HARVARD INSTITUTE FOR TROPICAL BIOLOGY AND MEDICINE

I

# REPORT ON SUGAR-CANE BORERS AT SOLEDAD, CUBA

GEORGE SALT

II

# DRY-SEASON STUDIES OF CANE HOMOPTERA AT SOLEDAD, CUBA

J. G. MYERS

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## REPORT ON SUGAR-CANE BORERS AT SOLEDAD, CUBA

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## DRY-SEASON STUDIES OF CANE HOMOPTERA AT SOLEDAD, CUBA

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# I. REPORT ON SUGAR-CANE BORERS AT SOLEDAD, CUBA

BY GEORGE SALT

ANNA C. AMES SCHOLAR IN HARVARD UNIVERSITY

AND

# II. DRY-SEASON STUDIES OF CANE HOMOPTERA AT SOLEDAD, CUBA

*With a List of the Coccids of the District*

BY J. G. MYERS

1851 SCIENCE EXHIBITION SCHOLAR FOR NEW ZEALAND, 1924



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# I

# REPORT ON SUGAR-CANE BORERS AT SOLEDAD, CUBA

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## INTRODUCTION AND ACKNOWLEDGMENTS

During the early part of 1925 it was the good fortune of the writer to spend nearly six months at the Harvard Biological Laboratory at Soledad, Cuba. About ten weeks of that time, scattered at intervals from March until June, were devoted to the study of sugar-cane borers, at first with the simple object of determining the status of Diatræa on the estate, but later with a more ambitious plan.

The meagre time it was found possible to devote to such a comprehensive subject, and the lack, during the course of the work, of literature which would have saved time and afforded guidance, were serious handicaps; and the writer feels that this report would be premature were it not that the need which it is intended to supply is so great. For that the subject is one worthy of our best attention will readily be granted after a consideration of the section dealing with the losses caused by the borers; and that the existing literature on Cuban sugar-cane borers is both scattered and scanty will be seen by a perusal of the appended bibliography.

There are in Cuba a number of scientific workers on various problems, especially that of the sugar-cane mosaic; there are, moreover, a large number of administrators and executives who are vitally interested in any factor which affects the production of sugar; finally there are a few, a very few, entomological workers and some one or two of these engaged particularly upon a study of borers. It is the hope of the writer that the present paper will have interest for each of these classes. Parts of it are contributions to our knowledge of sugar-cane insects and may be of use to entomologists; other parts, the section on the recognition of the borers for instance, are in-

tended primarily for workers not especially interested in entomology, and so have been written with as few technical details and terms as possible.

To Mr. and Mrs. E. F. Atkins, whose generosity afforded the opportunity to make this study, I tender grateful thanks. To the many kind folk at Soledad, and to Mr. and Mrs. W. E. Leonard in particular, I am deeply indebted for invaluable assistance in my work and for an unfailing hospitality which rendered my visit delightful. My acknowledgments are due and gratefully given to the specialists of the United States Bureau of Entomology for authoritative determination of the insects herein discussed, and to my father, Mr. W. Salt of Calgary, for preparing my photographs for reproduction. I am deeply grateful to Mr. J. G. Myers, my congenial companion in Cuba, for kindly criticism and invaluable assistance during the course of the investigation. To Dr. W. M. Wheeler and Professor C. T. Brues of the Bussey Institution, Harvard University, I wish to express my very deep indebtedness for valuable suggestions in the preparation of this report. Finally, I most heartily thank Dr. Thomas Barbour of the Museum of Comparative Zoölogy, Cambridge, whose encouragement has been to me personally an inspiration and whose enthusiasm for tropical biology has placed all future workers at Harvard House, Soledad, under a real and lasting obligation.

## RECOGNITION OF THE BORERS

Among the insect pests of sugar-cane in Cuba the most important from an economic standpoint are those familiarly known as "borers." Though belonging to the most diverse groups in the system of classification, these insects have in common the habit of boring into the sweet succulent stalk of the cane, thus providing themselves at once with nourishment and a place to live.

Four of these borers, belonging to three different orders of insects, came under the personal observation of the writer when, during the early part of 1925, he was privileged to visit the Harvard Biological Laboratory at Soledad, near Cienfuegos,

Cuba. These four — *Diatræa saccharalis* (Fabr.), the Sugar-cane Moth Borer; *Metamasius sericeus* (Oliv.), the Weevil Borer; *Xyleborus sp.* (probably *perforans* Woll.), the Shot-hole Borer; and termites of the species *Nasutitermes morio* (Latr.) — form the subject of the present report.

The Sugar-cane Moth Borer, *Diatræa saccharalis* (Fabr.), in its adult stage is a small moth about three or three and a half cm. in wing expanse. The pale straw-colored fore-wings are crossed with fine, light brown lines; the hind-wings, hidden under the fore-wings in repose, are white. (Pl. I–3.)

The female moth places her eggs on the leaves of the cane in clusters of from ten to forty; and is capable of laying on the average about two hundred eggs in all. In about five days the eggs hatch. The young larvæ feed for a short time on the leaves, but soon bore into the stem. Here they grow rapidly, finally assuming the familiar appearance of the "borer," a larva about two and a half cm. in length, cream-colored except for the dark brown head and prothoracic shield. (Pl. I–1.) Another form, in which the segments of the body are ornamented by numerous dark spots, occurs during the summer months and is found occasionally during the winter. (Pl. I–1A.) It is in this last larval stage that the borer does most of its damage, gorging itself on the tissues of the cane and satisfying its "sweet tooth" at the expense of the grower.

When full grown the larva bores toward the surface of the stem, usually perforating the rind to form an emergence hole, but sometimes leaving a very thin layer of the rind untouched. Just inside its tunnel the larva transforms into a brown pupa, a dormant stage doing no damage to the cane, but lying quiescent except for movements of its abdomen from side to side. (Pl. I–2.) After a rather variable period, usually about eight or nine days, the adult moth emerges. Larvæ, pupa, and adult are represented by illustrations.

The adult *Metamasius sericeus* (Oliv.), the Weevil Borer, is a beetle nearly one and a half cm. long; the head, thorax, and fore part of the elytra yellowish-brown except for a median black line running backwards from the head. The remainder

of the elytra is jet black, the legs and snout are fuscous. (Pl. I–7.)

By means of her beak, and the mandibles at its tip, the female makes a tiny hole through the rind of the cane and within its tissues lays one or more eggs. Again the damage is done by the larval stage. When full grown the weevil larva is approximately two and three tenths cm. long, rather stout in form, and legless, of a creamy-yellow color but with a bluish tinge sometimes showing through the transparent skin. The head capsule and prothoracic plate are reddish-brown. (Pl. I–5.) It is readily distinguished from the larva of the moth borer by the absence of legs and by its much stouter appearance, for though about the same length, it is nearly twice as great in diameter.

On attaining its full growth the weevil larva forms a cocoon by winding long fibres of the cane around itself. The cocoon, about three to four cm. long and one and a half cm. in diameter, is very strong and compactly woven, the fibres being usually wrapped around its short circumference rather than from end to end. (Pl. I–6.) Inside this cocoon the larva transforms into a cream-colored pupa, which gradually darkens, becomes harder, and finally pushes its way through the cocoon, to emerge a perfect insect.

The Shot-hole Borer, *Xyleborus sp.* (probably *perforans* Woll.) differs from the two borers just described in that it also bores into the cane as an adult insect whereas the two preceding live inside the cane only in the larval and pupal stages. It is a very small beetle, at most only three mm. in length, light brown in color, with darker brown on the hinder part of the abdomen. (Pl. I–4.)

The common termite boring into cane in Cuba is *Nasutitermes morio* (Latr.), which builds the familiar carton nests on trees and fence-posts along most Cuban roads. Another termite, *Leucotermes sp.*, also occasionally attacks cane. Winged and wingless forms occur, the wingless in two castes, soldiers and workers. These insects usually occur in large numbers together in one cane. They have a soft light-colored body seven

or eight mm. long, and move about actively by means of jointed legs. They are so readily distinguishable from the other borers that further description is unnecessary.

### Recognition of Borer Injury

Comparatively seldom, however, are the borers caught red-handed at their nefarious trade; adults of the moth borer are never found inside the cane, larvæ and pupæ only sometimes, depending on the season. Most usually all that is left is the empty pupal case, and frequently this too has disappeared. Of the weevil borer the customary sign is the empty fibre cocoon.

This being the case, necessary as it is to recognize the various borers, it is still more necessary for practical purposes to be able to distinguish the damage they cause, so that a piece of bored cane may be at once charged against the insect to which its injury is due.

To ensure this recognition a series of photographs of bored canes has been prepared, which, though almost self-explanatory, may be aided by a few words of description.

Simple drying of cane which sometimes simulates the appearance of a boring is readily distinguished by the general dried and shrivelled appearance of the cane throughout its whole length, and by the angular cross-section of the hollow centre. (Pl. IV.) It is frequently met in fields in which canes have been killed by root-rot or other disease.

Diatræa injury is easily recognized by the clear-cut, round tunnel, usually straight and only one or two internodes in length. It is almost invariably marked by a lining of red tissue, caused by the entry of a fungus which penetrates the walls and turns them a bright red. The external opening is a well-defined round hole about three mm. in diameter. (Pl. II.)

When younger cane is attacked by Diatræa it is usually bored at the top causing in young ratoon cane the familiar "dead heart." The tunnel in this case is inclined to be shorter and more tenuous, perhaps on account of the physical impediment afforded by the more numerous nodes. (Pl. II.)

Weevil injury cannot be confused with any other. From the beginning of its depredations the weevil borer is a ruthless destroyer of the tissue, the cane is practically hollowed, only the stout outer rind is left intact. The boring is not clean and regular, but is filled with brown granules of triturated wood and fæces, with shreds of the fibres. It may extend through several internodes, especially if there be many larvæ in it at once, usually through three or four and sometimes as many as six or eight. Soon after the beginning of the attack the cane becomes dry and the tissues turn brown. As a rule, there is no red rotting of the stalk such as is found in Diatræa borings. If the larvæ are not present, the unmistakable seal of the weevil borer is frequently left in the form of the fibre cocoons. The external opening is a much larger hole than that of Diatræa, from four to six mm. in diameter, and usually approaches the surface obliquely. (Pl. III.)

