerged, or females re-emerging from the ground after egg-laying.

We are indebted to Mr. C. T. White, Government Botanist, for the determination of the plants in the above list.

## Lepidiota frenchi Blackburn.

This species was named by the late Rev. Canon Blackburn, and the description appeared in the Transactions of the Royal Society of South Australia, vol. xxxvi, 1912. The type locality was given as "Queensland (Cairns); male from Mr. French, female from Mr. Lea."

As to the distribution of this species, Girault and Dodd (66) included Mossman, Cooktown, and Babinda. But by carefully breeding out the grubs Mr. Dodd (91) found that those from Cooktown were *Lepidiota* No. 683, a species later named *consobrina* by Girault; and the Babinda grubs proved to be *Lepidiota caudata* Blackburn. Mr. Jarvis, however, probably overlooked these data, for he (99) based his conclusions upon the unverified records published by Girault and Dodd. Subsequent observations go to show that this species belongs essentially to the open forest country, favouring areas well supplied with the native grasses; it has never been collected in the densely timbered scrub lands. Then, too, as far as we have been able to observe this species occurs only at Mossman, outside of the Cairns district, where its chief centre of action is about Gordonvale.

### IMPORTANCE AND NATURE OF INJURY.

Though the range of this species is apparently limited, the individuals sometimes emerge in tremendous numbers, and their offspring, the grubs, frequently do considerable damage to sugar-cane. Indeed, in their range, they are considered almost as destructive as the larger greybacked species. This is largely due to the fact that the grubs live almost two years in the soil, the very destructive third stage requiring fully a year to mature. Furthermore, these large grubs are able to start activities on the cane-roots in August or September, several months before the eggs of the greybacks are laid; hence their work at this season is particularly noticeable, especially on the late-planted crop.

My first experience with this pest was in a first ratoon crop of Badila near Gordonvale, in November 1917. As many as twenty-five large stage III grubs were found under a stool, near the grassy roadside, while further back in the field the average per stool was only five to eight. The infestation appeared to be in patches, a chain or so in extent, and these were more prevalent near the grassy borders of the field. About the same time I discovered plant cane suffering in a similar manner on several other farms near Gordonvale. In each case there was the same spotted appearance in the fields, comparatively small areas here and there being practically killed out, whilst adjoining cane was nice and green. The injury was particularly bad in a field where grass had been ploughed out preparatory to planting the crop. The grubs had eaten off all the roots of the young plants, and in some cases had bored right into the old seed-stalk, where we found them at work; in other instances they had cut off the young shoots, just as is the habit of the greybacks.

November, 1918, I found this species giving considerable trouble at Mossman. One ratoon field at the edge of town, though yellowed in patches by them, was not killed out; this was apparently due to the fact that the grubs were more abundant under bunches of grass that grew in the centres than they were in the cane itself. At Mowbray, too, in that district, I found this pest; it had killed out plant cane wherever it occurred on high spots in the field; moreover, cane in the low places was beautifully green, with no indication of grubs. Evidently, the beetles in their flight had bumped into these knolls, just as has been observed in the case of our other species.

## HABITS AND LIFE HISTORY.

*Emergence and Mating.*—Though this species has a two-year life-cycle, there is a considerable emergence every year. Usually a day or so after the first heavy rains of November or December have soaked the hard subsoil the beetles come out in hordes. When in a grass paddock at dusk, they appear to rise right from under one's feet, and on every side, in a seething swarm. After a wild flight of about ten minutes, they begin to settle on any convenient low objects, and mating takes place. The females always settle first, but each is quickly surrounded by several males; when one is attached the others fly away. The attached male always lets himself fall back as soon as union is secured, and hangs head downward supported only by the genitalia. So abundant are these mated couples that in places where they are unable to find sufficient low bushes they cover the fences, even hanging on the wires. Apparently their main concern is to mate immediately after emerging from the ground, night after night; this is kept up, as we have been able to demonstrate, during the whole period of their aerial life, which lasts for two or three months.

In a field of sugar-cane one really has a better opportunity to observe this mating flight. Half an hour after sunset swarms of beetles rise out of the ground simultaneously, on every side, when they begin flying close over the tops of the cane in great circles, as wide as the eye can see. The flight is much swifter than that of the larger greybacks and more direct, with no regard to any ordinary breeze. In dashing along so close to the tops of the cane they constantly strike against the leaves, producing a series of sounds very noticeable above the constant hum of the seething swarm. After flying for a few minutes, the females settle on the cane-leaves, and mating takes place, as has already been described. Since the duration of this act had never been definitely recorded, some attention was given to it. We found that there was little regularity in the time that they remained together, this ranging anywhere from twenty to twenty-nine minutes. Most of this time they were perfectly rigid, and remained so even when held in the hand. Near the completion of the act the male invariably began a movement of his legs, as if trying to escape, and finally set his wings in motion; then pulling himself loose, he flew away to the feeding-trees, leaving his mate in the cane.

These beetles, like the greybacks, have two definite flights each day—morning and evening; they differ, however, in that they spend the day in the soil, and eat comparatively little. The evening flight, which is primarily for mating, has been briefly described above. Field observations, on numerous occasions, all go to show that these beetles feed but little during the night, for they are usually found huddled up as if stiff and cold, when observed with a lantern. The morning flight begins just about half an hour before sunrise, when it is broad daylight. Beetles observed on the foliage at about 5·30 a.m. appeared to be stiff and lifeless. A few minutes before the flight started, however, each began to move the head and end of the abdomen. The antennæ were thrust far out, the plates extended, as if trying to sense the surroundings. In a moment the legs and wings began to move as they rose high on their toes and were off on their mad whirling flight. After about ten minutes or so, they began to settle on various stems, either dry or green, from 6 to 12 inches above the ground, and always with the head upward. In this position they remained perfectly motionless, with antennæ extended, for a short period of one to several minutes, when they turned and walked quickly to the ground. In an exceptional case, I saw a beetle wait twenty-five minutes before descending to enter the soil. Apparently there is a marked homing instinct among these beetles, for, in every case but one, those that I saw came to rest on twigs with a definite exit-hole at the base; and in most cases they crawled directly into this when descending. In the exceptional case, noted above, the beetle landed on a dry stick which was hanging but not reaching the ground. When he came to the end in his descent he appeared to be mystified, for it was still 6 inches to the soil; he turned round and climbed up, then came down again, reaching as far as he could below the end of the stick, as if trying to reach the ground. Still not satisfied, he climbed up a few inches, and when he came back down to the broken end he opened his wings and circled around to another stick, evidently the right one, for it had an exit-hole at the base.

After reaching the ground the beetles are often satisfied to simply get their heads covered in the hole. I have seen them with the hinder part of the body still exposed to view, even up till 8 a.m.; when the sun began to warm up they dug in.

This tardy habit of entering the soil is surely very detrimental to the species, for it exposes them to their natural enemies, both birds and parasites. In fact, on one occasion I observed a flock of ibises feasting on them shortly after the morning flight. The birds poked their long slender beaks into the grass at the base of each of the stems, and in most cases they got the beetle.

Excavation, on numerous occasions, showed that where the beetles enter the soil to hide during the day they do not go deep; usually those located were at depths of 4 or 5 inches.

Observations on the morning flight in fields of sugar-cane were very similar to those recorded above. Before the flight begins the beetles are to be seen sitting about on the leaves; they go through the same preliminary preparation of sensing the surroundings, and they have the same circling flight close over the tops of the plants, that I have noted in the evening; but their movements are so swift that it is difficult to observe any single specimen long. When ready to alight on the cane, they fly in small circles, and appear undecided just where to land; they then rest on the leaves for a few minutes, and fall to the ground.

I watched three specimens after they were on the ground, and it was fifteen to thirty minutes before they began to dig in, and in each case they crawled under the stool first, burrowing near the roots. Like the ostrich, they stuck their heads in, and then remained quiet for about fifteen minutes before burrowing deeper. About 6·30 a.m. the sun was getting on the ground; nevertheless, I could still see a part of the tail of each beetle at 7 a.m., so I marked the spots. At 2 p.m. we tried to dig them out, but only found one, though we went down a foot. This one proved to be a male, and was 4 inches straight down from where he entered the soil. Evidently the other two were gravid females, for, as I learned subsequently, these go deep to oviposit.

Though these beetles remain exposed so long after the morning flight ceases, it is an exceedingly difficult matter to find them, for they are so much the colour of the soil, especially on the red volcanic lands.

*Feeding Habits and Food Plants.*—In their native habitat, in the open forest, these insects usually feed on the foliage of the Moreton Bay ash and bloodwood, but where they occur in fields of sugar-cane far removed from these trees they have evidently been able to change their habit, deriving what little food they require directly from the cane-leaves (Plate III, fig. 2). I have gradually come to this conclusion because the beetles continue to infest certain fields near Gordonvale after all possible feeding-trees have been cleared away. And, as further evidence, I have found the beetles on the cane during the night, and they are there on the same leaves very early in the morning when they fly and re-enter the soil. Only occasionally, however, is there any indication that they have eaten the leaf upon which they have been sitting during the night. These observations, coupled with the fact that the alimentary canal is usually found nearly empty when beetles are dissected, point to the conclusion that they require much less nourishment than do the greybacks.

*Ovipositing.*—During the season 1920-21 I was able to give much more attention to this important phase of the subject; thus a considerable mass of data has been added to our files. In the present paper I will be able to summarise only the more important of these.

Most important, perhaps, is the discovery that the females of this species apparently have the eggs well developed and almost ready to lay when they emerge. Then, too, we have never known before that they continued to lay one set after another, during the whole of their aerial existence. And we had no definite knowledge of how or where the eggs were deposited in the field.

30th November, 1920, I dissected a lot of females of this species, and was surprised to find the eggs in every case nearly ripe, since the first emergence had occurred only two days before. The egg-tubes were dissected out, and I found that the general appearance of the ovaries was very similar to that already described for the greybacks (*see* Plate IV). Each of the tubes usually had two developed eggs and a smaller one; hence it would appear that at least twenty-four eggs would be laid in a set. I made a *camera lucida* sketch of one of the tubes, which showed an egg already passing downward to be laid (Plate XIII, fig. 2).

5th December, I made further dissections of beetles taken *in cop.*, and, as I expected, found that some of them had evidently laid, although this was only a week after the first emergence had been noted. The ovaries, in such cases, had a peculiar appearance, and the egg-tubes were considerably shortened (Plate XIII, fig. 3). In other specimens the eggs were still retained, but in some they had passed down the tubes (Plate XIII, fig. 1).

13th December, sixteen females taken *in cop.* were dissected, and evidently fourteen of these had laid, for only two contained ripe eggs; all the others had practically empty egg-tubes.

26th December, mating beetles were more abundant than usual, so I dissected thirty-eight females taken *in cop.* Among these I found the first conclusive evidence that the females continued their activities after they had laid their first batch of eggs. Twenty-one of this lot had empty egg-tubes, and in most of these the body-fat had been absorbed, and the alimentary canal almost invariably contained only a dark-coloured liquid, with no solid food. Furthermore, in one case there was a single ripe egg in the vagina, while all the egg-tubes were empty, except for the small ova next to the germaria. This proved definitely that they continued to mate after laying, and suggested that they probably would produce more eggs before succumbing. Only eight of these thirty-eight specimens contained ripe eggs; the remaining nine had ova in various stages of development.

27th December, I dissected the females of forty-seven pairs taken *in cop.* on cane-leaves, and found that forty-two of them had laid, though fifteen of this number had begun to form new sets. The remaining five had ripe eggs, in the following numbers: 22, 31, 35, 35, 34, an average of 31·4 eggs each.

5th January, 1921, the beetles continued in tremendous numbers, so that the mating pairs covered the posts and wires of the fence. I dissected seventy females taken *in cop.* They had all evidently laid; but fifteen of them were almost ready to lay again; of the balance, thirty-five had new sets well started, and twenty had evidently laid a second time, for their ovaries were practically empty.

29th January, mating still continued as usual, the pairs hanging thickly in low bushes, but the numbers were considerably reduced, so that they were not found on the fences. Twenty mating females were dissected, and I found ten of them with nearly empty egg-tubes, showing that they had recently laid; five had sets started with about one egg in each tube, half-size; the other five had eggs ready to lay again as follows: 15, 5, 15, 14, 15.

With this information we knew definitely that the beetles continued to mate and produce eggs as long as they lived. As to the number of eggs laid we can only conjecture, since they do not act naturally in confinement. Yet it is safe to assume that several sets are produced, for the beetles are usually on the wing for two months or more.

Many beetles were placed in cages with soil during the period of their abundance, in an attempt to study their laying habits. In some cases they were supplied with fresh leaves of Moreton Bay ash or bloodwood daily, and in others kept without food. Interesting observations were also made by keeping the beetles enclosed in soil, so that they could neither come to the light nor feed.

4th December, 1920, many pairs of beetles taken *in cop.* were confined in cages containing soil, with light above; half of these were fed and the others starved.

11th December, the cages had been cared for daily; the beetles were always found beneath the soil, and, in the case of those with food, slight evidence of eating was obtained. On this date one of the beetles, No. 4, without food, had deposited four eggs, loosely and singly in the soil.

15th December, this same beetle (No. 4) deposited fourteen more eggs; they were placed singly as before, each apparently in a small walled chamber. One of the beetles supplied with food, No. 1, laid two eggs.

18th December, the beetle in cage No. 1 had laid two more eggs. Another of the starved beetles (No. 3) laid twenty-three eggs, loosely and singly in the soil as above.

20th December, beetle in cage No. 3 laid another egg, and No. 4 had laid five more eggs.

23rd December, beetle in cage No. 1 laid eleven more eggs. Beetles dead in cage No. 3; total eggs twenty-four. In cages Nos. 7 and 8, without food, beetles dead, with no eggs.

After seventeen to twenty days the beetles without food died; those with food were alive. Three of the dead beetles were packed full of ripe eggs. When the food was daily changed it was found to be sparsely nibbled.

30th December, the beetle in cage No. 1 had laid seven more eggs. Beetle dead in cage No. 4; total eggs twenty-three.

6th January, 1921, beetle in cage No. 1 dead; total eggs laid twenty-two. Dissecting this specimen, five ripe eggs were found in the ovaries. The beetle in cage No. 5 with food was also dead; she had thirty ripe eggs in the ovaries; none had been laid during her confinement of thirty-four days; possibly the small space upset her.

10th January, the beetles dead in the remaining cages, with no eggs in the soil, though dissection showed large complements in the ovaries. The longest life in confinement with food was 38 days, average 25·66 days; without food, average 17·33 days.

Numerous experiments along this same line were carried out by Mr. Dodd, but the general results were not very different. The number of eggs obtained was very small; but dissection of the beetles indicated that they must have laid their first set before capture. Still, as several of the dead beetles when dissected, and that had not laid at all in confinement, were full of ripe eggs, it must be presumed that the unnatural conditions were felt by them. Confined conditions cause them to retain their eggs, and they may die still withholding them. The eggs were all fertile, even those laid right up to death; therefore the absence of the male does not interfere with their development. Confined space did not appear to have any influence on the length of life. The last beetle died 55 days after capture, and had been eating up to within a few days of death.

The difference in the length of life of those supplied with food and those starved is not great. The average for the former was 38 days, for the latter 29·3 days. Thus, apparently unlike *Lepidoderma albohirtum*, the adults of this species that have once fed can live for a long period when starved, and successfully develop eggs. Hence this may have an important bearing upon their distribution, as has been suggested above.

In order to learn how the eggs were deposited under natural conditions, I employed the same method that I used for the greybacks. Two gravid females were collected at the end of the morning flight, in a canefield, and placed in a large cage in the garden and supplied with males. They at once entered the soil. In the evening I watched the cage, and was rewarded by seeing the beetles emerge from the soil about 7 p.m. At the same time several males arose from the grass near-by and clustered around the cage.

After three days I examined the soil under the cage for eggs, with very satisfactory results. A trench was first dug outside the cage, and the soil was gradually shaved off the face of this until I found eggs at a depth of 8 inches. Each egg was in a well-defined, tiny oval cavity, about 5 millimetres long and less in width. The ten eggs in this set were placed rather close together, some of the cavities being not more than $\frac{1}{4}$ inch apart.

About 6 inches away I came upon another small set, at about the same depth. In this case I could find only five eggs. It is a very difficult matter to find the eggs, especially if the soil is damp, for each egg is enclosed in a small pellet of earth about $\frac{1}{2}$ inch in diameter.

I came upon the third set about 5 inches further in and 10 inches deep. Only nine eggs could be found; these were right down in the hard yellow-clay subsoil. A little further, and about 8 inches to one side, were eight more eggs, at a depth of about 7 inches. And, finally, there was a cluster of six eggs near the far edge of the cage, at a depth of 9 inches, thus making a total of thirty-eight eggs found.

Evidently we did not get all of them, for both females were found in the soil, and on dissection showed that they had completed laying. There is, however, the possibility that one of the beetles had laid before she was placed in the cage. The only male found was at a depth of 4 inches, which is very similar to our other observations on their hiding during the day.

10th January, 1921, I found eggs of this species under natural conditions in grass land. They were scattered in an area of a few inches, about 10 inches below the surface. Each egg, as usual, was enclosed in a tiny cell. This chamber is evidently made by the protruded portion of the vagina, which has chitinised spots protecting the cement glands. Furthermore, in some of the cells there is an evident opening on one side, through which the egg was laid. The compacting of the soil in forming the chamber naturally results in the particles clinging; hence the nodule effect around each egg. The chamber makes provision for the swelling of the egg as the embryo develops (Plate XIV).

I must now briefly refer to the peculiar behaviour of beetles confined in soil without access to either food or light. Three females taken whilst mating, 1st December, 1920, were used in this experiment. The three remained alive until 13th January, 1921; they appeared to behave as unemerged adults, and the absence of light seems to have had the effect of making them hibernate. 15th January, one was found dead; it had lived 43 days, and the body was full of ripe eggs. On 24th January, another died; this lived 53 days and was full of ripe eggs when dissected.

On 31st January, the last beetle was found in the act of ovipositing; 5 eggs were lying loose in the soil. Next day, 19 more eggs had been laid. On 2nd February the beetle was dead; on dissection 12 more ripe eggs were found in the ovaries; thus, counting all of these, she had a total of 36 eggs. Instinct had evidently caused it to deposit its eggs, or as many as possible, before succumbing. It lived 62 days without food or light.

Thus though the beetles remained apparently semi-torpid on account of the absence of light and food, and the development of the eggs was suspended, or at least deposition of them, they were eventually laid, which shows that food is not at all essential.

Again, in nature the species copulates repeatedly; this does not seem necessary, and the reason is not apparent, since this one could deposit her eggs 60 days after copulation. The eggs were fertile and hatched subsequently.

*Duration of the Egg Stage.*—22nd January, eggs dug out of the soil under the garden cage on the 8th, and probably laid on the 7th, hatched, giving a length of the stage as just 16 days. Numerous other records showed that this time was not much out of the way, though in a few cases a slightly longer period was required.

In all cases the eggs were kept in soil in small tins on the shelf of the insectary, and the soil kept moist. The temperature of the soil here would no doubt be several degrees less than under natural conditions.

Yet the length of the egg stage was greater than that of *L. albohirtum* under precisely the same conditions.

*Development of Larva.*—Since this species has a two-year life-cycle the grubs develop more slowly than those of *L. albohirtum*. During the feeding period of the first season—December to May—they pass through the first two stages, doing only slight damage, even where they are located in fields of sugar-cane. In the latter month, or before, they burrow downward and hibernate during the cool weather in resting-cells, 2 or 3 feet beneath the surface. As soon as the days begin to be warm in September or October they moult, changing to the third or final stage, and begin to burrow upward. It is at this time that they do their worst damage to the roots of cane. They continue active for a period of six or eight months, stunting the growth of the cane, even where it is not killed out altogether.

About April or May of the second year, these large fat grubs are fully fed and ready to burrow downward again, to form their pupation chambers. A great deal has been done in order to study the habits of the grubs at this season. The depth that they descend depends upon the character of the subsoil, just as in the case of the greybacks. In the red volcanic soils at Meringa, where most of our observations have been made, we have found the pupation chambers at depths varying from 8 inches to 24 inches, averaging 18·3 inches. The larvæ lie in these cells for five or six months, and gradually the walls of the chamber become coated with the discharges from the alimentary canal, so that the surface appears black and smooth when the grub is ready to pupate in October. Just before pupation takes place the body of the grub is very shrunken, and the skin is full of wrinkles; the insect appears almost lifeless.

*Pupation.*—It has always been past the middle of October before we found any pupæ in the field. Grubs kept in the insectary, too, pupated about this time. We have only two definite records of the duration of this stage.

14th November, 1918, a beetle emerged in the laboratory; the pupa, recently formed, had been dug from under blady grass at a depth of 24 inches, on 16th October. 18th November, another beetle emerged in the laboratory; the grub had pupated on 19th October. Hence it would appear that the duration of this stage is approximately one month. The beetles do not escape from the soil, however, often for a considerable period afterwards, since they must wait for the rains to set in. These usually begin in November or December, but may not occur sometimes until after the middle of January.

A chart has been prepared along the lines of one used by Mr. Davis (107), which illustrates graphically all the stages in the life-history of this pest, as has been described above (Plate XV).

## NATURAL ENEMIES AND CONTROL MEASURES.

The numerous natural enemies of *L. albohirtum*, dealt with further along in this paper, are equally effective against this species. Then, too, these factors in control have been discussed at considerable length in Bulletin No. 13.

Artificial control, too, must be along similar lines. Yet the fact that most of the devastating work of this species occurs during the early spring and summer necessitates some modification of our methods.

# Related Cane Beetles and their Allies.

BY ALAN P. DODD.

## LEPIDIOTA CONSOBRINA GIRAULT.

This species is so very closely related to *L. frenchi* that Girault and Dodd (66) referred larvæ from Cooktown to that species, and it was left later to Jarvis (99) and Dodd (91) to point out the distinguishing characters of the larval, pupal, and adult stages, designating the species as *Lepidiota* No. 683. So close is the relationship between the adults of *frenchi* and *consobrina*, that Mr. A. M. Lea, the eminent Australian coleopterist, did not consider the two distinct; he thought that possibly the latter might be a larger race of the former. It was not until 1918 that Girault, in "The Entomologist," of London, gave it the specific name, basing his description chiefly on the differences pointed out by the above writers.

As mentioned above, Girault and Dodd obtained the larvæ from Cooktown; Dodd (91) recorded the species from the neighbourhood of Gordonvale, and adults from Kuranda. Since then its limits have not been widened; it remains a rare species indeed around Gordonvale, but at Kuranda it appears to be the common species, emerging in small numbers in November and December.

Dodd has recorded a two-year life-cycle for the species. We have very little data to offer beyond what has already been published. Four stage III grubs were collected from red volcanic soil in October, 1917, and two were kept in confinement in soil; on 1st February, 1918, the two grubs were transferred to a cage containing a growing cane-plant; on 20th March the cane-plant was dead, and the grubs were eating the "set." By 14th September, 1918, they had pupated in cells measuring 55 mm. by 27 mm., at a depth of 8 inches against the bottom of the cage. Two stage II grubs were found on 27th April, 1918, and kept in soil; on 14th September, one was in a resting-cell in the middle of a hard lump of earth, the cell being regularly shaped, and smooth inside; both grubs were still in stage II. On 13th November, they had moulted to stage III, and had recommenced feeding.

In the past four years we have only two records of the adult beetles from the Gordonvale area. One was taken on 5th November, 1917, and the other was found in company with *L. frenchi* and *L. rothei* at dusk on 10th January, 1919. During the last two seasons we have not observed either the grubs or adults.

## LEPIDIOTA CAUDATA BLACKBURN.

Although in general appearance in the adult stage distinct enough from *L. frenchi*, the larva is less easily differentiated than that of *L. consobrina*. *L. caudata* takes the place of *L. frenchi* in the scrub lands around Innisfail, Babinda, Kuranda, the Atherton Tableland, and is even at Ravenshoe, at an elevation of 3,500 feet; it also occurs at Mossman. Its range appears to be strictly limited by the occurrence of the forest land, and we have not found it nearer than 12 miles of Gordonvale, southward.

Like *L. frenchi* in the forest land, it emerges in great hordes; and as the scrub areas have a greater rainfall, and the soil moister, emergence is considerably earlier than with its congener. Growers at Babinda have reported their emergence in August, but our earliest record is 10th September, and the latest 17th January. At this place in 1916, the beetles emerged in numbers on 12th September; in 1918 emergence took place about the end of September. At South Johnstone, in 1920, they were commencing to emerge on 12th October, and were plentiful at Babinda two days later. Mr. Roy Watson stated that the species occurred freely at Mossman, about the end of January, 1920, and an adult of a lighter colour than the coastal form was collected at Ravenshoe in February.

Their habits, in so far as studied, resemble those of *L. frenchi*. On emergence they fly to low bushes, fences, posts, &c., in fact any object, where they mate at once, following exactly the habits of their ally as observed at Meringa. The male invariably hangs head downward, as soon as connection is secured, and the pair remain perfectly motionless for about twenty minutes, when they break apart and fly to the feeding-trees for the night; at dawn they re-enter the soil to spend the day.

At Babinda the food plants are *Glochidion ferdinandi* and *Breynia cernua*, two closely allied trees in the family Euphorbiaceæ; the first-named has also been noted as a feeding-tree at Mossman.

*The Egg.*—Beetles kept in confinement deposited eggs at the bottom of the cage at a depth of about 4 inches; these were found singly in tiny cells, isolated, about $\frac{1}{4}$ inch from each other, and glued to the wall of the cell.

*The Grub.*—Girault and Dodd (66) confused the grub with that of *L. frenchi*, but Dodd (91) subsequently pointed out the distinguishing characters. As with the named species the life-cycle extends over a period of two years. Stage II grubs have been unearthed in January, May, June, and September, and stage III grubs in January, April, June, September, and October. The grubs are abundant in the yellow and other clayey loams of the scrub lands in cane areas, but as yet no specific case of their damaging sugar-cane has come under our notice. In view of their profusion, however, it would not be at all surprising if they should turn their attention to this crop.

