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Monthly Notes on Grubs and other Cane Pests.

(FOURTH SERIES.)

BY

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The Under Secretary,
Department of Agriculture, Brisbane.

SIR,—I have the honour to submit for publication, as Bulletin No. 15 of the Division of Entomology, a fourth series of Monthly Notes on the Grub and other Cane Pests, by Dr. J. F. Illingworth.

I have, &c.,

H. T. EASTERBY, General Superintendent.

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

Monthly Notes on Grubs and other Cane Pests.

By J. F. ILLINGWORTH.

CANE GRUB INVESTIGATION, JULY 1920.

As is usual for this season of the year, the weather has at last turned off dry; thus favouring the harvest of damaged cane, which has been progressing for the past month. The continued rains, well into June, resulted in exceedingly low density in certain areas for the first cut, but the c.c.s. is rapidly rising with the cooler weather.

On the other hand, climatic conditions have been most favourable for the development of natural enemies of the cane-grub; myriads of the grubs have succumbed to contagious diseases, parasites, and the numerous predators.

NOTES ON CANE GRUBS.

The long drought early in the year has resulted in a peculiar situation for the cane-grubs; some are still in evidence (15th July), fully three months past their usual time of going deep into the soil to pupate. Moreover, this delay has proved fatal to the large majority of them in the older infested districts. The rains, continuing for some time after the cool nights set in, brought about conditions ideal for the development of disease organisms, and in some fields these have multiplied with remarkable rapidity.

NATURAL ENEMIES ACTIVE.

Among these I may mention ibises, bandicoots, parasitic and predaceous insects, and contagious diseases. In certain fields at Greenhills there is a most remarkable decrease in the number of live grubs in the soil. At first I concluded that they had gone down to hibernate, but digging failed to disclose any of them deeper than 12 inches; natural enemies had evidently destroyed them.

Excavating recently in one of the worst-infested fields where earlier in the year there was an average of a hundred or more grubs per stool (in one case I found 134), I was unable to get an average of more than 4 alive. A typical stool, 9th July, gave—2 to 6 inches deep, 2 alive and 1 just destroyed by fungus; 6 to 12 inches deep, 1 alive and 1 sick with black spots on skin indicating a bacterial disease, 1 dead by fungus, and another dead, with black patches and very soft, due to bacterial disease. None were found deeper, though we dug down 3 feet. The soil was rather dry and crumbly, so that the dead grubs were easily broken up and difficult to discover—only the chitinous head-shield remaining for a time after decomposition of the soft body sets in.

Furthermore, experiment has demonstrated that diseased grubs usually come to the surface, where they are easily removed by predators —ants, ground beetles, mammals, and birds. In this same field I watched a flock of fully 500 ibises assiduously probing about the grubby stools;

and in almost every case the soil had been dug up at the roots by the omnivorous bandicoot in his search for the fat grubs. With all these grub-destroyers at work it is not hard to understand the rapid disappearance of the pest.

Muscardine Fungus.—I have found grubs every year at Greenhills, destroyed by this disease. Heretofore, however, the mortality has not been remarkable, for the grubs normally go down to hibernate in March, before the cool weather sets in. It is noted, from our experiments, that an epidemic can apparently occur only when there is lowered temperature and abundant moisture; hence the recent heavy death-rate is just what we might expect from the combination of these favourable circumstances.

I first noticed this remarkable mortality among the grubs about the middle of June, shortly after the rainy season terminated. In one stool, of the 32 grubs uncovered 12 had been destroyed by the fungus. The growth was a mass of greenish-white mycelium, extending into the soil for about 2 inches or more, from the stiffened body of the grub. In some cases the mycelium had attached itself to the underground portions of the cane, wherever the diseased grub had been in contact; in fact, we often discovered the disintegrated grubs by seeing the grey-green spores or mycelium on some portion of the root system. By the 1st July the percentage of dead grubs had more than doubled. The first stool that I dug gave 26 grubs, but 18 of them had been destroyed by the fungus. The ibises were in hundreds in this field, gathering up the larvæ within reach of their long bill. 13th July, we dug out many stools in the infested area, noting the per cent. dead in each; and though the weather was dry and the soil powdery, the deceased grubs were still everywhere in evidence. In a number of cases all the grubs that we found had succumbed (100 per cent.).

Following on this important evidence, we made a careful survey of all the infested area at Greenhills, to learn if this valuable disease was distributed throughout the plantation. This was done by digging out numerous stools in each of the infested fields, the result being indicated on the plan of the estate by an *x* for disease and an *o* for none. By this method I developed an interesting discovery: The fungus appears to be well distributed in all of the areas which are regularly attacked, but we have not been able to find it outside of this well-defined region, especially where the pest, in its erratic flight this year, caused the devastation of fields that are usually immune. Hence we must conclude that next year's infestation will come largely from the beetles that emerge in these newer devastated areas, i.e. where the fungus has not had time to become established. Apparently the spores, once introduced, continue in the soil from year to year, ready to bring about an epidemic when conditions are favourable. As indicated above, we have learned from experiment that a contagion can be brought about by excessive moisture when the weather is cool. I have demonstrated this with grubs in pots of the spore-laden soil. Hence it would appear that all that we require is water for irrigation under such conditions. The soil became dry too soon, which resulted in a cessation of the epidemic just before the finish of the last grubs. Undoubtedly, one more good rain about the beginning of July would have completed the work.

Bacterial Disease.—During the survey of the Muscardine fungus I discovered many grubs which had died of some bacterial disease. The diseased grubs had the same habit, as noted above, of coming to the

surface of the soil before succumbing. By digging, specimens were found presenting all stages of the disease, which usually appears at one of the spiracles or in the membrane between the segments of one or more legs; in the latter case, the affected appendage soon drops off and the disease rapidly progresses upward into the body. The affected parts have a peculiar shiny black appearance, which coincides with that described by Zae Northrup, who gave the name *Micrococcus nigrofaciens* to the organism causing the disease. This friendly organism was found to be well distributed in the United States.* Finally, at death, the body becomes very soft and black all over, totally different in appearance from specimens which have died from the fungus—the latter being hard and cheesy. Naturally, such macerated specimens quickly decompose in the soil, and it is almost impossible to find them after a few days. This accounts for the way that grubs disappear as if by magic in some instances, when climatic conditions are just right. The remarkable disappearance of the grubs at Fairymead in 1909 is a case in point. I have discussed this matter with Mr. Howe, manager of the Mulgrave Central Mill, who was located at the Lynwood estate at that time, and who made a careful study of the mortality of the grubs.† From all that I can learn, the mites which appeared in such numbers on the sick grubs were only an after-effect, the real cause of death being apparently due to a bacterial disease similar to the above. Mr. Howe also informed me that that district had been free from grubs for years, but that they had begun to give trouble again this past season.

I am multiplying both this disease and the Muscardine fungus, hoping to be able to widen the area of usefulness. Already several hundreds of the diseased grubs have been planted in widely separated fields where they are not known to occur. It may be possible in this way to establish them in any region where they are not normally active.

Parasitic Wasps.—Two species, *Campsomeris tasmaniensis* Sauss. and *C. radula* Fab., have been particularly abundant. The males are always seen, on sunny mornings, flying about in swarms close to the surface of the soil in the grubby areas. The females, too, though normally below ground, may be easily observed, for they emerge early in the day to feed at flowers, such as those of the pink burr, &c.

By digging numerous pits, about 3 feet deep, in infested fields at Meringa, I found that these friends were doing excellent service. The soil was red volcanic, very loamy and rather dry, hence the wasps had gone remarkable depths after their prey. In most instances the parasitized grubs were down 18 inches—the deepest 24 inches. Of the grubs unearthed 25 to 60 per cent. had been destroyed by these wasps. This is the highest record I have ever seen, and is undoubtedly due to the lateness of the grubs in hibernating.

The Beetle Borer.—Cutting operations being now in full swing, this pest does not appear to be as abundant as usual in the region about Cordonvale. I have not had reports from other districts, but I trust they have fared as well. The practice of burning the trash from practically all cane before cutting last year evidently accounts for this diminution of the pest. Undoubtedly it is a wise procedure wherever the borer beetle is doing considerable damage.

* Mich. Tech. Bulletin, No. 18.

† Aust. Sugar Journal, vol. 1, p. 65.

Colonies of the parasites *Ceromasia sphenophori* Vil. are being liberated, from time to time, from the large breeding-cage at the station; and I expect to get a fresh supply of the flies from Mossman, now that harvesting has begun there. Growers in other infested areas certainly owe a debt of gratitude to the Mossman Mill Company, and especially to Crees Brothers, for their kindly assistance in supplying these friendly insects; they have shown a spirit of co-operation it behoves us all to emulate.

CANE GRUB INVESTIGATION, AUGUST 1920.

We have been experiencing weather remarkably warm for this season of the year. Then, too, the heavy rains at the end of July, which reached to a depth of 2 feet in the loose soils at Greenhills, created a condition most favourable for the destruction of the few remaining grubs in the diseased areas. The results have been most encouraging, for it is now difficult to find healthy living grubs in what may be termed the old-infested area, i.e. that part of the estate bordering the forest of feeding-trees.

Furthermore, I am pleased to report the establishment of the Tachinid (*Ceromasia sphenophori* Vil.) parasites of the borer beetle in the Babinda area. They are being liberated in other districts.

Notes on Lepidiota Albohirta (Greybacks).

As indicated in previous reports, these grubs were very late in their activities this year, hence at the end of July I was not surprised to find many of them still feeding in the areas where no disease existed. Normally, at that time of the year they are all down deep in the soil pupating, or in some cases even changed to the adult beetle, waiting for the heavy rains to penetrate and soften the soil so that they can escape from their prison.

Disease.—I have followed up the rapid mortality in the old area at Greenhills, and have carried out numerous laboratory experiments with the two diseases to determine their virulence. Undoubtedly, cool weather is an important factor when combined with moisture. It was very noticeable that the death-rate was rapid when the nights were chilly, and fell off almost altogether with the advent of warmer weather.

In one experiment, I placed 36 healthy greyback grubs in a large pot of disease-infested soil from Greenhills. The weather was cool and the mortality rapid. The first week 21 had succumbed, 15 from the bacterial disease and 6 from the fungus. The second week was somewhat warmer, and 10 died—4 from bacteria and 6 from fungus. The third week finished the lot, 1 dying of bacteria and 4 of fungus. Hence, in the 21 days, 55 per cent. died of bacteria and 45 per cent. of fungus; total 100 per cent.

In other experiments, started later when the weather had warmed up considerably, the results were far less satisfactory. Apparently a difference of only a few degrees in the temperature makes considerable difference in the virulence of these diseases. On 2nd August I placed 19 healthy grubs in separate pots of the contaminated soil from Greenhills, watered them well, and set them on a table in a warm, sheltered position in the sun. After a week none were dead; the second week only two died of the fungus. I then removed the pots to a place under the laboratory, 10 degrees cooler, with the result that mortality rapidly increased; most of the deaths being due to the fungus.

Investigation has been carried on in other localities, in the hope that we might find these diseases widely distributed. Unfortunately, I have not been able to find them anywhere else in the Mulgrave area, though the Muscardine fungus is plentiful further up the line towards Babinda.