The Xyleborus boring is a small tunnel usually found on or near the node. Often, especially in dead and dried canes, there are several borings together, their openings clustered on the surface of the cane like so many shot-holes. The tunnels do not enter very far, and are so small that it is a difficult matter to follow them. They are not illustrated by a photograph.

Termite injury may be distinguished by the multiplicity of parallel passages, each one clear and distinct and separated from the next by a wall of tissue, which is quite stiff though it may be as thin as paper. There is usually no red rot present, but a general darkening of the tissues. (Pl. IV.)

A "dead heart" caused by a Diatræa larva is often found to contain between the brown, rotting, young leaves and usually also perforating them, numerous small larvæ not quite a centimetre long when full grown, creamy-white in color, and generally accompanied by a somewhat fishy odor. These are the larvæ of the small greenish fly, *Chætopsis debilis* Lw., which, rendered conspicuous by its spotted wings, is so ubiquitous in Soledad and its environs.

The larvæ feed not only on rotting cane hearts but also on

various ripe fruits, for I have noticed adults flying about bananas, mangos, and the fruit of a species of *Sterculia* whose odoriferous decomposing pulp contained larvæ apparently identical with those from the cane.

If the borer has already left its tunnel, these larvæ might be considered to be the cause of the injury. They are quite innocent of it, however; their presence is purely secondary and follows the rotting of the delicate tissues of the heart of the cane initiated by the cane borer. The fly, then, cannot be said to be either beneficial or very harmful, and it is mentioned in this place merely because the presence of its larvæ in rotting hearts might be taken by the uninitiated to be the cause of injury to the cane.

## *DIATRÆA SACCHARALIS*, THE MOTH BORER

### *A*. The Prevalence of the Moth Borer

#### 1. AMOUNT OF INFESTATION

(a) *Mill Survey.* As the sugar-cane is cut at Soledad, it is cleaned of its leaves and top. With swift, dexterous, slashing strokes, in the glare of the hottest sun, the cutter seems with but a single motion to grasp each stalk, cut and top it, with the back of his machete scrape off the adherent leaf bases and send it hurtling through the air, as two simple yard-long sticks, to his pile, two or three yards away. Each pile contains the cane from the area around it to a radius of about five yards. Later in the day bullock-drawn carts plough through the rustling trash, and, an armful at a time, each cart is loaded in four regular cross-wise stacks. At the nearest "apparatus" the cane is lifted bodily from the cart by four chains passed beneath it, and hanging poised for a moment as it is weighed, it is then lowered into a waiting railway truck. The cane from four carts is required to load a single car. Engines draw the cars from the various colonias to the mill, where they stand in the yards until needed. Then, one by one, they are moved to the scales, weighed, and their contents emptied into a hopper, whose movable bottom, leading to an escalator, carries away

the product of quiet sunny fields to the darkness and din of the factory.

The prevalence of Diatræa in the cane-fields of Soledad is indicated by the results of a mill count of over twelve thousand stalks of cane, made in the following manner. One hundred stalks were removed from each of the cars required for examination, after the car had been weighed and while it was standing ready to be emptied into the hopper of the elevator. A proportion was observed between the number of stalks examined from each colonia and the size of that colonia as indicated by its estimated production of cane. Thus from the smaller colonias only 500 canes (representing 5 cars) were tested, from the larger 1000, and from very large colonias even more, up to 1500 canes.

These results are summarized in the following table:

TABLE I. SUMMARY OF MILL SURVEY. CENTRAL SOLEDAD. CROP 1924–25

| Colonia | No. of canes examined | No. infested by Diatræa | No. infested by Xyleborus | No. infested by Metamasius | Total No. of canes bored * | Per cent of canes bored | Per cent of canes bored by Diatræa | Parasitism (No. of empty fly puparia) | Intensity Index (Diatræa only) |
|---|---|---|---|---|---|---|---|---|---|
| La Vega | 1,510 | 301 | 12 | 17 | 325 | 21.52 | 19.93 | 2 | 1.87 |
| Rosario | 1,023 | 59 | 3 | 0 | 62 | 6.00 | 5.7 | 1 | 1.627 |
| Josefa | 993 | 141 | 10 | 3 | 149 | 15.00 | 14.2 | 1 | 1.77 |
| Lajitas | 496 | 99 | 2 | 0 | 100 | 20.16 | 19.96 | 2 | 1.69 |
| Limones | 1,115 | 247 | 12 | 6 | 261 | 23.40 | 22.15 | 8 | 1.90 |
| Caledonia | 996 | 147 | 3 | 4 | 151 | 15.16 | 14.76 | 7 | 1.81 |
| Guabairo | 298 | 24 | 0 | 1 | 25 | 8.39 | 8.05 | 1 | 1.79 |
| San Estéban | 498 | 64 | 3 | 7 | 74 | 14.86 | 12.85 | 3 | 1.625 |
| Viamones | 507 | 65 | 0 | 1 | 66 | 13.01 | 12.82 | 2 | 1.93 |
| Dolores | 502 | 109 | 0 | 1 | 110 | 21.9 | 21.71 | 8 | 1.92 |
| Sixto Roque | 496 | 111 | 8 | 5 | 120 | 24.19 | 22.38 | 7 | 1.89 |
| Gutierrez | 1,013 | 341 | 22 | 10 | 358 | 35.34 | 33.66 | 16 | 2.09 |
| Cantabria | 1,314 | 284 | 9 | 3 | 292 | 22.22 | 21.61 | 11 | 1.93 |
| Manacal | 506 | 111 | 0 | 12 | 122 | 24.11 | 21.94 | 8 | 2.23 |
| Belmonte | 505 | 67 | 1 | 0 | 68 | 13.46 | 13.26 | 1 | 1.985 |
| Small colonias | 399 | 81 | 0 | 1 | 81 | 20.30 | 20.30 | 0 | .... |
| Totals | 12,171 | 2,251 | 85 | 71 | 2,364 | 19.42 | 18.49 | 78 | .... |

* There is an apparent discrepancy in the total number of canes bored, as it is not the sum of the numbers of canes attacked by the different borers. This is because a cane bored by two different insects, as occasionally happens, was listed under each of them, but was counted in the total as only one bored cane.

(b) *Field Survey.* In addition, a field survey was made of some 2600 canes. The method in this case was to take one hundred canes from the cutters' piles in the field. The cane examined was thus the same as that which could be seen at the mill, but was localized to a small surrounding area of a few square yards which could be studied intensively. These figures are tabulated in Table II.

TABLE II. SUMMARY OF FIELD SURVEY

| Colonia | No. of canes examined | No. infested by Diatræa | No. infested by Xyleborus | No. infested by Metamasius | Total No. of canes bored | Per cent of canes bored | Per cent of canes bored by Diatræa | Parasitism (No. of empty fly puparia) |
|---|---|---|---|---|---|---|---|---|
| La Vega .... | 927 | 254 | 9 | 34 | 290 | 31.28 | 27.40 | 5 |
| Rosario..... | 1,000 | 60 | 10 | 7 | 74 | 7.40 | 6.00 | 1 |
| Josefa ..... | 300 | 25 | 4 | 0 | 28 | 9.33 | 8.33 | 0 |
| Limones .... | 400 | 104 | 8 | 0 | 108 | 27.00 | 26.00 | 9 |
| Totals .... | 2,627 | 443 | 31 | 41 | 500 | 19.03 | 16.86 | 15 |

(c) *Disadvantages of the Field Count.* The field counts, which will be discussed in detail later and are given in summary here merely for the sake of completeness, were made rather as a study of particular field conditions than as a survey, and for two reasons are to be disregarded in this report as an index of the general prevalence of the borer. (1) Only a few colonias are represented and in these no proportion is observed between the number of canes examined and the size of the colonia. (2) The mill count for Diatræa is far more extensive and accurate than a field count involving the same time and amount of work could be. The count in the field is based on individual piles of cane representing but a few square yards; the count at the mill is based on cars each of which contains many piles, for not only do several piles go to make up a cartload, but the contents of four carts often from very different parts of the field go to make up a car. Thus, when a general sample is taken of a car, as is the case when canes are taken from the top at both ends and from the sides below, the sample is far more truly representative of the field than a

hundred canes taken from a pile representing only a very small area.

Even at this it will be noticed that the figures of the field count closely approximate those at the mill, and were all the colonias represented just as in the mill count, undoubtedly the results would correspond even more closely.

(d) *Summary.* Neglecting the field counts, then, and considering only those made at the mill, the borer infestation at Soledad is seen to be 19.42 per cent of all canes reaching the mill, Diatræa alone accounting for 18.49 per cent. That these figures, high as they are, are still far lower than those of many other centrals in Cuba is shown by the fact that at two other centrals for which the writer has data and at which 5300 and 6300 canes were examined in a manner exactly the same as that at Soledad, the infestation of Diatræa was 28 per cent and 31.78 per cent respectively.

### 2. SOURCES OF ERROR IN THE MILL SURVEY

It is very necessary to bear in mind that these figures do not represent the actual amount of borer infestation, but merely the amount of infestation in the cane going through the mill; in every case they are undoubtedly far too low, and for certain borers are so low as to be useless for all but comparison.

In the first place, each stalk as it is in the field before cutting arrives at the mill in two pieces, each of which must there necessarily be considered a unit. The percentage of infestation of these mill stalks, therefore, is not the same as that of the complete stalks in the field. This is a difficulty which cannot be avoided, but since, as will be shown later, the mill count cannot be claimed in any case absolutely to measure the prevalence of the borer in the standing cane, it may be neglected. It should be mentioned, however, that, as a moment's thought will suffice to show, this fault tends always to render the mill count too low and cannot in any case exaggerate the infestation.

It is obvious that the cane arriving at the mill, which is identically the same as that seen in the cutters' piles, does not

truly represent the cane as it is in the field: many infested canes become light in weight, shrivelled, or dry, and so are left in the field by the cutters, and at the mill are not seen. That significant discrepancies occur here is shown by two tests.

(1) A small area, of about five yards square, was marked out and cut entirely, every cane, dry or green, being considered. The figures thus obtained were compared with the immediately adjacent cutter's pile not more than five yards away. The average of two such tests showed 5.97 per cent more borer in the cane cut entirely than that in the cutter's pile. Since the latter represents the cane which goes to the mill, 5.97 per cent here represents the difference between the infestation apparent in a mill count and the actual prevalence in the field.