*The Pupa.*—Dodd recorded pupæ at a depth of less than 6 inches, from 10th September to 16th November. On 12th June, 1918, Girault found a newly formed pupa at a depth of 18 inches in a sandy canefield; and on 20th June two fully coloured pupæ were ploughed out in a loose, sandy-loam, old canefield.

## LEPIDIOTA SP.

We have received adults of this species solely from Gin Gin in the Bundaberg district, and it is quite possible that it is one of the pests of the southern canefields. The beetle is of about the same size as *L. frenchi*, but broader in proportion to its length; the colour is of a rather light polished brown. This may be the adult of *Lepidiota* No. 666, which grubs were obtained at Childers and Bundaberg in canefields and bear a close resemblance to the group of grubs containing *frenchi*, *caudata*, and *consobrina*.

## LEPIDIOTA SP.

Known to us only from the neighbourhood of Atherton, 2,500 feet, Cairns district, this member of the genus is somewhat smaller than *frenchi*, and the elytra are light polished brown in colour. The adults swarmed in vast numbers in January and February.

The species is of especial interest because of its depredations in grass paddocks near Atherton. Just behind the town near the show-ground, there is a paspalum paddock of about 30 acres, owned by Mr. A. Arnott, and early in March, 1921, when we visited the district it was a pitiable sight. One-third was quite dead, in great bare patches devoid entirely of grass, the remains of the shrivelled-up stocks lying on the surface, the roots having been completely eaten away; of the rest of the paddock much was very poorly and none bore a sturdy crop. Examination showed that the whole paddock was thoroughly infested with *Lepidiota* grubs, which were in great numbers within an inch or two of the surface, and thus often at the very stocks of the grass. In the denuded areas they were quite as plentiful as in the grassed areas.

On 15th March Mr. Arnott wrote—

"As far as I know, these grubs have only attacked paspalum, and I only know of a few paddocks affected besides my own. I first noticed the effects of the grubs about eighteen months ago, when the grass was a trifle yellow in patches; this season nearly half the paddock (of 30 acres) is eaten clean out and the balance is swarming with grubs. Corn is growing alongside, but does not appear to suffer. The grubs in the dry season are down from 2 to 4 feet in the red soil. I was sinking a well in October and found scores below 3 feet. They rise to within a couple of inches of the surface after the first heavy rains and shortly after (about the first week in January) the beetles appear and fly after dark. The flights only lasted about five weeks; after that only odd beetles were met with and now it is very rare to come across one. They do not appear to have any natural enemies in the ground; of course the birds eat them if they are exposed. I notice quite a lot of baby grubs hatching out lately but have not noticed the eggs. Should these grubs take to the corn lands, they would do an enormous amount of damage; it will only be a short time before the bulk of the paspalum is eaten out of the infested paddocks."

We were informed by others, that in other fields in the district small patches of grass have been killed in this way for some years, but the damage has been negligible.

*The Grub.*—On 6th March most of the grubs were in stage III, and a few stage I were observed, but no stage II. On 25th March Mr. Arnott sent twelve grubs, eleven in stage III, one in stage I. Since they are in stage III and doing their main damage in January and February, there is little doubt that this species, like all those closely related to *L. frenchi*, has a two-year life-cycle.

The stage III grub is hardly differentiated from that of *L. frenchi* except by its distinctly smaller size, the width of the head being 5·5 mm. in comparison with the 6·5 mm. of the named species. Thus it approaches, at least in size, nearer to the species designated by Girault and Dodd as No. 666, but there are at least six hairs on either side in the irregular row *inside* the epicranial sclerite (two on either side in No. 666).

## LEPIDIOTA FROGGATTI MACLEAY.

This fine large species occurs in the scrub lands of the Cairns and Innisfail districts, but is apparently not plentiful. An adult came to light at South Johnstone on 12th October, 1920; it was newly emerged. At the end of that month a few were on the wing at Babinda at dusk, in company with *L. caudata*. Our only record of this beetle in the Gordonvale area is of a single specimen shaken during the day from bloodwood foliage at Greenhills on 26th January, 1920, in company with *L. albohirtum*. Their habits appear to be very similar to those of allied species.

The adult has not been connected with its larva. There is hardly a doubt, however, that the large grub recorded as *Lepidiota No. 15* belongs to the species, as Girault and Dodd surmised (66). Dodd (91) suggested that the life-cycle probably covered two years. Our only record is of stage III and II grubs under grass-roots at Kureen, on the Atherton Tableland, on 1st October, 1920.

The large size of this grub suggests the thought that it could cause tremendous damage to sugar-cane, were the species in sufficient numbers. In this respect it is interesting to quote a letter from Mr. W. J. Henderson, of the Seventeen-mile Tramline, South Johnstone, dated 11th April, 1921, in reference to this species, specimens of which were forwarded at the same time:—

"The two large grubs in the bottle are fairly plentiful, but are mostly away from the stools, as I plough out plenty while ploughing between the drills, but only get an odd one under the stools."

## LEPIDIOTA PERKINSI BLACKBURN.

A single beetle from Kuranda, collected by Mr. F. P. Dodd, has been doubtfully referred here by Mr. A. M. Lea.

## LEPIDIOTA SQUAMULATA WATERHOUSE.

In the earlier history of the grub-pest of sugar-cane, *L. squamulata* is often referred to as the, or one of the. principal damaging agents; Shelton (4), Olliff (8), Tryon (19), "Scrutator" (27), and others have used this name. There is little doubt that some confusion had arisen, and that the species in question was *Lepidoderma albohirtum*. Through the kindness of the South Australian Museum, we have received a specimen of the true *squamulata* labelled "Cossack, North West Australia," and Mr. Edgar R. Waite (110) states that Mr. A. M. Lea reports that he has seen specimens of this species from West Australia only. Thus we can state with some degree of certitude that *squamulata* is not one of the Queensland sugar-cane pests.

## LEPIDIOTA GRATA BLACKBURN.

This is a smaller species, not unlike *L. rothei* in appearance, but somewhat larger and broader. Our sole specimen was received from Mr. F. Creamer, of Gin Gin, who captured it in February, 1918.

At the same time Mr. Creamer forwarded a number of grubs of a species of *Lepidiota* which were evidently damaging cane. These are very similar indeed to those of *rothei*, the anal path being bordered by a slightly convex row of from 12-15 setæ on either side, meeting across the path; but the size is somewhat larger, the width of the head being 6 mm.

(5 mm. in *rothei*). In view of the close resemblance of adult *grata* to that of *rothei*, it would seem perfectly feasible to connect the grubs from Gin Gin with the former species.

Mr. Creamer took the grubs from under a stool of cane that they had damaged; and wrote that on the next farm to his, owned by Mr. Laurisen, 6 acres of plant cane and 3 acres of second ratoons had to be ploughed out on account of the grubs, and that 2 more acres of plant cane and 5 more of ratoons had been eaten out.

The cane is damaged by this species about the middle of summer, just when *L. frenchi* is active; therefore it is very possible that this insect has a two-year life-cycle.

## LEPIDIOTA ROTHEI BLACKBURN.

We have not met with this species outside of the area immediately surrounding Gordonvale, but it is said to occur in the Northern Territory. It is a native of the forest, and does not penetrate into the scrub lands. The grubs are commonly found in fields either newly cleared of forest growth or with a plentiful supply of grass, their presence in clean canefields being rare; dark loam or clayey soils are favoured; in the red volcanic soil of Greenhills they do not occur to our knowledge, although beetles have been observed on the edge of the estate.

*The Adults* in normal seasons emerge in vast numbers; the earliest emergence record is 1st December, 1917; in the following years the dates for this event are 19th December, 1918, 15th January, 1920, and 13th December, 1920; this usually takes place concurrently with that of *frenchi*. However, in the past season, the last-named insect was first seen on 28th November, whereas *rothei* was not out until 13th December. Then, too, they did not occur in the immense hordes of former years: the grass areas in the township of Gordonvale have always been a favourite breeding-ground, yet this season not a single beetle was collected in this neighbourhood. They remained in evidence in the vicinity of Meringa until 20th January, on which date they were last observed.

In general the habits of adult *rothei* agree very closely with those of *frenchi*. Mating takes place immediately on leaving the ground, but whereas *frenchi* copulates on fences, posts, weeds, &c., *rothei* invariably chooses the lower leaves of small trees, at heights varying from 4 to 20 feet. Repeated observations have proved that the act of copulation endures between one and two minutes; this is a wide divergence from the habits of all the species of *Lepidiota* that we have studied. The following note on the subject from our files is of interest:—

"At 7·03 p.m. the mating of *rothei* was observed. The female was sitting on a leaf about 4 feet from the ground, so her activities in detail could be seen. The vagina was protruded so that the cement glands were visible, just as is the case when eggs are being laid (*see* ovipositing of *L. albohirtum*), and a small drop of milky liquid was forced out. In a moment two males appeared, and one immediately went into *cop.*; the other then flew away. As soon as union was secured the male hung head downward, but he only remained in this position for about one minute, when he climbed up on to the back of his mate, where he remained for about another minute, then broke loose and flew away. After about a minute the female also departed.

"This ability to break away easily is evidently due to the character of the genitalia. The penis of the male in this species is very slender and the pouch is very tiny; hence he has no difficulty in withdrawing it from the *bursa copulatrix*. In the case of *frenchi*, on the other hand, the whole of the genitalia is often torn away from the male in trying to separate them; after union is once secured, the male must wait for a considerable period to let the contracted muscles of the *bursa copulatrix* relax."

Mating continues right through the period of their aerial life.

The egg-tubes in this species are very even in their development. Females, collected on the first night of emergence, when dissected had about two eggs fully developed, while the other tubes were in all stages of growth, some just starting to form the first egg. More than ten eggs have not been found at once fully developed and ready to lay, on dissection the usual number varying from four to eight; thus it would seem that a few eggs are laid from time to time, as they develop.

Of six specimens collected from a box-tree (*Eucalyptus leptophleba*) at 5-30 a.m. on 14th January, 1921, one was an hermaphrodite; the female characters were four egg-tubes containing seven normal ripe eggs and four small, spherical, aborted ones; the male characters were six normal disc-like testicles and a penis.

The food plants to us are several kinds of *Eucalyptus*, viz., the poplar gum (*E. platyphylla*), blue gum (*E. tereticornis*), bloodwood (*E. corymbosa*), and box (*E. leptophleba*); a doubtful feeding-tree is the coconut, on which they were presumably feeding, but the observation was not verified.

The beetles are readily attracted to light. On 9th December, 1917, they were swarming and mating for the first time in great numbers at Meringa; a light-trap decoyed 289 *L. rothei*, 8 *L. frenchi*, and 2 *L. albohirtum*. The following night was rainy, but the catch included 53 *rothei*, 6 *frenchi*, and 3 *albohirtum*. On 12th December, another showery evening resulted in trapping 70 *rothei*, 1 *frenchi*, and 1 *albohirtum*. The light-trap attracted very few on 22nd December, viz., 8 *rothei*, 2 *frenchi*. The moon was at the full on 28th December, and though the beetles were very plentiful in the adjoining forest scarcely any came to the light. The number allured to the light on 9th December recalls the statement made by Dodd (91) with reference to the related species, *Lepidiota No. 215*, that "on the first night of emergence many were attracted to artificial lights, but none were present on the subsequent nights of the swarming."

*The Egg.*—We have a sole record of the discovery of the eggs in the field. At Meringa, 14th January, 1919, in a field of 3-foot ratoon cane, a search was made for eggs; on pulling up the stools, in two cases single eggs were found at a depth of 5-6 inches, apparently in loose earth, directly under the stools. The eggs hatched on 21st January, and proved to be this species. In confinement eggs were found to be laid separately, each in a tiny cavity, and the period of incubation varied from 9 to 12 days.

*The Grub.*—Breeding of the grubs in confinement has definitely established a one-year life-cycle. A grub hatched in December, 1917, had entered the pupal stage by 21st November, and the beetle was obtained on 17th December. They do not develop nearly as rapidly as those of *L. albohirtum*, the only related species which is known to have a one-year life-cycle. Thus in confinement, of nine grubs that hatched on 28th December, six were in stage II, and three still in stage I on 20th March;

they were all in stage II on 28th April; and on 12th June one was in stage II, one in stage III (these were the sole survivors). Of grubs that hatched on 2nd January, by 28th April one each was in stage I, II, and III; and a stage II larva was found as late as 28th June. Some of these grubs (stage III) were still feeding on 21st November. Girault and Dodd (66) give field records of 31st March for the earliest and 7th July for the latest stage II, and 19th March for the earliest stage III. In comparison with *L. albohirtum*, therefore, the first two stages are much lengthened; but then *rothei* does not cease feeding until late in the year, and there is apparently not the long wait in the pupal and adult stages in the ground.

*The Pupa.*—Three pupæ were obtained from a ploughed dark-loam forest field, depth of ploughing 8 inches, on 18th December, 1918. Dodd (91) has recorded the discovery of pupæ in the field on 26th November.

## LEPIDIOTA SP. No. 215.

Girault and Dodd (66) first recorded this species, but they only knew the grub stage; however, Dodd (91) subsequently bred the adults, and gave various notes on the life-history. So very closely allied is this insect to *L. rothei*, that Mr. A. M. Lea could not consider it distinct, and it still remains unnamed.

Like *rothei*, No. 215 inhabits the forest land in the vicinity of Gordonvale. In the 1914-15 season a large emergence was recorded from the recreation reserve, a grass field in the township, 21st January; a few beetles were seen here the following year. No further notes occur in our files, and the species was apparently not again recognised until this past season (1920-21), when a first emergence took place from the reserve mentioned above, on 5th January. This was indeed very late in the season, for *L. albohirtum* had been on the wing for fully six weeks, *L. frenchi* for five weeks, and *L. rothei* for three weeks; the extreme lateness of emergence in comparison with related forms has already been established. The following observations were made at the time; the note is taken from our files:—

"Just on 7 p.m. this evening (21st January), a large emergence of these beetles was witnessed in the recreation reserve. They were rising from the ground in numbers, circling round once or twice, and then flying high to the tops of a clump of bamboos; round these they circled in rapid flight, but soon settled and were quiet. The flight lasted only a few minutes; it commenced very early, and was over before that of *frenchi* began. Farther along the road, a few were seen swarming in several places around low weeds a foot or so from the ground, and several mated pairs were secured. After the flight among the bamboos, mating pairs could be seen high (20-30 feet), and a very few were observed at 10-15 feet elevation. The captured pairs, shut up over night, slightly ate the foliage of the Malvaceous weed *Sida cordifolia*."

These observations were verified on subsequent nights of the swarming, but by 13th January the beetles had mostly disappeared, probably through the action of a flock of myna birds (*Acridotheres tristis*) that roosted nightly in the bamboos, and at dusk each evening spread over the reserve just at the time when the beetles were issuing from the ground. Strange to say, none of the adults were seen except in this restricted locality. The following record of the mating habits is of interest:—

"A pair was seen to go into *cop.* at 6.58 p.m.; at 7.25, being too dark for further observation, they were moved and carried on the finger into a lighted room at 7.30; at 7.33 the male separated and flew away; the female took wing at 7.35 p.m. Thus copulation lasted thirty-five minutes; perhaps under undisturbed conditions the act would have occupied a longer period."

In our study of allied species, we have not met with so prolonged a time for the act of sexual union; this is in sharp contradistinction to the habits of *rothei,* where mating is not continued beyond a minute or two.

Practically no observations on food plants have been made; a single beetle was seen eating into the leaf of a cultivated *Aralia* (Araliaceæ). Confined specimens ate sparingly of Moreton Bay ash (*Eucalyptus tessclaris*), but, as with *frenchi* and *rothei,* it would seem that little food is required.

Several pairs were kept in confinement with moist fine earth and supplied daily with tender foliage. One specimen, a male, remained alive for 54 days. The males appear to live for a longer period than the females; thus, of those that died natural deaths, four males averaged 46·25 days, and five females averaged 30·6 days. Moreover, in the case of each pair where the female died naturally, the male always lingered on after her death. This is not in accordance with the established behaviour of other species, and requires further confirmation.

*The Egg.*—As with *L. frenchi,* on first emergence a complete set of fully developed (or nearly so) eggs is present; this set contains a smaller number than with *frenchi,* but a larger number than is the case with *rothei.* On the first night of emergence, 5th January, two females were dissected; one had 17, the other 19, ripe eggs, while there was a number of other eggs in various stages; a few of the egg-tubes had no ripe eggs, only very small ones. Four females captured on the following night had fully sized eggs as follows: 17, 18, 28, 22.

In confinement the greatest number of eggs deposited by one female was 23; and the most obtained by dissection and counting the number already laid was 30. The laying period would seem to be spread over a number of days, in this respect the species showing an affinity with *rothei.* The eggs are deposited singly, in tiny well-formed cells.

Eggs from these confined beetles, kept in moist soil on a shelf in the insectary, did not hatch for 20-23 days, in two separate cases. A more definite record fixed the duration of the egg stage as 22 days. This is an abnormally long period, and may be accounted for by the unnatural conditions; even so, eggs of *L. albohirtum* and *L. frenchi* were maintained in exactly similar situations, without inducing any such irregularity. There are no records of eggs found in the field.

*The Larva.*—Dodd (91) believed that a two-year life-cycle was required; his grubs were mostly obtained by following ploughs, and as very little of this work has been carried out during the past few years, subsequent records of their occurrence are almost non-existent. Two stage III grubs were secured by digging in the dark loam soil of the laboratory grounds at Meringa, on 30th December, 1920, and this is our sole note on the species. Grubs hatched on 2nd March from eggs obtained in confinement were still in stage I on 2nd May.

## LEPIDIOTA DARWINI BLACKBURN.

Although recorded from the Gordonvale area by Girault and Dodd, subsequent investigations have not disclosed the species, and its occurrence therefore needs confirmation.

## LEPIDIOTA No. 615.

Dodd records the grubs of this unknown species from the bed of the Mulgrave River, but it has not been met with since.

## HAPLONYCHA DILATATA LEA.

Girault and Dodd wrote of this species as No. 587; it was not named by Mr. Lea until 1917, the original description appearing in the Transactions Royal Society of South Australia, vol. xli, p. 512, the locality being given as Cairns. We are aware of its presence in the neighbourhood of Gordonvale only, and presumably it is a native of the open forest lands.

A large emergence occurred at Meringa on 20-22nd December, 1917, and on 29th November, 1918. At Greenhills a few odd beetles were noticed on 15th January, 1920, and they were abundant on 26th January and 3rd February. At Meringa the species swarmed in vast numbers on 6th December, 1920.

Unlike other related scarabæids, *H. dilatata* does not always emerge at dusk. None were seen on the evening of 5th December, but they were mating everywhere at 5 a.m. next morning, just as it was getting light, and continued even after sunrise. On another occasion they were noticed mating at 6 a.m., this being continued as late as 7.30 a.m., by which time the sun was quite warm, the morning being bright. On dull days they sometimes remain on the foliage until the forenoon is well advanced before seeking shelter among grass, rubbish, &c. The known food plants are the common guava (*Psidium guyava*), cockatoo apple (*Careya australis*), Moreton Bay ash (*Eucalyptus tesselaris*), bloodwood (*E. corymbosa*), besides others. The beetles are readily attracted to lights. In confinement the length of life of the adult has been found to continue for as long as 50 days.

*The Egg.*—Beetles in captivity deposited eggs singly and scattered through the soil, no cell being formed. The duration of the egg stage has been ascertained as 12 days, under the unnatural conditions of the insectary. No eggs have been found in the field.

*The Grub.*—We have no evidence to offer beyond that which has already been published (66) (91).

## HAPLONYCHA SETOSA BLACKBURN.

A considerably larger, lighter-coloured species than the former. A single specimen came to light at Kuranda in 1915.

## NESO FLAVIPENNIS MACLEAY.

This is the species designated as No. 650 by Girault and Dodd, and it would appear to be one of the most common and generally distributed of the smaller Melolonthids, at least in the sugar-cane areas. Lights prove very attractive to the adults, and one can usually find a few of them in this way during the wet season months, from the end of December right up into May. We have observed specimens at Mossman, Ravenshoe (3,500 feet), Kuranda, Gordonvale, Ingham, and Ayr, but no records have been made from Babinda or Innisfail, although it seems to be equally at home in forest and scrub lands. They swarm in great numbers around low shrubs and bushes. Very little is known of their food plants, the only one observed being *Homalanthus populifolius* (family Euphorbiaceæ); an example of this scrub tree, 20 feet high, growing in a garden at Kuranda, was much resorted to by the beetles. The larvæ are found in forest land, or in fallow or grassy canefields.

## NESO DUCALIS BLACKBURN.

In colour this species is of a rather light reddish brown, and more closely resembles *Haplonycha dilatata* Lea. Adults have been collected sparingly at lights at Gordonvale; swarming took place in considerable numbers on low bushes along roadsides in cane areas at Mossman, 27th November to 3rd December, 1918. Nothing is known as to the life-history.

## SCITALA.

Two undetermined species of this genus occur in the scrub areas around Babinda, where they are commonly taken at lights. In appearance and size they are very similar to *Neso ducalis.*

## FRENCHELLA FIMBRIATA LEA.

A very rare insect. A single example was captured from the foliage of *Eucalyptus* at Greenhills, January, 1920. It is a very similar beetle to those of the three foregoing genera.

## HETERONYX SOLLICITUS BLACKBURN.

Several species of this genus are met with in the Northern cane areas, flying to lights in large numbers; they are all small brown beetles, and scarcely distinguishable from each other. *H. sollicitus* is the most frequent, and is recorded by Girault and Dodd as No. 646. We have little data to supply on the subject. A first emergence was noticed at Greenhills on 14th January, 1920, a small number swarming on cane-leaves; the following evening they were very abundant on the trees in the forest, but were not observed feeding. On 5th December, 1920, they were in multitudes, feeding on Moreton Bay ash (*Eucalyptus tesselaris*), cockatoo apple (*Careya australis*), and rough-leaved fig (*Ficus opposita*); many pairs were seen *in copula*, the male hanging head downward like the Lepidiotas.

## ENGYOPS FLAVUS LEA.

A small yellow form, not very distinct from the species of *Heteronyx*; it occurs prolifically at Babinda, and flies to lights in great numbers.

## EPHOLCIS BILOBICEPS FAIRMAIRE.

The larvæ of this curious little species was designated No. 609 by Girault and Dodd, who recorded them from Gordonvale and Cooktown. Probably it is a forest dweller. The adults are not addicted to flying to lights, and have the peculiar habit of congregating in vast numbers, piled one on top of another, under the bark of trees in the forest. A large blue gum (*Eucalyptus tereticornis*) had them under loose bark on its sheltered side to a height of 25 feet. A small, dead, upright, and termite-ridden wattle held thousands under its hanging bark, in crevices,

&c., at Greenhills on 4th February, 1920, and on 1st February, 1921, the same tree served as an asylum for further hordes. In such a position they can be seen mating during the day, the male perched on the back of the female. One has to approach them very quietly, as a sudden movement will cause them to drop suddenly; first one will fall to the ground, then others, until in a few seconds hundreds are raining down, and in the course of a couple of minutes not one is left on the tree-trunk where just before they were in such numbers. At 8 a.m., 17th April, 1920, a cool fresh morning, many adults were watched leaving the foliage of a large poplar gum (*Eucalyptus platyphylla*) and seeking protection beneath the bark of its trunk; the leaves were ragged at the edges from the attack.

In 1918, stage III larvæ were found sparingly in various situations around Gordonvale from 18th February until 15th October; on this last date one was unearthed in a cell at a depth of 12 inches in a clay embankment under blady grass (*Imperata arundinacea*).

## EPHOLCIS DIVERGENS WATERHOUSE.

A rather larger form, that accompanies *E. bilobiceps*, but has never been collected in numbers.

## EPHOLCIS PACILIS WATERHOUSE.

We have several of this drab little insect, collected on flowers at Greenhills in January, 1920.

## LIPARETRUS ATRICEPS MACLEAY.

This lively little beetle is not uncommon at Gordonvale on the foliage of *Eucalyptus*, the poplar gum (*E. platyphylla*) being preferred. In this locality it appears earlier in the season than any other Melolonthid known to us, and is active on the foliage during the day.

We have a single specimen of a second species, *L. laratus* Macleay, also from Gordonvale.

## PHYLLOTOCUS NOVICULARIS BLANCHARD.

The genus *Phyllotocus* comprises a great many active little beetles, smaller than those of *Liparetrus*, that frequent flowers. *P. novicularis* has been taken in January on flowers at Greenhills.

## CHEIRAGRA VITTATA MACLEAY.

In this segregate are grouped a number of small beetles, very similar indeed to those of *Phyllotocus*. *C. vittata* has been collected on several occasions from Babinda, the males clustered on cane-leaves; the female is rare, and we have only one.

## MÆCHIDIUS.

Here fall a number of dull insects, with a more or less indented or concave front margin of the head; in this respect they resemble *Epholcis* but are of a more solid appearance. We are familiar with three species—*M. caviceps* Blackburn, *M. fissiceps* Macleay, and *M. rugosicollis* Macleay; they are attracted to light, and also assemble under the loose bark of Eucalypts.

## MIMADORETUS.

Two species are known to us, *M. niveosquamosus* Lea and *M. flavomaculatus* Macleay, both occurring sparingly in the scrub lands at Babinda and Innisfail, where they are usually attracted to light. In appearance they are not typical of the Melolonthid group (*Lepidiota*, *Haplonycha*), resembling more the Rutelides (*Anoplognathus*, &c.). *Flavomaculatus* is a striking little beetle with its semi-clothing of bright-yellow hairs. These two insects are of interest, since they are very closely related to the notorious Green Japanese Beetle (*Popilia japonica*) of the eastern United States.