While at Mossman recently, we made a thorough search for dead grubs in the limited areas where the pest appeared this year, but we had no definite results. Only two blackened remains were unearthed, but they were both decomposed and powdery, so it was impossible to say whether the bacterial disease had destroyed them or not.

The sudden disappearance of the pest at Mossman, a few years ago, suggests that the grubs might have been wiped out by an epidemic of these diseases. I was hopeful that we might find some diseased grubs as conclusive evidence, but in all of our digging the grubs appeared to be perfectly healthy, except as noted above.

I am inoculating quantities of soil with the diseased grubs, and distributing this to areas where it is not found at present. This will probably prove the most practical method of distributing the contagion. It will be recalled that our effort at breeding the Muscardine fungus on starchy material gave no apparent results when applied to the grubs in the soil.

Each dead grub produces literally millions of greyish-green spores, which soon become dry and dusty, so that they will inoculate bushels of soil if thoroughly mixed. It will be best to scatter this soil in furrows, as widely as possible, in infested fields. I must call attention, however, to the fact that may not be evident at once, that the disease works under exceptional climatic conditions only, such as we have experienced this year; yet the important object is to have the fields inoculated for such occasions when they do occur, for apparently the spores are able to maintain themselves for extended periods where introduced. I draw these conclusions because I have found evidence of the fungus every year in the same field at Greenhills, though there has been no epidemic until this season.

Tachinid Parasites of the Borer Beetle.

While in Babinda on 8th August I learned from Mr. P. C. H. Rutherford that he had just sent in to the mill the last of his cane from the block where I had liberated these parasites on 16th June last year. I went to the millyard at once and located the trucks by looking up the numbers at the weighbridge. I was surprised to find very few borer signs in the ends of the sticks, for the crop was fully 50 tons per acre and very soft—a condition ideal for these beetles; last season it was simply riddled by them. It will not be difficult to imagine my feelings when I found the puparia of the parasite in the first cocoon that I located with my penknife. Further search disclosed them in practically every infested stick that I opened; I found the maggots in the borer grubs, puparia in the cocoons, and even saw newly emerged flies resting on the sticks of cane. This is especially interesting since they must have developed in millions from the twenty flies liberated a year ago.

It is hard to estimate the value of the assistance rendered by these parasites. Careful figures in Hawaii showed that they brought down the infestation from 30 to 12·77 per cent. shortly after their introduction. On another plantation it was estimated that there was an increase in the sugar content amounting to ·98 ton per acre, which would mean 75,000

to 90,000 dollars for a plantation of 1,000 acres. Moreover, the following year, when the flies became better established, this figure was augmented by a further increase of 1·25 tons per acre, which would mean more than double the above annual saving.*

In the region where the flies are established at Moolaba, they will have every opportunity to spread, for this is the largest area supplying cane to the Babinda Mill; several blocks of 1,280 acres each are adjoining. Furthermore, the cane in that locality of abundant rainfall is of rank growth, and fully infested with the borers, under normal conditions. And, again, it will be an easy matter to extend their range to the Innisfail district, which usually suffers considerably from the pest.

Breeding Parasites Progressing at Meringa.—The large cage at the station has been continually stocked with the flies, and colonies have been liberated from time to time in the borer-infested fields along the Mulgrave River. So far we have been unable to find the parasites established here; hence, it will probably be well to continue our efforts for a time.

I had a wire from Mr. Crees, the manager of the Mossman Central Mill, stating that the parasites were abundant in the cane which was being cut on his farm; so I went over and collected as many as possible. Like most insects, at this season of the year, the flies had largely emerged; they were sitting about everywhere on the cane-leaves, and we found abundant empty puparia. Furthermore, most of the grubs in the fallen cane under the trash were not parasitized. It appears to be the off-season for their activities, since I found fully 90 per cent. of the grubs parasitized in May—at a time when all insect life is active.

The Linear Bugs Active.

This new pest of cane (*Phænacantha australica* Kirkaldy) is exceedingly abundant in many fields in this district, and it appears to be widely spread. I found it was just as prolific at Mossman and, last year, in the Innisfail region. Fortunately, it is a pest which increases rapidly during the dry part of the year only; hence we experience the greatest numbers during the cutting season—at a time when the growth of the cane is not materially interfered with. Nevertheless, when they are in such numbers, and all sucking from the under surface of the leaves, they must materially reduce the sugar content—a fact worthy of notice when the cane is sold on relative analysis. Furthermore, if these bugs turned their attention to the young cane they would be a serious menace.

Control Measures Advocated.—This is a pest that multiplies particularly in grassy fields; hence I would advocate clean culture, particularly clean headlands, and, as far as we know at present, firing the trash should help materially in eliminating them. Their close relatives, the chinch bugs of the United States, are greatly reduced by these methods.

CANE GRUB INVESTIGATION, SEPTEMBER 1920.

The weather has been ideal for the growth of sugar-cane—warm days with intermittent light showers. Plant cane has never looked finer; and weeds are held well in check by better methods of cultivation. Hence conditions are most promising, and with an early rainy season in prospect

*Hawaiian Sugar Planters' Assn., Ent. Series, Bulletin No. 13, p. 42.

we are looking forward to a maximum crop again. Fortunately, too, the diseases of the grubs in certain districts are still active, even though the pest has gone deep into the soil to hibernate and pupate. Furthermore, the digger wasps are everywhere in evidence in infested fields, so altogether there is hope for a material decrease in the grub-pest.

The Borer Beetle, too, is coming under control, for there is a marked decrease in their depredations in all of the areas where we have liberated the Tachinid parasites (*Ceromasia sphenophori* Vil.) bred at the station.

The Linear Bugs, on the other hand, have never been so abundant in cane areas. They undoubtedly are coming more and more from the wild grasses; and they certainly are a serious drain upon the sugar content.

Natural Enemies of Cane Grubs.

Digger Wasps.—It is interesting to record that certain farmers have made use of the advice to plant pigeon peas near cane areas; wherever these occur they are swarming with bees and wasps, which feed upon the nectar. These plants, though rather late in flowering this season, were of considerable value in keeping the wasps in the vicinity of the grubby areas.

It is well known that the females of these valuable insects are the workers, spending most of their time far beneath the soil in search of their prey. Hence they only come out when hungry; and their usefulness is greatly increased if they can be supplied with nectar close at hand. In other words, if no flowers are available the wasps go in search of them, and when fed are apt to seek the nearest grubs in the soil—in blady grass or other wild land, where there is no direct benefit to the cane-grower.

The male wasps, too, feed upon nectar, but they do not enter the soil. They fly about in great numbers just over the surface of grub-infested fields, waiting for the females to emerge from their strenuous duties. Fortunately, the so-called weaker sex is considerably larger among wasps than the indolent males; and, since she is the only one provided with a sting, she is able to lord it over the poor little fellow.

Diseases.—Both the fungous and bacterial diseases continue active in the areas wherever we have discovered them. Unfortunately, these friendly organisms are not generally distributed, though they occur in widely separated localities.

The bacterial disease is far less virulent than the fungus, under the same conditions. Nevertheless, they often go hand in hand, the grubs dying by a complication of ailments. Often the legs of the grub will become blackened and one or more will fall off—unmistakable symptoms of the bacterial complaint; then the grub will quickly succumb to the fungus, his body becoming hard and cheesy, and finally turning green as the spores develop. These spores are exceedingly small; even when viewed with a magnification of 400 diameters they appear as tiny oval bodies, and hardly more than $\frac{1}{10}$inch in length. Ordinarily, unless broken apart, they are attached end to end, like a string of sausages, for these fruiting bodies are formed from the branching tubes of the mycelium (the vegetative part of the mould). Wherever the mycelium comes to the surface of the dead grub it branches profusely, and each of the tips then becomes constricted into a line of numerous spores. Hence the numbers produced by a single grub are unthinkable; a tiny speck of this green powder taken on the point of a pin and placed under the microscope is a

revelation, for the mass of spores is beyond counting. Therefore it is easy to understand how the soil becomes thoroughly inoculated with this contagion, as it is ploughed and cultivated. Furthermore, probably a single spore is sufficient to bring about the disease, when ingested with the soil by the grub, if the climatic conditions are right.

Beetle Borers and their Parasites.

This terrible pest, second in importance only to the white grubs in Queensland, destroys approximately one ton of sugar per acre, and, where the infestation is severe, considerably more. Furthermore, it is a pest that is rapidly spreading to new districts through the distribution of infested seed-cane. Then, too, where cane from infested districts is hauled long distances to mills, the grubby sticks are dropped along the line, sometimes a whole load spilling in one place. It is noticeable that the fields adjoining such railways have become infested during the past few years. This is particularly the case at Mourilyan and also at Hambledon; the latter brings part of its supply from far up the Babinda line. I have seen the cane come into the mill perfectly riddled with the borers, especially following the 1918 cyclone.

It is very encouraging that the Tachinid parasites are becoming established, for there is a tremendous improvement already noticeable where the flies have been liberated. Undoubtedly the net increase in sugar, due to the checking of this single pest in the Cairns district alone, is sufficient to pay all the expenses of our investigation for many years to come.

I am continuing the breeding of the flies, liberating them in increasing numbers in the vicinity of Gordonvale, until such time as we find them established here.

Linear Bugs.

This new pest (*Phœnacantha australica* Kirkaldy) is still in hordes in many fields, particularly those that are very grassy and where the headlands are full of grass. Where these insects have been working extensively, the leaves show a decided yellowing, many of them being dry and dead at the tips, the fields having an appearance similar to that caused by the leafhoppers in Hawaii before that pest was brought under control.

It is an easy matter for these hordes of bugs, with their beaks all inserted in the under surface of the leaves, to reduce the sugar content fully a ton or more per acre. Unfortunately we have not yet had an opportunity to make a careful estimate of this loss here; but it is enlightening to recall the serious depredations caused by leafhoppers in Hawaii, where the cane was so reduced in sugar content by these sucking insects that in many cases it hardly paid for milling. However, the reports of the growers show most remarkable results from the introduction of the minute egg-parasites from the Cairns district. These tiny wasps, so small as to be scarcely visible to the naked eye, multiplied and spread so rapidly that soon after their introduction it was estimated that they saved the industry 1,500,000 dollars annually. It is interesting here to digress, for the same species of leafhopper is found throughout Queensland; and still most growers do not know that these insects exist. They are everywhere present, but in such small numbers that they do no appreciable damage, since they are held completely in control by natural enemies.

Unfortunately the linear bugs are not so well controlled; and they work so insidiously that it is a difficult matter to get at an exact estimation of the damage done by them. If they reduce the sugar a ton per acre in badly infested fields—and this is not improbable—the loss for the whole industry is tremendous. There is no better argument for clean cultivation, at least keeping the grass down within the cane paddocks and along the headlands. Furthermore, it will undoubtedly be found profitable to use fire for their destruction, as often as possible, burning the surrounding grass lands as well as the trash from the cane.

CANE GRUB INVESTIGATION, OCTOBER 1920.