(2) Examination of dried sticks left on the field by the cutters compared with the cut cane from the same area afford the same data as the above test in a different way. At La Vega a field was thus tested during the cutting. The amount of infestation according to the cutter's pile in one place was 22 per cent. Without going outside an area of a radius of four yards from this pile, a hundred dead sticks left by the cutters were picked up, — no claim is made that all the dead sticks present were found, — and this hundred sticks showed a borer infestation of 52 per cent, making the average for the two hundred canes from the same area 37 per cent, or 15 per cent higher than the cutter's pile indicated. There can be no doubt that the mill count is too low as an absolute measure of the prevalence of Diatræa in the cane.

The count may be low, moreover, owing to the failure of the observer to note all bored stalks. When an investigator is examining hundreds of canes for a small round hole often obscured by dirt, he is very apt to miss one occasionally; but since all bored canes are put on one side and later cut open and the tunnels examined, it is impossible to count as a bored cane one that is sound. This factor, therefore, is not balanced; all errors tend to make the count too low. With care, of course, the number of mistakes can be reduced so as to be insignificant,

but the danger is ever present, especially in canes lightly bored or in which the Diatræa larva is young.

In spite of these limitations and sources of error the mill count for Diatræa is of great use, and not only is, but probably will continue to be, our chief source of information on the prevalence of the borer in Cuba. Its ease of execution and the ready representation of large areas it permits commend it for extensive surveys; and as well as affording exact comparative data between fields, districts, or centrals, it does give a very exact measure of the loss in cane entering the mill. Indeed, as a means of ascertaining the prevalence of a pest, the mill survey of sugar-cane for Diatræa, so far as cane entering the mill is concerned, is almost unique in economic entomology for its accuracy.

### 3. INTENSITY OF THE INFESTATION

When the bored canes as shown by the small perforations of the rind had been separated from the sound stalks, they were split open and the boring traced throughout its course with a knife. Parasitism, the stage of the borer, and many other data were thus collected, and especially was recorded the number of internodes of each cane which were injured. This amount of boring of the bored cane the writer has been calling the *intensity* of the infestation as distinct from the *percentage* of infestation or *prevalence* of the borers. As a unit of this intensity the writer has used an *Intensity Index* by which is meant the average number of bored internodes per bored cane. A percentage of internodes bored, necessitating a count of sound internodes as well, would perhaps have been better, but was not undertaken. A count of some hundreds of canes gave an average of about twelve internodes per cane, so that, if necessary, the figures given may be approximately converted to a percentage of internodes bored.

One of the most interesting facts in connection with the intensity of the boring is the correlation it shows with the percentage of infestation. If a graph be drawn having measured along one ordinate the percentage of infestation and along the

other the intensity index, and these figures for the various colonias be plotted, they will be found to be arranged in a broad but definite band, those having a high percentage of infestation also having a high intensity. A glance at the graph (Fig. 1) will show that this correlation is quite high.

Moreover, it will be noticed that the points of the graph may be roughly joined to form two distinct lines, each line following the general tendency of an increased intensity with an increased percentage of infestation, but following it on a different ratio. Lajitas alone seems to be outside the general plan.

This double-line graph seems to suggest that the intensity varies only within certain limits; above these limits the stalk is probably killed and does not reach the mill. The prevalence of the borer is not so limited, however. It is suggested that the intensity varies with the infestation within limits; those limits being reached, the moths tend to spread themselves over more canes rather than to reinfest canes already bored. Further reference to this two-lined graph will be made later.

### *B.* The Distribution of the Moth Borer

There is a wide range in the percentage of infestation of Diatræa in the various colonias at Soledad, the lowest being 5.7 per cent at Rosario, based on a count of 1023 canes, and the highest 33.66 per cent on the colonia of Gutierrez, based on a count of 1013 sticks. The factors influencing such a distribution undoubtedly warrant investigation.

The annual rainfall is approximately the same over the whole of Central Soledad. The variety of cane grown is uniformly Crystalina. The burning of trash is practically never practised in any section, nor is cane burned before cutting, accidentally or with intention, in any one colonia more than another. With these three important factors — rainfall, cane variety, and burning — uniform, the central is ideal for a study of the factors influencing the local distribution of Diatræa.

As the starting-point for field investigations Rosario and La Vega were chosen, having a Diatræa infestation as shown

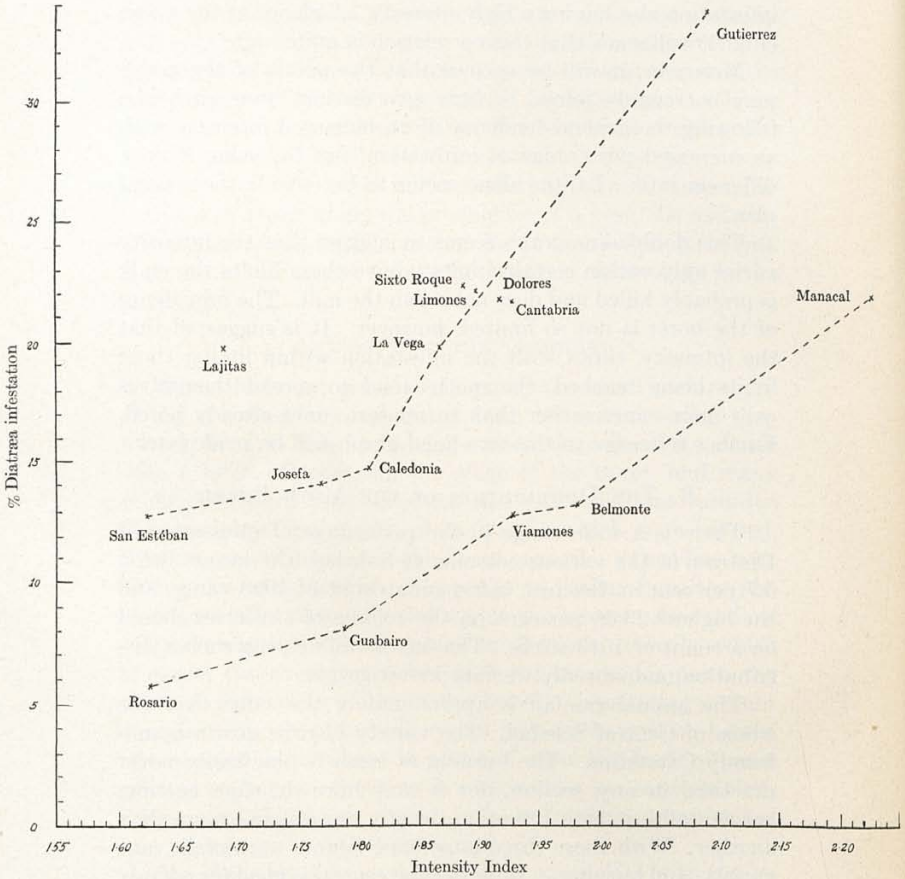


FIG. 1. GRAPH SHOWING CORRELATION BETWEEN THE PER CENT OF THE DIATRÆA INFESTATION AND ITS INTENSITY

by the mill count (Table I) of 5.7 and 19.93 per cent respectively. Counts made in the field at cutters' piles supported this large difference, giving at La Vega 27.4 per cent and at Rosario 6 per cent (Table II), with the advantage of being localized to definite fields or parts of a field.

At Rosario a start was made at the base of a hill; the Diatræa count was 18 per cent. Half-way up the hill the count was exactly 12 per cent, and on the first pile at the top only 6 per cent. A little farther on the crest of the hill, at the same altitude as the last, the count was 7 per cent, and again, a few yards over but still on the very top of the rise, only 6 per cent. Removal of the cane put an end to further counting.

At La Vega four adjacent piles were examined on the very top of the rise from a wide valley planted with cane. These four piles, adjacent in position, were very close in infestation, giving the figures 22, 25, 25, and 26 per cent, or an average of 24.5 per cent. A pile was next examined several yards down the slope; it showed 31 per cent borer. Another pile about five yards farther down the hill showed 42 per cent. Finally, a pile in the valley bottom showed 48.27 per cent.

The regularity of the increase of borer from hillside to valley bottom in this case exactly parallels the case at Rosario.

Furthermore, when the colonias are considered as a whole, Rosario, a notoriously hilly and rolling colonia, has but 5.7 or 6 per cent of boring; La Vega, for the most part low land, indeed, in the part examined consisting of a drained swamp, has 19.93 or 27.4 per cent according as one considers mill or field counts.

A further study was made at Rosario, but unfortunately the hillside chosen for examination showed practically no boring at all, of five tests one being free of Diatræa, another infested only 1 per cent, and so on. So that, though there was an increase of one half of one per cent at the bottom as compared with the top, the difference was not so striking as before.

At Limones the test was made in a hilly field of Uba cane. The top of one hill showed 22 per cent, its base on one side 23 per cent, and its base on another side, at right angles, 28 per

cent. A pile on the top of a neighboring hill, however, gave 31 per cent, the only pile in the whole investigation which did not follow the general rule. Removal of the cane again prevented further investigation.

This gradation of borer infestation is too striking to be overlooked, and deserves and needs additional investigation. Unfortunately the ending of the crop at Soledad prevented further examination of the point in this way.

Support is given to the above-suggested thesis, however, by a consideration of the colonias as a whole. The arrangement of the colonias in the graph (Fig. 1) forming two lines has already been mentioned. When attention is focussed on the colonias which go to make up these lines, it is seen that the lower of the lines, including colonias of a lower average infestation, is composed of hilly colonias: Rosario, Guabairo, Belmonte, Viamones, and Manacal. Belmonte has some low-lying land, but I was fortunately able to trace the cane examined from that colonia to the fields whence it came, in each case from a hillside, so that for our purpose Belmonte is entirely a hilly colonia.

The other line, on the contrary, comprises colonias for the most part low-lying and flat. San Estéban and Josefa, flat plains bordering on the river; Caledonia, largely of low lands, part of it a reclaimed swamp; La Vega, already mentioned as being low-lying. The next four colonias occurring in a group are somewhat mixed: Dolores, Cantabria, Sixto Roque, and Limones all have both hilly and low lands, and unfortunately in this case it was not possible to locate definitely the tested cane, though that from Dolores and Cantabria may be said almost certainly to have come from valley lands.