## STETHASPIS SQUAMOSUS LEA.

Of the general aspect of *Mimadoretus* but of larger dimensions, this is a rare and recently described scrub form; our specimens are from Babinda and Kuranda.

This is the last of the Melolonthid group, and we now come to the brightly coloured beetles of the Rutelid group (*Anoplognathus*, *Calloodes*, &c.).

## ANOPLOGNATHUS BOISDUVALI BOISDUVAL.

The Christmas Beetle, as it is commonly called, has been recognised as one of the cane-beetles for many years. We have come upon references to it as far back as 1896 (23), under its synonymic name of *A. lineatus*. It appears to be widely distributed, and is the most common member of the genus in the Cairns district. Girault and Dodd (66) recorded the larvæ as far south as the Clarence River in New South Wales.

*Emergence and Habits of Beetles.*—The adults emerge with the first rains, as soon as *Lepidoderma albohirtum* is on the wing. In 1918, following two nights' rain, beetles were noticed for the first time on 24th November, and they were plentiful on the same trees on 10th January. They were abundant on their feeding-trees on 15th January, 1920, a very late season. Odd ones flew to lights at Babinda on 30th October, 1920; and emergence took place at Gordonvale about 27th November, following soaking rains at intervals since 12th November. Yet, strange to say, when digging a trench at Greenhills on 5th January, 1921, a living adult was found in its pupal cell at a depth of 10 inches. By the end of January it was scarcely possible to secure the beetles.

The general habit of Rutelides, as opposed to the Melolonthids (*L. albohirtum* is an exception in the latter group), is to remain on the feeding-trees during the day, and the Christmas beetle is typical of its tribe. They remain exposed on the leaves, even in the bright sunlight, throughout the day; in this situation the male can often be seen perched on the back of his mate, though it is very doubtful if copulation occurs before dusk. A sharp jar usually causes them to drop to the ground and hide, but sometimes, more especially if the afternoon be waning or the day be dull, they will take flight for a considerable distance to another tree.

Five food plants are known in the Gordonvale area, all Eucalypts, namely, the blue gum (*E. tereticornis*), poplar gum (*E. platyphylla*), Moreton Bay ash (*E. tesselaris*), bloodwood (*E. corymbosa*), and box (*E. leptophleba*). Of these the first two are the most important; the poplar gum grows throughout the lower-lying or swampy forest land, while the blue gum is restricted to certain localities; but both are invariably attacked. The three other trees seldom suffer depredations, and then apparently only when the foliage is very young.

*Oviposition.*—On 17th January, 1919, Mr. Girault, while following the plough in a headland at Greenhills, found 9 eggs, at a depth of 5 inches, and scattered by the plough; these hatched on 21st January, and were identified as this species. While digging a trench in a field at Greenhills on 5th January, 1921, we collected 53 eggs, loose in the soil, with no sign of an egg-chamber or even nodules around each egg; they were scattered in the soil in an area of about 4 inches, 2-6 inches below the surface. In comparison with the eggs of *Lepidoderma albohirtum*, they were very white, even bluish white, and were quite spherical in form.

There is very little doubt that the females are able to deposit a comparatively large number of eggs. One, captured as she was about to enter the grass on the morning of 13th January, was dissected and found to contain a set of 32 fully developed eggs. On 18th January, 1921, several weeks after the adults first emerged, a female collected from a feeding-tree had 50 eggs ready to lay, and it is very probable that this was not a first set. These beetles have eight egg-tubes in either ovary, each tube containing 3 or 4 eggs; thus it would be possible to deposit 64 eggs at once. Mr. Jarvis confined a number of adults, and obtained the following sets of eggs from separate females: 36, 34, 57, 63, 48, 39, 56, 29, 35.

*The Grub.*—The grubs occur in varied situations; they are abundant enough in the volcanic soil of Greenhills, which contains very little humus; black and forest loam soils are equally attractive; but they would appear to have a particular penchant for piles of trash, decaying rubbish in general, and even half-sandy vegetable-refuse heaps. Although prolific enough, we have not yet had an instance brought to our notice of definite damage to sugar-cane caused by these grubs. In neglected fields of cane and grass at Greenhills they were especially plentiful on 8th February, 1921.

Girault and Dodd stated "that it is obvious that the species has a life-cycle of more than one year"; they gave the periods for the three stages as 22nd November to 18th April for stage I, 16th March to 6th November for stage II, and throughout the year for stage III. Later, Dodd remarked that stage III larvæ found in November and December had recently moulted from stage II.

Subsequent investigation has supplied most puzzling data, most of which go to support former observations, but a few are in direct opposition. Herewith we summarise some of the supporting evidence. On 2nd December, 1920, the plough at Greenhills unearthed three stage III grubs that had recently moulted from stage II, in fact the cast skin of one was ploughed out with the grub; stage III grubs were also found on 5th January (surely too early for a first-year development?). In 1918, Mr. Girault noted the stages of all of the grubs that he collected by following the plough, with the following results for each month:—February, 1 stage I, 68 stage II, 121 stage III; March, 42 stage II, 87 stage III; April, 103 stage II, 329 stage III; May, 68 stage II, 185 stage III; June, 20 stage II, 65 stage III; July, 2 stage II, 1 stage III. It will at once be noted that the ratio of the two stages does not radically change in a period of several months; now if the species had a one-year life-cycle it might reasonably be supposed that in one of these months, probably March or April, the percentage of stage II would suffer a considerable drop through the development of the grubs, and that in the course of another month this percentage would be negligible.

Now we will take the conflicting records. In December, 1918, Mr Jarvis obtained eggs in confinement, and by 7th April most of the resultant surviving grubs were in stage III. On 3rd February, we collected 4 stage II, not long moulted from stage I, from a field at Greenhills, and kept them in confinement; on 29th March a recently moulted stage III resulted. Again, on 9th February we took 14 stage II from the same locality, and on 24th March 1 was found to be in stage III, but 3 others (the only survivors) were still in stage II on 23rd April. We can offer no suggestion for the contradictory nature of the records, other than that the abnormal conditions of confinement might be responsible.

Newly hatched stage I larvæ were found in the field on 5th January, 1921, and we continued to pick them up until 23rd March. The earliest stage II was procured on 18th January. Of 31 grubs collected on 8th February, 15 were in stage I (48·4 per cent.), 14 in stage II (45·2 per cent.), and 2 in stage III (6·4 per cent.).

The life-cycle of the species cannot be satisfactorily determined until it is bred right through from the egg stage to maturity.

## ANOPLOGNATHUS POROSUS DALMAN.

In ten years' collecting of scarabæids at Gordonvale, three adults of this species have been discovered, and we have no further captures besides those mentioned by Dodd (91); thus it must be a very rare form. These Northern specimens differ somewhat from the Southern ones, and Mr. A. M. Lea has identified one as a doubtful variety of the insect in question.

The true *porosus* is exceedingly abundant in New South Wales; Froggatt, in "Australian Insects," 1907, states that the larvæ have been ascertained to be injurious to strawberry plants, eating off the roots.

In appearance the adult closely resembles *A. boisduvali*, but is rather smaller.

## ANOPLOGNATHUS SMARAGDINUS OHAUS.

Referred to by Dodd as No. 686, it is known to us only from the scrub areas of Babinda and Innisfail, where it occurs in vast numbers. At the former place, on 30th October, 1920, they were emerging at dusk and flying to the feeding-trees, where copulation took place in the usual manner, the male resting on the back of the female. They remain on the trees during the day, and copulating pairs were observed at 11 a.m., in bright sunlight. On 10th November, they were not nearly so plentiful, and on 22nd November none could be collected. Several food plants are favoured, including the scrub wattle, *Acacia mangium* (Leguminosæ), river hibiscus, *Hibiscus tiliaceus* (Malvaceæ), the low shrub *Tristemma virusanum* (Melastomaceæ), and the tall erect shrub *Breynia cernua* (Euphorbiaceæ), all of which plants are seriously attacked.

The larvæ are not uncommon in the clayey canefields round Babinda, but we have little exact data on their presence.

## ANOPLOGNATHUS PUNCTULATUS OLLIFF.

Very prevalent in the Cairns district, wherever scrubs or even isolated patches of scrub occur, where they can always be found, in the season, on the foliage of the tree *Litsea ferruginea* (Laurineæ); at Babinda we have taken them in numbers from young examples of *Barringtonia calyptrata* (Myrtaceæ). Their habits are very similar to those of related species.

At Meringa a considerable number was on the feeding-trees on 24th January, 1921, late in the season. Of those secured 61 per cent. were males. Most of the females had eggs developing, about half formed—presumably not a first set; two had eggs nearly ready to lay, 30 and 28 respectively. Like *boisduvali* there are eight egg-tubes on either side; thus they are capable of laying a large number of eggs.

Dodd (91) unsuccessfully attempted to breed the stages; he obtained eggs in confinement, but the resultant young larvæ refused to live in the fine soil. Perhaps, like others of its relations, the grub exists in the sand of river-beds, &c.

## ANOPLOGNATHUS FRENCHI MACLEAY.

This beautiful "Gold Beetle" occasionally flies to lights in the scrub areas of Babinda and Innisfail, and in these localities can sometimes be collected in moderate quantities from the Malvaceous tree *Hibiscus tiliaceus*. The life-history has not been studied.

## ANOPLOGNATHUS MASTERSI MACLEAY.

*A. mastersi* in appearance favours *A. frenchi* but is rather more robust. We have not seen this beetle from the Cairns district, but in the vicinity of Ingham and on the Lower Burdekin it is not infrequent. At Macknade Mill they were gathered and paid for at the rate of 1s. 6d. per quart by the Beetle Destruction Fund, though there is no evidence to show that they are destructive to sugar-cane. One of the principal beetle collectors at this place supplied the information that they were to be found on bamboo and pink burr, and that he was certain they fed on the burr leaves.

## ANOPLOGNATHUS ROTHSCHILDI OHAUS.

Of about the size of *A. mastersi* but quite dull in colour, this is indeed a rare species. The very few adults in our collection were attracted to lights at Babinda.

## ANOPLOGNATHUS ABNORMIS MACLEAY.

Another very rare form; the odd specimens procured by us are from Babinda. It is a smaller insect than *rothschildi*, with which it closely agrees except for the presence of two irregular black stripes toward the lateral margins of the pronotum.

## ANOPLOSTETHUS LÆTUS R. & J.

This is a splendid beetle; a little larger than the Christmas beetle, the typical form is pale grass-green with yellowish-green legs. However, there are two diverse and striking varieties; one is of a peculiar and beautiful opalescent violet shade; the other is of a rich coppery red.

Very rarely, too, there is a fourth variety of a rich orange, but this is not constant, merging on the one hand into the green form and on the other into the red variety.

It occurs both at Cairns and Innisfail, but is extremely local in its distribution. For instance, in the former district we are aware of its existence only in one small area of an acre or two. Here it was discovered devouring the fresh leaves of young, second-growth bloodwoods (*Eucalyptus corymbosa*) during the first ten days of February, 1920, and was quite plentiful. In this same localised area a few were seen on 7th December, 1920, but it was a fortnight before emergence was general; by 11th January only odd ones were met with, and by 25th January they had disappeared. In this season they were not half as abundant as on the former occasion.

The green variety predominates at the rate of about 4 to 1. Of 245 beetles collected during the past season, 199 (81 per cent.) were of the green, 22 (9 per cent.) were of the red, and 24 (10 per cent.) were of the violet forms.

Three females were dissected on 5th January, 1921. The ovaries had usually one perfect egg, and one or more undeveloped ones, to an egg-tube; the egg is very large, when compared with those of related species, elongate-oval, and irregular in outline.

### CALLOODES GREYANUS WHITE.

This conspicuous chafer is widely distributed in Queensland, but does not appear to be numerous anywhere, and in several years' collecting only odd specimens have been taken from feeding-trees or at lights. It breeds in the pure sand of river-beds, and for further information on the life-history and habits we refer our readers to Girault and Dodd (66), who had considerable data on the subject. In the bed of the Clohesy River, a tributary of the Barron, 30 miles from Cairns, multitudes of the adults that have bred there have been dug up.

### CALLOODES ATKINSONI WATERHOUSE.

An uncommon species, of which we have seen examples from Innisfail. It also occurs in company with *Anoplostethus lætus* in that before-mentioned limited area of young bloodwoods near Gordonvale. The two species are found together, but *C. atkinsoni* is much the rarer, is not so addicted to the very young foliage, and usually frequents taller trees. Its emergence and occurrence at this location coincided with those of *A. lætus*. It has been found breeding in association with *C. greyanus* in the sandy bed of the Clohesy River.

### CALLOODES RAYNERI MACLEAY.

We are not aware of the presence of this species in the Cairns district, but it has been captured at light in the Ingham neighbourhood, and we have seen specimens from the Lower Burdekin. It also occurs in Southern Queensland.

### REPSIMUS ÆNEUS FABRICIUS.

Girault and Dodd reared the species from grubs obtained in sandy-loam or sub-sandy soils. Our only records are of the adult stage. Several were seen on foliage on 26th January, 1920. In the 1920-21 season beetles were collected on 7th December, 12th December, 4th January, all at Gordonvale. They can be found scattered through the forest on young bloodwoods (*Eucalyptus corymbosa*), twelve or even more on a tree. Another food plant is the river cherry (*Eugenia tierneyana*), the young foliage of which is sometimes considerably eaten.

They are active beetles, and may be observed buzzing about the feeding-tree in bright sunlight. When a tree is jarred, they often do not fall to the ground; in most instances they drop a short distance, and then take flight. Active copulation has been witnessed at 2 p.m.; the male rests on the back of the female.

## **ANOMALA AUSTRALASIÆ** BLACKBURN.

This beetle is interesting because of the fact that one member of the genus, *A. orientalis*, is a notorious foe to sugar-cane in Hawaii. However, the Australian species, according to Dodd (91), is held well in check by parasites; thus, fortunately, it does not appear that it is ever likely to attain the dimensions of a pest. In all its stages, *Anomala*, as its name implies, differs in many particulars from related insects; in the larva the arrangement of setæ on the under surface of the apex of the body is not present in any of the other Rutelid larvæ known to us, and this character caused Girault and Dodd (66) to ally it with the Lepidiotas, the adult not then having been determined; the pupa, too, differs markedly from those of *Anoplognathus* and its relations; and the habit of the adult of feeding on nectar is peculiar, and recalls the true flower-frequenting scarabæids (Cetonidæ).

We have obtained adults and grubs from several cane districts, viz., Ingham, Innisfail, Cairns, and Mossman, and also from Cooktown. The earliest emergence noted is 16th November, 1920, at Meringa, following a few days' heavy rain. In this locality in the previous season, they did not appear until 15th January; the season was exceptionally late, and none of the other scarabæids were on the wing more than two or three days earlier. In the past season they were observed nightly until 11th January, which would give a maximum length of the aerial life as 56 days. In confinement the longest period of existence was 38 days.

A few extracts from our files on their habits may prove of interest:—

"Greenhills, 14th January, 1920. Just before dusk many adults were seen resting singly on sugar-cane leaves. Later, at dusk, numbers were swarming and mating on low shrubs. After dark, many were found quiescent on the cane-leaves, sometimes a few to a plant, or as many as twenty to a leaf; in all several hundred were counted. The sweetish odour that they emit was noticeable at a distance of several yards. The lantern held a yard or so away annoyed them, and most took to flight. In swarming they invariably select the extreme tops of cane-plants and weeds."

The sweetish odour mentioned above has been commented on previously, and is no doubt due to their habit of frequenting flowers. Whether they absorb the nectar, or eat the flowers, is still a moot question; in this respect the following note by Mr. Girault is worth quoting:—

"At 9 p.m. I visited the lantana, where the *Anomala* were last night. They were still feeding on the flowers, eating the corolla. When I approached these bushes, the beetles became greatly agitated on account of the light and clustered about me in numbers."

The lantana flowers are especially favoured, and it is quite possible that the great abundance and rapid expansion of this noxious plant may mean a corresponding increase in the number and distribution of *Anomala*.

It is a rather curious fact that males predominate in the swarming clusters; thus of 34 collected in this way 26 were males. At 5·30 a.m. on 11th January, 11 beetles were clustered together on two stalks of cane; these were dissected and all proved to be males.

Another note from our files is given:—

"It was rather surprising to find an *Anomala* resting on the back of a *Lepidiota rothei* female; the latter was exuding a drop of moisture from the end of the abdomen as is the habit when ready to mate, and the *Anomala* was evidently trying vainly to mate with her; these were collected. Another similar pair was observed; they were watched for several minutes, though it was getting quite dark, and the male repeatedly tried to secure union, without success. This pair dropped into the grass and it was too dark to find them."

*Ovipositing.*—No observations on this phase of the life-history have been made in the field. In the breeding-cages the eggs were deposited singly and loosely, as with *Anoplognathus*. We are ignorant of the number of eggs laid; very few were obtained from the beetles kept in confinement. Of eight females dissected on 17th December, 1920, the following sets of developed eggs were in the ovaries:—22, 10, 7, 11, 20; while three had none showing—supposedly these had laid. Three separate notes on the duration of the egg stage give the periods, 12-17 days, 12 days, 13 days, an average of slightly over 13 days.

*The Larvæ* are plentiful enough in certain situations; the volcanic soil of Greenhills harbours them in moderate quantities; refuse heaps of decaying vegetable matter are favourite locations; and, too, they can be procured from heavy-loam scrub-land canefields. Probably the species inhabits the scrub areas or those adjacent to scrub, for the grub is noticeably rare in the forest cane lands. We have never obtained them in sufficient abundance to suggest that they were injurious; yet, under laboratory conditions, they readily killed small cane-plants, gnawing them through at the base.

Although the larvæ have not been reared through from the egg stage, there is little doubt that the life-cycle is completed within a year. Thus, in confinement larvæ hatched in December were in stage III in cells preparatory to pupating in the following May. Moreover they develop at a very rapid rate, or at least a portion does, probably due to the better conditions of nourishment. In the insectary, of grubs that hatched on 16th December, some were in stage III by 17th February; and of a lot hatched on 20th December, part was in stage III on 24th February. Field evidence, indeed, serves to show that progression may be still more expeditious under natural conditions. At Greenhills, on 30th January, 1919, ploughing in a field of ratoon cane resulted in 2 stage I, 3 stage II, 1 stage III; and on 2nd January, 1919, following a plough in a headland on the same estate yielded 5 stage I, 11 stage II, 4 stage III; in this season the first emergence of the adults was recorded on 27th November; thus five weeks had elapsed between the time of emergence of the beetles and the finding of stage III grubs. In the 1920-21 season, adults were first observed on 16th November, and on 16th December digging in the vicinity produced a stage III larva recently moulted from stage II. This abnormal development is not invariable;

of 34 grubs collected on 8th February, 1921, 9 were in stage II; eight of these were kept to ascertain their growth; five were still in stage II on 23rd February, and the last to moult did so early in April. Dodd (91) has listed stage II larvæ in the field as late as 16th April. However, this is unusual; as a matter of fact, it is very rarely that this stage is met with after the end of February in a normal year.

As the grubs often attain stage III very early, so their maximum growth may be achieved exceptionally quickly, when they finish feeding and go into cells preparatory to pupating. These fully fed individuals have a characteristic appearance, being of an opaque yellow tint, the last segment of the abdomen showing semi-transparent; their bodies contain nothing but fat. Twenty-five healthy stage III grubs were collected at Greenhills on 9th February, and retained in pots of soil at the laboratory; one of these was already yellow and in a cell on 23rd February, and the majority went into hibernating quarters during March and April. Again, of eight normal stage III taken in a refuse heap of decaying vegetation on 19th February, five were in cells on 9th March. Therefore, their active feeding period in the grub stage endures for only a few weeks, and the greater part of their pre-adult life is spent in hibernation. When in this condition, however, they are not passive; emptied out of their cages and the cells broken up, they quickly dig in again, and when next examined will have again constructed their quarters.

It was thought that perhaps these yellow specimens might be parasitized; several were dissected without finding any trace of parasitic larvæ. Yet those that remain over after the normal time of pupating have commonly been discovered to contain dipterous maggots. One of these yellow grubs, unearthed at Greenhills on 25th January, 1921, was dead on 3rd February, with a large maggot in its body.

Out of the soil the grub is very active, and, moving on its venter, its rate of locomotion is much faster than that of *Anoplognathus* and similar species that travel in this way.

*The Pupa.*—Our notes contain no references to the pupal stage in the field. However, at Greenhills on 3rd August, 1920, digging a trench under cane-stools gave one larva in its pupating cell at a depth of 18 inches, and three in cells at 24 inches. Another trench yielded four in cells at 12 inches, and six at 18 inches; none were deeper, though the trench was excavated to a depth of 36 inches.

## CACACHROA DECORTICATA MACLEAY.

This day-flying species is of interest chiefly on account of its divergence in the larval state from the general habit of the Cetonidæ of living in decaying wood; its grubs are very plentiful in the soil at the base of blady grass (*Imperata arundinacea*) and other native grasses. Girault and Dodd (66) devoted considerable time to the study of this species, and as we have little subsequent data we have not recapitulated their notes on the life-history. However, it certainly seems that the adults have not been so numerous latterly as in 1912-14. In the 1919-20 season a few were first observed flying low over the ground in the forest and edge of canefields on 16th January, and up to the end of that month they were captured sparsely on flowers of swamp mahogany (*Tristania suaveolens*) and cork-tree (*Evodia accedens*). Again, in the past season large numbers were not observed; on 31st December, they were plentiful on a flowering river cherry (*Eugenia tierneyana*).

At Greenhills on 11th January, at 9.50 a.m. a pair was noticed on a cane-leaf, about to couple. They were captured and held on the finger, but this disturbance did not affect their mating. The male clung to the back of the female, moving to and fro, and at the same time stroking his legs along her side; after a minute or so he secured union, balancing outward and backward on his legs, but not letting go and hanging. The action lasted for a minute, when they separated and flew away.

## XYLOTRUPES AUSTRALICUS THOMSON.

The great, lumbering Elephant Beetle is well known to everyone in the coastal districts of Queensland. They occur plentifully on Poincianas, on the trunk and branches, feeding on exuded juice after the manner of the true Stag Beetles (Lucanidæ). During the summer months occasional ones are attracted to light, and their unwieldy flight is easily recognised. Besides the *Poinciana*, two other feeding-trees are known, namely, the white cedar (*Melia composita*) and *Glochidion ferdinandi*.

The fat sluggish grubs can always be unearthed in refuse heaps of decaying vegetable matter, and they habitually feed on this decomposed material. They are in no way injurious, and are found in canefields in isolated cases.

## HORONOTUS OPTATUS SHARP.

Very little is known of the habits of *H. optatus*; it breeds in the almost pure sand in the bed of the Mulgrave River. Adults are now and then collected at lights during the first four months of the year. One flew to light at Mossman, 8th April, 1920.

## SEMANOPTERUS DEPRESSIUSCULUS MACLEAY.

As with *Horonotus*, *Dasygnathus*, *Isodon*, &c., the habits of the beetles are obscure. The grubs live, around Gordonvale, in alluvial, sandy-loam rubbish heaps; but they occur in the heavy-loam scrub soils of the Babinda area. In some of the paspalum paddocks at Ravenshoe, 3,500 feet, on 1st March, 1921, grubs in stage III were dug up beneath the grass, and the beetles themselves were quite common beneath logs in the fields. Two of these grubs were kept in confinement, and when examined on 23rd April a pupa was obtained and a beetle in its cell. Possibly, like *Isodon*, development is very rapid, and there may be more than one brood in a year. Adults have also been collected in August, October, and December.

## DASYGNATHUS AUSTRALIS BOISDUVAL.

A common and widely distributed species that has been met with everywhere in sugar-cane districts from Mossman to the Tweed River of New South Wales. The beetles are seldom observed; the few that have been collected were mostly either dug out of the soil or picked up behind ploughs, from 24th September to 6th December. The following note by Mr. Girault from our files is given:—

"Roaming through a canefield at Gordonvale about dusk on 29th November, 1911, I would occasionally observe a smooth round hole leading down into the moist soil (dark loam; rain fell during most of this day, once a hard shower), with a small pile of earth around the entrance. These holes were all traced to the ends, with the result that a small scarabæid was found which stridulated violently when handled. The cane here was about 2 feet high, and was free of all extra vegetation. The beetles were about 4 inches down from the surface and appeared to have entered the ground to no purpose, since all of them were males. After dark, though raining, an occasional adult was observed on the wing."

A beetle captured by Mr. Jarvis, flying over a moist bed of ferns in a garden on 23rd October, 1918, at Meringa, was confined, and deposited 15 eggs. That observer states:—

"The eggs are evidently deposited each one in a cavity by itself, the cavity being large enough to allow room for the egg to expand whilst maturing. The cavities particularly noticed were in each case made in small nodules of consolidated soil."

Mr. Jarvis also established the fact that the life-cycle is not continued beyond a year. Larvæ hatched from the above eggs during November; of the 11 that remained alive on 17th February, 6 were in stage II, 5 in stage III; thus they had attained stage III within three months; all were in stage III on 3rd March, and on 5th June were in pupating cells; a pupa was obtained on 29th July.

Grubs can be secured from various situations, but they are not abundant in the volcanic soils, being chiefly addicted to the moist, heavy, dark loams. Although frequently met with, they are rarely numerous; consequently they can hardly be counted a menace to sugar-cane.

However, confined larvæ readily killed cane-plants, and in the field a specimen has been taken where it had bored its way 6 inches up into a cane-stalk. In March, 1921, they were the only grubs ploughed out in fields on the Lower Burdekin, and during the same month they were plentiful under trash in the middle of the cane-rows at Macknade.

## ISODON PUNCTICOLLIS MACLEAY.

Like so many of the Dynastid beetles that live principally in the soil, do not devour folige, and do not fly in countless swarms, *Isodon* adults are only seen occasionally. We have obtained specimens at lights from 10th October to 5th March.