Weather conditions could not have been better for growing cane; light showers have continued throughout the dry season, and both the young plants and the ratoons give promise of an excellent crop. Furthermore, these favourable climatic conditions have done much to stimulate diseases among the grubs, so there is every prospect of a considerable diminution in these pests.

As indicated in former reports, the beetles were very erratic in their flight last season, and they missed many areas altogether that have regularly been infested in former years. This fortunately was the case in the Innisfail district; the crop, being practically free from grubs, has cut splendidly. A few places, however, like Greenhills, in the Cairns district, have never had a worse year. Early in the season the estimate for that estate was about 12,000 tons, but the grub injury became so widespread that practically all the fields were affected, and hundreds of acres were a total loss. It is distressing to report that only 2,400 tons could be harvested; and most of this was very short and light, so that it hardly paid for cutting in many instances.

Fortunately, nature is now lending us a hand in these devastated areas; not only have the grubs been practically wiped out in places by fungous and bacterial diseases, but on top of this we find that the parasitic wasps, *Campsomeris* sp., were never more abundant; the males are flying about over the surface of the ground in thousands, thus indicating that their mates are numerous below, searching out the grubs. Apparently these wasps have multiplied exceedingly during the past few months; and undoubtedly they are kept in the infested area by the abundance of flowering weeds which are now growing on the fields thrown out of cultivation. Chief among these, the wasps appear to favour the pink burr, which has nectaries on the petioles as well as those in the flowers. Early in the morning, before the sun is hot, the female wasps are to be seen on these plants in great numbers. The males I have often found, clustered together roosting on weeds at evening, when the weather is damp and cool. Under such conditions it is possible to gather a handful in one spot. Male wasps are said to have no sting, but I found that these fellows were able to pierce the skin with the three prongs borne on the terminal segment of the abdomen, and apparently they produce some poison, for there is a very strong odour of formic acid; at any rate, the feeling was not very comfortable where they punctured my fingers.

During this off-season for the grubs, a number of other pests have continued troublesome; chief among these I might mention cutworms, grasshoppers, and the linear bugs.

Arsenic for Cane Grubs.

It is very satisfactory to report that the cane is making most excellent growth in all of the plots treated with arsenic, and especially in the plot where the poison was applied at the rate of 200 lb. per acre, which was done to see if a heavy dressing of arsenic would in any way hinder growth.

During the past few months I have experienced considerable difficulty with white grubs in the garden. In preparing the soil for cucumbers, &c., I worked fresh cowdung thoroughly into each hill, covering with soft earth. By this treatment the cucumbers invariably failed, the vines yellowing and drying up before fruit was produced. I found that the soil was full of grubs, attracted by the manure, and they had evidently eaten all the roots from the plants. These were mostly the larvæ of *Isodon puncticollis* Macleay, which must be very rapid in development, for no grubs were in the soil when the hills were prepared a few weeks previously.

I tried arsenic in this case as a control measure, with excellent results. Hills in which the grubs were present in all stages were dusted with the poison at the rate of about 80 lb. per acre, and this was worked well into the soil. A fortnight later practically all the grubs had disappeared in the treated hills, though but very few of the blackened dead ones were seen; probably the others were removed by ants, which were abundant in the hills. Also, it was observed that there was no diminution in the number of grubs in the untreated hills.

It will probably be found best to apply the poison to the manure when preparing the hills for planting, similar to the placing of the arsenic in the drill with cane-plants.

Cutworms.

The Army Worm (*Cirphis unipuncta* Haw.) has continued to give trouble in various sections. They are often destructive to young corn, and appear to prefer ratoon cane just as it is beginning to shoot out. Though this pest has a number of excellent parasites, it often gets away from them for some reason, and does a lot of mischief.

Recently I experienced a serious outbreak at Malanda, on the Tableland, where the caterpillars were in such numbers that they spread from a grass paddock, which they practically killed out, right through a field of oats, stripping it to stubble, and ending up in a field of young corn which was eaten off to the ground level, before the army was ready to pupate. In this case no parasites were in evidence.

Grasshoppers.

Some time ago I called attention to a plague of grasshoppers (*Locusta australis* Brunner) at Meringa. Evidently what were left of that flight reproduced well, for recently young hoppers came forth in extreme numbers. They travelled like a flock of sheep in one general direction, and wherever they camped to feed the vegetation was eaten to the midribs. In the last nymphal stage, which they had reached when my attention was called to them, they were stripping the leaves of even the old cane, and playing havoc with the young plant.

I at once set about to control them, lest, if they were permitted to reach the winged stage, they might possibly fly more widely and prove a serious menace.

Figure 1.—Destruction of Sugar-cane by Grasshoppers. Photo taken shortly after they entered the field; the young hoppers are to be seen on the leaves near the centre of the picture.

Figure 2.—Destruction of Sugar-cane by Grasshoppers. A view showing the condition in which the field was left; the green leaves were eaten right down to the midribs. The leaves showing in the lower part of the picture were too dry for food.

I made several lots of a poisoned bait, using the formula which proved so successful in Kansas:—

Bran	20 lb.
White arsenic	1 lb.
Molasses	2 qts.
Lemons	3
Water	3½ gallons.

The arsenic was mixed with the bran dry; the lemons were then minced in the meat-grinder and added with the molasses and water, stirring so as to dampen the mash thoroughly. It was found that the oil from the rind of the lemons greatly increased the attractiveness of the bait.

The mash was sown broadcast, as advocated, in strips through the infested area. I found it very satisfactory to sow it only in every third or fourth centre between the cane-rows, for the young hoppers quickly crawl to the treated strips. Sown broadcast, the particles are so small that there is little danger of poisoning birds or poultry, and the greatest number of insects will get it in the shortest time.

The results were most remarkable, for even the winged insects were found eating the bait upon the ground. About four hours after treatment I examined the field and found many sick hoppers, which had already crawled under the stools of cane, where they were too weak to get out of the way. Next day the dead hoppers were everywhere, especially under the stools or any trash that happened to be lying about. It was practically a clean sweep of both young and adults. I was surprised that the winged insects could be handled so effectively, especially since the cane was standing, and there was an abundance of green feed everywhere about.

Linear Bugs.

These sucking insects (*Phœnacantha australica* Kirk.) continue to be exceedingly abundant in widely separated localities. They certainly do a lot of damage by removing so much sap from the mature plant. Naturally this must draw seriously upon the stored sugar in the cane.

I have never seen these bugs more abundant than I found them in the vicinity of the South Johnstone Experiment Station. The cane adjoining the scrub simply swarmed with them—hundreds sometimes beneath a single leaf, and all with their beaks inserted. Is it any wonder that the leaves turn yellow and die back from the tips?

While studying the death-factors of these insects, I found that the adjoining scrub was literally full of the adults; they were roosting all over the vegetation, apparently without regard to the kind of plant. In the cane a good many were caught in spider-webs, and a few were destroyed by the larger Reduviid bugs, which are regularly predaceous in their habits. The most important enemy that I was able to discover was the ant *Pheidole megacephala,* which destroys many of them when they are down in the grass on dark, wet days. Undoubtedly many of the eggs are parasitized or eaten by predators, but they are so small and difficult to locate that this phase of the problem requires considerably more investigation.

Beetle Borer.

Fortunately these insects are not so abundant this season, though they are gradually becoming more widely spread. The Innisfail district has not suffered this season as much as usual, for some reason. Yet this

immunity cannot be due to the parasites, for I was unable to find any trace of the flies that have been liberated there from time to time. I discovered on my recent trip that wherever the signs of the borers were particularly noticeable the ants had taken possession of their runs, cleaning out the frass and destroying most of the grubs. During wet weather these valuable predators must effect a material reduction of the pest. It is a well-known fact that ants must get out of the saturated soil with their brood, and the borer runs are ideal habitations when cleared of the frass. Apparently they find it difficult to dislodge the borer, however, once he has formed his cocoon, which is a mass of compactly woven cane fibres.

Standover cane from Mount Sophia showed the greatest damage from borers this season, hence we have recently liberated a considerable colony of the parasites in a near-by field where the cane is to be cut late, so as to give the flies a chance to get started.

Sugar-cane Leafhoppers on the Tableland.

I was interested, while examining the cane growing at Malanda and at the State Farm, Kairi, to note that leafhoppers were more abundant than at lower elevations. This coincides with observations in Hawaii, where the pest gives considerably more trouble in the elevated areas, since the egg-parasites are not so effective under lowered temperature.

The cane was rather yellow and stunted, not having the dark-green colour and the vigour common to the lowlands; still this may have been due to the continued drought, for all the surrounding pastures were dry and brown.

In several instances I found leafhoppers dead and sticking to the leaves, where they had succumbed to some kind of a fungous disease.

CANE GRUB INVESTIGATION, NOVEMBER 1920.

Though the weather has been rather dry of late the prospects remain excellent for the next season's crop. Light showers have helped out so that the young cane has not suffered so far, and there is now every prospect for continued rains. There has already been sufficient precipitation at Babinda to start the emergence of the beetles and at the same time stimulate the growth of the crops. Consequently, all insect life is more in evidence in that humid belt than in the vicinity of our station.

As indicated in my August report, the Tachinid parasites (*Ceromasia sphenophori* Vil.) of the borer beetle were found fully established in the field where they were liberated last year at Moolaba. Just recently, however, investigation has shown that these valuable insects have spread most wonderfully, covering an area of approximately 50 square miles. In fact, they have spread to all of the farms lying south of the mill, extending 7 miles with nearly 6,000 acres of the best cane on virgin soil, much of it on the river-flats, which produce exceedingly heavy crops.

Beetle Borer Parasites.

Through the cordial co-operation of Mr. A. L. McColl, manager of the Babinda Mill, I was able to make a comprehensive survey of the status of the Beetle Borer (*Rhabdocnemis obscura* Boisd.) in that district, at

the end of October. I am also particularly indebted to Mr. George Robinson, the efficient assistant cane inspector, who took me on the rail-motor to the most favourable locations for investigation, and gave me other valuable assistance.

I was at once struck with the scarcity of borer injury in the whole district; the improvement over conditions prevailing last year was most marked. At the time that I liberated the flies at Rutherford's farm, 16th June, 1919, every stool appeared to be injured, and many of the stalks were totally ruined before they were sent to the mill. Now, however, there is hardly more than an average of 1 per cent. of the canes bored, as far as I was able to determine by an examination of the butts on the trucks.

Undoubtedly the flies had a most excellent chance to become established in that location, for the cane was thoroughly infested, and stood for several months after the parasites were liberated. Then, too, there was young cane alongside infested with borers, which stood over until this season. A brief search revealed the parasites well established in this; we then proceeded to the farm of G. M. Reid, where we saw our parasitic flies sitting all over the trucks of green cane, sipping at the juice at the ends of the sticks; they had evidently just emerged that morning after the cane had been loaded.

Passing on down the line to the south, we came to a rake of trucks with burnt cane from the Bartle Frere estate (W. Thiel's), and found the parasites also roosting on the sticks feeding on the exuded juice. This was indeed surprising, for this cane was about 2½ miles from the place where the flies had been liberated.