Neglecting for lack of data Sixto Roque and Limones, with the exception of Lajitas, which does not seem to fit in with the general scheme, the colonias fall definitely into two groups, the hilly ones having on the average a lower infestation, the low-lying ones a higher infestation, but both running through the same range of intensity.

While regretting the paucity of his evidence on this point, the writer is forced to the conclusion that topography has

much to do with the distribution of Diatræa; that in low-lying lands and valleys the infestation tends to be high, and on hilly or high lands the same tends to be low.

This, of course, is not an explanation; it itself requires elucidating, and that the writer is unable to do, as the shortness of his stay did not permit investigation of the point. He suggests, however, that the more succulent and green growth in valleys during the dry season, and particularly during January, might attract the moths, which would lay eggs and cause the bored cane that is apparent in March and April, the months when this survey was made.

This suggestion is borne out by a remark made by J. C. Hutson (1916) in his article based on the report of H. W. B. Moore in British Guiana. He says, "This seems to show that among wild plants, *D. saccharalis* has a preference for more or less aquatic grasses, and may indicate that wet weather might be favorable to this borer in the cane-fields." While the preference of Diatræa for aquatic grasses does not necessarily mean that wet weather is favorable to it (indeed, the opposite has been claimed by Wolcott, 1915), it seems plausible that the preference of Diatræa for aquatic grasses might lead to the greater infestation of the green succulent growth of cane in low lands and valleys.

The absorbing subject of the physiological condition of the cane in relation to its infestation by Diatræa seems here to invite speculation. In a suggestive sentence in the discussion of one of his interesting papers on the biology of aphids, Davidson (1921, page 63) says, "Experience in breeding aphids shows that in investigating the reproduction on different hosts, the following factors must be considered: (*a*) The physiological condition of the plant, especially with regard to its age, temperature, light and food." It seems more than probable that the physiological condition of sugar-cane may have much to do with the various life processes of the borer. The relations of an insect pest and its plant hosts may yet be found to be as strikingly correlated with the physiological state of the plants as they have hitherto seemed to be linked up with the affinities of the various food plants in the system of classification.

Attempts to determine other factors, including notes on soil, presence of weeds, and proximity to roads or *guardarayas*, gave only negative results. Canes counted at Josefa and at La Vega, to see whether fields were more seriously infested at the sides or in the middle, showed that where the altitude was the same, there was no difference. The presence of considerable *Bidens sp.* in the cane at Rosario suggested that parasites might be attracted to the fields there by this plant and thus keep down the borer. This idea was not elsewhere supported, however, nor has the writer commonly seen the Cuba fly, *Lixophaga diatrææ*, at *Bidens* flowers.

### *C.* Losses Due to the Moth Borer

An analysis of the losses suffered by the sugar industry in Cuba due to the Sugar-Cane Moth Borer, as based on investigations at Soledad, shows that these may be grouped as "Field Losses" and "Mill Losses" according as they become apparent in the field or the mill.

The field losses reduce the tonnage yield of cane, and include: 1. Losses due to seed-piece infestation (decreased germination, etc.). 2. Losses due to stalks killed. 3. Loss in size and weight of stalks infested. 4. Indirect losses due to borer attack. Mill losses, although they might be analyzed further, are here treated as one, the decrease in the sugar content of the cane which becomes apparent during the milling operation.

#### 1. SEED-PIECE INFESTATION

Cane being cut up for seed-pieces in Cuba is usually carefully examined. Only older, more experienced men are employed in selecting the canes and in cutting them to the proper length. It must not be supposed, however, that the care they exercise by any means eliminates bored cane from the seed; for one who has watched the operation must have noticed that the method of selection is peculiarly ineffective as an examination for borer injury.

The attention of the cutter is fixed solely on the cut end; if the cane is there sound and healthy, it is cut off again twelve to

eighteen inches farther up, and the seed-piece drops on the pile. Dried or rotting stems are in this manner readily noticed, for the drying or rotting extends down the length of the cane; but borer tunnels, unless they happen to show on the cut ends, are missed, no matter how riddled the intervening ten to sixteen inches may be.

Counts of seed-pieces at Soledad show that much bored cane is used as seed. At Limones, two cutters of six and nine years' experience in selecting seed were found to be cutting seed-pieces of which 24 per cent were bored, 13 per cent being rather severely injured. At Santa Teresa, of 358 seed-pieces examined, 40, or 11.17 per cent, were bored. At Josefa, of 1169 seed-pieces examined, 120, or 10.26 per cent, were bored. The amount of bored cane used as seed is undoubtedly closely correlated with the amount of bored cane in the field from which the seed cane is taken. This suggests one of the methods of control to be discussed later, the use for seed of a field of cane as nearly free of borer as possible.

It having been shown, then, that under existing conditions of seed selection much bored cane is being planted, it remains to show the results of planting this injured seed.

In an attempt to estimate the losses in germination of seed injured by the borer, experiments were carried out in the field on two colonias. At Santa Teresa the experiment was on rather a small scale. Two short adjacent rows were planted, one containing 39 bored, the other the same number of sound seed-pieces, set sufficiently far apart to render counting of the individual stools easy. A month after date of planting, 61.5 per cent of the bored cane had germinated, and 68.2 per cent of the sound. Thanks to the interest and kindness of Mr. R. Emerson, student of Entomology at Harvard House, it is possible to add further that on the eighth of August, two months after date of planting, there were 33 stools in the row of bored seed-pieces, or 84.6 per cent germination, and 36 in the row of sound canes, of which therefore 92.3 per cent had grown.

The experiment at Josefa, fortunately, was more compre-

hensive. Five rows of bored and five adjacent rows of sound cane were planted. After a month the young shoots were counted as follows: bored cane 84.87 per cent germinated; sound cane 97.81 per cent germinated. Again, the writer is indebted to Mr. Emerson for completing his data, as after still another month this observer found that 90.51 per cent of the sound seed-pieces had produced sturdy stools, but only 77.3 per cent of the bored had done likewise. Counting the individual canes, however, he found very little difference in the production of shoots by bored and unbored seed-pieces. The bored seed that had germinated had produced an average of 2.11 canes per stool, the sound seed 2.19 canes per stool.

The chief effect of planting bored seed-pieces, therefore, seems to be rather a complete failure to germinate on the part of many of the seed-pieces rather than a retardation of growth or weakening of the subsequent shoots.

This germination loss in the opinion of the writer is to a large part secondary; that is, the failure of the seed-pieces to develop is not directly due to the presence of the borer tunnel, though in some cases it may be so, but more largely to the opening of the seed-piece to attack by various soil-fungi and insects, from which it is normally protected by its tough outer rind and, at the cut ends, by the nodes.

The use of bored seed-pieces also gives rise to the danger of distributing and preserving the borers. Moth borers present in planted cane are known under some conditions, when the cane is not too deeply planted, to be able to make their escape. The distribution of borers in this way in Soledad is of minor importance, as very little seed cane is transported, each colonia growing its own. The preservation of the pests depending on their ability to emerge from planted seed cane was not investigated. It may be reported, however, that during the time of planting (May 20 to June 15) the borer was largely present as mature larvæ and pupæ, the most favorable stages for preservation in planted cane; but that during the same period very heavy rains made the condition of the soil extremely unfavorable for the emergence of the adults.

### 2. STALKS KILLED

Figures already quoted have indicated the large number of dead stalks found in fields attacked by borers. In a field at Caledonia a very large number of dead sticks were lying about among the trash after the crop, and of these 58 per cent had been bored by Diatræa. At La Vega 52 per cent of the dead sticks lying about had been bored by Diatræa, and most of the remainder by another borer to be mentioned later; whereas, of the living stalks of the same area, only 22 per cent were attacked. In another field, 7.2 per cent of the living stalks were infested, but 16.19 per cent of all stalks living and dead. In still a third field at La Vega, by cutting a small area of cane entirely, taking both dead and living stalks, 13.4 per cent of the stalks were found to be dead; the dead stalks 100 per cent bored and the living only 48 per cent. Unfortunately this last is the only absolute count of the proportion of dead to living stalks available; but from it and from the three instances of which the data are comparative, one is justified in assuming that at these points a fairly large proportion of canes were killed by borer attack.

The killing of young ratoon canes by the borer, causing the brown rotting of the growing point and young leaves known as "dead heart," was apparent at Soledad in June only to a slight extent, and counts of this injury were not undertaken.

Accurate measurements of the loss in stalks killed by borers would necessitate investigations covering at least a complete year, with very careful elimination of other factors. Dead canes are soon rotted, bored canes die, sound canes are bored, and new canes spring up in the stool; the process is a continuous one, and only by following it through its movement and complete cycle can the real death toll of the moth borer be established.

### 3. LOSS IN SIZE AND WEIGHT OF STALKS

Comparative weight and length measurements were made of a number of bored and sound canes. The total lengths were found to be almost exactly equal, but the weight of the bored

canes considerably less than that of the sound. It was felt early in the experiment, which was conducted in May, that such a test would have to be made earlier in the year to be conclusive. By May there has been a second infestation of canes, some are attacked after having almost completed their growth, and the true effects of the borer which would be apparent earlier in the year are obscured. Moreover, as the crop is over in May, it is the loss previous to this, during the cutting period, that is economically important.

A count was made also to determine the effect of borer injury on the production of nodes. The time of the year was also unfavorable to this study. The results of a single count of some twenty canes, bored and sound, showed in an equal length of cane an exactly equal number of nodes.

It is obvious that, since canes are killed by the borer, others, perhaps a still larger number, are at any one time in the process of being killed, are weakened, and their growth retarded.

### 4. INDIRECT LOSSES

There are undoubtedly many indirect or secondary losses in the field due to borer injury. For instance, a correlation has been demonstrated between borer and rat injury. This correlation was noted also at Soledad, canes gnawed by rats were very frequently found to be bored canes, the tunnels leading from the damaged part of the stalk.

Ants and other insects are very frequently found to make their nests in borer tunnels, eating away much of the tissue in enlarging their nests. A further note on this subject will be found appended. (Appendix II.)

Probably the chief secondary injury, however, is the opening of the cane to inroads of various fungi. The borer tunnel is almost invariably surrounded by a red lining due to the entrance from the tunnel into the tissues of the cane of a fungus which stains the surrounding parts a bright red. Other fungi are often present, and these supplement the destruction of the borer, killing plants which otherwise might be able to survive the attack of the insect.