In September and October, 1920, an opportunity to acquire information on the life-history presented itself. During the former month, "hills" were prepared with cowdung for planting cucumbers; the manure was worked well into the soil, and covered with a few inches of earth. Two or three weeks afterwards the manure in these places was swarming with young grubs, and many *Isodon* adults were present, some of which were dead. Soil that had been left for about a month after treating in this way had grubs in all three stages, showing that development must be very rapid. As many as 70 large grubs were discovered in one "hill"; hence in many cases the cucumbers refused to grow, their roots having been eaten clean away. There seemed no doubt that the beetles were attracted by the manure; that the grubs lived on this substance and subsequently attacked any adjacent vegetable matter.

Experiments were then instituted for the purpose of determining the life-history. "Hills" were prepared with manure on 23rd October, and when examined on 2nd November grubs were hatching. On 25th November most of these had just entered stage II, and on 17th December the majority had just moulted to stage III; by 15th January three had recently pupated, and beetles emerged from these on 22nd January, giving a pupal period of about seven days. Thus the entire life-cycle was consummated in less than three months. Since it has now been ascertained that this species completes its life-cycle in so short a time, it might reasonably be supposed that there is more than one brood a year; furthermore, Dynastids similar in appearance (*Semanopterus*, *Pentodon*, &c.) may possess analogous habits.

The occurrence of larvæ in isolated patches in canefields, instanced by Dodd (91), may have some relation to the presence of manure in the soil.

## PENTODON AUSTRALIS BLACKBURN.

This is indeed a rare species in the Cairns district, and in the past six years not a single specimen has been recorded. The larva remains unknown to us.

## EOPHILEURUS DENTATUS BLACKBURN.

Our collection contains two specimens, both caught at lights in December; they somewhat resemble *Semanopterus depressiusculus*, but are fully twice as large.

## PSEUDHOLOPHYLLA FURFURACEA BURMEISTER.

Note by J.F.I.—During the preparation of this paper I tried repeatedly to secure specimens of the Isis cane-beetles for identification. Even an appeal to Mr. Tryon, who had carried out extensive investigations in that district, brought no results. Therefore, after the termination of my engagement I visited Childers, in June, and managed to secure specimens (both grubs and beetles) of the principal culprit. Through the kindness of the South Australian Museum, the species has been determined, as above, by Mr. A. M. Lea, their entomologist. His references are as follows:—

"*Holophylla furfuracea* Burmeister, Handbuch der Entomologie, 4 (2), p. 426 (1855), Neu Holland."

"Blackburn, Transactions of the Royal Society of South Australia, 1911, p. 181-184, comments at length on the species, and on page 196 proposed the new genus *Pseudholophylla* for the species he supposed it to be. The specimen he had before him we now have, also another of the same species from Bowen. Until Blackburn's identification can be proved to be erroneous by comparison with the type (if this is still extant), it must be accepted as correct, and you would be justified in dealing with the species under the name *Pseudholophylla furfuracea* Burm."

# A Comparison of the Male Genitalia of Cane Beetles.

Working with other groups of insects, I learned how useful were the chitinous parts of the male intromittent organ for specific determination. Unfortunately, I have not recently had access to papers by Forbes and others, who used such characters for separating the Scarabæidæ. Yet, with the tremendous variety of these beetles occurring in Australia, it is frequently a rather difficult matter to separate species on other external characters. A case in point is *Lepidiota consobrina* Girault, which was confused for some time with *L. frenchi* Blackburn. The grubs of the two species were easily distinguishable, and Mr. Dodd (91) cleared the matter up by breeding them out, when he discovered some slight differences in the adults. Referring to Plate XVI, however, it will be noted that the genitalia of these two species bear little resemblance. And, again, the adults of *Lepidiota rothei* Blackburn and *L. No. 215* are very similar in appearance, but it will be seen that they are easily separated by referring to these characters.

Watching mating beetles, I first observed the pouch-like bursa (Plate XVI, fig. 4, *aa*) extending from the end of the penis, just as they separated. In a moment, however, this was retracted within the chitinous structure. Apparently this bursa fits inside the *bursa copulatrix* of the female during mating. At any rate it has exactly the same form and size, the surface being covered with exceedingly small hairs.

I have only had time to touch upon this systematic phase of the problem, but undoubtedly its possibilities are many for exact determination of species.

# A Study of the Factors of Control.

As has been suggested in a previous section, man himself is undoubtedly responsible for much of the damage that has resulted from the attacks of these pests upon his crops. In his clearing and cultivation of the land he has seriously interfered with most of the natural agents which normally have a retarding influence upon the grubs, preventing them from assuming the proportions of a pest. Most important, perhaps, is the effect upon the native bird life of clearing large areas; not only are their nesting places destroyed, but worse, many of the most valuable species are themselves frequently killed by thoughtless individuals. To be sure, excellent laws for the protection of these feathered friends are now on the statute-books, but unfortunately these laws are seldom enforced, especially in the newer districts. Therefore it is the duty of every citizen to become as familiar as possible with the habits of the commoner birds of his locality, so that he can lend his support to the protection of those that defend his crops. Indeed it is only when public opinion is so educated that we can hope that our bird laws will serve their true purpose.

Again, cultivation has had a retarding influence upon parasitic insects. Most of these feed upon nectar in the adult stage; hence the removal of all native flowering plants, due to the clearing of the land, has pushed them far back into the wilds, leaving the pests in our fields to multiply without these restrictions. Obviously, the thing that we can do is to again attract these friendly insects by planting more nectar-bearing flowers, especially in the waste places and along the headlands.

And, further, the clearing of the land is a hardship to numerous other predators which normally live upon the grubs and beetles; yet it is possible to do much to encourage these.

Finally, our destructive methods of agriculture require a word of warning. The grubs or larvæ of these pests normally feed upon decaying organic matter in the soil, hence, naturally, do little damage to growing plants in rich soils. Ordinarily, however, fields near timber soon become grubby, probably because all the waste organic matter is continually removed by burning, for the grubs are then compelled to seek their supply of organic matter from the living roots. Commonly such conditions prevail in soils that will not scour well, and hence stick to the ploughs; consequently it is almost impossible to plough in the trash, and the farmer usually follows the custom of burning everything, until his land soon becomes too poor to work. Therefore it is most important that we change our methods on such soils. Some suggestions on this point will be given later on in the section where I deal with the subject of conserving humus.

## NATURAL CHECKS.

These include climate, organic diseases, predatory mammals, lizards, frogs, birds, insects, &c., also parasitic insects and poisonous plants.

*Meteorological conditions* undoubtedly have an important relation to control of these pests; we now know that both excessive heat and excessive moisture may prove their undoing. As an instance of the first we have the following interesting observations by Mr. Jarvis (80) :—

"A noteworthy instance of direct control brought about by hot weather occurred towards the end of this month. On the 19th instant, we experienced a maximum dry temperature of 95° F., followed on 20th instant by 98° F., the wet bulb on both days registering 86·5° F., while the wind was from the warm quarter (N.W.). During the morning of the latter day, cane-beetles (*L. albohirtum*) became strangely agitated, and instead of remaining, as usual, on their food plants, were observed to be taking short erratic flights, or congregating on the shady side of tree-trunks, evidently in a vain attempt to discover a cool resting-place. Later, in the afternoon, a party of blacks who were collecting at Meringa told the manager of 'Carrah' plantation that large numbers of cane-beetles were dying and dropping from the trees.

"Finding their account to be correct, Mr. Greenaway communicated with this office, and the matter received personal investigation. Upon reaching the locality in question, the ground was seen to be strewn with dead greyback beetles, mostly under or in the vicinity of Moreton Bay ash trees (*Eucalyptus tessclaris*). No less than 25 were collected from beneath one gum-tree of medium size, and in a space containing two square chains taken at random on forest land, Mr. Hadley picked up 98 specimens. Of these 27 were males, 49 females, and 22 of undeterminate sex owing to injury by ants. The above area was hastily examined, so no doubt we overlooked several specimens hidden among herbage, &c. The occurrence of such heavy mortality acquires additional interest from the fact of its having happened about seven days after the emergence of these beetles, and, consequently, before they had had time to oviposit. I dissected several, and in all cases found the ovary only partially developed. Two specimens contained 26 eggs each, most of which were more than half grown."

Following upon the excessive rains of 1917, our fields were flooded and I found many apparently lifeless grubs lying about in the water on the surface of the soil. This at once appealed to me as a possible important means of control. Much to my surprise, however, I found that these apparently drowned grubs soon revived when taken out of water. I then followed this up with brief experiments to see how long it was possible for the grubs to resist submergence. Though these experiments were not extensive enough to be conclusive, I found that the grubs ceased all noticeable activities after being in the water for about fifteen minutes, though I was rather discouraged to learn that it took approximately four days to kill them by drowning.

Recently, at my suggestion, Mr. Dodd made the following very careful check on these experiments:—On 29th March, 1921, fifty pots were prepared with soil, and each supplied with a healthy stage III grub of *Lepidoderma albohirtum*; after the grubs had entered the soil, at 2 p.m. the pots were filled with water so that it was an inch deep over the surface. At 2.30 p.m., 30th March, the grubs were taken out of ten of the pots and placed in moist soil; they were all rigid and motionless, and appeared to be full of water. At 3.30 p.m. seven were moving. The next morning these had burrowed into the soil and were perfectly normal, while the other three were dead and limp.

At 1.30 p.m. 31st March, ten more were taken out of the water and treated as before. At 2.10 p.m. three showed signs of life, and the others had lost their rigidity. At 3 p.m. eight were reviving, though none were active; at 4.30 p.m. the other two began to revive. The next day seven had entered the soil, and one was fairly active on top, another was barely moving, and the remaining one limp; these last three died soon after.

On 1st April ten more were removed at 2 p.m.; eight of them were rigid on the surface of the soil and the other two limp and floating, evidently dead. At 3 p.m. there was no sign of life, though some of them had lost their rigidity. An hour later one was moving; this had entered the soil next morning, and two more were moving, but one of these finally succumbed: hence there were eight fatalities.

2nd April another ten were removed at 11.30 a.m., and they were mostly rigid. At 4 p.m. three of them were digging into the soil; the remaining seven did not recover.

The last ten were taken out of the water on 3rd April, mostly limp, and none revived.

From the above we found that 30 per cent. of the grubs died after a submergence of one day; 30 per cent. after two days; 80 per cent. after three days; 70 per cent. after four days; while they all succumbed when submerged for five days. Hence we may safely conclude that an overflow which flooded the fields for one or two days would only destroy the weaklings, while three or four days would begin to have a vital effect even upon the strong, and none could withstand an inundation of five days.

These experiments have demonstrated that the grubs usually come to the surface when the soil is flooded, and in a few cases, especially in the younger stages, their bodies float, thus exposing the spiracles on the upper side to the air. In such instances Mr. Dodd found that the grubs do not succumb, even when in the water for five days; yet they would be carried away by the current.

Hence it would appear that it is rather hopeless to attempt to drown the grubs by irrigation, though those that were too deep to get out in time might succumb if the soil was kept saturated long enough. There is no doubt, however, that irrigation would prove an important factor in grub control in other ways, as will be taken up later on.

*Diseases** are frequently of tremendous importance in the control of grubs, especially under unfavourable climatic conditions. Two distinct diseases occur in our Northern districts, though, unfortunately, they are quite localised. These are the green Muscardine fungus (*Metarrhizium anisopliae* Metsch.) and a bacterial disease which is probably *Micrococcus nigrofaciens* Northrup.

Wherever these diseases were present they practically wiped out the grubs, under the peculiar conditions which prevailed during the season of 1920; hence it would appear that we might profitably assist nature by inoculating all of our grubby fields by distributing the spore-laden soil.

*Predatory Mammals* which probably have a considerable bearing upon the control of the grub-pest are the bandicoots (*Perameles* sp.), pouch mice (*Antechinomys, Sminthopsis, Phascologale*), flying-foxes (*Pteropus* sp.), and on most farms we find hogs, which are inveterate destroyers of grubs, especially if they can be turned into the fields when a crop is being ploughed out. Some dogs, too, have been observed following the ploughs and eating the large grubs.

* Since diseases and the following natural checks have been fully discussed in Bulletins Nos. 12 and 13, these important agents will be only summarised here.

We have had considerable evidence that the bandicoots live upon cane grubs and beetles when these are available, but there is still some question as to whether they do not do as much harm as good, because in their search for grubs they destroy many cane-roots. There appears to be no direct evidence in regard to the many species of pouched mice, but since they are all insectivorous and will eat both grubs and beetles when in confinement (19) they are probably very useful, and the farmer should learn to distinguish the difference between these and the ordinary rats and mice which are usually destructive to his interests. Flying-foxes are usually considered an unmitigated curse because of their destruction of fruit, but there is some evidence (50) that they feed rather extensively upon cane-beetles in season.

*Lizards* are of such monster size in Queensland that it is not usual to think of them as friends and allies of the farmer. The short, thick-bodied, blue-tongued lizard (*Tiliqua scincoides*), however, is well known among growers as a grub destroyer (48). The iguanas (*Varanus* sp.), on the other hand, are usually looked upon with disfavour because of their raids upon eggs and young chickens, but since they are of arboreal habits and large size—ranging to 7 feet—they frequently devour the large cane-beetles.

*Frogs*, too, are of great variety and size, and, since they occur in most of the settled areas and feed at night upon any available insect, they are among our most useful allies.

*Birds*, under natural conditions, are probably the most useful among the natural enemies of the grub-pest. They receive far too little encouragement among growers. A great variety of birds feeds upon our destructive cane-pest, both in the grub and beetle stage, so it will be interesting to briefly enumerate a few of the most important of them.

I consider the ibises, without question, at the head of the list; two species visit the Cairns district, the straw-necked (*Carphibis spinicollis*) and the white (*Ibis molucca*). It is unfortunate that we do not have these birds with us throughout the year, for they make a clean sweep of all the grubs and beetles they can find.

Crows (*Corvus australis*), too, are also worthy of much consideration, for they are inveterate destroyers of the grubs as well as many other forms of insect life. They do not occur in the Cairns dinstrict, but farther south they are constantly after the ploughs, destroying pests wherever obtainable.

Hawks are usually our allies and friends, in spite of the bad repute that they are in. There is no question, however, that the large brown scavenger hawk (*Hieracidea berigora*) is of particular value to the cane farmer; though these hawks will eat flesh when available they do not kill animals, as far as I have been able to learn, and they feed largely upon pestivorous insects. They should never be killed; in fact, the same is true of most of our hawks and owls, for as a class they are undoubtedly friends of agriculture.

The laughing jackass (*Dacelo leachii*) is also a bird that is fond of both grubs and beetles. Dissection has demonstrated that they feed principally upon these pests whenever they are available.

Of the smaller birds that follow the ploughs we have the peewee lark (*Grallina picata*) and the Indian mynah (*Acridotheres tristis*). We also find these birds in the feeding-trees very early in the morning devouring cane-beetles, in company with the yellow-breasted fig-birds.

(*Sphecotheres flaviventris*), the leatherhead (*Tropidorhynchus buceroides*), the blue jay (*Graucalus melanops*), and the drongo (*Chibia bracteata*). The shining starling (*Calornis metallica*), though usually considered a fruit-eater, feeds largely upon beetles in season.

Other birds that are probably just as useful are the cuckoo pheasant (*Centropus phasianus*), which normally spends much of its time in the canefield; the nightjars or goatsuckers (*Eurostopus* sp.); and the mopokes (*Podargus* sp.). All of these insectivorous birds feed upon our pests, but they are seldom seen because of their retiring habits.

In the vicinity of habitations poultry usually feed greedily upon these pests, so it is advisable to have a few choice feeding-trees where they can be shaken each morning for the fowls to pick up the beetles.

*Predaceous Insects, Mites*, and *Centipedes* also do much to hold our pests in check. The predaceous insects whose habits have been particularly studied are several species of Asilid flies, a giant Elaterid beetle, a Pentatomid bug, and the omnivorous ant (*Pheidole megacephala*).

The robber flies (Asilidæ), so called because they are sometimes destructive to honey-bees, are really valuable insects. They are predaceous at every stage of their life, and it is the larvæ of these that are of particular interest to the cane-farmer. The largest and most abundant form in the fields is *Promachus doddi* Bezzi, the larva of which is creamy white, long and tapering at each end, with no feet. These are frequently turned up when ploughing, and are well-known destroyers of the cane-grubs.

In our grubby canefields we sometimes also find larvæ of a giant Elaterid (*Agrypnus mastersi* Pascoe), which lives primarily upon the grubs. Mr. Dodd kept one of these in confinement for almost two years in a tin of damp earth, during which time it ate over 250 cane-grubs; and still this period apparently represented not more than one-half of its larval life.

The Pentatomid bug (*Amyotea hamata* Walk.) referred to is commonly seen in the feeding-trees, and on two occasions specimens of this species have been taken with their beaks inserted into cane-beetles, which they paralyse and suck dry.

The omnivorous ant named above probably does little real damage to our cane-beetles under natural conditions, since these pests are rather too large for them to handle where there is freedom for movement; yet these tiny foes destroy both grubs and beetles while they are in close quarters in the breeding-cages.

Mites, too, are usually more troublesome in the breeding-cages than they are in the open fields. It is not uncommon, however, to find them in the fields, especially when the grubs are troubled by diseases, &c. An instance of this case was reported from the Isis district in 1909 (42), in which the mites were thought to be the real cause of the mortality among the cane-grubs. Mr. Tryon, however, decided that they were not parasitic, and that the grubs were dying from some other cause (41).

The large centipede of the tropics is a well-known predator, since it usually congregates among habitations eating cockroaches, &c.; yet it is interesting to learn that it sometimes lends a hand in the destruction of cane-grubs, as was discovered by Mr. Girault, and later Mr. Jarvis (86) had a similar experience with a specimen.

*Parasitic Insects.*—Australia is also rich in these natural enemies of the Scarabæidæ. Those whose habits have already been studied somewhat belong to the Hymenopterous families Scoliidæ and Thynnidæ, and the Dipterous families Dexiidæ and Tachinidæ. The members of the first three families are parasitic on the grubs; the Tachinids here have only been bred from the adult beetles.

The Scoliid wasps are undoubtedly the most useful. Froggatt, in "Australian Insects," states that about fifty species have been described from Australia. Yet we have learned that their value is considerably reduced by hyperparasites. Two of these were bred out on several occasions by Mr. Dodd—a Bombylid fly and a Rhipidophorid beetle.

During our work in the Cairns district we have collected the following species:—*Campsomeris radula* Fabr., *C. tasmaniensis* Sauss., *C. ferruginea* Fabr., *C. carinifrons* Turner, *Scolia formosa* Guer., *Discolia soror* Sm., *Liacos insularis* Sm., *Anthrobosca morosa* Sm., and *Tiphia intrudens* Sm. var. *brevior* Turner. The first two and the sixth are very common in our canefields, the others being more rarely taken at flowers in the uncultivated areas.

During 1917 and 1918 we did considerable breeding work with the first two *Campsomeris* species named above. This work has been fully recorded in our Bulletin No. 13. During the day the males of these two species of wasps frequently swarm in great numbers over the surface of the soil in fields that are badly infested with grubs. Their mates, normally working in the ground, are more seldom seen, though they are probably equally numerous. On sunny mornings these female wasps come out for a brief period, to feed upon the nectar of flowers or honeydew, where it is available.

These wasps paralyse the grubs completely, in fact overdoing it at times, so that the grubs frequently die too soon for the larvæ of the wasp to develop. And, again, it was interesting to observe that these parasites appeared to have a natural love for killing; when put in soil with several grubs they were usually not satisfied until they had stung the lot, though in no case was more than one laid upon.

Since the climate in the Cairns district is so tropical—the temperature even on the coldest winter nights seldom dropping to 40 deg. Fahr. —these wasps are active the year round. The complete life-cycle for the wasps studied during spring, summer, and autumn ranged from forty to sixty days, and though the development would naturally be somewhat retarded in winter, there is no question that they continue to breed at that season. Hence there are probably four complete broods annually, corresponding somewhat to the four seasons.

Fortunately these parasites are able to adapt themselves to several hosts, so that they are able to find some species of grub available at almost every season. We discovered by breeding work, however, that the grubs must be closely related, for the wasps took no notice of those belonging to a different subfamily.

The importance of nectar for these wasps cannot be over-estimated. They will not stay and work where they cannot find a supply of this sweet food, and they would not lay in cages without it. Hence, in order to attract and maintain a good supply of these friends in the vicinity of grubby fields, attention must be given to this problem. Corn grown in the headlands or near fields of sugar-cane often supplies this need. through the honeydew, which is excreted by the common leafhopper pest of this plant.

These wasps bury their prey deep, so that the number of cocoons turned up by the plough gives little evidence of their abundance in the field. I have found their cells with grubs or cocoons usually at depths of 2 feet or more—in one instance 42 inches. Hence the percentage of parasitism can only be ascertained by digging deep in various parts of the field. By this method I frequently found 25 per cent. of the grubs had succumbed to their work, and in one instance as high as 60 per cent.

Evidently the numerous species of these wasps are considerably hampered by natural enemies, else they would be more abundant. For many years, in other countries, it has been known that Scoliids were preyed upon by various species of Bombylid flies and Rhipidophorid beetles; hence it was not surprising when Mr. Dodd (91) bred these from Scoliid cocoons.

The habits of the Thynnid wasps are very little known, yet there is scarcely any doubt that they are enemies of Lamellicorn grubs. Australia appears to be the natural home of this family of wasps, for, as Froggatt states, of about 400 described species 300 are peculiar to this country. Some of the larger species in the Cairns district are commonly taken while feeding on the honeydew of corn leafhoppers. The females being smaller and wingless are very inconspicuous; yet these may frequently be collected while mating, for the male carries her about with him while feeding.

Australian Dexiidæ are usually large, beautiful flies. Mr. Dodd (91) has reared eight species from cane-grubs, though he came to the conclusion that the percentage of grubs destroyed by them was very small. The following species are rather common in cane areas at times: —*Rutilia inornata* G. & M., *R. splendida* Don., *R. pellucens* Macq., and *Amenia imperialis* Rob. Desv.

These flies do not enter the soil after grubs as do the wasps, so their larvæ are probably usually deposited in loose ground, or dropped into natural cracks in the soil, where they may themselves seek their prey.

Though Tachinids have been reared from Lamellicorn grubs, as Davis (104) records, we have only bred flies of this family from the beetles. Two undetermined species have been frequently bred out, the most abundant being a small brown species, several maggots of which occur in a single beetle. The other, a conspicuous large Tachinid, with gold and black on the thorax, is peculiar in that never more than one maggot has been found in a host, in which case the beetle may live for a considerable period and even deposit eggs.

*Reports of Poisonous Plants.*—There is some question as to whether the leaves of certain trees and other plants are poisonous to beetles. Considerable attention was given at the time to a report of a correspondent of the Mackay Sugar Journal (27). This referred to a persimmon tree in an orchard on the Pioneer River. Many dead beetles were found under this tree for two successive years, and the leaves were much eaten. It was said that beetles confined after feeding on this plant soon died, while some from a fig lived for a considerable period. However, nothing apparently ever came of this report, for it was found that persimmon trees in other localities did not have this desired effect upon the beetles.

2nd July, 1920, I had a communication from a grower at Hambledon, who urged me to introduce a species of *Pittosporum* from Victoria, for he contended that it acted as a death-trap to the beetles, that they died soon after alighting on the foliage, and the dead beetles were seen on the ground. Since several species of this genus are recorded by Bailey in North Queensland, no investigation was made of this matter.

Considerable has also been written on the poisoning of stock by sorghum, and this plant has frequently been recommended as a green crop for grubby land. The management of Goondi Mill made some investigation during 1909 (39), but the trials gave no results. Subsequent trials in the Innisfail district also showed that there was no noticeable result upon the grubs, more than what would result from the application of any green crop.

## CULTURAL MEASURES.

There is no question that intelligent cultural measures go a long way toward saving our crops from the ravages of grubs. Hence, throughout my investigation I have given special attention to these factors in control; they have been developed along the following lines:—(1) Ploughing during summer, (2) planting methods, (3) stimulating vigour in the plant, and (4) ploughing out infested crops before the grubs hibernate.

(1) When the beetles are ready to oviposit they naturally seek out areas covered with growing cane or other grasses; hence if the fields are in clean fallow and are being ploughed at that season, preparatory to early planting, there is little opportunity for the beetles to infest them. And even where the beetles do oviposit more or less on such land, being attracted by bunches of grass and weeds that have escaped the ploughs, subsequent ploughing has a tendency to eradicate them. This method of checking the grubs was successfully pursued at Farleigh Plantation, Mackay, many years ago. Mr. F. W. Bolton (2) said that the grubs had been extremely numerous seven years before, but that they had got rid of them by ploughing the paddock up *in the face of summer.* The land was then left to fallow for a season, and given two subsequent cross-ploughings. Being thus kept on the go without cropping the grubs were completely eradicated. In another instance (7) where similar conditions prevailed, there was like success.

As to methods of planting in their relation to grub control, I wish to compare early and late operations, and also call attention to the benefit of deep drills, deep-rooting varieties, choice of plants, and spacing.

(2) In my monthly reports I have said much on the subject of late planting; really, in farm practice it has much to commend it. The soil can be most easily prepared and rid of couch and other troublesome grasses during the dry season, &c.; yet my main idea was to facilitate thorough cultivation during the flight and ovipositing of the beetles. Though we have learned since that the eggs are deposited much deeper than we had formerly supposed, usually far below ordinary cultivation, especially in the loose red volcanic soils, I still maintain this is a valuable factor. The benefit, however, does not come so much from the destruction of the eggs, but is probably due more largely to the increased vigour which it stimulates in the plant. This phase of the problem is dealt with in another section farther on.