I was now anxious to know how widely the parasites had spread, so we continued across the Russell River and right down to the end of the line to Mr. S. H. Warner's farm, where, though the borers were very scarce, we found the parasites, which were evidently holding them well in check, fully 3½ miles from where the flies were first liberated.

Returning, we stopped for a few minutes at the camp on the farm belonging to J. Maranoni, on the Queensland National Bank estate, where I found a single stick showing borer signs. Cutting this open I located three grubs and each contained two maggot parasites—unmistakable evidence of their valuable work.

On our way back to Babinda, about 3½ miles from Rutherford's, on the other side, I found the flies on trucks of green cane on a farm recently purchased by Mr. G. Cole from Mr. E. Otes.

From the way that we found the newly emerged flies sitting all over the trucks of cane in the field and because the parasitized cane is often lost off during transit to the mill, I concluded that the flies would quickly spread to the area immediately surrounding the mill. This we have since been able to demonstrate. Mr. A. P Dodd, assistant entomologist, and I, have just concluded the survey, with results that are most gratifying, the parasites being established everywhere that we looked for them. Hence we now know that they cover the whole area lying to the south of the mill, which furnishes the great bulk of the mill supply, i.e. 6,000 out of the total of 7,000 acres. Furthermore, it is gratifying to learn that the cane is cutting so much better than anticipated that the mill has recently had to revise its estimate, making an increase of 10,000 tons. Undoubtedly this advance is due largely to the activities of the Tachinid parasites in checking borer injury; hence the increased growth.

As I have indicated in a previous report, the monetary value of these flies has been carefully determined in Hawaii, where it was found that they saved approximately a ton of sugar per acre the first year, with a further increase of 1¼ tons when they got fully to work, i.e. £30 to £65 per acre as prices go here at present. Multiply this by the 6,000 acres benefited, remembering that the possibilities of spreading are practically unlimited.

The outlook for the future is most encouraging, especially considering Australia's normal sugar shortage, since we find that the flies do so well, even in our wettest regions where the beetle borer appears to be particularly destructive. And, moreover, true parasites, such as these Tachinids, can never become a pest, for the parasites can only develop in the larvæ of the host; once the host becomes scarce, the parasites are likewise reduced in numbers, until the balance of nature is finally reached, with just a few of the pest which inevitably escape, and a few parasites to search them out—neither greatly in evidence.

Regarding the question of the effect on these flies of burning the trash, let me say that I do not think they will be seriously hindered by the fires. I have come to this conclusion from observations at Messman, where, though all the cane is burnt every year before harvesting, the flies continue on duty wherever the beetle borers are in evidence. I still favour burning on all infested land, for it certainly destroys many pests in the fallen trash. Furthermore, infested fields are usually those rich in humus, so the trash is not so much required for fertility.

Beetles Emerging at Babinda.

Several light showers have started the emergence of beetles in this district. *Lepidiota caudata* Blkb., usually the earliest to come out, began to appear in numbers on 14th October, and fresh specimens continue to come to light (15th November). About 1st November I found a few *Lepidiota froggatti* Macl. and *Lepidiota albohirta* Waterh., both on feeding-trees. At the same time various species of *Anoplognathus* began to appear, particularly *A. punctulatus* Oll. and *A. smaragdinus* Ohaus, which swarmed in hordes over the wattles and other feeding-trees. It is interesting to note that these beautiful green beetles remain on the trees during the day, where they continue to feed; and I have observed many mating pairs even at noon when the sun was very hot.

Linear Bugs.

For some reason this pest has considerably abated about the Mulgrave region, so I was interested to note that these bugs were present in great numbers in some sections of the Babinda area, particularly in those fields where there was abundant grass along the tramlines and in the headlands. In such fields I found young nymphs in all stages (10th October), especially on the ground at the roots of the grasses, and the leaves of the cane were covered with them on the under sides. In such cases it might be well to kill the grass with a spray of sodium arsenate, where there is no danger of stock getting at it. Treated thus it would be easy to burn within a few days, if it were possible to do so without destroying the cane.

Campsomeris Wasps.

I have called attention to the value of nectar-bearing plants in the vicinity of grubby areas, so that these wasps might be enticed and assisted in their destruction of the pests. While at Babinda, I was interested to

note the number of female wasps feeding on the flowers of a wild raspberry which grows abundantly by the roadsides adjoining cane areas there. Possibly the prevalence of these plants attracts so many of the wasps that they hold the grubs in check. At any rate, there has been no extensive injury from these pests in the Babinda area.

The depth, too, at which these parasitic wasps go after grubs in the soil is most remarkable. Recently, at Greenhills, while excavating under stools of cane for the study of the grubs, we found two cocoons of the wasp at a depth of 42 inches, in soil so hard that we could barely chip it out with the spade. It is a known habit of this wasp to burrow with the grub, after she has paralysed it, as deep as possible into the soil, so that her young will not dry out too much, i.e. she tries to get down where the soil is permanently moist.

Arsenic for Grub Control.

Recent experiments with this poison in the garden for the destruction of the grubs of *Isodon puncticollis* Macl. have proved its merits. In the preparation of hills for cucumbers, &c., as reported last month, I mixed fresh cowdung with the soil. Shortly after the plants began to spread, and before they even flowered, they became yellow and stopped growing, so that they quickly died out altogether. Investigation showed that the soil in these pits was simply alive with grubs of the above species in all stages; the beetles, evidently, were attracted in the first instance to the cowdung, and as the grubs increased in size they destroyed the young feeding roots of the plants. By dusting the cowdung with dry arsenic, using approximately the same amount that we have been applying to cane-drills (80 lb. per acre), I prevented any grubs developing, though the adult beetles were found in this poisoned soil, evidently laying.

Following this, I tried dusting the pits where the plants had died, mixing the poison with the soil, and left all the full-grown grubs (40 to 60 in each). Four days later I was unable to find any living grubs in these treated pits, though several living beetles still remained.

These results are very encouraging, for evidently arsenic is quick-death to these grubs, even when full-grown. And, moreover, we have already demonstrated that cane-plants are not in any way injured by the application of this dry form of the poison to the soil.

Since the *Isodon* grubs are very similar in habits of feeding to our regular cane-grubs, these experiments lend further evidence to this important problem.

Furthermore, our extensive experiments at Greenhills, where we have numerous plots to determine the value of poisons for the destruction of soil-pests, are progressing favourably. Now that the rains have started, the beetles will soon emerge; then after two or three months we shall know the outcome, upon which our hopes are based.

CANE GRUB INVESTIGATION, DECEMBER 1920.

Splendid rains have fallen during the past month, and conditions could not be better for crops. Naturally the days are somewhat oppressive in summer in this humid climate, but it is just what the cane requires; one can fairly see it grow. If we escape a cyclone there is every promise that the cut next season will be a "top-notcher."

Cane-beetles began emerging on 18th November here, yet I am pleased to report that they have not appeared in excessive numbers. Fortunately, the Muscardine fungus and other natural agencies destroyed the vast majority of the grubs on the Greenhills estate, last season; hence there is a marked decrease in the number of beetles that came out, particularly in the fields that have been regularly infested.

Considerable attention has been given, during the past month, to a study of the biology of cane-beetles in general, particularly their mating habits, egg-laying, &c. As is probably well known, the greybacks are only one, though the most serious, of the numerous species of beetles that depcsit their eggs in cane land. Hence our investigation naturally covers all important pests of sugar-cane.

Emergence of Cane Beetles in the Cairns District.

It was about five days after the soaking rains beginning on 12th November, that we found the first greybacks on the feeding-trees. Yet the height of the flight was not reached until about the end of the month, following the heavy downpour of 25-27th November. *Lepidiota frenchi* began to appear immediately following the latter rain at Gordonvale, and by 10th December this species was out in considerable numbers, especially in the areas where they were troublesome last season. As is well known, this species has a two-year life-cycle, and the heavy emergences of the beetles occur in the even years—1916, 1918, 1920. *Lepidiota rothei* emerged somewhat later, for I found the first specimens mating on low bushes at dusk on the evening of 13th December.

On the other hand, *Anomala australasiæ* and *Anoplognathus boisduvali* emerged in considerable numbers, following the first rains. The *Anomala* is rather peculiar in its habit of feeding on the flowers of the lantana. The fragrance which these beetles often give off is probably due to the nectar they absorb from the flowers. The Christmas beetle (*A. boisduvali*) is very partial to blue and poplar gums; it is seldom that one finds them on other feeding-trees.

The greybacks usually go to the Moreton Bay ash, wattles, figs, bloodwood, blue gum, and even the new growth of the tea-tree and apple (*Careya*). We have made the interesting discovery that it is the custom of these beetles to feed for a brief period—a day or so—on the cane-leaves, before flying away to other feeding-grounds. Banana plants in the cane areas are also invariably considerably eaten.

Beetle Emergence Heavy at Mossman.

This was once a region seriously devastated by beetles, but fortunately during the last decade the district has suffered little from these pests. Recent reports, however, state that the beetles have appeared in great numbers, which is not encouraging, yet I hope they will confine their activities to the uncultivated areas.

Mating Habits of Lepidiota Albohirta.

Heretofore we have had no definite knowledge of the mating habits of this species, due largely to the fact that the beetles favour large, tall trees, hence are too far up for easy observation. The mating activities of *L. frenchi* and *L. rothei*, on the other hand, are easily observed, for when they emerge at dusk they fly to low bushes, and even copulate while hanging on wire fences or any other available objects. The males in these species invariably slide backwards and hang head downwards, as soon as connection is secured; here they hang perfectly motionless and rigid for about half an hour, when they separate and begin feeding.

This year we were fortunate in finding greybacks 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 other species of *Lepidiota*. It is interesting, however, to record that we have now demonstrated that all of these beetles copulate repeatedly during the period that the eggs are developing; I have even taken mating pairs when the abdomen of the female was packed full of ripe eggs, ready to oviposit. Furthermore, the males go from one female to another, as I have repeatedly observed. I have also made similar observations on the polygamous habits of the other species of *Lepidiota*.

Feeding Habits of Lepidiota Frenchi.

This species, unlike the greyback, apparently feeds very little during the period that the eggs are developing. Dissections of copulating beetles invariably showed the intestines empty, even when the eggs were almost fully developed. This is in marked contrast to the greybacks, which are always packed full, from end to end, during the whole period that they are on the wing.

The fact that *frenchi* is able to develop eggs with very little or possibly even no food helps to explain their damage to cane far removed from any possible feeding-trees. In such cases, when the beetles emerge in great numbers, they hang up on the wire fences to copulate, and are so numerous that one could gather them by the bucketful. Here they have no opportunity to feed, and apparently go back into the ground, emerging on successive evenings to copulate, until the eggs are ready to lay. Where feeding-trees were available, we have found these beetles on Moreton Bay ash, bloodwood, blue gum, and guava, but in no case was there much evidence of feeding. Then, too, when we confined the beetles in cages, they scarcely touched the leaves provided fresh each day. Furthermore, beetles placed in cages with no food oviposited as usual. The adults are able to endure this period of starvation because the grubs store up greater quantities of fat, before hibernating, than is the case with the greybacks.