### 5. MILL LOSSES

The mill losses caused by Diatræa in Soledad are apparent chiefly as a decrease of sugar content. This loss was measured by experimental milling of bored and sound canes and analyses of the resulting juice. The cane used was in all cases Crystalina, the coupled groups of canes came from the same locality and were in every way comparable, except that the one group was bored, the other sound. Each test was of 20 canes, 10 infested and 10 clean.

The results as grouped in Table III show the average loss based on eight analyses to be a decrease of 1.84 per cent in the

TABLE III. ANALYSES OF JUICE OF BORED AND SOUND CANES

| Colonia | | Wt. of cane in lbs. | Per cent extraction | Brix | Sucrose | Purity | Per cent sucrose extracted | Difference due to boring in cane |
|---|---|---|---|---|---|---|---|---|
| Limones | Sound | 19.646 | 64.50 | 20.50 | 18.83 | 91.85 | 12.15 | |
| | Bored | 15.810 | 62.30 | 18.95 | 16.31 | 86.07 | 10.16 | 1.99 |
| | Sound | 18.392 | 69.02 | 21.00 | 19.46 | 92.66 | 13.43 | |
| | Bored | 18.392 | 65.91 | 19.80 | 18.11 | 91.46 | 11.94 | 1.49 |
| | Sound | 18.898 | 68.80 | 19.5 | 17.91 | 91.85 | 12.32 | |
| | Bored | 17.127 | 65.19 | 18.8 | 16.69 | 88.78 | 10.88 | 1.44 |
| La Vega | Sound | 16.368 | 66.66 | 19.2 | 17.76 | 92.5 | 11.84 | |
| | Bored | 14.949 | 63.43 | 17.2 | 14.87 | 86.45 | 9.43 | 2.41 |
| | Sound | 16.214 | 66.82 | 19.1 | 17.52 | 91.73 | 11.71 | |
| | Bored | 15.763 | 65.45 | 18.7 | 16.81 | 89.89 | 11.00 | 0.71 |
| | Sound | 18.667 | 68.18 | 18.8 | 17.53 | 93.24 | 11.95 | |
| | Bored | 15.114 | 66.01 | 15.6 | 12.32 | 78.97 | 8.13 | 3.82 |
| Dolores | Sound | 20.933 | 67.95 | 18.3 | 17.35 | 94.81 | 11.79 | |
| | Bored | 19.987 | 65.55 | 16.6 | 15.24 | 91.81 | 9.99 | 1.80 |
| | Sound | 19.448 | 67.14 | 17.2 | 15.89 | 92.38 | 10.67 | |
| | Bored | 13.937 | 65.43 | 16.6 | 14.88 | 89.64 | 9.74 | 0.93 |
| Average difference in percentage of sucrose extracted for eight tests ..... | | | | | | | | 1.84 |

sugar content of the cane; or, considering 11.98 per cent, the average sucrose content of the sound canes examined, as the normal, a loss of 15.2 per cent of the sugar in the cane.

Tests were also carried out in which canes bored at one end were selected in the field, the injured ends cut off, and the remaining sound parts compared with parts of canes sound throughout their entire length. These analyses show that there is a decrease of sugar content of about 2 per cent in parts of canes apparently free of borer, but influenced by borer attack elsewhere on the stalk.

Still a third series of tests was made in which were used separate bored and sound internodes. In these tests bored stalks were divided by a cut through the node into bored and unbored internodes, and bored internodes were compared with the immediately adjacent sound internodes of the same stalk. The average decrease in the sugar content of the bored internodes was 2.25 per cent.

There is, therefore, a loss of sugar throughout the entire length of a bored cane, but the loss is greatest in those particular internodes which are injured.

Other slight losses, of course, occur in the milling of bored cane; a decrease in purity requiring further purifying, a decrease in extraction necessitating the handling of more bagasse, the decrease in sugar in the juice making necessary more evaporation. These, however, are slight and are negligible in comparison with the loss in sugar content.

An interesting correlation showing that the borer plays a major part in decreasing the purity of the normal juice is afforded by a comparison of the borer infestation figures and official mill records of analyses of juice from various colonias. These analyses are part of the annual report of Mr. E. L. Symes, chemist at Soledad, and represent analyses of normal juice taken at various times throughout the crop. Both borer and purity figures in the graph (Fig. 2) are for the crop of 1924–25.

The enormous damage done by the borer may be more vividly realized if it be pointed out that with a Diatræa infestation of 18.49 per cent, a loss of 15.22 per cent of the sugar in the bored canes, and a crop of 120,623 bags, Central Soledad lost 3493 bags of sugar during the crop of 1924–25 solely be-

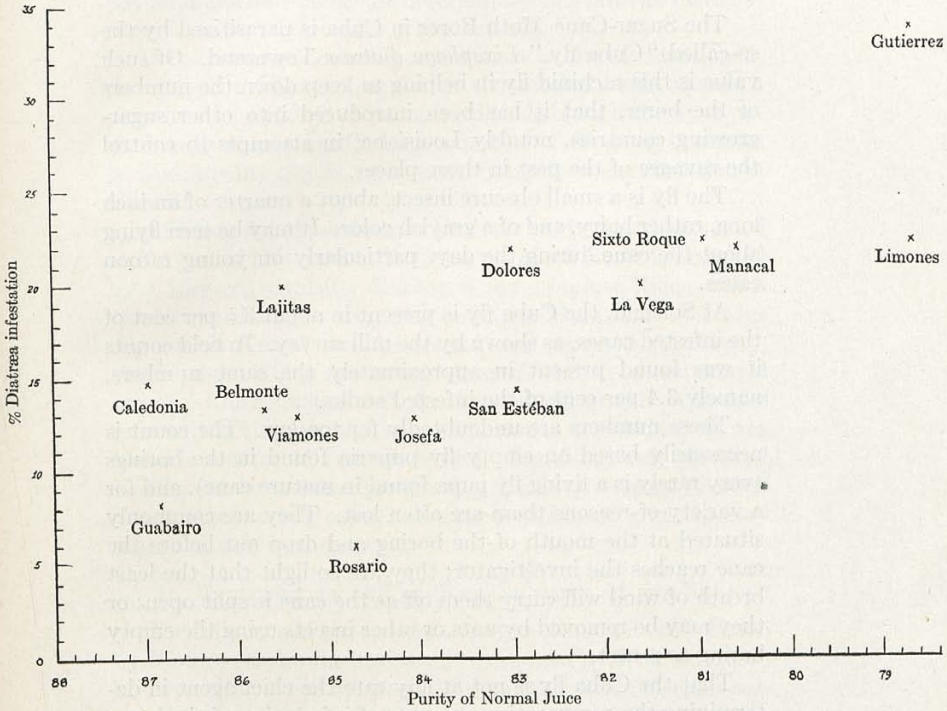


FIG. 2. GRAPH SHOWING THE NEGATIVE CORRELATION BETWEEN PER CENT OF DIATRÆA INFESTATION AND PURITY OF NORMAL JUICE

cause of the decrease in sugar content of canes injured by the one species of borer. When it is considered that this is but one of the ways in which the borer satisfies his "sweet tooth," it will be realized what a costly incumbent he is.

### *D.* Parasitism

The Sugar-Cane Moth Borer in Cuba is parasitized by the so-called "Cuba fly," *Lixophaga diatrææ* Townsend. Of such value is this tachinid fly in helping to keep down the numbers of the borer, that it has been introduced into other sugar-growing countries, notably Louisiana, in attempts to control the ravages of the pest in those places.

The fly is a small obscure insect, about a quarter of an inch long, rather hairy, and of a grayish color. It may be seen flying about the cane during the day, particularly on young ratoon canes.

At Soledad, the Cuba fly is present in about 3.5 per cent of the infested canes, as shown by the mill survey. In field counts it was found present in approximately the same numbers, namely 3.4 per cent of the infested stalks.

These numbers are undoubtedly far too low. The count is necessarily based on empty fly puparia found in the borings (very rarely is a living fly pupa found in mature cane), and for a variety of reasons these are often lost. They are commonly situated at the mouth of the boring and drop out before the cane reaches the investigator; they are so light that the least breath of wind will carry them off as the cane is split open; or they may be removed by ants or other insects using the empty boring as a nest.

That the Cuba fly is not at any rate the chief agent in determining the comparative amounts of infestation of the borer in various localities, is shown by a consideration of Table I. If the fly were responsible for the low infestation on certain colonias, notably Rosario and Guabairo, we should expect to find a relatively high percentage of flies there; or if the high infestation at Gutierrez were due to the absence of sufficient numbers of the fly on that property, we should expect few flies

there. Such is not the case, however; on the contrary, as a rule the higher the infestation, the more flies found. Since this is precisely what would be expected as a matter of mere chance, — for the greater the number of borers, the greater the chance of finding parasites, — there is no doubt that the Cuba fly is not an important factor in determining the present distribution of the borer throughout the central.

In the absence of other figures than those already mentioned, showing that about 3.5 per cent of the infested stalks contain a parasite, the writer is of the opinion that, though the fly is undoubtedly accounting for large numbers of the pest, it cannot be said, by any means, to be controlling the borer situation in Soledad.

A further list of parasites of Diatræa will be found appended at the end of this report. In Cuba the Moth Borer is attacked by a tiny egg parasite, *Trichogramma minutum* Riley, which parasitizes the eggs. *Apanteles diatrææ* Mues. and *Microdus stigmaterus* Cress., two braconids, are reported (Holloway, 1919b) to be killing the larvæ. A small whitish ichneumonoid cocoon, which might well have belonged to an *Apanteles* species, was the only sign of such parasites at Soledad. It was found in a deserted Diatræa boring. Two fungi were observed on Diatræa larvæ; one, presumably *Isaria* (*Cordyceps*) *barberi* in some six or seven cases, the other an unknown greenish-gray fungus in only two cases.

### *E.* Varieties of Sugar-cane and the Moth Borer

The influence of the variety of sugar-cane on its infestation by *Diatræa saccharalis* has been investigated by Wolcott (1922) in Porto Rico. On the basis of numerous fields of cane surveyed he arranged ten varieties or groups of varieties according to their percentage of infestation as listed on the next page.