On the other hand, there is this to be said against late planting. Where the attack of the grubs is particularly severe, the growth stops before any cane is made: hence the crop is a complete failure. Whereas, cane planted early usually has developed good-sized sticks before the grubs destroy the roots, and in exceptional cases, when it is not lodged by wind, it is possible to get a fair cut. Once it falls, however, deterioration quickly sets in, so the cane is condemned as unfit for milling; furthermore, it is a terrible job to get such a heavy crop off the ground and prepare the soil for replanting.

Since infested cane is uprooted so easily, it is of advantage to plant deep. Though the grubs sometimes eat through stalks, letting them fall over, the main trouble is that cane with roots too near the surface has no support when these are eaten. In our Meringa experiments, 1918-9, we had the drills made as deep as possible, with the result that the cane all stood up, even though the work of the grubs was rather severe in some of the plots.

From time to time we have investigated the rooting systems of various varieties of sugar-cane, particularly in regard to depth, and their resistance to grub attack. Though Badila is a fairly soft cane, it usually roots well; yet it seems to suffer particularly from grubs. D 1135, on the other hand, is generally recognised as an extremely hardy cane, and we found that it was an especially deep rooter, most of the main roots going straight down. At Mossman, where the grubs were once very destructive, this cane is considered most resistant to them—in fact that district has had little trouble from the pest since they have adopted this variety extensively.

For experiment, we tried D 1135 at Greenhills, but the soil was too rich for it. Though the roots held well in the ground, even when grub-injured, the canes were too long and limber, so that they bent over; then, too, wherever they touched the soil, roots developed at the nodes, and though the tops remained green it was a serious problem to harvest it. This variety, however, does splendidly on poor forest land, where Badila or other less hardy canes will not make a crop.

It is generally conceded that plants poor in sugar germinate best. It has also been observed that plants from short, grub-injured cane strike well, probably for the same reason. For our Meringa plots, we got the plants from a grubby field, the cane being so short that we scarcely got more than one plant from a stick. However, the strike was perfect.

During a visit to the Herbert River districts in March, 1921, I was much interested in some most valuable experiments along this line, that were being carried out by Mr. E. D. Wilkinson, manager of the Macknade Mill. These referred, primarily, to the use of top-cuts only for plants, and wider spacing in the drill. His results were most suggestive for application to our problem.

Mr. Wilkinson has kept careful record of the weight of cane from each stool, for each successive crop, and even his third ratoons had a most remarkable development—twenty-five large, thrifty sticks per stool. Yet there has been no cultivation or chipping since the plant crop. He has demonstrated that the top-cut is far superior to any of the others in germination, giving a perfect strike, while, taking an average of all the plants of a long stick, only about 80 per cent. germinate. He first cuts off the white cabbage-end, then takes a plant 12 inches long; the balance of the stick is discarded, and he has found that it pays to do this.

In planting his drills are 5 feet apart, and he experimented both with spacing of 3 feet 6 inches and 5 feet in the drills, in comparison with a continuous line of abutting plants, which is the current field practice. Most surprisingly, the plots planted 5 feet square have given the heaviest yield per acre right through all the crops. Mr. Wilkinson explained that this can be done by using top plants only, and thus getting a perfect strike at the start, for he has also demonstrated that replanting the misses does not pay. These retarded stools never come to much in the plant crop, and though it is the popular belief that they catch up in the ratoon this is not the case; his individual records show that a small stool at the beginning remains a small stool always; he pointed some of these out to me in the third ratoon crop.

As to manipulation, the plant crop was well cultivated and kept free of weeds; when cut the trash was left where it fell, evenly distributed over the ground, with no relieving over the rows. Any stiff weeds that pushed through were cut off with a sickle, using care not to disturb the blanket of trash. When the cane had gotten well started, about February, ammonium sulphate was applied by throwing it under the stools as much as possible, to avoid feeding the grass in the centres. This gave the cane such a boost that there was no further trouble with weeds. The successive ratoon crops were handled in the same way, and the results were most instructive. The trash had all rotted down into a thick covering of black loamy humus, and even the nutgrass had been smothered out in the centres by the dense shade of the luxuriantly growing cane.

I was at once impressed with the possibilities of these manipulations in our work, for grubby soils are sadly lacking in humus. This phase of the problem is discussed in later sections.

(3) There are numerous factors that increase the vigour of the plant, and all of these should be considered as valuable aids in combating grubs; for cane in a thrifty growing condition will resist injury to a considerable degree. Among these factors I would suggest the advantage of a thorough preparation of the soil, application of lime, supplying humus, cultivation, fertilisers, and irrigation.

Thorough preparation of the soil before planting undoubtedly pays under any condition, for it makes the crop get away with a jump. Furthermore, repeated ploughing, as has been shown above, does much to free the land from grubs. Lime, too, being practically wanting in most of our tropical soils, improves the physical condition and assists materially in developing a supply of humus, since a satisfactory green crop can hardly be grown without it. Furthermore, it improves the health of soil bacteria and fungi, which are all-important in nitrification, humus-forming, &c.

With present methods of farming it is not surprising that humus is usually lacking wherever the land has been worked for a few years. It is a well-known fact that the grubs must have organic matter; if they cannot find sufficient in the soil, they attack the living roots. Moreover, experiments have shown that they prefer humus and decaying organic material, and that they will leave the roots alone as long as they can get this natural food.

On 19th April, 1918, two sets of experiments were started at the insectary, using megass mixed with soil in large pots; untreated soil was used for checks. In the first experiment, a large handful of megass was mixed in soil about 5 inches below a cane-set in each pot; one pot was kept as a check. 2nd May, when the cane was about 4 inches high, twelve second-stage grubs of *Lepidiota frenchi* were placed in each pot, in holes about an inch deep made in the surface of the soil around the sets. On 26th November the cane in the check-pot was practically dead, while that in the treated pots was green and almost normal in appearance. On 17th December the soil was turned out of all the pots. The check had seven grubs, three feeding on set and remains of large roots near top of soil, and four finishing roots below set that had been bitten off higher up. All the megass had been eaten in the treated pots, and the grubs had just begun on the roots of the cane.

In the second experiment the treatment was much the same, except that the megass was placed nearer the set in each case. On 24th May five second-stage grubs of *Lepidiota frenchi* were placed in each pot. On 24th October the cane in the check had died after making leaves a foot long. The soil was turned out and four grubs were found, one in stage III, eating in end of set. On 17th December the cane in the treated pots began to show signs of injury. No megass was left, and the grubs had begun to eat the roots of the plants.

While it would hardly be practical to treat canefields with megass, the same end is accomplished by the frequent use of green manures, and the conservation of trash and other refuse from the crops. Probably there is no treatment more adaptable to grubby soils than that devised by Mr. Wilkinson, as outlined above.

I have also emphasised surface cultivation mainly because of its value for increasing the vigour of the crop, hence making the plants more resistant to attack. Furthermore, I was able to show, by an extensive series of experiments that I carried out at Greenhills during January and February, 1919 (105), that cultivation was effective in destroying a part of the young grubs. The best results, as one would naturally expect, came from the frequent use of the pony plough, working as near the stools as possible. The ordinary one-horse scarifiers were next in the order of effectiveness, and the harrows came last. And, again, in our Meringa plots we had unmistakable evidence of the value of cultivation; for even in the check-plot, which received no other treatment than thorough cultivation extending well into February, the cane cut a fair crop.

Fertilisers are important in the growing of any crop, but this is particularly true with sugar-cane, for experiments have demonstrated that a 30-ton crop removes from the soil 102 lb. of nitrogen, 65 lb. of potash, and 45 lb. of phosphate. Land not supplied with these elements rapidly becomes depleted, and soon it will not produce paying crops. By using lime the natural unavailable potash of clay soils is gradually liberated; so artificial application of this element is not required so soon on new land. Nitrogen, however, is highly essential for the maximum profit, especially when we consider the stimulus that it gives to cane being injured by grubs. If sulphate of ammonia is used, it must be applied only after the rains have set in, else its effects are largely lost. The usual practice of applying 2 cwt. of this salt per acre does not give maximum results; it could well be doubled, making two applications, and would show a handsome profit.

I am sorry to repeat, as I have reported previously (108), that meatworks manure appears to make the grubs more destructive to the cane-roots. In all of our plots where this fertiliser was used we had a falling-off of 4 to 6 tons of cane per acre. Along this line it may be noted that W. T. Paget (23) stated that where Townsville manure was used the grubs were bad, while there were none on the untreated land.

It was my thought to make use of this attraction by mixing arsenic with the fertiliser for the destruction of grubs, as had been done by Mr. C. E. La Caze, on the Herbert River, years ago (56); but in our experiments the amount of poison used was evidently not sufficient.

Irrigation, where it is practicable to apply, would undoubtedly have a very beneficial effect as a control measure. In 1892, it was reported (10) that Mr. E. G. Munro of Grassy Hill, writing to the "Queenslander," said that cane suffers from grubs only in dry and not in wet land, and that in the latter the grubs were found to be in a dormant state. Mr. Munro tested this matter by irrigating some stools, with the result that the unirrigated cane died, whereas the irrigated stools had a vigorous growth. Furthermore, the dry districts on the Lower Burdekin do not suffer any injury from grubs, though the soil is a loose loam perfectly adapted for them and the natural feeding-trees of the beetles are plentiful. Possibly the constant irrigation which is resorted to there is one of the important factors.

(4) Where a crop has already been ruined, it is well to plough it out as early as possible, so as to get the birds, &c., to destroy as many of the grubs as possible, before they go down to hibernate. Naturally these pests are usually centred under the stools; so these should be broken up by harrowing and cross-ploughing, to get rid of the grubs before cane is planted again; for these large fellows usually take a final nip at the young shoots, causing considerable expense for replanting.

## ARTIFICIAL CHECKS.

After reviewing the extensive list of natural and cultural checks which retard the development of cane-beetles, one would think that none would survive to require further repressive measures. It has been the experience of workers in economic entomology, however, that normally the vast majority of the offspring of any insect are controlled by natural means, only a very small percentage of the individuals of even our worst pests requiring artificial repression. Insects are so prolific that man's chances, for surviving even, would be small if he had to meet them all single-handed.

I have tried to make some estimate of the natural mortality among cane-beetles at Greenhills by averaging the number of eggs and grubs per stool of cane at the beginning of their development, and comparing this with the number of beetles just before they emerge. In no case have I found more than 25 per cent. surviving; and where the Muscardine fungus was active less than 2 per cent. escaped. Yet there are enough to ruin hundreds of acres of beautiful cane, if not controlled artificially.

Reviewing various factors in these treatments, I will discuss them under the following divisions:—(1) Deterrents for grubs, (2) insecticides, (3) collecting, and (4) removal of feeding-plants of the beetles.

(1) For years it has been the hope of growers, as well as entomologists, to procure some substance which they could place in the soil to drive the grubs away. Many experiments have been made in Queensland, dating back into the early nineties, using all sorts of substances, but without success. Either the substance used had no effect, or, where

more or less distasteful to the grubs, was either too expensive or injurious to the cane-roots. Mr. Tryon (19) experimented with common salt, which had been advocated, and found little or no benefit, except when applied in such quantities as would involve a large monetary outlay and be injurious to the cane-plants. He also experimented with kainit and found that the grubs survived an immersion in a fairly strong solution of this potash salt; moreover, in the soil it had no influence on the grubs.

Mr. W. T. Paget (23) reported that he had also tried salt, kainit, lime, and potash on his fields at Mackay, with only negative results. The Colonial Sugar Refining Company (36) (38) refer to the use of moth-balls and a substance called vaporite, which were applied in the fields at Greenhills, but proved absolutely useless. Along this same line, Mr. Jarvis (72) experimented with dichlorbenzol, which was imported from Germany at considerable expense. This, when used in heavy doses, was effective in destroying grubs that were compelled to remain near the fumes, but the expense would prohibit its use in the field. Mr. Jarvis (82) also experimented with creolin, creosote, and borax, finding them effective against the grubs when used in large doses, but the price was prohibitive for field practice. His experiments also indicated that salt-petre, barium chloride, and hellebore were ineffective when applied to the soil.

(2) Insecticides that have been more effective, and that have met with practical application for years, are—Kerosene emulsion, carbon bisulphide, cyanide of potassium, and arsenic in various forms.

Mr. Tryon (19) states that it has been proved experimentally that sugar-cane grubs die in ground saturated with kerosene emulsion. In the United States this treatment was formerly used rather extensively for destroying grubs in lawns, &c., but it has gradually been replaced by other treatments, since the expense is almost prohibitive.

One of the oldest remedies, as well as one of the most effective under certain favourable conditions, is the injection of carbon bisulphide into the soil, though its use, too, in recent years, has been made almost prohibitive by increasing prices. Mr. Tryon (19) suggested its application for the destruction of cane-grubs, quoting references to its successful use in the United States. A decade or so later it was used rather extensively at Mossman and Mulgrave (38), with apparently good results. Eight drams of the chemical per stool was injected into the soil 2 inches deep, one or two injections being given to the stool according to whether it was small or large, the requirement per acre being about six gallons, one man doing about one acre a day. It was suggested that best results were secured when the ground was dry, for otherwise the remedy would not act. It was also found that it was best to make the injections above the grubs, the heavy vapour permeating the soil downward. As the carbon bisulphide, in large lots, costs 20s. per five-gallon drum at Southern ports, the cost per acre was approximately 34s. Smaller doses were applied at Mulgrave, viz., 3½ drams to the older and 2 drams to the smaller stools, at least two treatments being given; 60 acres alluvial river-flats were treated at a cost of about 30s. per acre. One farmer of the district also applied a mixture of two parts carbon bisulphide and one part kerosene on old cane attacked by about twenty grubs per stool, with the result that the treated cane recovered, whilst that surrounding it was practically killed. Investigations were said to have shown that 80 per cent. of the grubs were killed by the treatment. The remedy in some instances was applied too late, after the grubs had eaten off most of the roots of the young cane; hence it proved ineffective.

Mr. Tryon (45) brought to the attention of the growers experiments that had been carried on in France, using a solution of cyanide of potassium for the destruction of soil-frequenting insects, with a view to its application for scarabæid grubs. Apparently, however, no immediate use was made of this information. Mr. Jarvis (82) made some preliminary laboratory experiments, using the above information, and got rather effective results in killing grubs in the soil, but the investigation was not continued, due to the high price of the chemical, which was almost unprocurable.

During the recent campaign against the green Japanese beetle, in New Jersey, Mr. J. J. Davis (107) used sodium cyanide in solution on a very extensive scale; this was applied to grass land, while the grubs were near the surface. Tank wagons with a capacity of 600 gallons, drawn by tractors, were used in this work. He found that it required 160 lb. of the salt with 12,000 gallons of water per acre to kill 95 to 100 per cent. of the grubs.

Arsenic, though an old and standard remedy as an insecticide, was apparently first used successfully in combating cane-grubs by Mr. C. E. La Caze (56) on the Herbert River. He reported to me that he was eaten out year after year, losing many thousands of tons on his three farms. Being faced with bankruptcy he decided upon extreme measures. When he learned that white arsenic would destroy termites (white ants) he at once decided to try it for the destruction of the grubs. He hit upon a plan of mixing the poison with meatworks manure, and arranged to have the mixing done at the meatworks. Since arsenic was cheap, he used 14 lb. for each cwt. of the manure, and applied 5 cwt. of this fertiliser per acre, placing it in the drill before planting. He said the results were immediately noticeable, and that there had been no further grubs on that land since.

These results were most interesting, but since I was told that many of the beetle feeding-trees were removed about that time, this may have also had an important bearing upon the disappearance of the grubs. At any rate the results were not conclusive, and the experiment should be repeated with proper check-plots.

Mr. Girault (57) also, recognising that the grubs swallow a great deal of earth, experimented with poisons in the soil, and though his work was on a laboratory scale he found that this treatment was effective against the pest.

Continuing this line of investigation, Mr. Jarvis (88) finally modified the application by combining the poisons with green foliage of cowpea, which he buried in the pots with grubs. He experimented with Paris green, London purple, and white arsenic, using these poisons at the rate of 8 oz. to 1 cubic foot of soil, from which he got effective results. In devising a means of applying this remedy in the field, Mr. Jarvis advised ploughing a trench close alongside the stools, and sowing cowpeas in the bottom, leaving the furrow open while they grew. In practice this would hardly be wise procedure, for it would be apt to dry the ground out too much. Mr. Jarvis (98), however, had a small plot treated in this way on a farm near Gordonvale. The cane had been planted in August; the drills made alongside and sown with cowpeas on 25th January; and this green crop was dusted with Paris green, at the rate of 8 lb. per acre, and turned under, close against the cane, on 14th February. During March the adjoining cane on each side of this test-plot was treated with carbon bisulphide. Since the grubs were not noticeably destructive even to untreated cane, the final results of the experiment were inconclusive.

In my own preliminary experiments with arsenic during 1918, however, I based my judgment as to the amount required upon the above experiment, but increased the dose to 10 lb. in most instances, in one case using 20 lb. The results (108) from these experimental plots at Meringa were very satisfactory, but evidently not so much due to the poison used as to other factors in the control, i.e. cultural measures, &c.

In subsequent field experiments I gradually increased the dose, finally using only the white arsenic. I mixed the dry poison with soil from the Greenhills estate, and found that it required a comparatively large amount to be quickly fatal to grubs put into it. Yet when I used approximately what would be 80 lb. per acre all the grubs died in 1-4 days. During the 1920 season we treated large areas both at Meringa and at Greenhills, dusting the poison in a furrow made close against the side of the stools, and covering it in. In these experiments we used arsenic at the rate of 20 lb., 40 lb., 60 lb., and 80 lb. per acre. A drought season followed, so the grubs huddled close under the stools and went fairly deep, to maintain the necessary moisture. Few appeared to have gotten out far enough to get the effect of the poison; hence the results of the treatment were most discouraging.

In May, 1920, we started another series of experiments at Greenhills, this time placing the poison in the drill, either just before or soon after the cane was planted. In all forty-six plots, of five rows each, were used, the treated plots alternating with untreated checks. In this work we used arsenic at the rate of 40 lb., 60 lb., 80 lb., 100 lb., and in two plots 200 lb., to see if it had any injurious effect upon the plants. One of the experimental fields was in a section of the estate that usually shows grub injury soonest, and this was planted to the variety D 1135. It was treated with the poison on 12th May, when the drills were partly filled and the cane a few inches high. On 24th February, 1921, the devastation of the grubs began to be evident in the checks. We found 45 grubs under the first stool that we examined, and 13 of them had reached the third stage. A stool in the plot with 200 lb. of arsenic only had 5 living grubs, and we discovered 4 that had recently died of the poison. None of these grubs had reached the third stage. A stool in a check alongside gave 18 grubs, and 4 of them had reached the third stage. Digging a stool in the plot with 100 lb. arsenic we found 11 grubs, 2 being in the third stage. Next, in the plot where 80 lb. arsenic had been applied, there were 7 grubs to a stool, 1 having reached the third stage. In a plot with 60 lb. arsenic, 8 grubs were found under a stool, 1 having reached the third stage. Digging a stool in the plot with 40 lb. arsenic, we got 9 grubs, 3 in the third stage. A check-stool alongside had 18 grubs, 10 in the third stage. Hence it will be noted that there was a marked decrease in the grubs in all of the treated plots, the best results being where the greater amounts of arsenic had been used. Moreover, in the treated cane, most of the grubs had apparently died before they reached the third or very destructive stage; hence these plants showed no injury, though the checks alongside were somewhat fallen.

11th March the cane in the plot with 200 lb. arsenic was standing erect, in marked contrast to the check-plots on either side in which all the stalks had fallen flat on the ground. It was so encouraging that I decided to have a photograph made of it (Plate XII). The plot with 100 lb. arsenic was not quite as perfect, some of the stools being somewhat fallen; and the injury was proportionately more where less poison had been used. The 80-lb. plot was fair, the 60-lb. plot showed little benefit. and the 40-lb. plot none. It was very evident that we must increase the dose to 200 lb. for control. The plant cane in all the Badila plots of the other field was still green.

Following upon these observations there was a solid month of deluge. Water stood in the field in lakes, and in some places the cane was washed away. To make matters worse, there was considerable wind, so most of the heavy cane was lodged. In our Badila plots, where we had applied arsenic in the drill before planting, the cane was all severely injured by the grubs, so that there was no noticeable difference in the treated and untreated plots. Digging in the saturated soil, 13th April, I found all the grubs near the top; hence the excessive moisture had compelled them to leave the lower stratum where the poison had been placed, and they had continued their destructive work, eating right into the stalks near the surface of the ground, in some cases. Moreover the encouraging results that I have noted in the D 1135 field were also somewhat obscured by the effects of the wind and water. The erect cane in the poisoned plots had lodged, but it still held its head several feet above that in the checks, for its roots were solidly in the soil and practically uninjured by grubs.

This evidence was encouraging, but it is still inconclusive; I had hoped to be able to clear the matter up with all the various experiments that we had in hand; but the indication is now that for best results the poison should be placed nearer the surface, especially for wet seasons.

At first thought it would appear to be an easy matter to poison the adult beetles, especially the greybacks, which are such voracious feeders. Indeed Mr. Tryon (19) recommended the use of arsenicals for this purpose; but states that field applications were disappointing. After experiments with beetles in confinement he concluded that they are either very tolerant of poisons, or if they succumb to them it is only after a considerable interval has elapsed, since, he says, they die no sooner than do other beetles that in confinement subsist on unpoisoned food. Mr. Jarvis (70), also, experimented on beetles in the laboratory, but his results, too, were very inconclusive: beetles eating the poisoned foliage lived for 9-10 days while those without poison died in about 14 days. Furthermore, experience in the United States with beetles of the genus *Lachnosterna* showed that they were almost immune to the ordinary poisons. Still I would urge further experimentation along this line with the use of proper controls.

(3) Collecting beetles is a time-honoured practice; for many years it has been the principal method of combating similar pests in Europe. It must be recognised, however, that there they have a tremendous population, and labour being cheap they have been able to collect practically all of the pest at a minimum outlay. In this new country, where the uncultivated natural breeding-ground of these pests is so

many times greater in extent than the comparatively narrow cultivated belts, this method of coping with the problem appears to be hopeless. In fact, if all the beetles were captured and paid for at the ruling rate of 1s. to 2s. a quart, there would not be money enough in the State Treasury to settle the bill. Undoubtedly some relief comes from this practice, especially where the beetles are collected persistently for years; but a review of the figures and history of collecting in the worst-infested districts gradually led me to the conclusion that the expense was too great when compared with the results. Furthermore, other factors were probably largely responsible for the remarkable disappearance of the pest in certain districts, especially those which suddenly become immune.

The celebrated economic entomologist Mr. Albert Koebele (1) first recommended hand-collcting of these terrible cane-pests in Australia, and the Colonial Sugar Refining Company (10) (35) (36) have persistently worked on this advice at their Queensland mills. Mr. Tryon (19) (46), too, has repeatedly urged this procedure. With deference to the opinions of these experts, let me say that the difficulties of collecting beetles while they are on the feeding-trees have greatly increased in recent years. Lantana in many places occupies the ground to such an extent under the trees that it is almost impossible to secure the beetles once they are shaken off.

We have demonstrated recently, however, that all the beetles flying to the cane in the morning are gravid females ready to oviposit. By dissecting I found that these had an average of 26 eggs each. After the morning flight ends at 5.30 a.m., the beetles have a rest for a considerable period, hanging upon the cane-leaves. Hence, between the time the flight ends and about 7 a.m., it will probably prove practicable to collect these females daily, during the whole of the aerial life of the beetles. Where the cane is not too high, it is possible to see the conspicuous grey beetles on several rows at a time, as one walks through the field, so that it is not difficult to collect a good lot each morning. This procedure would certainly be far easier and more profitable than picking up the grubs later in the season after they have become injurious; for every beetle picked from the cane-leaves at that time saves 26 grubs from hatching.

On the other hand, it will be remembered that at times during the flight a considerable majority of the beetles in the feeding-trees are males—I have found as high as 86 per cent.—so it is a waste of funds to pay for the collection of these.

Mr. Koebele (1) suggested the use of light-traps for the destruction of cane-beetles. The Colonial Sugar Refining Company (10) gave considerable attention to the trapping of beetles at Hambledon in the early days. Casks were placed in and around fields; each cask was partly filled with water, a tallow lamp was made fast to a board nailed across the top, and tar or molasses was smeared all over the outside of the cask. It was reported that thousands of beetles were caught in this manner.

Beetle collectors have told me that it is a well-known habit of the greybacks to fly to lights, especially when a lamp is placed under the feeding-trees in the middle of a white sheet. Mr. Jarvis (68) experimented somewhat on this phase of the control, and constructed an elaborate trap, the design of which was published (81) later. Yet comparatively few beetles were caught. Of the total of 170 beetles, caught on three successive nights, 131 were males, which certainly does not commend the utility of this method of coping with the pest.

(4) The removal of feeding-trees has been recognised for many years as a most practical means of getting rid of the beetle trouble. Mr. Tryon (19) was among the first to recommend this means of combating cane-beetles. The history of the pest in Queensland goes to show that depredations usually cease after the timber is cleared away. Mr. William Beal (28) remarked at the Agricultural Conference at Mackay, in 1899, that in his district (Childers) about 30,000 acres of scrub was felled during the preceding ten or twelve years, with a considerable decrease in the pest. Mr. W. T. Paget (29), too, at the same meeting said that many of the principal feeding-trees had also been removed in his district (Mackay), but he did not consider that this was responsible for the disappearance of the pest. He reported that they were free of the pest after a fight of many years.