Grub Parasites Abundant at Greenhills.

As I have mentioned in former reports, the males of the *Campsomeris* wasps continue abundant, flying over the surface of the soil of the infested areas. Since we found that the males and females were in about equal numbers, when we were breeding these useful insects, we naturally conclude that every male above ground has a mate below, searching out the grubs. This is certainly encouraging; though no greyback grubs are available at this season, there are several other destructive species, i.e. those having a two-year life-cycle. These will tide the wasps over until the *albohirta* grubs develop for a month or so; then the wasps will probably have all that they can do.

Destruction of Feeding Trees.

In the area that we cleared last year, bordering the fields on the Greenhills estate, many suckers had grown up; to save brushing these off, I was fortunate in being able to destroy the foliage by a grass-fire soon

after the beetles emerged. Undoubtedly by this method some of the beetles were consumed, and it certainly is the most rapid and easy method of ridding the area of leaves on which the beetles might feed. I was pleased to see that another grub-infested area near Gordonvale has been treated in the same way very effectively. It certainly saves a tremendous amount of labour, which would be required to brush over areas that had been previously cut.

Beetle Borer Parasites.

Recent observations at Babinda have extended materially the known area where these friendly insects are active; undoubtedly they will soon extend to every portion of that district.

In casting about for an explanation of the remarkable success of these Tachinids at Babinda, when they have apparently failed to become permanently established in other centres, even where far greater numbers of the flies were liberated, I have come to the conclusion that the Babinda success is due solely to the fact that standover cane was available for the flies to breed in during the season that the fields are normally bare. These flies have a life-cycle of about five weeks, so if they can find no borers in standing cane for that length of time they must naturally die out. The exigencies of the case at Babinda make it impossible to harvest all of the crop, so there are inevitably a few fields throughout the district that must stand over uncut. This condition has proved a blessing in disguise, for it has been worth fully £25,000 to the district the past season, in the reduction in borer injury. Let me urge, then, that some small areas throughout the district here and there be left until such time that the ratoons begin to make cane again. In this way I am satisfied that the parasites will remain permanently established in spite of their natural enemies, for their rate of multiplication is tremendous, each female being capable of producing 500 or more during her life; and, with a life-cycle of only five weeks, one can easily estimate by geometrical ratio that the results would be so enormous that in a year they would be unthinkable. I am now satisfied that this is the main factor in maintaining the parasites permanently in any district, and it should be observed, especially at the time that the first flies are liberated.

At Mossman, where the flies became so well established, they were at first liberated in the mill nursery, where much of the cane stood over during the period that other cane was cut. From this centre they have gradually become distributed in plants to every part of the district. Now that they are established they find sufficient standover cane to pass successfully the trying period when cane is usually milled.

Linear Bugs (Phenacantha Australica).

I have called attention to the relation of these bugs to diseases of various sorts on cane-leaves, but a most remarkable instance of this came to my notice on a Mulgrave River farm recently. Old ratoon cane which was swarming with these bugs was burned preparatory to cutting, hence many of the insects were driven across the headland into a field of young plant-cane; they extended into this only about ten rows from the headland, but the leaves soon became badly blighted with tip-wither, a disease which begins at the margins of the leaf and gradually extends downwards; the affected portions of the blade dry up and leave a brown demarcation separating it sharply from the green midrib, which succumbs more slowly, dying backward from the tip. It was very evident that

the bugs were the direct cause of this trouble, for the disease was worst in the portion of the field where the bugs were most numerous, and none of the leaves showed any trace of the disease further back in the field where there were no bugs.

CANE GRUB INVESTIGATION, JANUARY 1921.

The outlook for the next season's crop is most promising, for growing conditions are perfect, as far as climate is concerned. We must expect, however, considerable devastation from grubs in some of their favourite haunts. Greenhills, as usual, appears to be coming in for her full share. Fortunately, most of the several hundred acres of plant-cane on this estate was treated with arsenic, so that I hope for a thorough demonstration of the efficacy of this method of control. As mentioned last month, we can also hope for some immunity on certain of the ratoon fields, because of the removal of feeding-trees along one side of the estate.

Mr. Dodd and I have made material progress in a knowledge of the habits of the several species of cane-beetles, in the field, by working early and late during the present flight. Since the end of November, it has been necessary to start observations by 5 a.m., keeping them up daily even through the holidays; and it is usually 9 p.m. before the work is completed for the day. Furthermore, these strenuous duties must be kept up for a few weeks longer, until the aerial life of these pests naturally comes to an end.

Aerial Habits of Cane Beetles.

Lepidiota aibohirta.—We have now very definite information on these greyback beetles. Most important, perhaps, is that they are not satisfied with laying one set of eggs, for under normal conditions they continue this reproductive process as long as they are able to be on the wing. It has naturally been supposed that when they flew into the field and laid their eggs they died. This is seldom the case, however, for we have clearly demonstrated that they return to the feeding-trees and form a fresh set, though sometimes a smaller one, which they are usually able to bring to maturity.

Again, as is well known, these beetles have two daily flights, morning and evening. We have found that the evening flight, between 7 and 8 o'clock, is primarily a mating flight, the beetles coming from the cane or from other feeding-places, if they are already stationed in the trees, the males seeking out the receptive females. After 8 p.m. copulation ceases, and all of the beetles feed quietly. About 5 a.m., again there is activity in the camp, and the morning flight begins. In this they simply seek better locations among the foliage for the day; or in the case of females ready to oviposit, after circling a few times as if by instinct, they take a bee-line to a favourable location. I have seen them thus, between 5 and 5.30 a.m., coming into the cane in great numbers. At the latter time on clear mornings their flight ceases, and they settle on the cane-leaves with their heads up; here they cling for a considerable period, perfectly motionless; and, finally, as the rays of the sun begin to warm them up, they fall to the ground and usually crawl under the nearest stool, where they enter the soil; in doing so the head works under any convenient object, which is used as a fulcrum to assist them in getting in.

Of the numerous specimens collected on the cane-leaves at the termination of the morning flight, I have failed to find a single beetle that was not packed full of ripe eggs; and when these were given soil of the proper moisture, &c., they invariably laid at once, and soon reappeared on the surface, hungry and ready to start life all over again.

Furthermore, we have demonstrated that the beetles frequently make their first meal upon the cane-leaves when they come out of the soil, both at the time of the original emergence from the pupal cell and after they have oviposited. They sometimes stay upon the cane-leaves for the first day in each case; and during this period they usually eat out considerable notches in the leaf-blade, very similar to the destructive work of grasshoppers, cutworms, &c.

Lepidiota frenchi is second only in importance to the above, so we have given it special attention. This species also has the two daily flights, like the greybacks; they apparently differ from them, however, in being able to subsist entirely on the cane-leaves, when other feeding-plants are not available. This, undoubtedly, is largely due to the fact that they eat but little, compared with the greybacks, and their eggs are well developed when they first emerge. In fact, they are evidently able to lay within a week after coming out. Thus they have a considerable saving of energy, which must naturally be expended by the larger species to form the eggs from the beginning, after the beetles appear above ground.

On numerous occasions I have observed these beetles during the evening flight, in cane areas far removed from any feeding-trees. Under such circumstances, ignoring the financial aspect, the experience is most interesting. One waits expectant; everything is quiet, when suddenly, about 7 p.m. as dusk approaches, a seething horde appears out of the ground; everywhere there is apparent confusion as the myriads of beetles whirl to the right and left, frequently striking the cane-leaves, in their mad search for mates. After approximately ten minutes the flight is over, and all is quiet again, for the beetles have come to rest in pairs upon the leaves of the cane or any other available object. About half-an-hour later, when it is getting quite dark, there is a second minor flight composed largely of the males, which always fly away from their mates as soon as copulation is completed. After circling about for a brief period they apparently again settle on the cane-leaves, for both sexes can be found there in the early dawn. In fact, I have gathered quantities of them as they sat there quietly, all covered with dew, on the topmost leaves; under these conditions they appear cold and stiff, for they drop to the ground if the leaf is touched, making no attempt to fly away. Just preceding 5.30 a.m., when the morning flight starts, all the beetles begin to stretch themselves, moving their heads and legs; at the first signal hum, however, they are all off for a little exercise before going into the soil. It appears to be the habit of gravid females to settle on the ground at once, where they soon crawl under stools, and burrow in, to oviposit. The males, on the other hand, alight first on the leaves, and after a brief rest crawl down and enter the soil, but do not go so deep.

Fortunately, this species is not yet addicted to a life in cane areas; they much prefer the open forest lands, with the numerous low bushes, among the grass. When such lands are cleared, however, and planted to cane, they have no recourse. Moreover, I do not know of a single case where they have moved from grass areas into cane lands that were formerly free from them.

Ovipositing of Cane Beetles.

Lepidiota albohirta, as we have always supposed, naturally lays her eggs at the base of the cane-stools. Heretofore, however, we have had little field evidence on which to base this conclusion, other than that the resulting grubs are usually to be found there. This, apparently, is due to the fact that no one has gone deep enough in digging.

I first placed a number of gravid betles, collected from the cane in the morning, in a cage in the garden; and a few days later excavated to locate the egg-chambers. I was considerably surprised, however, to find that they burrowed so deep; the nine egg-chambers thus located varied in depth from 10 to 14 inches, with an average of 26 eggs each.

With this information I was able to work more intelligently in the field. We dug two trenches in one of the old, abandoned grub-infested fields at Greenhills; 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 in various sizes, up to a fortnight old, and twelve egg-chambers of the greyback beetles. These varied in depth from 8 to 18 inches, averaging 12¾ inches; the clusters of eggs varied from 23 to 33 in a set, with an average of 28.2.

Aneplognathus boisduvali.—In one of these trenches we also found a set of 53 newly laid eggs of the Christmas beetle, which is also a troublesome pest of canefields, and several grubs of this species in both the first and third stages. We also found an adult male beetle still in his pupal cell about 10 inches deep.

Lepidiota frenchi was handled in much the same way that I did with the greybacks, placing a cage in the garden, and I found that they too go much deeper to oviposit than has been anticipated by former investigation. Furthermore, they do not lay all their eggs in one basket, as the greybacks do, but scatter them about in several parcels in the soil, each egg in its own tiny cell, the number varying from 5 to 10. They were placed at an average depth of about 8 inches, in heavy clay soil. Later I found eggs in the field, under natural conditions, at a depth of about 10 inches.

This species lays on an average about 30 eggs for the first set, soon after emerging, and is evidently able to produce successfully a second set before succumbing. Hundreds of mating pairs may be seen almost any evening during the two months that they are on the wing. They are not at all particular where they hang up to copulate, for when numerous they hang on the wire fences, or in fact upon any object that presents itself. Recently I took fifteen pairs, hanging one couple upon another, on a small dry stick not more than 2 feet high in an open field.

Anomala australasiæ is apparently much more rapid in development than any of the above; at any rate, some of the grubs had already reached the third stage by 16th December, just one month after the parent beetles were first observed on the wing. This small green beetle is becoming more and more abundant in cane areas, and the grubs undoubtedly do considerable damage. The eggs are probably laid from time to time as they develop, for new sets are usually in a process of development in all the females dissected shortly after the primary emergence.