Various other factors — varying rainfall in the different parts of the island, the burning or non-burning of trash, and the counting of fields in which the stand of cane was not pure but composed of several varieties — so complicate this list, however, that it is of very little use. The author himself points

INFESTATION OF CANE VARIETIES (after Wolcott, 1922)

| | Per cent |
|---|---|
| Cavengerie | 18 |
| Yellow Caledonia | 23 |
| Rayada | 30 |
| "B 3412" | 34 |
| Other Demerara varieties | 34 |
| Otaheite or Caña blanca | 47 |
| Other Barbados varieties | 49 |
| Crystalina | 52 |
| Guanica varieties | 56 |
| "D 117" | 61 |

out that the only definite conclusion that can be drawn is that in the moister sections of the island Yellow Caledonia and Cavengerie are least infested.

Bourbon cane has been reported (Anon., 1913) to be but slightly attacked by Diatræa in British Guiana; and the variety "Demerara 625" is said by Wolcott (1913) to be fairly resistant to the pest.

On the infestation by the moth borer of cane varieties other than Crystalina at Soledad, but few data can be given. The cane grown under field conditions there is almost entirely Crystalina, with a little Uba cane in two colonias, and small experimental plots of other canes at Limones.

So far as Diatræa is concerned, my meagre data show very little difference in the infestation of Crystalina and Uba under the same or similar conditions of growth. Uba cane at Limones showed in five counts 21, 22, 23, 28, and 31 per cent infestation, respectively. Though no Crystalina was growing sufficiently near and under sufficiently similar circumstances to make a direct comparison, it is to be noted that the general average for Limones is 22.15 per cent, that of the above five counts 25 per cent. Such a difference is decidedly inconclusive.

One field of Uba cane at La Vega was particularly observed. On May 8, the cane being then about a year old, the whole field was found to be so seriously attacked by Diatræa that it had a brown appearance due to the dead tops of the majority of the canes. In every case this brown condition was found to be concomitant with the presence of the borer, and in every

case the green stalks were found to be borer-free. So regularly were only the hearts bored and the stems free from injury that for a long time it was thought that the infestation was due to the top-borer, *Elasmopalpus lignosellus* Zeller, which insect, incidentally, was not met at Soledad. Emergence of the moths, however, showed that the insect in question was *Diatræa saccharalis*.

In two patches of considerable extent on the southern face of the field the cane appeared to be very nearly 100 per cent bored. A narrow strip running through the centre of the field, on the other hand, appeared to be entirely free; this strip followed a small drainage ditch and was composed of very small scattered canes. Throughout the remainder of the field counts were made and indicated an average of 61.79 per cent of the canes bored.

The powers of recovery of the Uba cane seemed to be very great, for within a month, after a gradual change of color, the field was again perfectly green. The recovery was due to the development of axillary buds; as many as six of these on one stalk sent out shoots, giving the head of the cane a somewhat bushy appearance.

Mr. E. L. Symes, chemist at Soledad, made sugar tests on this cane, pitting green, presumably borer-free stalks, against dry, bored stalks. His results are shown in the first two tests of Table IV. A very considerable loss in sucrose may be noticed. Unfortunately the writer is unable to say how this test was controlled or whether the stalks used were otherwise sound.

The third test of Table IV was made for the writer by Mr. B. O. Stewart, assistant chemist. The canes used in this test came from one small area, practically all from two stools. The "bored" stalks, moreover, were carefully examined and were perfectly sound in the part used, but were from top-bored canes. The loss, therefore, is due to the drying out of a part of the stem, itself uninjured. Again the decrease in sugar is considerable.

TABLE IV. SUGAR TESTS OF BORED UBA CANE

| State of cane | Number of Stalks | Total weight in pounds | Pounds per stalk | Per cent extraction | Brix | Sucrose | Purity | Per cent sucrose extracted |
|---|---|---|---|---|---|---|---|---|
| Green (sound) | 21 | 20.11 | 0.96 | 65.21 | 21.15 | 17.30 | 81.80 | 11.28 |
| Dry (top-bored) | 19 | 20.12 | 1.06 | 64.89 | 19.96 | 10.03 | 50.25 | 6.51 |
| Green (sound) | 9 | 4.90 | 0.54 | 68.39 | 19.30 | 11.91 | 61.71 | 8.14 |
| Dry (top-bored) | 9 | 2.96 | 0.33 | 41.27 | 19.30 | 4.41 | 22.85 | 1.82 |
| Sound | 10 | 7.77 | 0.77 | 68.98 | 18.22 | 11.33 | 62.18 | 7.81 |
| Bored | 10 | 5.86 | 0.58 | 58.35 | 20.96 | 9.43 | 44.99 | 5.50 |

Two series of figures are available for Cavengerie: one at Soledad, where this variety and Crystalina from the same district, and arriving at the mill in the same car, showed an infestation of 17.65 per cent in the red cane, and only 8.74 per cent in the Crystalina; another at a different central, where the Cavengerie was bored 32.25 per cent and the Crystalina 27.92 per cent. These tests are not sufficiently controlled to make the matter definite; but judging from other counts made on Cavengerie without comparison with Crystalina from adjacent fields, it seems probable that the former is usually more seriously bored than the latter.

During a brief visit paid to a central in another part of Cuba, an opportunity was found to study another cane, presumably but not certainly "Cuba 35." This variety of cane was bored 93.18 per cent as compared with an infestation of only 19.64 per cent in Crystalina from neighboring fields. Unfortunately it was impossible to visit the stand of this cane and make direct comparisons with adjacent Crystalina in the field, so that but little emphasis is placed on the figures.

### *F.* METHODS OF CONTROL

In view of the fact that, though their work is very beneficial, the parasites of Diatræa are not entirely in command of the borer situation at Soledad, the practice of control measures is recommended. There are certain methods of repression

which, if put into use, will tend to reduce the ravages of the borer.

The seed used should be as free from borer injury as possible. This result can be obtained most easily by selecting as the field to be used for seed, one in which the borer infestation is very low. Moreover, since the borer seems more prevalent in valleys and low-lying lands, the writer suggests using seed from the tops or upper slopes of low hills rather than that from flats. The training of seed-cutters to make a more careful examination of the seed and to discard bored seed-pieces is more difficult to practise, but is not impossible and is highly desirable. In planting the seed, care should be taken to cover it well, as there is evidence that from seed-pieces covered to a depth of two or three inches the moths are unable to emerge.

The removal of "dead hearts" from young ratoon cane is recommended for certain fields. It is a more expensive control measure and it is not suggested that any attempt be made to inspect all fields and remove all "dead hearts," but merely all fields in which they are numerous and conspicuous, or where the borer infestation was severe in the previous year.

A practice which will undoubtedly be of great benefit is that of harvesting badly infested fields early during the crop. Early milling will prevent the emergence of a flight of moths and the deposition of their eggs. Low-lying lands, along rivers and in swampy areas, should be harvested as early as possible although, unfortunately, these are the very lands on which the cane takes longest to ripen.

A procedure which is thrifty as well as of value in the control of the borer is that of sending every cane through the mill. Cutters should be encouraged to include in their piles canes that are light in weight and even shrivelled, such as are at present discarded. Canes dropped from cars and carts, particularly in heavily infested districts, should be collected and burned; railway lines from infested areas to the mill and in the mill yard should be kept free of canes from which borers may emerge. The collection and burning of dry infested canes would be perfectly satisfactory were it not that it is only a

single step from this procedure to the practice of burning-off trash, and without strict supervision that step would probably be taken by Cuban workmen.

The growing of corn near cane is to be discouraged. Experiments carried on in Louisiana and elsewhere show that the moth borer also heavily infests corn stalks, and that the corn acts as a very suitable breeding ground. In one or two instances at Soledad corn was seen left standing to shrivel and dry after the ears had been removed, and in two instances also on private land, cane and corn were found growing in alternate rows, a practice indeed to be condemned. What corn is necessary should be grown in compact plots, and upon removal of the ears every stalk should be completely destroyed. In this way the corn, which is much favored by the borer, may be used in the nature of a trap.

The burning-off of infested fields before cutting, or of trash after cutting, is not to be recommended. It has been shown in Louisiana, and is undoubtedly true in Cuba, that burning-off is very detrimental to the spread of a small egg parasite which is very beneficial in parasitizing the moth borer. Moreover, certain data in connection with another borer to be discussed later show that burning is not efficient as a method of killing borers in the stalks.

In summary, by way of control, it is recommended that:

Borer-free seed should be selected by more careful examination by the cutters, by the selection for seed of a field free from borers, and by the use for seed of cane grown on hills or slopes;

Seed should be planted deeply (two to three inches);

"Dead hearts" should be removed from badly infested fields;

Badly infested fields and low-lying lands should be cut early in the crop;

All canes should be sent to the mill and ground;

The growing of corn among cane should be discontinued and the stalks of all corn grown should be carefully destroyed;

Burning-off should not be practised.

## *METAMASIUS SERICEUS*, THE WEEVIL BORER

The Weevil Borer, *Metamasius sericeus* (Oliv.), has been mentioned frequently in the literature as a minor sugar-cane pest in the West Indies, and in one or two instances, over limited areas, it or its near relative, *M. hemipterus*, has been reported as doing considerable damage. The weevil borer of the West Indies is related to the Hawaiian Sugar-cane Borer (*Sphenophorus*) *Rhabdocnemis obscurus* (Boisd.) of which an account is given by Van Dine (1911).

### *A.* Prevalence

In a total of 12,171 canes examined as the mill survey at Soledad, only 71 canes were found to be infested by Metamasius, an infestation of only 0.58 per cent of the stalks.

If this figure represented the true infestation, the damage done by the weevil borer would be negligible, and it might be considered a minor sugar-cane pest. The truth is, however, that mill counts of Metamasius prevalence are utterly inadequate, and from field surveys to be given in detail later it will be seen that *Metamasius sericeus* in Soledad is no longer a minor sugar-cane pest, but must be considered as one of the most important insect enemies of the cane.

The reason for the inadequacy of a mill count lies very simply in the fact that so greatly is the cane damaged by the weevil borer, so quickly is it killed, dried, and shrivelled, so light does it become in weight, that but very few bored stalks (usually those only recently attacked) ever reach the mill at all; the vast majority are left on the field, to rot and to produce in turn a new generation of weevils.