Mr. C. E. Jodrell, discussing control measures for this cane-pest at the Mossman meeting of the A.S.P.A. (63), remarked that he had some experience, seeing that he had been paying into the Grub Fund for twenty-three years. He said that many of the growers began to think they were on the wrong lines altogether. They had left harbourage for beetles along the fringes of creeks, and the insects flourished; but wherever these had been cleared a very material diminution of the pest resulted. If the £20,000 spent in grub and beetle collection had been put into brushing the banks of creeks and felling scrub, they would have dealt with the grub long ago, and the value of the country would have been improved by the clearing. He continued that the C.S.R. Co. some years ago employed a number of men at this work on the Johnstone River, and since that time neither he nor his neighbours had had a stool of cane attacked by the grub. Prior to that period there had been years when the crops were eaten down; since dealing with the harbourage for the beetles, and cutting it well back, they had had no trouble. He said it seemed to him foolishness to seek to do away with the beetles by collecting them, whilst they were allowed to breed in millions in suitable refuge all around.

Trapping the beetles by keeping only a few of their favourite trees has also been repeatedly recommended. Mr. Tryon (19) suggested the planting of the Moreton Bay fig-tree (*Ficus macrophylla*) near farm homesteads, where the beetles could easily be shaken off and collected. He further urged that this would prove of especial value when the grub-pest had been reduced to small proportions, thus affording an easy opportunity for keeping its ravages within comparatively harmless limits.

I think it is now generally recognised, among growers in districts where the grubs are troublesome, that it is a wise procedure to have a number of the choice feeding-trees in the yard where the beetles may be shaken off daily for the fowls. Where other feeding-trees have been removed on the farm, it is possible to catch the pest in this way in tremendous numbers. In planting feeding-trees, however, it must be borne in mind that some sorts soon grow so large that it would be impossible to shake the beetles off the branches, and hence the purpose would be defeated.

# Conclusions and Recommendations.

Scientific investigation may be compared to investment; properly administered it pays tremendous dividends. This fact has been repeatedly demonstrated in Hawaii, especially since 1904, when the ravages of the Australian leafhopper made it necessary to establish departments of entomology and pathology. A review of the history of their work for 1905 shows a staff of seven entomologists, three pathologists, four chemists, three agriculturists, one illustrator, and one stenographer. The president in his address for that year said—

"The establishment of the station on its present basis has entailed considerable expense in the purchase of grounds and erection of buildings. The running expenses from now on will be considerably more than ever before. The amount lost, however, in the past year alone, by the ravages of insect pests, would have paid the cost of establishing fifty stations on the new basis and operating the same for a number of years to come."

Shortly after the introduction of the leafhopper parasites from Australia, the growers estimated that their entomologists had saved them an annual loss of more than 1,500,000 dollars. Furthermore, other problems that have developed subsequently have been handled just as efficiently by their large staff of scientific workers.

Entomological problems in Australia are even more tremendous, so that they will continue to demand constant attention as long as crops are grown. Even with sugar-cane alone, pests are so destructive that a considerable staff of trained investigators might be profitably employed. I appreciate this all the more after working four years on these terrible grub-pests; hence I am keenly interested in having this particular problem carried forward rapidly to a conclusion. While it is never satisfactory to give up an investigation in the middle, this is especially true when success is in sight. Yet I trust our present promising measures will be continued and that their profitable application in the field can be demonstrated.

In future work with poisons I would suggest combining arsenic with conservation of humus, following the method outlined above in Mr. E. D. Wilkinson's experiments. Furthermore, arsenite of soda could be used with advantage for controlling the weeds, and it would then combine with the humus. From my earliest reports, it will be noted, I have consistently advocated the importance of humus in checking the damage of grubs to our crops; moreover, there is probably no easier way to destroy them than by combining this organic matter with the right amount of poison. This phase of the problem remains to be worked out by field experiment.

Again, since meatworks manure is evidently attractive to grubs, it is probably only a matter of finding how much poison to use with this fertiliser to get results. It will be recalled that Mr. C. E. La Caze reported successful control after an application of 70 lb. of arsenic per acre, though there may have been other factors entering into his results, since he kept no check-plots. At any rate, this is a suggestive line of control, which is particularly easy of application, since it fits splendidly into ordinary field practice. The amounts of arsenic should be varied, for experiment, to learn how much of the poison is required for results. I would suggest using 80 lb., 100 lb., 150 lb., and 200 lb. This could best be mixed during the manufacture of the manure, thus avoiding the handling of the poison by inexperienced men. Applying the fertiliser with the ordinary manure spreader, it will be best to keep the delivery pipes near the roots of the cane, for with ordinary conditions the grubs remain close under the stools. Moreover, our experiments have shown that for best results the poison must not be placed too deep in the soil; so it will probably be best to make the application after the drills are partly filled in by cultivation.

Then, too, further experiments should be tried with poisons for the destruction of the beetles, especially the greybacks; for, since they are such voracious feeders, there is a possibility of success. A few of their favourite feeding-trees could be treated for a test. I would suggest dusting experiments as well as spraying, and a trying-out of calcium arsenate, comparing it with the lead arsenate. Both of these poisons may now be had in the powdered form; so dusting, being more economical, has come much into vogue for the control of leaf-eating pests.

In Bulletin No. 12 I have recommended the further introduction of friendly organisms. The experience of Hawaii, however, teaches that that work must be entered into wholeheartedly for a successful outcome. It requires years of the most strenuous work, but the final results must certainly pay. A well-trained field entomologist should be despatched as soon as possible, and given a free hand for at least five years. New Guinea, Java, and the Philippine Islands will probably prove the richest locations for this investigation.

## ANNOTATED BIBLIOGRAPHY.

(1) 1891. KOEBELE, ALBERT.—Sugar Cane Insects in N.S.W. Insect Life iv. 385-389.

Trip to Clarence and Tweed Rivers in January, 1891. Recommends collecting beetles and grubs, also the use of light traps.

(2) 1892. BULTON, FRED W.—Eradicating Grubs. Sugar Journ. & Trop. Cult. i, 232.

At Farleigh, Mackay, seven years before, grubs extremely numerous. Summer ploughing was done, followed by two cross-ploughings. The land was thus rid of grubs by constant working of the soil during their feeding stage.

(3) 1892. "JASEUR."—Grubs in Cane (*Lepidoderma albo-hirta*). Sugar Journ. & Trop. Cult. i, 210.

The grubs severe two previous years on Herbert and Johnstone Rivers.

(4) 1892. SHELTON, E. M.—Letter to C. V. Riley. Insect Life v, 45.

*Lepidiota squamulata* said to be the principal cane-grub. Refers to a fungus from France for the destruction of grubs.

(5) 1892. SHELTON, E. M.—Grubs in Sugar Cane (Editorial). Sugar Journ. & Trop. Cult. i, 159.

Refers to correspondence with Dr. C. V. Riley, which was published in Insect Life v, 47.

(6) 1892. TURNER, R. E.—Insect Pests (*Lepidoderma albo-hirta*). Sugar Journ. & Trop. Cult. i, Oct. Supplement p. 5.

Life-history and control measures. *See also* Editorial, p. 182.

(7) 1893. Editorial—Grubs in Cane. Sugar Journ. & Trop. Cult. ii, 86.

Referring to eradication of grubs in the soil by thorough cultivation during the summer.

(8) 1893. OLLIFF, SYDNEY.—Rept. on a Visit to the Clarence River District. Agr. Gaz. N.S.W. iv, 373-387.

On p. 379 he mentions several kinds of beetle larvæ under cane; Christmas beetle (*A. concolor* Burm.), and cockchafers (*Lepidiota squamulata* Waterh., *Lepidoderma albo-hirtum* Waterh., and *Heteronyx*) : none very numerous.

(9) 1893. TRYON, H.—Insects as Fungus Hosts. Trans. Nat. Hist. Soc. Qld. i, 51-59.

A general review of the relation of fungi to insects.

(10) 1894. COLONIAL SUGAR REFINING CO.—Grubs and Insect Pests (orig. rept. pub. 1893). Sugar Journ. & Trop. Cult. iii, 103, and contd. 124.

Gives figures of hand-picking in Denmark in 1887, also other parts of Europe. Notes on life history at Hambledon, &c.; the grubs first in serious numbers there in 1889; no damage in 1894. Mr. Munro, of Grassy Hill, tried irrigation and found that it made the cane grow vigorously while the unirrigated cane died.

(11) 1894. Editorial—Grubs and other Cane Pests. Sugar Journ. & Trop. Cult. iii, 99.

Discusses fungous diseases of grubs, &c., also other control measures.

(12) 1894. Editorial—The Grub Pest. Sugar Journ. & Trop. Cult. iii, 246.

Discusses control measures, hand-picking, &c.

(13) 1894. "SCRUTATOR."—The Grub Pest (*Lepidiota albohirta*). Sugar Journ. & Trop. Cult. iii, 247.

Information secured from W. T. Paget, on life-history, feeding-trees, &c.

(14) 1895. Editorial—The Grub Pest. Sugar Journ. & Trop. Cult. iv, 115.

Suggestions for cane pest destruction fund. Also, destruction of feeding-trees.

(15) 1895. Editorial—The Grub Pest. Sugar Journ. & Trop. Cult. iv, 279.

*Lepidiota albohirta* again swarming. Funds collected in districts from Mackay northwards for the destruction of beetles.

(16) 1895. JAMES, F.—The Grub Pest. Sugar Journ. & Trop. Cult. iv, 253.

Suggests deeper planting.

(17) 1895. PAGET, W. T.—The Grub Pest. Sugar Journ. & Trop. Cult. iv, 116.

*Lepidiota albohirta* did great damage at Mackay during two previous years.

Outline of an Act for the destruction of beetles and other noxious pests.

(18) 1895. PAGET, W. T.—The Grub Pest. Sugar Journ. & Trop. Cult. iv, 226.

Agricultural Conference, Mackay. In 1893 grubs were serious at Mackay, but in 1894 they were much worse. Beetles ate cane when feeding-trees were cut. He demonstrated by breeding that the pest had a one-year life-cycle. Deep-rooting canes resist the grubs. Gives extensive figures as to hand-picking in Europe in 1887.

(19) 1895. TRYON, H.—Grub Pest of Sugar Cane. Dept. Agric. Brisbane, July 1895; pub. 1896.

The most comprehensive survey of the subject: historical, nature of injury, life-history and habits, feeding-trees, natural enemies, control measures, &c.

(20) 1895. WALLER, E. S.—The Grub Pest. Sugar Journ. & Trop. Cult. iv, 115.

Considers the cane-grub confined to scrub lands. Recommends removal of all feeding-trees, and protection of native birds.

(21) 1896. Editorial—The Grub Pest. Sugar Journ. & Trop. Cult. v, 142.

Discussion of control measures in Europe.

(22) 1896. PAGET, W. T.—The Grub Pest (*Lepidiota albohirta*). Sugar Journ. & Trop. Cult. v, 116.

Discussion on collection of beetles with extensive figures for that district.

(23) 1896. PIONEER FARMERS' ASSN.—The Grub Pest in Mackay (*Lepidiota albohirta* and *Anoplognathus lineatus*). Sugar Journ. & Trop. Cult. v, 147.

Discussion of control measures. Mr. Paget had tried lime, kainit, salt, potash, &c., without results. Paris green did not kill the grubs in the soil. Where Townsville manure was used the grubs were bad, while there were none on the untreated land.

(24) 1896. Report—The Grub Pest (*Lepidiota squamulata*). Sugar Journ. & Trop. Cult. v, 287.

Discussion of control measures. Two illustrations of cane-beetles.

(25) 1896. TRYON, H.—Grubs. Sugar Journ. & Trop. Cult. v, 5, 91, 118, 145, 173.

Discusses methods of control at length.

(26) 1897. Editorial—The Grub Pest. Sugar Journ. & Trop. Cult. vi, 25.

Discussion of control measures employed in Europe and elsewhere.

(27) 1898. "SCRUTATOR."—The Grub Pest (*Lepidiota squamulata*). Sugar Journ. & Trop. Cult. vii, 146.

In an orchard on Pioneer River a persimmon tree had many dead beetles under it for past two years. The leaves were much eaten, and the ground was white with the corpses of the beetles. Beetles confined after feeding on this tree soon died, while some from a fig lived for a considerable period. *See also* Editorial, p. 244.

(28) 1899. BEAL, WM.—Cane Grubs. (Agr. Conf. Mackay.) Qld. Agr. Journ. v, 133.

In the Childers district about 30,000 acres of scrub were felled during the preceding ten or twelve years, with a marked decrease in the pest. Thorough cultivation destroys grubs. £300 to £400 spent for collecting beetles in 1898.

(29) 1899. PAGET, W. T.—Cane Grubs. (Agr. Conf. Mackay.) Qld. Agr. Journ. v, 136.

"The grub originates in the blady-grass country—i.e. the forest country," but congregates on scrub timber to feed. After destroying four tons of beetles on their estate in 1894, the cane was ruined the next year just the same. Many of the principal feeding-trees were removed, though Mr. Paget did not consider that this was responsible for the disappearance of the beetles. In 1899 the cane was free of them.

(30) 1899. POTT, G.—Cane Grubs. (Agr. Conf. Mackay.) Qld. Agr. Journ. v, 136.

In the Proserpine district, bandicoots were plentiful and grubs scarce. They go after the grubs. The birds, also, destroy an enormous quantity of grubs and should be protected. Much of the trouble probably was due to the destruction of birds by the kanakas.

(31) 1899. SWAYNE, E.—Cane Grubs. (Agr. Conf. Mackay.) Qld. Agr. Journ. v, 134.

Mr. Swayne stated that it had been 25 years since the grubs first appeared in the Mackay district, and in 1891-2 their numbers were so great that they threatened the stoppage of the industry. During 1895 the Agricultural Department voted £1,500 to assist in their destruction. From 1896 to 1899 they collected $50\frac{1}{4}$ tons of beetles at an expense of £2,649 19s. 7d. Levy 6d. per acre; and 6d. per lb. was paid for beetles.

(32) 1902. BOYD, A. J.—Extermination of the Cane Grub. Qld. Agr. Journ. x, 468.

An excellent description of the mole, *Talpa europaea* ?; urging its introduction for the destruction of the grubs. *See also* xix, 328.

(33) 1902. FROGGATT, W. W.—A Natural Enemy of the Sugar-cane Beetle in Queensland. Agr. Gaz. N.S.W. xiii, 63.

Gives an account of Mr. J. C. Clarke's observations at Hambledon Mill, dealing with wasp parasites of cane-beetles. Also advocating certain flowering plants to attract the wasps.

(34) 1902. TRYON, H.—A Parasite of Sugar-cane Beetle Grubs. Sugar Journ. & Trop. Cult. xi, 151.

Life-history and habits of a wasp, *Dielis formosa* Guerin, Also published in Qld. Agr. Journ, x, 133.

(35) 1904. COLONIAL SUGAR REFINING CO.—Notes on the Means of Checking the Grub Pest. Printed Circular, 1st November, 1904.

The following methods proved inadequate for coping with the pest:—

1. Collecting beetles.
2. Cutting down feeding-trees.
3. Collecting grubs when ploughing.
4. Sowing fungus.

In 4 the efforts appeared to be abortive; 3 did good; 4 probably the best, but not extensive enough. Of 1,500 beetles, 62 per cent. were females. First week after emerging, no recognisable eggs; third week after emerging, one-fourth had recognisable eggs. Eggs about 20 on an average. Several sets may be deposited,= maximum 60 eggs. Grubs come to the surface under trash during wet weather; 25 kerosene tins of grubs picked up in this way from two acres, i.e. 100 gallons of grubs; one gal.=1,300 grubs, weight $8\frac{1}{2}$ lb.,=65,000 grubs per acre. If no trash is present the grubs collect under the cane-stools, hence do more damage to the crop.

(36) 1907. COLONIAL SUGAR REFINING CO.—Pests. Ann. Rept. 1907, 15-33.

Discusses tremendous loss occasioned by grubs, especially in the Hambledon district, i.e. 20,000 tons cane during 1906-7,= £20,000 net. Grubs worse on well-drained land. Discussion of experimental control measures—carbon bisulphide, moth-balls, &c. Review of knowledge of life-history. The period 1897-1907, Homebush Mill, Mackay, collected 21,822 lb. of beetles; very few collected 1904-7, and crops fairly free. Review of history at Hambledon, p. 32.

(37) 1907. TRYON, H.—Salt as a Remedy for the Cane Grub. Qld. Agr. Journ. xviii, 360.

Discusses experiments, which proved negative.

(38) 1908. COLONIAL SUGAR REFINING CO.—Grubs. Ann. Rept. 1908, 27-39.

Loss of cane 40,000 tons at the five Northern mills. £2,800 spent for destroying 31.73 tons of beetles. Also £1,000 spent at Mulgrave Mill for collecting; 6d. to 2s. per qt. or lb. List of feeding-plants. Exact notes on application of carbon bisulphide, p. 34, from Mossman to Mulgrave. Remedy usually applied too late. European collecting figures, p. 38.

(39) 1909. COLONIAL SUGAR REFINING CO.—Grubs. Ann. Rept. 1909, 43-52.

During 1908-9 approximately £50,000 loss from grubs in the Cairns district. £1,500 spent for picking 14 tons of beetles and 2 tons of grubs. Notes on injecting cyanide, p. 47. Experiments at Goondi with sorghum for the poisoning of grubs proved negative, p. 50. North found least damage on best cultivated farms, pp. 52-3.

(40) 1909. GIBSON, ALFRED.—Fowls and the Grub Pest. Aust. Sugar Journ. i, 184.

An extensive experiment, using travelling fowl houses, &c.

(41) 1909. TRYON, H.—A Cane Grub Parasite. Aust. Sugar Journ. i, 79.

The mites infesting the grubs were held not responsible for their deaths, Lynwood Estate, Isis district.

(42) 1909. YOUNG BROS., Messrs.—A Cane Grub Parasite. Aust. Sugar Journ. i, 29.

A mite attacking grubs.

(43) 1910. BARNARD, F. W.—Carbon Bisulphide for Cane Grubs. Aust. Sugar Journ. i, 481.

Six gallons used per acre on loamy soil with success, i.e. 8 drams injected under each stool of cane, as near as possible. A man treats one to one and a-half acres per day. Late-planted cane most successfully withstands grub-attack.

(44) 1910. *Mackay Mercury*.—Cane Grub Destruction. Aust. Sugar Journ. ii, 274.

During 1909 the receivers destroyed 22 tons of grubs in the Mackay district alone.

(45) 1910. TRYON, H.—Cane Grub Destruction. Aust. Sugar Journ. ii, 88; *see also* 209.

Use of cyanide of potassium in a liquid form for grubs in the soil.

(46) 1910. TRYON, H.—The Cane Grub Pest. Aust. Sugar Journ. ii, 409.

General control measures, especially beetle capture by hand.

(47) 1911. *Mackay Mercury*.—Grub Pest in Mackay, *Lepidiota albohirta*. Aust. Sugar Journ. ii, 443.

Notes on life-history, and the weight of beetles, 250=1 lb., 560,000=1 ton. Beetles in the Mackay district paid for at 6d. to 9d. per lb. The money is derived from a tax of 1d. per ton of cane sent to the mills, subsidised by the Government at the rate of 10s. in the £. In 1910, £1,440 14s. 6d. was expended for destroying 22 tons of beetles in Mackay.

(48) 1911. MAUGHAN, J. C.—Natural Enemies of the Cane Grub. Aust. Sugar Journ. ii, 161.

Brown lizard eating grubs.

(49) 1911. PRITCHARD, G. H., Secty. A.S.P.A.—Entomologist for the Sugar Industry. Aust. Sugar Journ. iii, 199.

During the 1910-11 season over £3,000 was spent in the eradication of grubs in the Cairns district. They had destroyed 22 tons of beetles and 9 tons of grubs. Boys made £1 a day collecting insects. 25,000 to 30,000 tons of cane lost annually through grubs in the Cairns district.

(50) 1911. TRYON, H.—Grub Pest of Sugar Cane, *Lepidiota albohirta*; a neglected aspect. Aust. Sugar Journ. ii, 532.

A discussion of natural enemies—(1) Predatory mammala; (2) predatory birds; (3) predatory insects; (4) parasitic insects; and (5) plant parasites (fungi and bacteria). Fungus prolific at Goondi in 1895. Fungus cultures from France had previously been sown in that locality. No subsequent trouble from grubs there. Suggests application of fungus to other fields. Mr. Jodrell referred to flying-foxes killing beetles; and also his experience with the fungus. Mossman spent £4,000 collecting beetles, during six years, with no apparent result.

(51) 1911. TRYON, H.—Natural Enemies of the Cane Grub. Aust. Sugar Journ. iii, 62.

Discussion of bandicoot and pouched mice as grub destroyers.

(52) 1912. DE CHARMOY, D. D'E.—Report on *Phytalus smithi* Arrow, and other Beetles injurious to Sugar-cane in Mauritius. Port Louis Govt. Printing Office, 1912.

Describes experiments with various control measures, most of which were ineffective. Hand-picking was finally resorted to.

(53) 1912. Pritchard, G. H., Secty. A.S.P.A.—Deputation to Minister for Agriculture. Aust. Sugar Journ. iii, 632.
Annual losses from cane-grubs estimated at £100,000.

(54) 1913. Colonial Sugar Refining Co.—Grubs (*Lepidoderma albohirtum*). Chem. Rept. 1912, 41-44.
Several beetles damage cane. Difference in size is great; Childers beetles one quart = 960, while at Goondi the greybacks go 200 to the quart.

(55) 1913. Editorial—Entomological Work in Queensland. Aust. Sugar Journ. v, 541.
A strong editorial dealing with the investigation of the grub-pest.

(56) 1913. Editorial—Arsenic for Grub Destruction. Aust. Sugar Journ. v, 472; *also see* 514.
On the Herbert River Mr. C. E. Lacaze had excellent results in the destruction of grubs, by adding 12 lb. of white arsenic to each cwt. of meatworks fertiliser used for manuring his cane. *Note.*—Mr. Lacaze later said that he used about 6 cwt. of the manure per acre, hence about 70 lb. of arsenic.

(57) 1914. Girault, A. A.—Cane Grub Investigation. Aust. Sugar Journ. v, 819.
The pupæ of the beetles sometimes at a depth of 4 feet, but the resulting beetles emerge. The grubs eating earth may be killed readily by adding poison to the soil.

(58) 1914. Girault, A. A.—Work of the Entomologist; Life History of the Cane Grub. Aust. Sugar Journ. vi, 374.
General notes on life-history of grubs, stating that pupal stage lasts from three to four weeks.

(59) 1914. Girault, A. A.—White Grubs of Sugar Cane in Queensland. Qld. Bur. Sugar Exp. Sta., Div. Ent., Bull. No. 1.
An excellent popular survey of the situation, with recommendations for future work.

(60) 1914. Jarvis, E.—Cane Grub Destruction. Aust. Sugar Journ. vi, 582.
Insect parasites and fungous diseases.

(61) 1914. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vi, 628.
Notes wet weather during August causes grubs to pupate near the surface.

(62) 1914. Tryon, H.—Cane Grub and Muscardine Fungus. Aust. Sugar Journ. vi, 631.
Green Muscardine fungus from Samoa said to already occur in the Cairns district. Named *Metarrhizium anisopliæ* (Metschnikoff) Sorokin. This fungus found in 1901 on Mr. Blackwell's farm, also at Highleigh; again, in 1908, at Hambledon. This article summarises information on this important subject.

(63) 1915. A.S.P.A. Meeting.—Government Entomologist on the Cane Grub Pest. Aust. Sugar Journ. vii, 343.
Mr. Jodrell remarked that if the £20,000 spent for grubs and beetles had been used for removing feeding-trees they would have been rid of the grub long ago. Mr. Jarvis stated that the eggs were deposited in soil at a depth of 5-7 inches, and that ploughing would destroy both them and the young grubs.

(64) 1915. A.S.P.A. Meeting.—Visit of the A.S.P.A. to Hambledon and Greenhills. Aust. Sugar Journ. vii, 375.

The Greenhills estate had been leased for three years for the sum of £10,000. The crop, estimated at 27,000 tons, was reduced to less than 3,000 tons by the grubs. During 1914 about 15 tons of grubs were collected and destroyed; 4d. to 8d. per lb. was paid for collecting.

(65) 1915. A.S.P.A. Meeting.—Visit to the Entomological Laboratory at Gordonvale. Aust. Sugar Journ. vii, 410.

It was mentioned that ploughing in a crop of green maize apparently made the crop more immune, by supplying the grubs this humus.

(66) 1915. Girault, A. A., and Dodd, A. P.—The Cane Grubs of Australia. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 2.

Detailed technical descriptions and life-history notes on the various species found in land planted to sugar-cane.

(67) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vi, 727.

Suggests that the destruction of 11½ tons of grubs has lessened parasites in the district.

(68) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vi, 803.

Notes on the use of light trap; a few beetles attracted. mostly males. Also notes on *Metarrhizium* fungus.

(69) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vi, 891.

Further notes on light traps. Notes on *L. frenchi*; 475 beetles weigh a lb. Spraying food plants for cane-beetles.

(70) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 62.

Results of experiments with poisons for the destruction of cane-beetles. Arsenate of lead required 9-10 days to kill; checks lived 14 days. 276 beetles collected 27th January to 8th February were 196 females and 80 males, i.e. near end of aerial life.

(71) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 140.

Theoretical measures for the control of the cane-grubs.

(72) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 214.

Experiments with dichlorbenzole on grubs.

(73) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 301.

Notes on a predaceous Elaterid beetle larva, destructive to white grubs and their beetles.

(74) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 448.

Experiments with light traps, poisons, &c.

(75) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 525.

Summary of work at Gordonvale laboratory.

(76) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 591.

Theoretical control measures for beetles. Pupæ 12-15 inches deep in dry volcanic soil; 20 per cent. perished.

(77) 1915. Jarvis, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 656, illustrations 649.

Emergence of *Lepidiota caudata* abundant at Deeral; this species said to be destructive to sugar-cane.

(78) 1915. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 735.
Theoretical suggestions; topographical study of infestation suggested.

(79) 1916. A.S.P.A. Meeting.—Grub and Beetle Fund Contributions. Aust. Sugar Journ. vii, 892.
Recommendation to make contributions compulsory.