Lepidiota rothei has not been much in evidence this season, though it has a one-year life-cycle, and has been very abundant in former years in the vicinity of this station. Evidently they have had a natural setback some way. Dissection would indicate that the eggs are not laid in regular sets; rather that they are deposited a few at a time, as the beetle enters the soil for its daily hibernation. Mating habits resemble those of the other *Lepidiota* in that the male hangs head downward during copulation; but the period in this species is very short, lasting not more than two minutes.

Control Measures.

Hand Picking.—A few words on this subject may be of interest, for it may prove practical to gather the gravid female greybacks from the cane-leaves after the morning flight, say from half-past 5 until about 8 o'clock. Every beetle so destroyed removes approximately 26 grubs from that stool of cane. When the flight is at its height it is possible for a man to gather a considerable quantity of the beetles in an hour or so by walking up and down the rows. If the cane is not too high one can see the beetles on a strip three or four rows wide.

On the other hand, my investigation further emphasises the futility of collecting generally upon the feeding-trees, especially if done more than two weeks after the primary emergence. In one lot that I gathered thus, I found that 86 per cent. were males, the remaining 14 per cent. being females that had laid their eggs and were empty. Possibly these females would develop more eggs, but this is questionable, especially late in the season. Nevertheless, a week later, when I dissected a collection of greybacks from Greenhills, I found an excess of females, indicating that the males had already begun to die off from old age, since they had been on the wing for six weeks or more. Furthermore, most of the females are now back at the feeding-trees, in an endeavour to produce more eggs before they too succumb.

Natural enemies are doing their share in the control of these pests. Muscardine fungus is still in evidence in the grub-infested fields at Greenhills, as demonstrated by our excavations there, for we frequently come upon its activities. It does not often appear to be effective in the destruction of the newly hatched grubs, but I have recently noted the full-grown grubs of *Lepidiota frenchi* which had succumbed to this disease.

The grub-infested areas always swarm with *Campsomeris* wasps; and I have recently found that several species of Asilids also frequent these fields, laying their clusters of eggs upon the leaves of the cane. The young are exceedingly numerous, and upon hatching drop to the ground and enter the soil in search of the young grubs about the stools. These tiny larvæ are very effective, once they locate the grubs, which are their natural prey. In my laboratory experiments with them, they have already killed 12 young grubs in as many days. They burrow into the grub at any point, but preferably the back, where they cannot be reached, and suck out the body-juices. Apparently they have some power to paralyse the grub, for it soon ceases activities when set upon.

The beetles, too, have their enemies, which attack them while in the feeding-trees throughout the day. Naturally many species of birds reap a harvest, and we are breeding out some new species of flies that attack them. Furthermore, Mr. Dodd recently found a most interesting bug, *Amyotea hamata,* about half-an-inch in length, which sets its beak into its prey and puts it out of action. When discovered, this bug had a full-sized greyback many times its own size, but the beetle was kicking his last. When the bug was put into a glass jar with another beetle it soon punctured it, right through the wing-cover, and the beetle died. This predator would be most useful if it would only appear in greater numbers.

CANE GRUB INVESTIGATION, FEBRUARY 1921.

Weather conditions continue perfect for the growing crops. The rains are well distributed, so that practically all the moisture is used; and fortunately there has been no heavy wind so far.

I have recently had a very favourable report from Mr. George Hing, Innisfail, that practically no beetles emerged in the region of Stockton paddock, near his farm, where they usually swarm on the feeding-trees in such countless hordes that it is the principal collecting ground for the Goondi area. This fact may possibly be explained by the following:—

During 1895 a fungous plague appeared among the grubs on the southern portion of the Goondi estate. *"During previous years the cane-grub had proved highly destructive, and at the conclusion of an unusual wet period, during April and May, large numbers of dead grubs were encountered in ploughing the land. One planter (Mr. W. Molle) found that, in spots where this was specially noticeable, two-thirds of the grubs encountered had succumbed; and another (Mr. Jodrell) that over considerable areas 40 to 50 per cent. of the grubs had died with special features. These characteristic features were the development of a white fluffy mould, eventually covering the entire surface, and the acquirement by the dead insect of a cheese-like consistence so that it could be broken across, whilst the dead grubs not exhibiting these features became soft and putrid in the ordinary manner. . . . It was, however, noteworthy that, for some years subsequent to the appearance of these fungus-affected grubs, no trouble from the notorious pest in question was remarked."

Since last year was so favourable to the working of fungous diseases, and since about 98 per cent. of the grubs in the badly infested area at Greenhills succumbed to various natural causes, it is quite possible that the grubs have had another setback in those portions of the Innisfail district wherever the fungous spores occur in the soil.

Unfortunately this does not appear to be the case in the newer portions of the district, especially some of the isolated areas supplying the South Johnstone Mill. Every year there has been considerable trouble with grubs along the narrow strip of cultivated land known as the Seventeen-mile. I have just had a conversation with Mr. W. J. Henderson, who told me that the grubs had already ruined some of the fields there. From what I can learn these grubs are not the young of the greyback beetle, but probably belong mostly to the following scrub species:—*Lepidiota froggatti* Macleay, *L. caudata* Blackburn, and the common green species, *Anoplognathus smaragdinus* Ohaus.

In these isolated localities, where the Muscardine fungus does not yet occur, it certainly should be worth while to spend a considerable sum to inoculate all the grubby fields with spore-bearing soil, secured from

* Tryon, H., Aust. Sugar Jour. ii, p. 533.

locations where the grubs have succumbed to the disease. This would not be a difficult or very expensive matter, for a ploughman could easily drop a small pinch of the infested soil here and there in the furrow as he went along; or in uncleared land it could be buried a few inches deep with the shovel every chain or so throughout the field; the closer the better for results. It must be understood, however, that during normal years results from this fungus may not be noticeable; but we build hope on the fact that it acts like a plague to grubs during moist cool weather, such as we experienced during June and July, 1920, wherever they come in contact with it. The important thing is to have the spores in every grubby situation ready for such conditions. I would recommend the use of Pest Destruction Funds for such inoculation work throughout each district; but no money should be wasted by treating fields not already suffering from grubs, for probably the spores would die out in time under such conditions. In grubby fields, on the other hand, we have demonstrated that the disease continues on, year after year, when it is once thoroughly established in the soil.

The Greyback Beetles.

Scientific Name.—I find by going into the matter that this notorious pest has, in recent years, been sailing under an assumed name. Hence it is with pleasure that I must acknowledge the assistance rendered by Mr. A. M. Lea, entomologist, of the South Australian Museum, in properly placing the insect.

In 1875 the species was named *Lepidoderma albohirtum* by C. O. Waterhouse;* and this apparently has been the name that it has gone under ever since in New South Wales. In Queensland, however, most of us appear to have followed Tryon's lead,† using the name *Lepidiota albohirta*; and, moreover, the species was so determined for us by Mr. Lea, 14th May, 1914. Recently, however (7th January, 1921), at my request Mr. Lea sent a copy of the original description, together with Blackburn's classification of this species; hence I have no doubt that it belongs in the genus *Lepidoderma*.

Development.—At Greenhills the grubs of this species have developed very rapidly; a few were even in the third stage on 8th February. Digging in one field on that date we found 26 per cent. of the grubs still in the first stage, 73 per cent. in the second, and 1 per cent. in the third stage.

The cane continues to grow splendidly, showing no signs of the devastating effects of this terrible pest. We have found the grubs exceedingly numerous, however, in the abandoned fields bordering on the feeding-trees, and, even though we have not done any digging in the good cane, I rather consider this a hopeful indication. That is to say, the fields which are now thrown out of cultivation may act as a trap-crop; for the beetles have certainly deposited their eggs there in great numbers—fully 100 per stool—and this may go far toward saving the cultivated fields.

Furthermore, a few of the greyback beetles were still on the feeding-trees on 8th February. Of those collected only 30 per cent. were males,

* Trans. Ent. Soc. 1875, p. 201.

† Tryon, H., Grub Pest of Sugar-cane, Qld. Dept. Agric. July 1895.

which is additional evidence of their shorter life. Dissection of the females, too, brought out further interesting evidence, especially as to their egg-producing proclivities, for 37½ per cent. of them had ripe eggs —the sets averaging 23·66 eggs. Of the others, 50 per cent. had eggs well advanced, and 12½ per cent. had just laid what was probably their third or fourth sets, and had returned to the feeding-trees to try it all over again, before succumbing.

As indicated in my previous report, I was sure that the beetles, under normal conditions, laid more than one set of eggs; for as early as 24th November I dissected one female and found eggs ripe and ready to lay. Evidently this beetle had emerged about 12th November, following the first heavy rain. The majority of this species, however, did not come out so early; hence they probably laid their first eggs between 7th and 15th December. Then, since it takes the beetle approximately only a fortnight to produce a set of eggs, several sets might easily have been produced by each female during the time they were on the wing.

As to the number of eggs produced in each set, there is considerable variation. Usually about two eggs ripen in each of the twelve egg-tubes at the same time; hence we might expect sets of 24. This, however, is far from constant, for often three eggs ripen in some of the tubes at the same time, while in other tubes only one develops. It is not uncommon to find sets of about 20 eggs; and frequently there are 33 to 36 in one egg-chamber—in fact, we had one beetle in a cage that laid a set of 46. The average of the season, however, derived both by dissection and from a count of those in the soil, is 24·6 eggs in each set. Hence we get some notion of their possibilities when they are on the wing for two months or more, all the while mating and producing eggs.

Lepidiota Frenchi.

This species, too, has remained long on the wing. They first appeared at the end of November, and, as already noted, the eggs were almost ready to lay when they emerged. They, like the greybacks, have continued to mate and produce fresh sets. I collected 20 mating pairs at the end of January, and found that 5 of the females had ripe eggs ready to lay, 5 had new sets of eggs well advanced, and the remaining 10 had empty egg-tubes, showing that they had just laid, and were mating to try and produce a further set.

Muscardine Fungus.

Results of recent investigation of this disease at Greenhills have been most encouraging. Even in December, when the young grubs were just hatching, there was evidence of it, particularly upon the third-stage grubs of *L. frenchi*. During January, however, it became prevalent upon the young grubs during a few days of cool weather following the rains; and at that time most of our young grubs in the insectary succumbed to it quickly—in some cases 100 per cent. of those that were in pots of the Greenhills soil. Early in February we made a count of the grubs dug up in the field, and 13 per cent. of those that we could find had been killed by this disease. Perchance there is moist cool weather before the grubs go down to hibernate, we may look for an epidemic similar to that of last year.

Linear Bugs (Phlenacantha Australica).

Heretofore I have not observed nymphs of this species beginning to appear before April, so I was interested, on 10th February, to find both eggs and young on the soil at the roots of grasses in canefields along the Mulgrave River. Mating pairs of the bugs were everywhere in evidence on the cane-leaves. Evidently this pest is going to be more prolific than usual this season, since they are starting so early.

CANE GRUB INVESTIGATION, MARCH 1921.