A true estimate of the prevalence of the weevil in cane fields requires a different method of procedure from that used for the moth borer. The tissues of the cane are so completely destroyed by Metamasius that what little solid tissue is left quickly dries and shrivels, and the cane is almost always killed very soon after it is attacked. For this reason a count of Metamasius prevalence made on living stalks in the field

would be of but little more use than a mill count; and it becomes necessary when estimating Metamasius infestation to treat with the dead as well as the living canes.

In this regard it must be mentioned that it has been claimed that *Metamasius sericeus* (Anon. 1917) and its near relative, *M. hemipterus* (Urich 1915) attack only diseased cane or cane previously attacked by another borer. Numerous observations at Soledad, however, show that *M. sericeus* certainly attacks cane free from other borers, and the writer is convinced also that it attacks cane that is quite sound. Certainly under experimental conditions this was the case; and in all instances in which cane infested by Metamasius in the field was found at a sufficiently early stage of the attack, it appeared to be perfectly free from disease. As has been said above, however, the damage done by this borer is so extensive and rapid that there is every opportunity for bacteria and fungi to follow quickly.

Whether the weevil borer is the cause of the death of *all* dead canes in which it is found is really another matter. It may be, of course, that the weevil also infests dead canes, but the writer is of the opinion that, for the present, since Metamasius can and does attack sound canes, when a Metamasius boring is the only sign of injury on dead canes in the field the damage should be attributed to that insect. Any other course leads one to absolve the weevil borer and overlook what is certainly capable of being a serious pest. Accordingly, in the following, dead canes found attacked by Metamasius have been laid to its account unless other cause of death could be found. Though this course may possibly slightly exaggerate the situation, it is felt that it will draw attention to a potential pest greatly deserving of study. It may be mentioned here that the closely related *Rhabdocnemis obscurus* (*Sphenophorus*) of Hawaii attacks sound canes.

In an area at La Vega cut completely and every stalk dead and alive in that area considered, the surprising Metamasius infestation of 23.95 per cent of all stalks was found. It is felt, however, that this was an exceptionally badly infested field. In another case, a cutter's pile showing absolutely no sign of

the weevil borer, the shrivelled stalks lying around were gathered, over one hundred being found within a radius of four yards from that particular pile, and were found to be 32 per cent infested by Metamasius, as well as 52 per cent by Diatræa. At Caledonia 8 per cent of Metamasius infestation was found, and at Rosario, where a mill count of 1023 canes revealed no sign of this borer, 3 per cent was found in the field.

The true state of affairs with Metamasius at Soledad is that it is present in every colonia of the central; if not shown in the mill survey, it was readily found in the field. Basing his opinion on various data collected, some in the way of actual counts, and some as estimates or mere observations of the prevalence, the writer is convinced that of all canes living and dead in the fields of Soledad, not less than 8 per cent are bored by Metamasius.

When it is recalled that the cane practically always succumbs to Metamasius injury and that, therefore, there is a direct field loss of almost every cane attacked, it will readily be conceded that this borer should no longer be considered a minor pest of sugar cane at Soledad, and that steps for its control are highly desirable and necessary.

Records of the occurrence of Metamasius in four other centrals in Cuba were obtained, and undoubtedly it will be found to be well distributed throughout the island. Of its prevalence at these centrals, of course, nothing definite can be written; only mill counts or mere records of its occurrence in the field are available.

### *B.* Losses Caused

The losses caused by Metamasius are practically limited to that of stalks killed, a field tonnage loss. So little reaches the mill that the sugar content loss is negligible, and there is no germination loss, for the injury to the cane is too readily discernible for any seed selector to pass Metamasius-bored cane as seed. As has been indicated above, however, the actual loss caused in just this one way, may amount to as much as eight per cent of the total crop, truly a waste to be prevented if possible.

### C. Biological Notes

The female weevil lays her eggs in slits cut into the cane by means of her mandibles. This seems to be a very necessary provision for the young larva, as in many trials the writer has found the legless larva utterly incapable of entering even the cut end of a cane, much less the tough outer rind unless a slit or tunnel was prepared for it. The borer's movements seem to depend entirely upon its ability to exert an expansile force against the walls of the tunnel by means of the angular dilatation of the terminal abdominal segments.

The larva eats voraciously, and when full grown is about 2.3 cm. in length, creamy brown, with a bluish color showing through its semi-translucent skin. Many larvæ occur in one stalk, as many as twenty-seven in a single cane, ranging from very small ones, five mm. in length, to full-grown larvæ. As many as twelve or fourteen internodes of a large cane will sometimes be bored by this insect.

The facts that many larvæ feed in one stalk, and that they are unable to cross from one stalk to another, may be of some little importance in their control when it is mentioned that they are very cannibalistic. On many occasions, the number of borers in one of the cages being short, a search revealed only the head capsule left, and this sometimes partly eaten. Two borers held together in the palm of the hand will nip each other until one wriggles away.

The length of the larval life was not determined; time did not suffice to complete the process of breeding from egg to pupa. It is probable, however, that it is about six weeks. When about to pupate, the larva constructs a cocoon by winding long fibres of the cane around itself, thus forming an oval structure 27 to 32 mm. long and 12 to 16 mm. in diameter. Inside this it pupates, the pupal stage lasting about ten days, though the freshly formed adult usually remains a shorter or longer time in the cocoon before it breaks its way out into the world. The adult, already described, is an active insect, sometimes flying readily when disturbed, sometimes more sluggish.

It should be mentioned that the larvæ seem to be fully able to complete their development and emerge as perfect insects if confined to a single small piece of cane, though this may soon get very mouldy, and later very dry and shrivelled. This fact is important in showing the ability of the young larvæ to complete their development when the cane they inhabit has been killed by older larvæ feeding in the same stalk, or when the cane is left on the field after cutting.

The observations available are too incomplete to show definitely when the flights of Metamasius take place. The following data, however, may throw some little light on the subject. On March 13 the weevil borer was present as full-grown larvæ, pupæ, and adults still in cocoons. On April 28 only empty cocoons were found; on May 9 full-grown larvæ, pupæ, pupæ and adults in cocoons, and empty cocoons. On May 18 larvæ only, some very young indeed, others nearly full grown; on June 5 larvæ, on June 10 pupæ; and on June 16 some weevils emerged in captivity from pupæ taken on June 10. From July 1 until the 9th records of adults flying in the fields are numerous. There seems, then, to be a flight of adults about the third week of March and another the first week of July; but whether the conditions found on April 28 and May 9 represent another flight about May 1, the data are too meagre to show.

### *D.* Control

Control measures against Metamasius should be devised as far as possible of such nature that they may also tend to reduce the status of Diatræa, two objects being thus served at once. Whether such ideal methods can be suggested remains to be seen. The problem is complicated by the existence of alternative food plants, the banana and coconut (Anon. 1917, Ashby 1917).

No parasites of Metamasius could be found in Soledad. Some seventy-five larvæ were kept, but the only deaths were those due to the cannibalistic propensities of the borers themselves. This, fortunately, is no proof that parasites do not exist, and they should be diligently sought. In other countries

enemies of the closely allied *M. hemipterus* are known. Crawley (1916) mentions the ant *Ectatomma quadridens* as attacking the larvæ in British Guiana. A fungus, *Sporotrichum globuliferum*, has been found on *Metamasius hemipterus* in Cuba by Johnston (1917), and in Porto Rico, Stevenson (1918) artificially infested the same weevil with the green muscardine fungus, *Metarrhizium anisopliæ*. Quite probably these two fungi as well as the ant would attack *M. sericeus*.

The burning of cane or trash is apparently not efficient as a control measure. A field of uncut cane happening to be burned at about 5 P.M. on May 8, it was visited the next morning at 6.30 A.M. to see how the borers had withstood the fire. The following results were obtained with Metamasius: Dead, 1 adult, 1 pupa, 6 larvæ; Alive, 1 adult, 1 pupa, 10 larvæ. (These larvae as well as the pupa were kept alive to make sure that they were not injured.) There were also, in the canes examined, 59 empty cocoons. Thus, of the 79 insects represented, 59 had already made good their escape and 60 per cent of the remainder survived the fire. Of course, whatever eggs the weevils already emerged may have laid in the field may have been destroyed; but burning in this case was apparently of very little use. The burning of trash after the crop may be more effective, as in that case the sticks are all dry and would burn more readily. Probably but few borers would survive, but accurate data are not available. In view of the fact that burning-off is considered detrimental to the control of the moth borer and that its efficiency is in doubt as a control measure for the weevil, it is not recommended. The only general control measure my data allow me to suggest is the sending to the mill and grinding of all canes in the field. If this were done thoroughly for perhaps two crops, all dead stalks being thus destroyed, a noticeable decrease of Metamasius would undoubtedly ensue. Moreover, this method would also be very beneficial in the case of the moth borer; it would be a case of killing two birds with one stone.

Though no actual study was made of the prevalence of Metamasius in various cane varieties, it may be mentioned

that of several hundred stalks of Uba cane examined, not one was seen bored by Metamasius. Wilson (1921) has published a short table showing the amount of infestation of different cane varieties by *Metamasius sericeus* in the Virgin Islands.

### *XYLEBORUS*, THE SHOT-HOLE BORER

No list of insects attacking any tropical plant would seem complete were not a member of the genus *Xyleborus* included. Sugar-cane at Soledad has its representative in the form of a *Xyleborus* species, probably *perforans* Woll. Species of Xyleborus from sugar-cane have been reported in various islands of the West Indies and in British Guiana (Bodkin 1913, Van Dine 1913, Smyth 1919, Urich 1915), and probably occur throughout Cuba. At Soledad this beetle was present in every colonia.

The Shot-hole Borer, as it is commonly called, is considered by various writers (for example, Van Dine 1913) to bore only into diseased canes, particularly those attacked by the rind disease, *Melanconium sacchari*. While the present writer has noticed that this beetle is far more commonly met in such diseased canes, he has found the adults quite ready to enter perfectly sound cane in the laboratory; and in the field, canes with only the beginning tunnels of a Xyleborus gallery frequently appeared to be in the same condition. Since this borer is one of the ambrosia beetles which are known to cultivate fungi in their galleries, it is not surprising that Xyleborus tunnels should appear to be made in fungus-infested canes.