(80) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 797.
Experiments with oils, &c., for bait-traps to attract beetles, without result. Aerial movement of beetles influenced by topography, trees, soils. Effect of extreme heat on beetles on the feeding-trees; large numbers found dead on ground.

(81) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. vii, 902.
Investigation of Ovipositing; unsuccessful, only one set of 13 eggs found. Dissection showed that 24 eggs matured at one time. Sketch of light-trap for beetles is included with notes on number captured, which was very small.

(82) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 62.
Larvicides tested: (1) creolin, (2) cyanide of potassium, (3) borax, and (4) creosote all proved deadly to the grubs, but too expensive for general use. The solutions of saltpetre, barium chloride, and hellebore, on the other hand, were not effective.

(83) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 121.
A further study of larvicides.

(84) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 218.
Notes on occurrence of Muscardine fungus at Meringa.

(85) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 625.
Suggests light-traps again for beetles, also field trials of the use of poison baits.

(86) 1916. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 679.
Notes on effect of arsenic compounds on growth of sugar-cane. Notes on centipede destroying cane-grubs.

(87) 1916. JARVIS, E.—Notes on Insects Damaging Sugar Cane in Queensland. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 3.
Brief descriptions of various insects found in canefields Natural insect enemies of cane-beetles listed, with brief notes on repressive measures.

(88) 1916. JARVIS, E.—On the Value of Poison Bait for Controlling Cane Grubs. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 4.
Brief laboratory experiments with arsenic on plant tissue as a bait for cane-grubs.

(89) 1916. Review—Poison Baits for Controlling Cane Grubs, Jarvis. Aust. Sugar Journ. viii, 373.
A review of Bulletin No. 4 of the Qld. Bureau of Sugar Exp. Stations, Div. Ent.

(90) 1917. CHARMOY, D. D'E. DE.—Report on the Importation of Scoliid Wasps from Madagascar. Dept. Agric. Mauritius, Dec. 1917.
Calls attention to the importance of nectar-bearing plants for success with these wasps.

(91) 1917. DODD, A. P.—The Cane Grubs of Australia, part ii. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 6.

A continuation of the studies begun in Bull. No. 2, with notes on natural enemies, hyperparasites, &c.

(92) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 741; illustration 738.

Experiments on the relation of arsenicals to the growth of sugar-cane. Notes on egg-laying of greybacks.

(93) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 832.

Notes on ovipositing of greybacks.

(94) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. viii, 917.

Notes on light-trap for cane-beetles, also upon the emergence of *Lepidiota frenchi*.

(95) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. ix, 30.

Mentions collections of beetles as a control measure, with figures indicating results in Europe; also refers to destruction of feeding-trees.

(96) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. ix, 121.

Notes on dipterous parasites of cane-beetles; also refers to common parasites of the grubs.

(97) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. ix, 221.

Notes on the development of *Lepidiota frenchi*, suggesting control measures.

(98) 1917. JARVIS, E.—Combating Insect Pests. Aust. Sugar Journ. ix, 230.

Refers to experiments with Paris green in the field at Innisfail and Meringa, with inconclusive results.

(99) 1917. JARVIS, E.—Notes on the Habits and Metamorphosis of *Lepidiota frenchi* Black. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 5.

Very brief notes on habits, with descriptions of the stages.

(100) 1917. MUIR, F.—The Introduction of *Scolia manilæ* Ashm. into the Hawaiian Islands. Ann. Ent. Soc. Am. x, 207.

This parasite was introduced to combat *Anomala orientalis* Waterhouse, which was first recognised in the Hawaiian Islands during July 1912, supposedly from Japan. This paper not only describes the successful methods used in establishing this wasp, but other valuable notes on death factors of the beetle are given, i.e. other parasitic and predaceous insects, bacteria, fungi, &c.

(101) 1918. BALLOU, H. A.—Feeding Habits of the Parasites of Hardback Grubs. The Agric. News, Barbados, xvii, 250.

Advocates nectar-bearing plants for attraction of wasps which parasitise cane-grubs. The writer cites the successful work done with these wasps in Mauritius.

(102) 1918. CHARMOY, D. D'E. DE.—The Importation of *Tiphia parallela* from Barbados to Mauritius. Dept. Agric. Mauritius, Scientific Service, Bull. No. 6.

(103) 1918. ILLINGWORTH, J. F.—Monthly Notes on Grubs and other Cane Pests. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 7.

A series of twelve monthly reports, covering the investigations of pests of sugar-cane for the season 1917-18.

(104) 1919. Davis, J. J.—Contribution to a Knowledge of the Natural Enemies of Phyllophaga. State of Illinois Natural History Survey Bull. Urbana, xiii, article v.

Life-histories are given of the various parasitic and predaceous insects attacking the Melolonthid beetles of the genus *Phyllophaga*. Particulars are also given of other diseases caused in white grubs by Nematodes, Protozoa, bacteria, and fungi, with a list of the birds, mammals, and amphibia that prey upon them.

(105) 1919. Illingworth, J. F.—Monthly Notes on Grubs and other Cane Pests, 2nd series. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 8.

A series of twelve monthly reports covering the investigations of the pests of sugar-cane for the season 1918-19.

(106) 1919. Muir, F.—The Progress of *Scolia manila* Ashm. in Hawaii. Ann. Ent. Soc. Am. xii, 171.

Records the successful reduction of *Anomala orientalis* by means of the above parasite.

(107) 1920. Davis, J. J.—The Green Japanese Beetle. Dept. Agric. New Jersey, Circ. No. 30.

Describes procedure for the control of this pest, which was first recognised during 1916, evidently brought from Japan in soil with plants. Beside clean culture and thorough cultivation, cyanide was used extensively to kill the grubs while near the surface of the soil.

(108) 1920. Illingworth, J. F.—Monthly Notes on Grubs and other Cane Pests, 3rd series. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 10.

A series of twelve monthly reports covering the investigations of the pests of sugar-cane for the season 1919-20.

(109) 1921. Illingworth, J. F.—A Study of Natural Methods of Control for White Grubs. Qld. Bur. Sugar Exp. Sta., Div. Ent. Bull. No. 12.

Results of experiments with the green Muscardine fungus and bacterial diseases for grub control.

(110) 1921. Waite, E. R.—Letter, 4th March 1921.

Occurrence of *Lepidiota squamulata* Wath. and *Anoplognathus concolor* Burm.



By Authority: Anthony James Cumming, Government Printer, Brisbane.

PLATE II.—GRUB INJURY TO THE ROOTSTOCKS OF SUGAR-CANE.

Showing typical results following a serious infestation. In extreme cases these underground portions of the plant are entirely devoured by the grubs by the time they have finished their development.

Plate III.—Typical Injury to the Leaves of Sugar-cane by the Adult Beetles.

Fig. 1. Showing the result of one feed of *Lepidoderma albohirtum* Waterhouse, immediately following emergence from the soil and before leaving for the feeding-trees, where it remains for about a fortnight, during which time the eggs are developed.

Fig. 2. The work of *Lepidiota frenchi* Blackburn, which, fortunately, is a smaller eater, for this species may remain right in the cane during the whole of its aerial life.

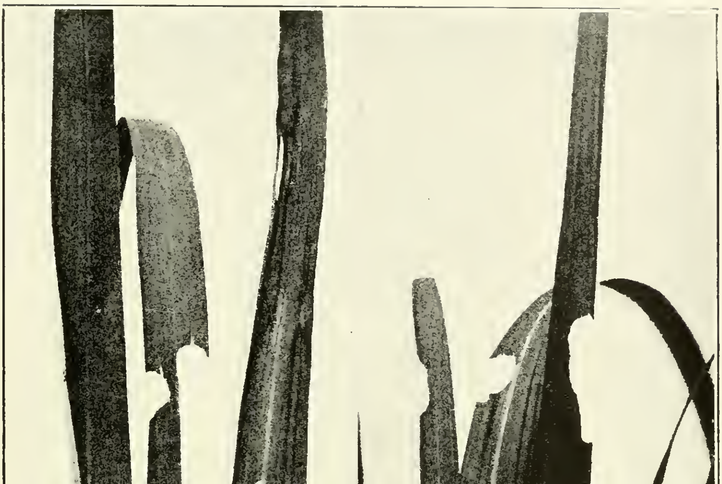


Plate IV.—Reproductive Organs of Female Lepidoderma albohirtum Waterhouse. × 5. Taken from Beetle Three Days after Emerging.

*Bc.* Bursa copulatrix.

*Cg.* Cement gland.

*Et.* Egg tubes.

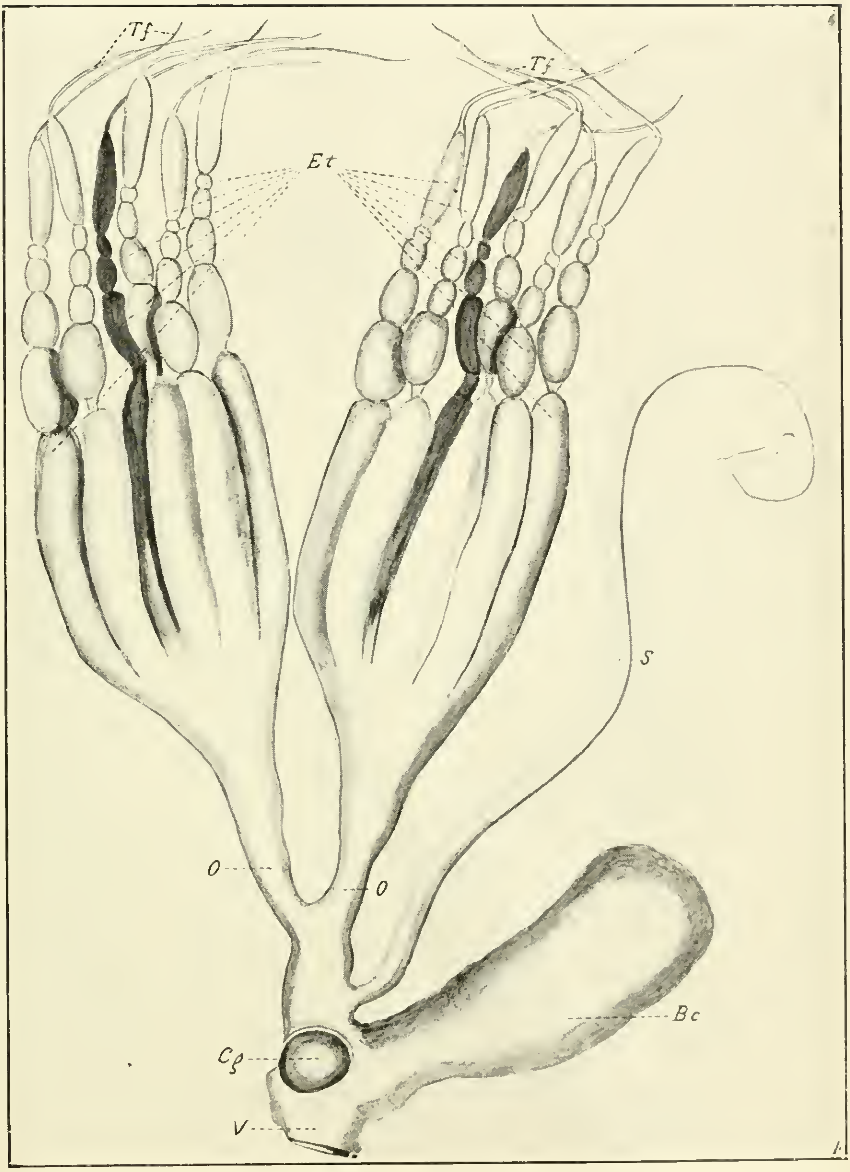
*G.* Germaria.

*O.* Oviduct.

*S.* Spermatheca.

*Tf.* Terminal filaments.

*V.* Vagina.



Tf
Tf
Et
S
O
O
Bc
Cg
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Plate V.—Stages in Development of Lepidoderma Albohirtum Waterhouse. × 5.

1. Egg tube from beetle before emerging.
2. Egg tubes from beetle shortly after emerging.
3. Egg tubes from beetle a fortnight after emerging, when ready to oviposit.
4. Newly laid egg.
5. Egg taken from soil one week after laying.
6. Egg taken from soil two weeks after laying; ready to hatch.
7. Newly hatched grub.

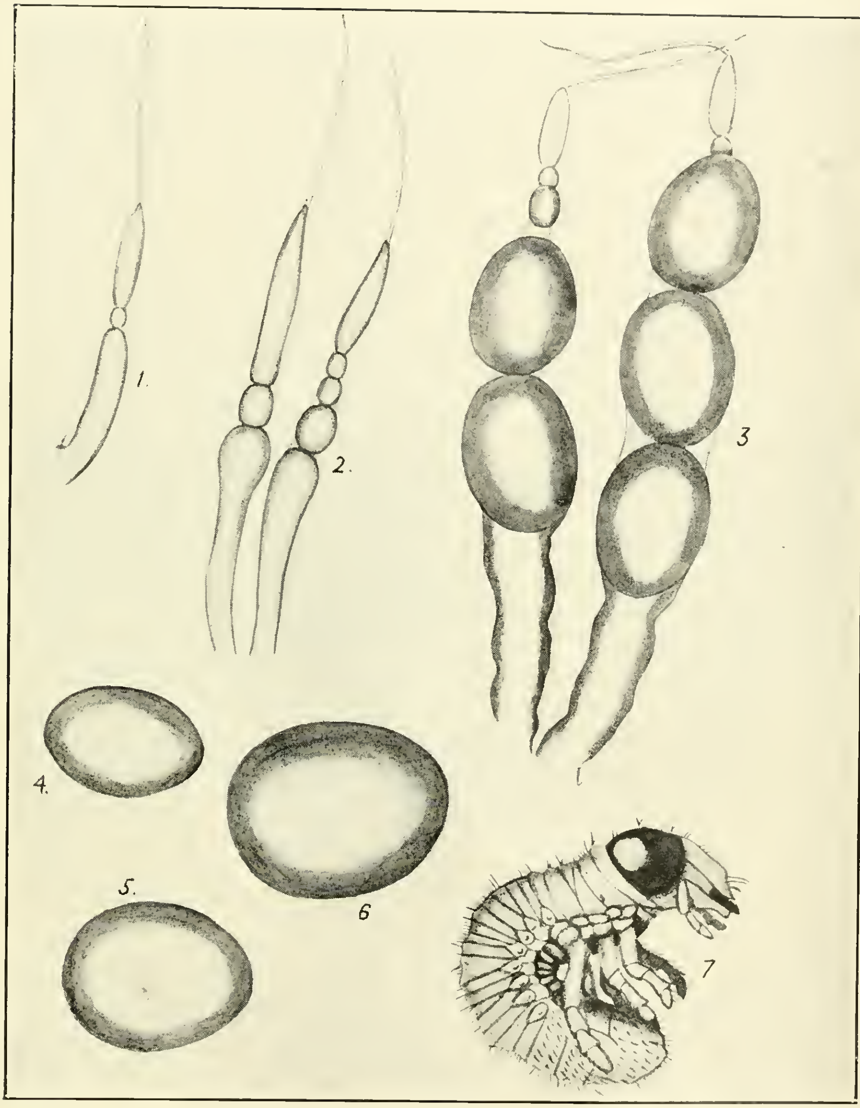
1.
2.
3
4.
5.
6
7

Plate VI.—Egg Tubes from *Lepidoderma albohirtum* Waterhouse, near the end of their Aerial Period, after they had laid several sets of Eggs. × 6.

1. Part of an ovary from a beetle which had just laid a full set of 28 eggs, 4th January, 1921, showing the shrivelled condition of the egg tubes, and a ripe egg which was left in one of the oviducts.

2. Two egg tubes taken from a beetle 4th January, 1921, a few days after she had laid. Note that in one tube the eggs were starting to form again, while the other tube was somewhat deformed.

3. An egg tube taken from a beetle collected on the feeding-trees 8th February, 1921—evidently a few days after she had laid.

4. An egg tube taken from a beetle collected on a cane-leaf 8th February, 1921—evidently shortly after she had laid, when she was ready to return to the feeding-trees again.

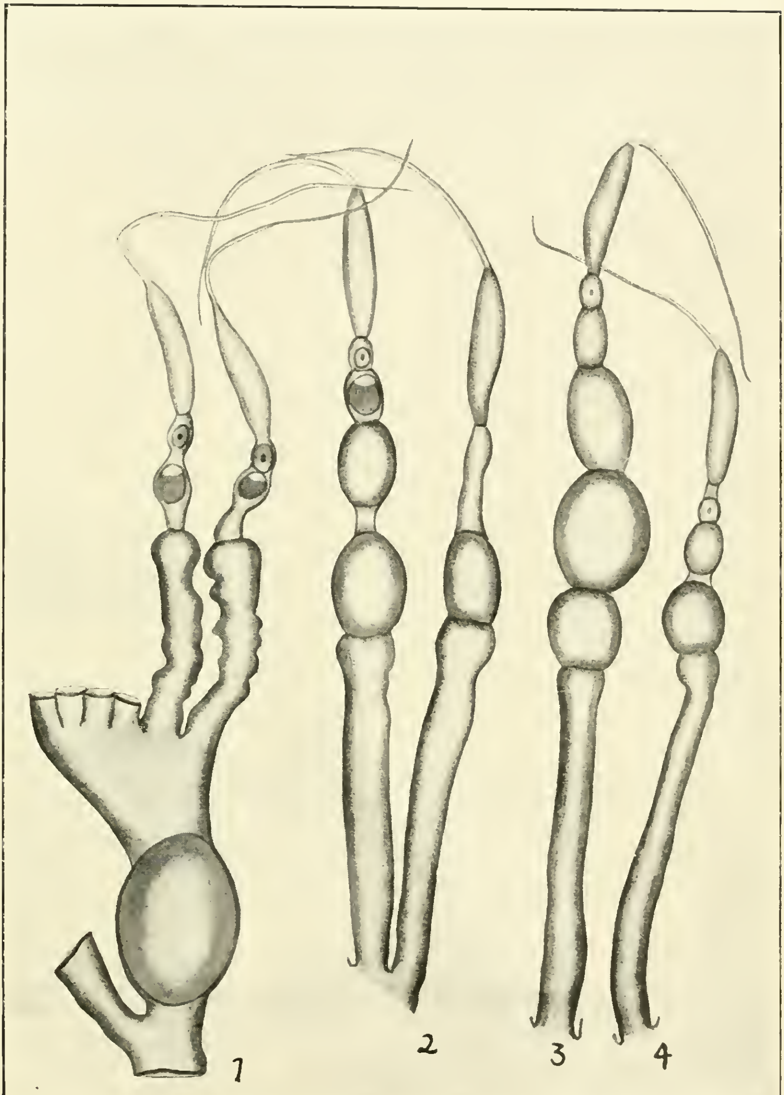
1
2
3
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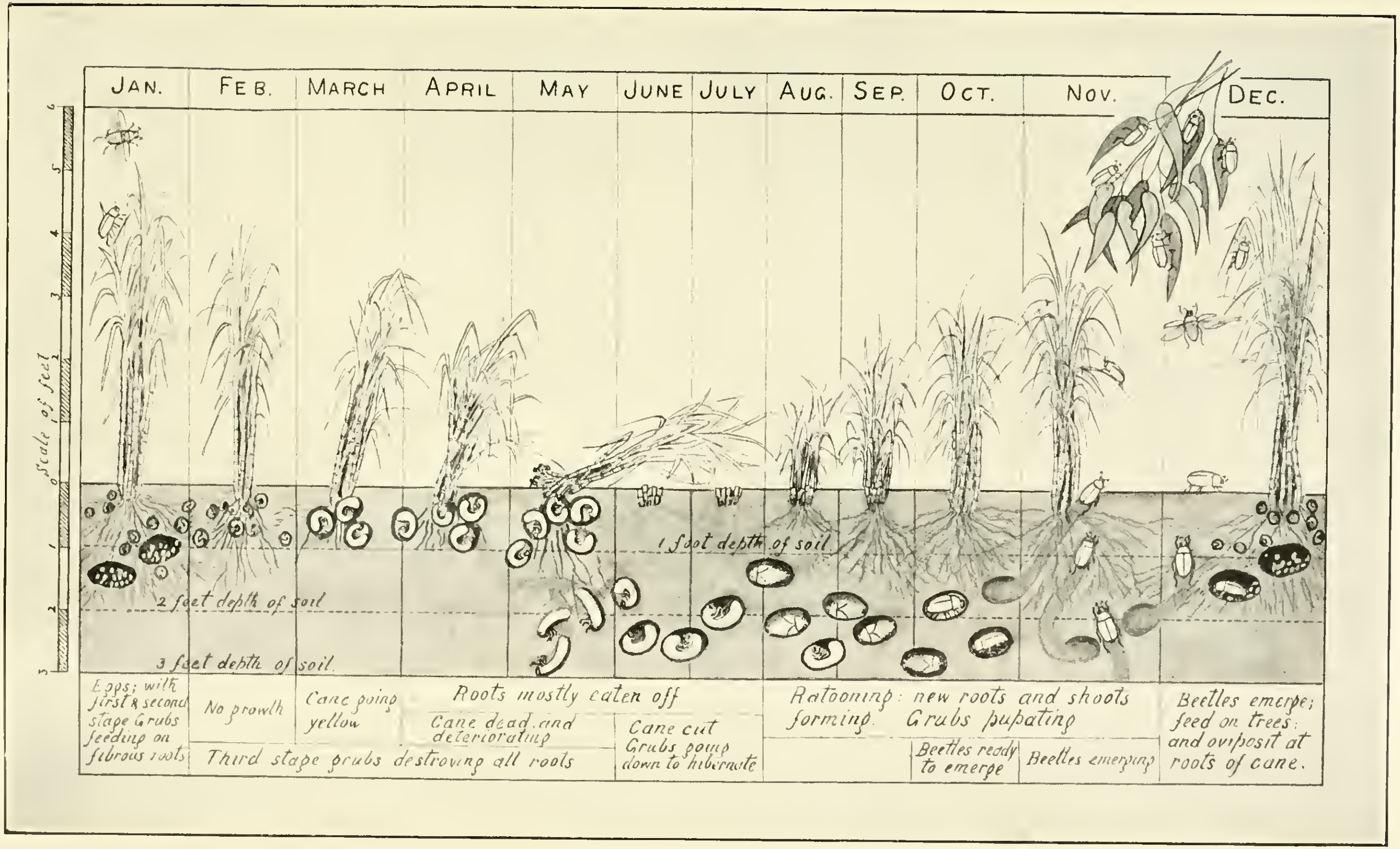
Plate VII.—Graphic Illustration of the Life-cycle of the Greyback Beetle, *Lepidoderma albohirtum* Waterhouse, showing the results of its activities upon the growth of Sugar-cane.



JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEP.
OCT.
NOV.
DEC.
Scale of feet
0
1
2
3
4
5
6
1 foot depth of soil
2 feet depth of soil
3 feet depth of soil
Eggs; with first & second stage Grubs feeding on fibrous roots
No growth
Cane going yellow
Roots mostly eaten off
Cane dead and deteriorating
Third stage grubs destroying all roots
Cane cut
Grubs going down to hibernate
Ratooning: new roots and shoots forming. Grubs pupating
Beetles ready to emerge
Beetles emerging
Beetles emerge; feed on trees: and oviposit at roots of cane.

Plate VIII.—Lepidoderma albohirtum Waterhouse.

Diagram showing the relative abundance of the stages for each period of the year.

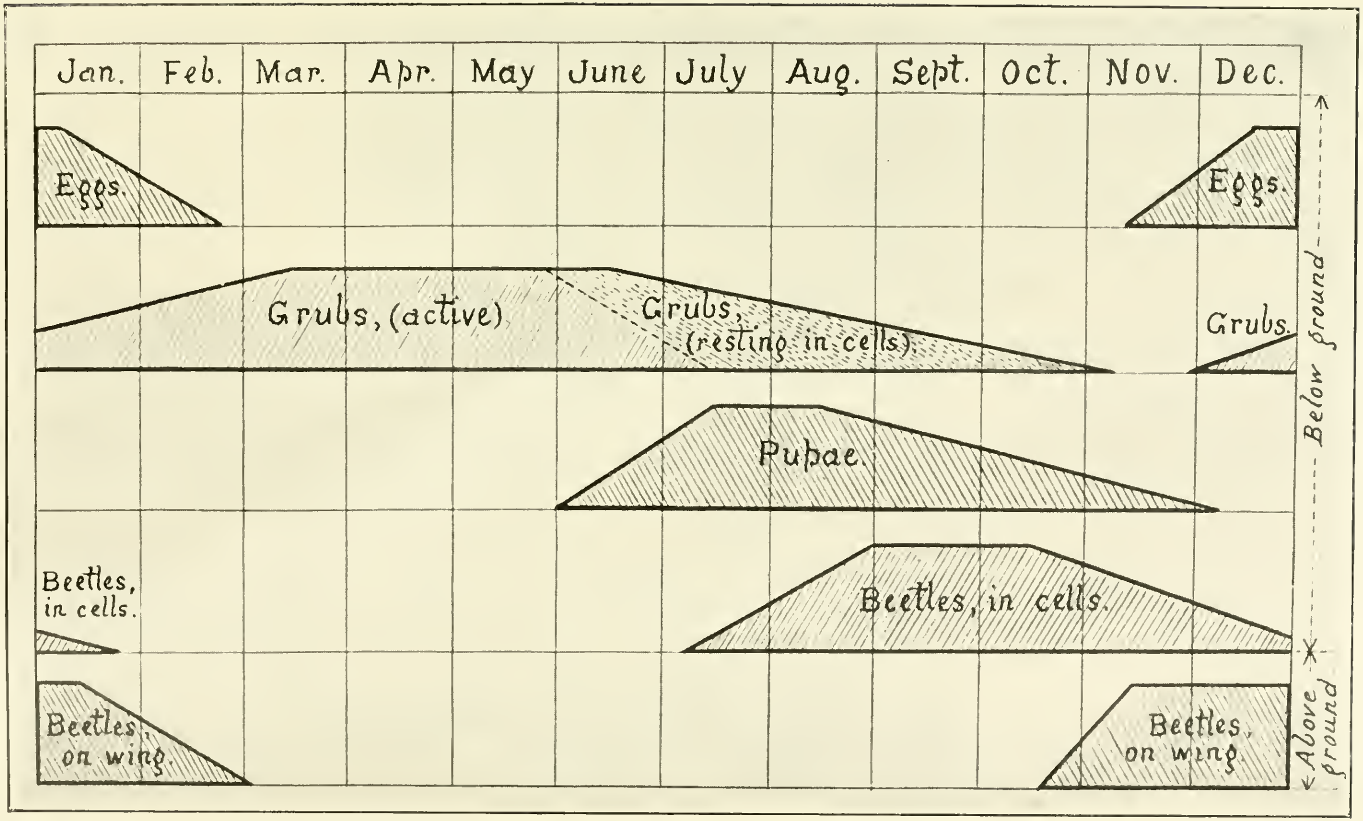

Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Eggs.
Eggs.
Grubs, (active)
Grubs, (resting in cells).
Grubs.
Pupae.
Beetles, in cells.
Beetles, in cells.
Beetles, on wing.
Beetles, on wing.
Below ground
Above ground

Plate IX.—Cane Beetles and their Allies; all Natural Size and Colour.