Rains have continued during the past month, so that the soil is now (15th March) thoroughly saturated and all the watercourses are flooded bank-high. Between showers the weather has been exceedingly oppressive; hence conditions could hardly have been better for the growing crops. Fortunately, too, these tropical disturbances have not developed much wind, so most of the cane is standing well. Babinda district, as usual, has come in for her full share of the deluge—an average of about an inch per day for the months of January, February, and March—yet the cane there is making splendid growth.

Grub injury is beginning to show at Greenhills; and arsenic, where used in sufficient amount, is already showing encouraging results.

Development of Lepidoderma Albohirtum.

This species, as usual, has developed very rapidly in the red volcanic soils. Digging in the fields at Greenhills on 11th March showed that 73 per cent. of the grubs had already reached the third stage, which is the period in their development when they are most destructive; 26 per cent. were in the second stage, and only about 1 per cent. still remained in the first stage. Since straggling beetles were on the wing up to about the middle of February, the duration of the first and second stages is apparently something less than a month each. The final stage, on the other hand, remains with us right up to cold weather, and even then the grubs frequently continue for several months deeper in the soil in their hibernating chambers.

In spite of the super-saturation of the soil, much of the cane at Greenhills already looks as if it were suffering from extreme drought, i.e. the terminal leaves are rolling, giving the characteristic piping appearance, and the beautiful dark-green colour has gradually changed to yellow, and in a few places where the grubs are particularly abundant the leaves have become almost dry and brown in colour. Stools of cane in this condition can easily be lifted right out of the ground with one hand, for the roots have been eaten entirely away and even the underground portions of the stalks badly gnawed. During the prevailing wet weather the grubs are just under the surface of the soil and near the cane, so that when the stools are pulled out bodily most of the grubs are disclosed. These vary in numbers considerably in different parts of the field, chiefly with regard to the distance to the feeding-trees, but it is not at all uncommon to find 20 to 50 in a single stool, especially in the ratoon cane.

Arsenic for Control of Cane Grubs.

Most of the plant cane on the Greenhills estate was treated with arsenic at the time of planting, the poison being placed in the drill at the rate of about 80 lb. per acre. This cane has made excellent growth, except in a few places on the rising ground, where grub injury is already showing.

In our two experimental fields on this estate we have 46 plots, each having a width of 5 rows (25 feet). Right through, the treated plots alternate with checks, so that we may get a better line on the real effect of the poison. As was noted almost a year ago, we used arsenic in the following amounts per acre:—40 lb., 60 lb., 80 lb., 100 lb., and 200 lb. One field was planted to D 1135 and the other to Badila. The first was planted in April, 1920, so that there is fully 7 feet of cane on it. The poisoned areas were treated during May, 1920, when the cane was almost a foot high, but before the drills were filled. This field has always been one to show grub injury first, so, as usual, much of the cane is already (15th March) suffering there. Most of the checks have fallen, due to the excessive wet weather, while the treated plots show varying degrees of immunity. On 11th March I was much interested to find the cane in the plot treated with arsenic at the rate of 200 lb. per acre standing erect, while the check-plots at either side and at the end had fallen. It was good enough for a picture, for this standing cane had made excellent growth, far ahead of that in the checks. Five rows away on one side was cane treated with arsenic at the rate of 100 lb., which was somewhat fallen; and the plot with 80 lb. of arsenic, on the other side, was not quite as good. 60 lb. of arsenic showed some value, though the cane in the checks had not fallen so badly in that part of the field and the results were not so apparent. The plots treated with 40 lb. of the poison hardly show any results so far. The injury has not developed far enough in our Badila field for results upon the appearance of the cane. Digging, however, showed that there were fully 50 per cent. less grubs in the treated plots than in the checks, and, furthermore, the grubs were not so far developed. We found about 73 per cent. of the grubs in the checks had reached the third stage, while practically none had gotten to that stage where the heavier doses of arsenic had been applied. It will probably be interesting to have the following exact figures of the number of grubs that we found during our examinations:—

24th Feb., 1921.—Field D 1135—

Check: 3 stage I, 29 stage II, and 13 stage III, or a total of 45.

Plot treated with 200 lb. arsenic: 1 stage I, 4 stage II, or a total of 5; and 4 dead second-stage grubs were found, that had just succumbed to the poison.

The next check-plot had 2 stage I, 12 stage II, and 4 stage III, or a total of 18.

A stool in a plot treated with 100 lb. arsenic gave 1 stage I, 8 stage II, or a total of 9; and 1 dead of arsenic.

The plot treated with 80 lb. gave 2 stage I, 4 stage II, and 1 stage III, or a total of 7; and 1 dead of arsenic.

The check gave 2 stage I, 6 stage II, and 10 stage III, or a total of 18.

A plot treated with 60 lb. of the poison gave 1 stage I, 6 stage II, and 1 stage III.

Where 40 lb. of arsenic had been applied we found 6 stage II and 4 stage III, or a total of 10 grubs.

From the above figures it would appear that most of the grubs are destroyed by the poison during the second stage, just before they reach the very destructive period in their development. The dead grubs only last a few days in the soil before disintegrating, which accounts for finding so few dead in the soil.

It is too soon to offer conclusive remarks on how much arsenic is necessary for complete control of this pest, or which method of application is best; nevertheless the results are encouraging.

White Grubs Destructive to Grass Paddocks at Atherton.

A species which resembles very closely our cane-grubs has been doing rather serious damage to grass-lands in the vicinity of Atherton. Mr. Dodd recently did some investigating in this district, and found the grubs very near the surface, where they were destroying the roots of the grass, but fortunately in rather localised areas. I have been able to secure specimens of the beetles of this species through the kindness of Mr. Wilson of the Babinda Mill staff, who was on the Tableland during their flight, and was thoughtful in securing specimens for us.

These beetles are different from anything that we have in our collections, so are evidently a localised species. It may be remarked, however, that this is a pest which might easily become very important, especially on crops like corn, if not repressed in some way.

CANE GRUB INVESTIGATION, APRIL 1921.

For the past month (15th April) the Cairns district has been deluged with rain; the streams, rising far over their banks, have flooded portions of the river-flats for many days at a time, while some fields have been washed away altogether, the land being left a barren waste of sand and stones. Furthermore, during this downpour we had considerable wind, and much of the heavy cane, even on the uplands, was laid flat on the ground, particularly in fields damaged by grubs. These pests, too, have continued their devastation with unabated zeal, working close to the surface of the saturated soil; hence many of our hoped-for results with arsenic, where it was placed in the bottom of the drill with the plants, has been negated. Fortunately, however, these weather conditions, which have been so unfavourable for the growth of the cane, have stimulated the development of the diseases of the grubs, wherever the spores occurred in the soil. And again, the grub resistance of D 1135 has been most marked.

Grub Devastation and Arsenic.

At the earliest possible opportunity when our floods abated (13th April), I went over to the Greenhills estate, where the most distressing situation was revealed; hundreds of acres of cane had turned brown, the leaves being almost dry, and some entire fields where the crop was particularly heavy had been flattened by the wind. The grubs had done serious damage practically all over the plantation. The plant-cane, most of which was treated by applying arsenic in the bottom of the drill along with the plants, also suffered severely. Investigation showed that the grubs had been forced out of the layer where they would have normally been in contact with the poison, because the soil was super-saturated, and that they were eating right into the stalks at the surface.

In our experimental field of D 1135, in which the arsenic was applied in May, 1920, after the drills had been pretty well filled in by rains and cultivation, we found results more encouraging. Though the winds had bent all the cane down, as is usually the case with this variety, that in the plots which had been treated with sufficient arsenic was still firmly rooted and growing strong. Furthermore, as an illustration of the

resistance of this variety, I found that even the cane in the checks, where the roots had been entirely eaten away by the grubs, had rooted from the nodes, wherever they touched the soil; this cane was growing strong again, with no indication of a shooting of the lateral eyes, as is commonly the case with Badila under similar circumstances.

The treated plots referred to in the March report, especially the one that had arsenic at the rate of 200 lb. per acre, showed splendid colour. Digging out a stool we found no grubs and the roots were most vigorous, about 12 inches in length. This favourable result is apparently due to the poison being nearer the surface, where the grubs continued to get it, even when forced upward by the excessive wet.

I was hopeful that this year we would be able to get conclusive results, but there is evidently much more to be learnt in regard to this feature of the problem of grub control, particularly as to the amount to use and the method of application; yet, though I am compelled to leave just when success seems imminent, I trust that this experimentation will be continued, even if it must be done by the individual growers, for I feel thoroughly confident of the ultimate success of these efforts.

Grub Diseases.

In my reports for January and February I alluded to the presence of the Muscardine fungus again in the fields at Greenhills. Naturally, the excessive moisture of the past month has been ideal for the development of these lowly organisms; hence a real epidemic has developed among the grubs in the fields wherever the spores occurred in the soil. On the 13th April we dug three stools in one of the abandoned fields in the same place where the grubs had died off in such numbers last season, and found only three living grubs, though there were many remains of grubs in various stages of disintegration, that had succumbed both to the Muscardine fungus and the bacterial disease. Since, earlier in the year when the grubs were just hatching, we found an average of over a hundred per stool in this location, it would appear that the contagion has again destroyed fully 99 per cent. of the pest in these favoured spots. Unfortunately these diseases do not occur throughout the plantation, for if they did it would be a serious blow to the grub-pest there.

In previous reports I have recommended the inoculation of infested fields with this spore-laden soil, and consider this a most feasible line of experimentation. Moreover it has occurred to me that this application could probably be most easily made by sprinkling a little of the infected soil over the plants in the planter. In this way every part of the field would probably become inoculated at the same time. Once we found a successful method of establishing these friendly organisms throughout our grubby areas I feel confident that it would go far toward mitigating this terrible damage.

Southern Trip.

During the month, in compliance with an urgent request from Mr. Gillies, the Minister for Agriculture, I went to Homehill to confer with the members of the Inkerman Farmers' Association, on a borer which they reported had been doing considerable damage to their cane. Fortunately I found that this was not the New Guinea beetle (*Rhabdocnemis obscura* Boisd.) which they had reported, but the far less destructive native moth borer (*Phragmatiphila truncata* Walk.),

which is usually held well in check by the two hymenopterous parasites, *Apanteles nonagriæ* Olliff and *Euplectrus howardi* Olliff. These borers were only seen in old standover cane and were doing little damage, so artificial control measures were not advisable.

A much more serious borer that I found there, in some of the sandy-loam fields near the river, was the large Termite (white ant), *Mastotermes darwiniensis* Froggatt. Fortunately this pest is not general, for if it were no cane could be grown. The whole pithy contents of long sticks had been removed from bottom to top, leaving only a thin hard rind, which still supported the green leaves of the plant. These same "ants." I am informed by Mr. G. F. Hill, are notorious devastators in the Northern Territory, where they will not permit sugar-cane to grow at all, and even hollow out and ringbark large trees such as figs, coconuts, &c. Moreover, they also destroy every organic product that is left within their reach, even eating one's boots if left on the ground overnight.

A disease closely resembling the Top-rot of Hawaii, described by Dr. N. A. Cobb,* really gives more trouble on the Lower Burdekin than any of the insect pests. This is not a very virulent disease, however, and it will probably be soon overcome by judicious selection of plants, especially in a region of such little rainfall.