Fig. 1. *Lepidiota frenchi* Blackb.

Fig. 2. *Lepidiota consobrina* Girault.

Fig. 3. *Lepidiota grata* Blackb.

Fig. 4. *Lepidiota rothei* Blackb.

Fig. 5. *Lepidiota froggatti* Macl.

Fig. 6. *Lepidiota* No. 215.

Fig. 7. *Lepidiota caudata* Blackb.

Fig. 8. *Xylotrupes australicus* Thoms., female.

Fig. 9. *Xylotrupes australicus* Thoms., male.

Plate IX

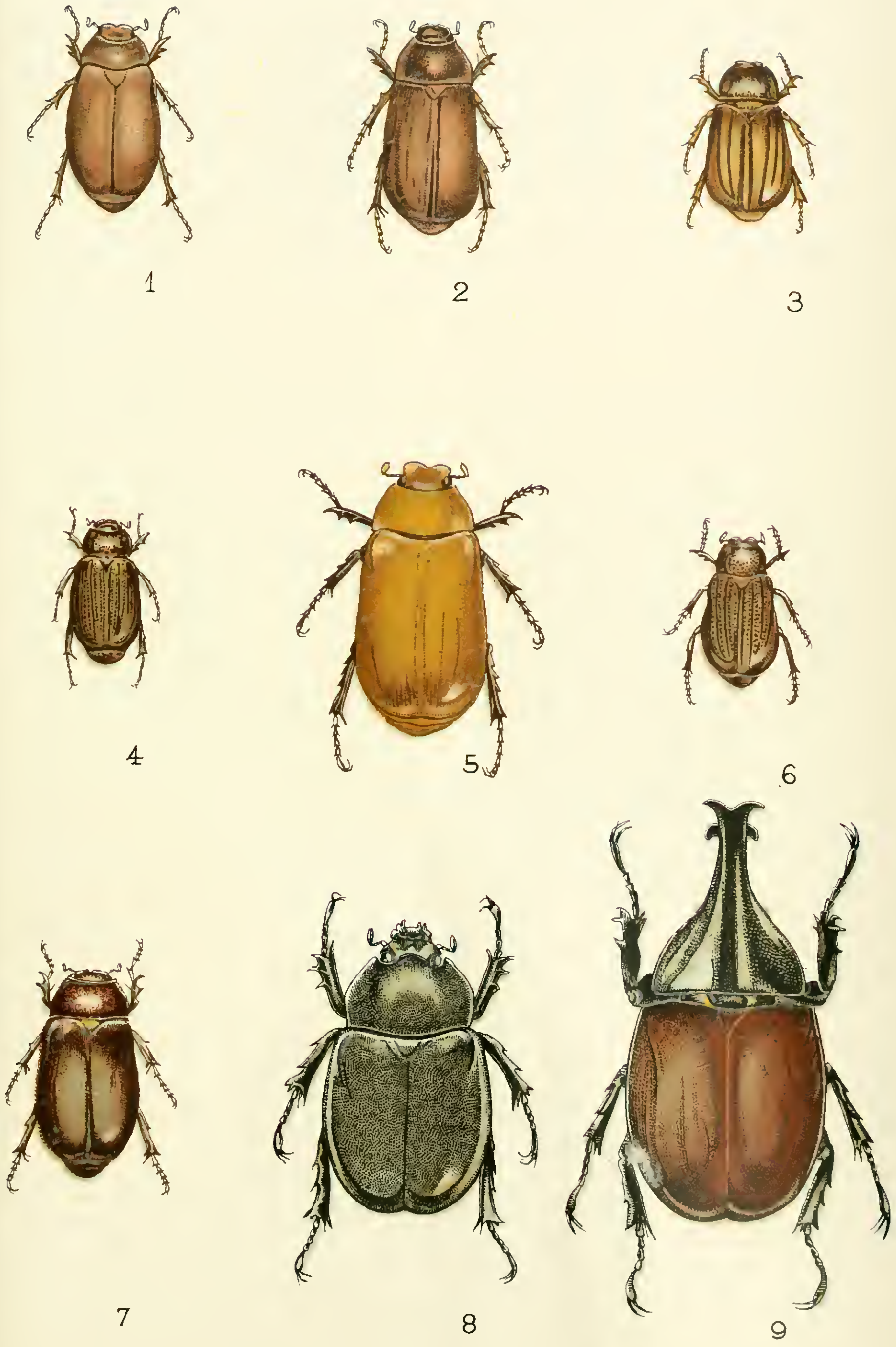



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Plate X.—Cane Beetles and their Allies; Natural Colours; Enlarged where Indicated.

Fig. 1. *Isodon puncticollis* Macl. $\times$ 2.

Fig. 1a. *Isodon puncticollis* Macl. Natural outline.

Fig. 2. *Cacachroa decorticata* Macl. Natural size.

Fig. 3. *Cacachroa decorticata* Macl. Dark var. Natural size.

Fig. 4. *Epholcis bilobiceps* Fairm. $\times$ 3.

Fig. 4a. *Epholcis bilobiceps* Fairm. Natural outline.

Fig. 5. *Engyops flavus* Lea. $\times$ 3.

Fig. 5a. *Engyops flavus* Lea. Natural outline.

Fig. 6. *Dasygnathus australis dejeani* Macl. Natural size.

Fig. 7. *Haplonycha dilatata* Lea. $\times$ 2.

Fig. 7a. *Haplonycha dilatata* Lea. Natural outline.

Fig. 8. *Neso flavipennis* Macl. $\times$ 3.

Fig. 8a. *Neso flavipennis* Macl. Natural outline.

Plate X

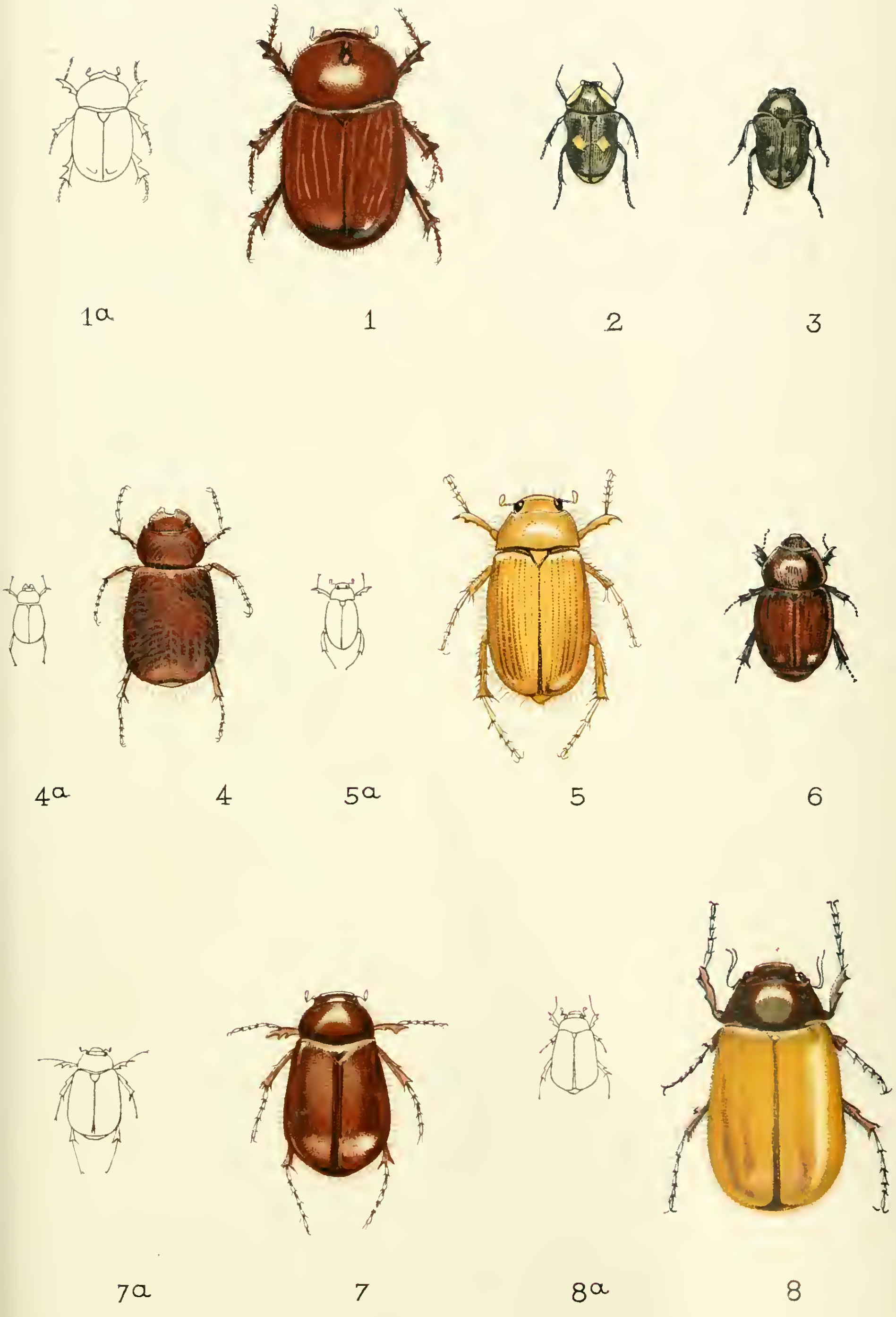


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PLATE XI.—CANE BEETLES AND THEIR ALLIES; ALL NATURAL SIZE AND COLOUR.

Fig. 1. *Anomala australasiæ* Blackb.

Fig. 2. *Repsimus æneus* Fabr.

Fig. 3. *Anoplognathus frenchi.*

Fig. 4. *Anoplognathus punctulatus* Oll.

Fig. 5. *Anoplognathus boisduvali* Boisd.

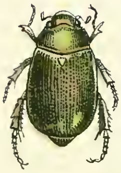
Fig. 6. *Anoplognathus smaragdinus* Ohaus.

Fig. 7. *Anoplostethus lætus* R. & J. (green variety).

Fig. 8. *Anoplostethus lætus* R. & J. (red variety).

Fig. 9. *Anoplostethus lætus* R. & J. (purple variety).

# Plate XI



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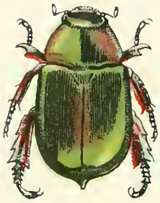

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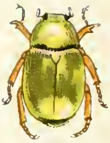

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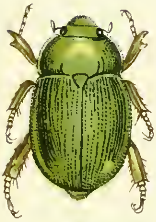

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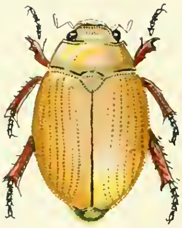

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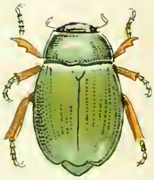

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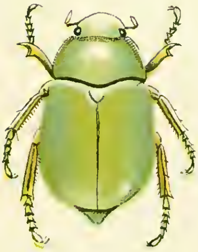

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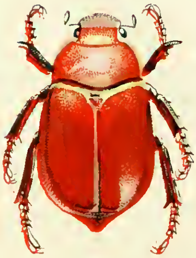

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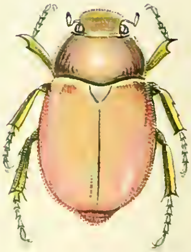

9

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Plate XII.

Showing the value of arsenic for the control of cane-grubs. The five rows standing erect in the centre of the picture were treated with white arsenic at the rate of 200 lb. per acre. The fallen cane at the right and left was untreated, and the roots were entirely eaten away.

Plate XIII.—Egg Tubes from *Lepidiota frenchi* Blackburn. × 8.

Fig. 1. A typical egg tube taken from a beetle, 5th December, about a week after the first emergence of this species had been noted.

Fig. 2. An egg tube from a beetle taken *in cop.*, 30th November, two days after the first emergence was seen. The first egg, it will be noted, has moved along the tube, ready to lay.

Fig. 3. Egg tubes from a beetle taken *in cop.*, 5th December; evidently she had just laid.

Fig. 4. An egg tube from a beetle taken *in cop.*, 13th December, about a fortnight after the first emergence had been noted; evidently a new set is under way.

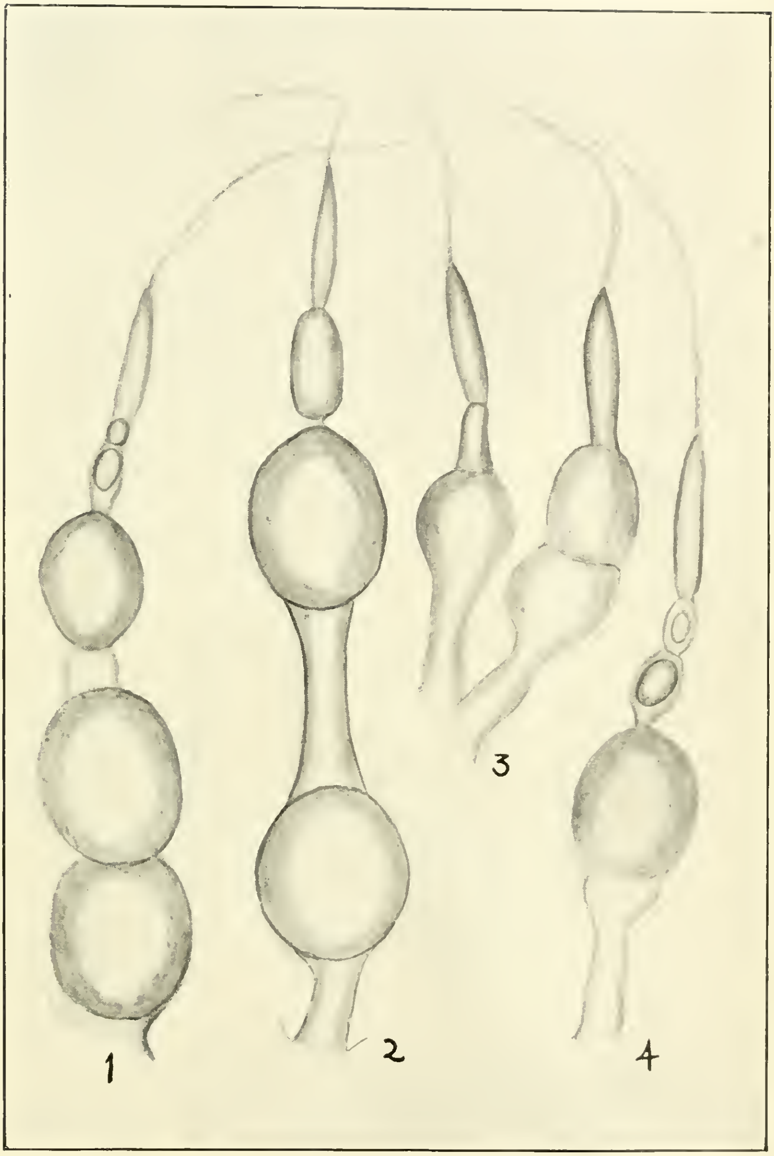
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Plate XIV.—Nodules formed by Lepidiota frenchi when Ovipositing.

Upper figure shows general distribution of eggs in soil, taken soon after laying.

Lower figure shows same eggs, about a week later; arrows indicate opening in nodule through which the egg was inserted.

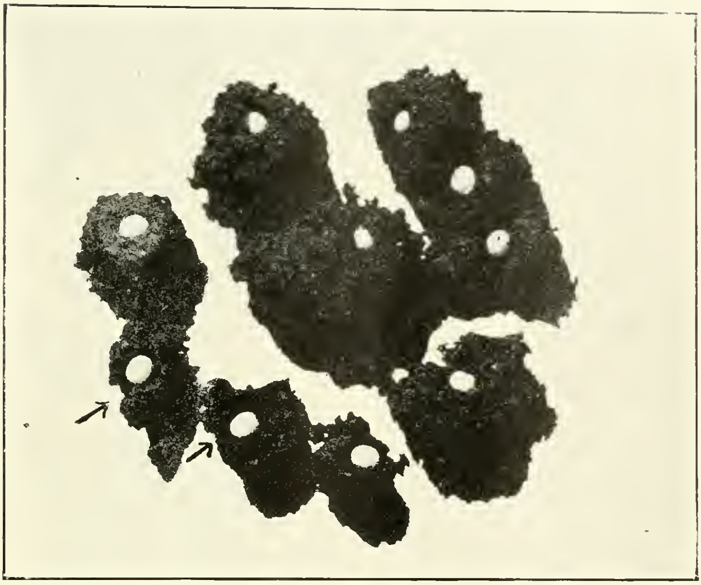


Plate XV.—Graphic illustration of the Life-cycle of *Lepidiota frenchi* Blackburn, showing the results of its activities upon the growth of Sugar-cane.

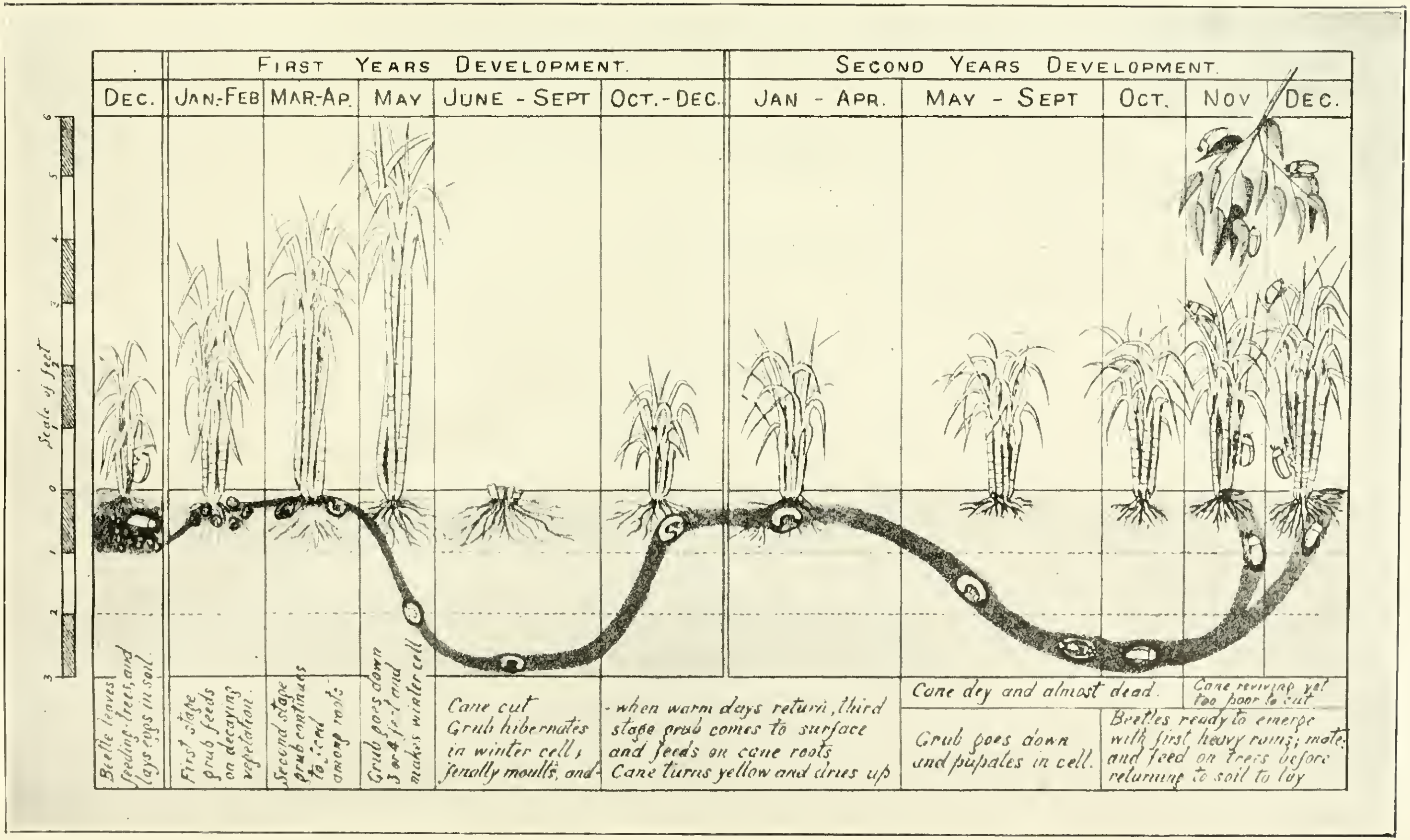

First Years Development.
Second Years Development.
Dec.
Jan.-Feb
Mar.-Ap.
May
June - Sept
Oct.-Dec.
Jan - Apr.
May - Sept
Oct.
Nov
Dec.
Scale of feet
0
1
2
3
4
5
6
Beetle leaves feeding-trees, and lays eggs in soil.
First stage grub feeds on decaying vegetation.
Second stage grub continues to feed among roots.
Grub goes down 3 or 4 feet and makes winter cell
Cane cut
Grub hibernates in winter cell, finally moults, and
- when warm days return, third stage grub comes to surface and feeds on cane roots
Cane turns yellow and dries up
Cane dry and almost dead.
Grub goes down and pupates in cell.
Cane reviving yet too poor to cut
Beetles ready to emerge with first heavy rains; mate and feed on trees before returning to soil to lay

Plate XVI.—A Comparison of the Male Genitalia of Cane Beetles. × 4.

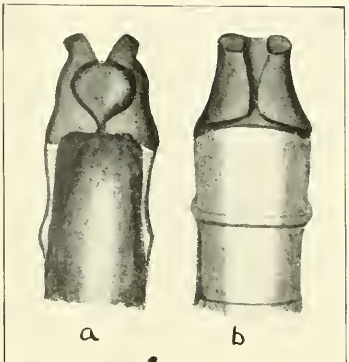
Fig. 1. *Lepidoderma albohirtum; a* ventral, *b* dorsal view.

Fig. 2. *Lepidiota rothei; a* ventral, *b* dorsal view, bursa extended.

Fig. 3. *Lepidiota* No. 215; *a* ventral, *b* dorsal view.

Fig. 4. *Lepiodiota frenchi; a* ventral, *aa* the same with bursa extended, *c* lateral view.

Fig. 5. *Lepidiota consobrina; a* ventral, *b* dorsal view.

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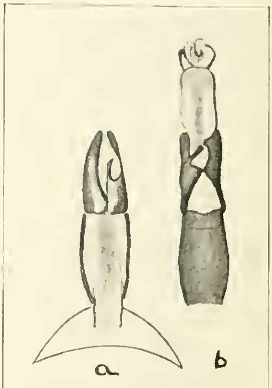


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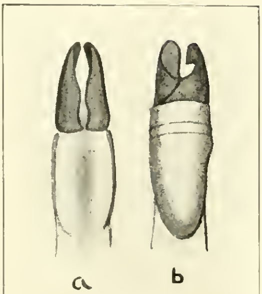


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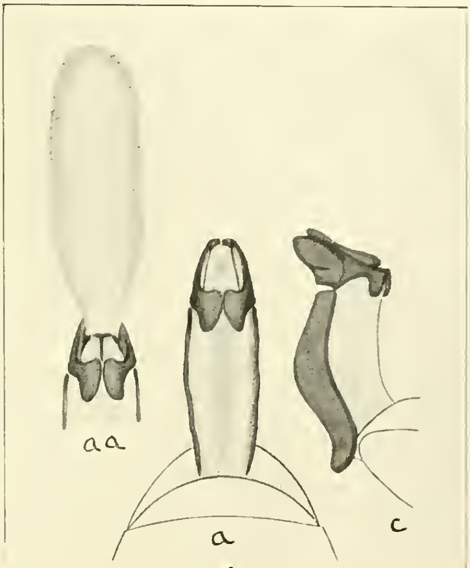


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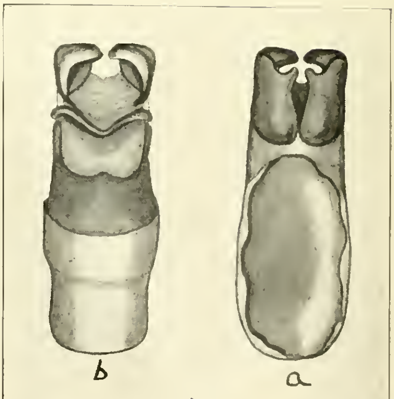


5

Plate XVII.

Showing the vast extent of the fields of sugar-cane ruined by the grubs on the Greenhills Estate. The picture, however, gives only a partial idea of the injury; the leaves being dry and brown suggested severe drought, yet the soil had been saturated for weeks.