During a hurried survey, both at Inkerman and at Pioneer, I was surprised to find grubs so scarce behind the ploughs. I was told, however, by observant farmers that the ibises (*Carphibis spinicollis* Reich. and *Ibis molucca* Cuvier) were always there, and I also saw great flocks of crows (*Corvus australis*) following the ploughs; though few grubs were turned up, they found many earthworms, &c. The ibises, I was told by Mr. A. C. F. Hemsley, a collector of birds' eggs for the Associated Museums, breed in great colonies near the mouth of the Haughton River. This evidently accounts for the continued presence of these efficient grub-destroyers in those districts, and probably accounts largely for the scarcity of grubs. Unfortunately the ibises are absent from the Cairns district from about February to June, at a time when they could be of the utmost service to us in destroying grubs, and the crows, as far as I know, do not occur at all.

I had many courtesies extended to me during this brief visit to the Lower Burdekin Valley, both by the farmers and the officials of the Pioneer Mill, which greatly facilitated my investigations, for which I wish to express my most sincere appreciation.

CANE GRUB INVESTIGATION, MAY 1921.

Following the deluge of March and April in the Cairns district, we have had almost constant daily showers, keeping the soil in a state of saturation. While this excessive moisture has improved the appearance of dying cane in grubby fields, it has made it very difficult to keep the young plant crop clean. Cane on the forest land, where there is scarcely an indication of grub injury, is making splendid growth, especially the D 1135, which is a variety splendidly adapted to the poorer soils. This cane, however, is unsatisfactory for the rich scrub lands, for the growth is too rank, and the stalks being so slender invariably lodge and root

* Hawaiian Sugar Planters' Assn., Div. Path. and Physiol., Circ. No. 5; and also given more fully in Bull. No. 6.

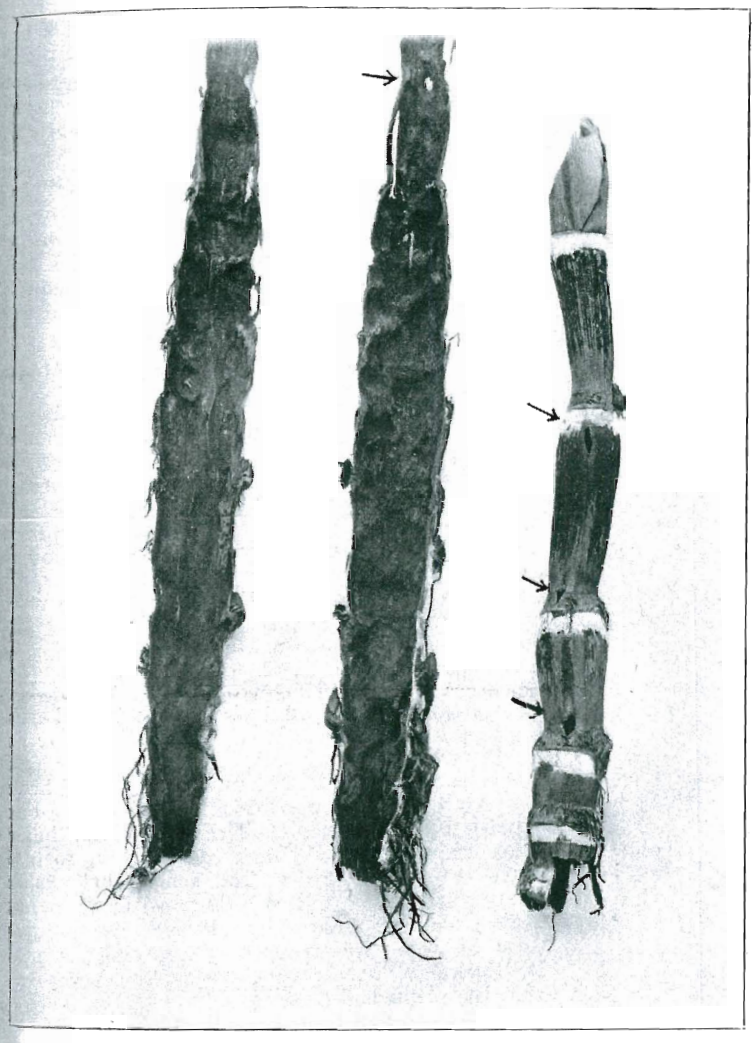

Figure 3.—Destruction of Sugar-cane by the Giant Termite, *Mastotermes darwiniensis* Froggatt. The whole pithy contents removed; the cavity extending the entire length of the stalks. The arrows point to openings in the rind made by the "ants."

to the ground wherever the joints touch. This we have found to be the result in our experimental plots at Greenhills; hence it will be a very troublesome cane to harvest.

The abnormal weather conditions, moreover, have upset our experiments with arsenic, though the fungous disease has caused a real epidemic again among the grubs, the excessive moisture and cool nights being just the conditions required for perfect development of these lowly organisms.

Effect of Flooding upon Grubs and Sugar-cane.

During the excessive rains of 1917 I found many apparently lifeless grubs lying about in the water on the surface of the soil. This appealed to me as a possible method of control, so I made some further observations. Much to my surprise, however, the apparently dead grubs soon revived when taken out of the water. Experimenting, I found that it required several days' submergence to really kill them.

Following upon the recent floods, we again took up this phase of the problem. By using pots of soil with one grub in each and submerging them we were able to get definite data. These showed that an overflow of 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 of the grubs could withstand an inundation of five days. These conclusions were further borne out by field observations, after the soil dried out so that we could dig in it.

The effects of flooding on the cane, however, was rather disastrous, causing the terminal shoot to rot, probably because of the silt that settles into the soft growing tissues. This results in a growth of the lateral buds, with a loss which may vary from 50 per cent. upward.

Grub Devastation and Arsenic at Greenhills.

The appearance of the cane on this estate is enough to make the strongest heart discouraged. The heavy standover crop, which went flat through the wind during April, is shooting badly at the eyes, so that it will probably deteriorate so much that it will be unfit to mill, and hence result in a total loss. The ratoon crops, too, were nipped in the bud, so that they came to nothing. The May 1920 plant cane, however, though the leaves had mostly dried brown by the action of grubs on the roots, is beginning to recover; new roots are forming and the terminal shoots are showing green again. This cane, though the stalks were fairly heavy, did not fall much, since it was planted very deep. It will probably give a fair cut.

There has been much correspondence on the use of arsenic; so I realise how anxiously growers are watching the results of our experiments. I am distressed, therefore, to report that placing the poison in the bottom of the drill with the plants has given no results, no matter what quantity was used, even up to 200 lb. per acre. This may possibly be due to the excessive moisture forcing the grubs to the surface, where they fed on the stalks without getting the poison.

On the other hand, where the arsenic was dusted alongside the young shoots when they were about 12 inches high, in May, 1920, the drills being pretty well filled in, we got results. These were most apparent, however,

Figure 4.—Devastation of Sugar-cane by Grubs at Greenhills. This heavy standover crop went down with the wind because the roots had all been eaten away.

where the poison had been used at the rate of 200 lb. per acre; cane treated with 100 lb. showed some injury, 80 lb. more, beneficial results being scarcely noticeable where 40 lb. was used. From time to time during the development of the grubs, we have removed stools of cane in the various plots to determine the effects of treatment. To review briefly:—Examination on 8th February, while the grubs were mostly in the first stage, showed scarcely any difference in the number per stool, whether treated or untreated. On 24th February, however, there was a marked difference, most of the grubs by that time having reached the second or third stage; the first untreated plot that we examined gave 45 grubs per stool, as has been noted in an earlier report, and there were very evident results in all of the treated plots, most of the larger grubs having been killed by the poison. By 11th March most of the cane in the checks was so badly injured that it fell out of the ground, while the treated plots, particularly the one with 200 lb. arsenic, showed results, though these decreased with the amount of arsenic that had been used. 11th May we excavated a cubic yard of soil in several plots, to determine definitely the effect upon the grubs; in the check-plot where we had found 45 grubs per stool on 24th February, we were now able to locate only 13 grubs full-grown, and 8 of these had been killed by the *Metarrhizium* fungus; furthermore, powdery green dust was also observed in the soil, where other grubs had disintegrated. Hence this disease had probably destroyed 90 per cent. of them in this check-plot; the roots of the plants were entirely eaten away and even the stalks gnawed badly. A similar excavation in the plot treated with 200 lb. arsenic disclosed only 2 large grubs, and these were about a foot away from the drill, where the poison had been applied; the roots in this case were solidly in the ground and almost perfect, being 12 inches or more in length. In the plot treated with 100 lb. arsenic the results were not so satisfactory; 6 large grubs were found, one of which had succumbed to the fungus; the roots of the plants, however, were still firmly in the ground, and the cane in fair condition. Since the cane in the plots with less than 100 lb. of arsenic showed little or no improvement over that in the checks, we did not take time to excavate in these.

I think we may conclude from these results that to be effective the poison should be placed about the plants near the surface. It is a heavy chemical; hence has a tendency to work downward during cultivation, and with the action of water.

In former years, when the whole of the cultivated ground on the Greenhills estate was planted to sugar-cane, there was a rather well-defined so-called immune area (*see* plan in my bulletin No. 8); most of the infested fields at that time were along the border, next to the timber, especially on the windward side. Last year, however, for the first time these infested fields (the shaded area on sketch) were thrown out of cultivation. It would appear now that this was responsible for the general infestation of the balance of the estate, the beetles being simply compelled to travel further in order to secure suitable conditions for ovipositing.

Beetle Borer Troublesome.

The publication of the beneficial results from the introduction of parasites of the beetle borer (*Rhabdocnemis obscura*) at Babinda has brought numerous letters from growers in various parts of the State, some of them even writing from districts outside the range of this pest, the latter of course mistaking the work of the widely distributed moth

borer (*Phragmatiphila truncata*) for it. Unfortunately, the wet weather has seriously interfered with the continuation of our collection and breeding of the parasites (*Ceromasia sphenophori*), and since I am compelled to give up the work before it is completed, let me urge growers, especially in the near-by districts, to make their own arrangements for getting material from Babinda. Since the flies are widely distributed in the whole area south of the mill, especially around Moolaba, it will not be difficult for anyone to secure borer-infested cane, cut up in short lengths, so that it can be put into a bag for shipment. To place this parasitized cane in the borer-infested field, I would advise preparing the soil between the rows, so that each stalk could be covered with about an inch of finely pulverised soil. This should be done only in a field which is to stand for two months or more, so as to give the flies a chance to escape, reproduce, and spread into other fields before the cane is cut. Let me also urge, again, the importance of a continuous supply of standing cane in each locality, so that these valuable flies can maintain themselves. Since a generation only requires five weeks, cutting all the cane at one time gives them no chance to find borers; hence the flies naturally die out without being able to reproduce. It is not necessary, however, to leave cane in every field, for a small area every mile or so is quite sufficient to keep them going in the district. Under normal conditions of harvesting this need cause no waste, for such cane may be cut late in the season after the other fields have come on again.

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