Some attempt was made to determine the status of this beetle, but with little success. The slight infestation indicated by the mill count (only 0.7 per cent) is probably far too low, both because the boring is very small and easily overlooked, and because undoubtedly diseased and dried canes are more commonly attacked and these, of course, do not always reach the mill.

The losses due to this borer at Soledad are negligible, the boring is very small, and in no case did it seem to have any great effect on the sound canes found attacked.

## TERMITES

About a dozen cases of termite injury to mature cane were found during the investigations at Soledad, mostly due to *Nasutitermes morio* (Latr.) but in one or two cases to *Leucotermes sp.* The question arose whether the termites were primary pests or whether they entered the cane through the boring of some other insect. There were certain doubtful examples, but on at least three or four occasions it seemed certain that the termites were themselves the original borers.

The losses caused in mature cane are, therefore, negligible; whether those caused in seed-pieces may be so lightly dismissed is another question. Several cases of the infestation of seed pieces by termites were noticed and it may be that the failure to germinate of many seed-pieces is attributable to termite injury. Investigation of this phase was not undertaken.

## GENERAL SUMMARY

1. At Central Soledad, Cuba, during the crop of 1924–25, *Diatræa saccharalis* (Fabr.) infested 18.49 per cent of all canes arriving at the mill.
2. As a measure of the absolute prevalence of Diatræa on the estate the mill count is far too low; but as a means of determining the infestation of the canes arriving at the mill, it is very accurate.
3. A correlation exists between the prevalence or percentage of infestation and the intensity of that infestation: the larger the percentage of infestation of canes in a field, the greater the number of internodes of the individual canes bored.
4. There is a wide range in the per cent infestation in the various colonias at Soledad, the distribution seeming to be influenced by topography. Hills are infested to a less degree than valleys, and the hilly or high-land colonias of the central have a lower percentage of infestation than the low-lying or flat colonias.

5. In explanation of this distribution it is suggested that, since Diatræa seems to have a preference among wild plants for aquatic grasses, the physiological state of the sugar-cane in low lands and valleys may be more attractive to the moths.

6. Much bored cane is used as seed at Soledad. The loss due to the planting of bored seed-pieces is found to be considerable and to be largely due to the failure of the buds of the planted bored cane to develop.

7. Severe losses are caused in standing cane. Stalks are opened to the attacks of other insects, fungi, and bacteria; their growth is retarded, and they are weakened, made light in weight, and sometimes killed.

8. The sucrose content of bored cane at Soledad is 1.84 per cent less than that of sound cane: canes attacked by Diatræa lose 15.2 per cent of their sugar.

9. Purity of normal juice of the various colonias for the crop of 1924–25 varies inversely with the percentage of infestation by Diatræa for those colonias, showing that the moth borer probably exerts great influence on the general purity of the juice of the whole central.

10. Only 3.5 per cent of the bored canes at Soledad were found to contain traces of a parasite (*Lixophaga diatrææ* [Towns.]). This figure is probably far too low.

11. Brief mention is made of the infestation of various cane varieties by Diatræa.

12. Methods of control for the moth borer are recommended as follows:

    Borer-free seed should be selected by more careful examination by the cutters, by the selection for seed of a field free from borers, and by the use for seed of cane grown on hills or slopes;

    Seed should be planted deeply (two to three inches);

    "Dead hearts" should be removed from badly infested fields;

Badly infested fields and low-lying lands should be cut early in the crop;

All canes should be sent to the mill and ground;

The growing of corn among cane should be discontinued and the stalks of all corn grown should be carefully destroyed;

Burning-off should not be practised.

13. The weevil borer, *Metamasius sericeus* (Oliv.), is shown to be more prevalent at Soledad than was previously supposed or than a mill survey shows. It is considered to be sufficiently numerous to be looked upon as a serious pest.

14. Metamasius may cause an estimated direct field loss in the standing cane at Soledad of as much as 8 per cent of all canes grown.

15. A few notes are presented on the biology of the weevil borer.

16. The best method of control for the weevil borer is considered to be the careful collection and milling of all stalks; dry infested stalks should not be allowed to remain in the field.

17. Injury caused by *Xyleborus sp.* (probably *perforans* Woll.) at Soledad is practically negligible.

18. Injury to mature cane by the termites *Nasutitermes morio* (Latr.) and *Leucotermes sp.* at Soledad may be considered negligible, although these insects may be more injurious to cane planted for seed.

# APPENDIX I

## PARASITES AND PREDATORS OF DIATRÆA

HYMENOPTERA

**Ichneumonidæ**

*Mesostenoideus sp.* *D. saccharalis* and other species, larva. British Guiana. Bodkin 1913, Cleare 1923.

**Braconidæ**

*Iphiaulax medianus* Cam. (not Szépligeti 1901). *D. saccharalis*, etc., larva. British Guiana. Bodkin 1913, Cleare 1923.

*Iphiaulax sp.* *D. saccharalis*, etc., larva. British Guiana. Bodkin 1913, Cleare 1923.

*Iphiaulax grenadensis* Ashm. (*Ipobracon*). *D. saccharalis*. British Guiana. Turner 1918.

*Iphiaulax saccharalis* (Turner) (*Ipobracon*). *D. saccharalis*. British Guiana. Turner 1918.

*Microdus diatrææ* Turner. *D. saccharalis*. British Guiana. Turner 1918.

*Microdus stigmaterus* Cress. (*Bassus*). *D. saccharalis*, larva. Cuba. Holloway 1919b.

*Apanteles diatrææ* Mues. *D. saccharalis*. Cuba. Muesebeck 1920.

*Apanteles sp.* *D. saccharalis*, larva. Cuba. Holloway 1919b.

*Microgaster harnedi* Mues. *Diatræa sp.* U. S. Muesebeck 1922.

*Cyanopterus sp.* *D. saccharalis*, etc. Trinidad. Urich 1915.

*Cremnops parvifasciatus* Cam. *D. saccharalis*, etc., larva. British Guiana. Bodkin 1913, Cleare 1923.

*Cremnops sp.* *D. saccharalis*, etc., larva. British Guiana. Bodkin 1913.

**Chalcidoidea**

*Trichogramma minutum* Riley. *D. saccharalis*, etc., eggs. Porto Rico, Mexico, Texas, Louisiana, British Guiana, Barbados, Java, Cuba. Various authors.

*Trichogramma fasciatum* Perk. *D. saccharalis*, eggs. Mexico, Russia, Turkestan. Girault 1913.

*Trichogramma nanum* Zehnt. and

*Trichogramma australicum* Zehnt. *D. striatalis*, eggs. Java. Van der Goot 1915.

*Ufens niger* (Ashm.) *D. saccharalis*, eggs. Texas. Holloway and Loftin 1919.

*Heptasmicra curvilineata* Cam. *D. saccharalis*, etc., pupa. British Guiana. Bodkin 1913, Cleare 1923.

**Serphoidea**

*Phanurus alecto* (Crawford). *D. saccharalis*, etc., eggs. British Guiana. Bodkin 1914, Cleare 1923.

*Phanurus beneficiens* Zehnt. *D. striatalis*. Java. Van der Goot, 1915.

**Formicidæ**

*Iridomyrmex humilis* Mayr. *D. saccharalis*. Predator on eggs, larvæ, and pupæ. Louisiana. Holloway and Loftin 1919.

*Ectatomma quadridens* (Fabr.) *D. saccharalis*. Predator on eggs and larva. British Guiana. Crawley 1916.

DIPTERA

*Sargus sp. D. saccharalis*. British Guiana. Bodkin 1914, Hutson 1916.

*Lixophaga diatrææ* (Towns.) (*Euzenilliopsis*). *D. saccharalis*, larva. Cuba. Holloway 1919b.

Tachinid fly, unknown. *D. saccharalis*, etc. British Guiana. Bodkin 1913.

*Tachinophyto* (*Hypostena*) *sp. D. saccharalis*. Porto Rico. Van Dine 1913.

Dexiid fly, undetermined. *D. saccharalis*, etc. British Guiana. Cleare 1923.

*Sarcophaga sternodontis* Towns. *D. saccharalis*. Cuba. Van Zwaluwenberg 1923.

COLEOPTERA

*Leionota quadridentata* (Fabr.). *D. saccharalis*, etc., predator on larvæ and pupæ. British Guiana. Bodkin 1913.

Elaterid beetle. Predator on larvæ and pupæ of *D. saccharalis*, etc. British Guiana. Bodkin 1913.

*Chauliognathus marginatus* (Fabr.). Predator on larvæ of *D. saccharalis*. Louisiana. Holloway and Loftin 1919.

Carabid beetle larva. Predaceous on larvæ of *D. saccharalis*. British Guiana. Hutson 1916.

DERMAPTERA

Earwig. Predator on larvæ and eggs of *D. saccharalis*. Florida. Holloway and Loftin 1919.

PSEUDOSCORPIONIDA

Pseudoscorpion. *D. saccharalis*. British Guiana. Hutson 1916.

AVES. ICTERIDÆ

*Holoquiscalus niger brachypterus* (Cassin). *D. saccharalis*. Porto Rico. Brau de Zuzuarregui 1922.

FUNGI

*Isaria* (*Cordyceps*) *barberi* Giard. *D. saccharalis*, larva and pupa. Porto Rico, British Guiana. Van Dine 1913, Bodkin 1913.

*Metarrhizium anisopliæ* (*Metsch.*) (Green Muscardine fungus). *D. saccharalis*, etc. Trinidad. Urich 1915.

## APPENDIX II

### ANTS INHABITING DIATRÆA BORINGS IN SUGAR-CANE

EARLY in the course of the above-described study of *Diatræa saccharalis* at Soledad, it was noticed that many of the canes arriving at the mill contained nests of ants in the Diatræa borings. A record was kept of the frequency with which the various species occurred. Later on, in the field, further notes were made of the same nesting habit.

Though many of these ants probably had no actual connection with the moth borer and used the boring only after it was deserted by its original tenant, it may be that some occasionally attack Diatræa larvæ, pupæ, or eggs. In any case, such records may be of use when the ethology of *Diatræa saccharalis* comes to be properly worked out, and it has been considered wise to bring them together in this place.

It may be that some of the species enlarge the boring considerably; evidences of slight further injury were noticeable in some cases, but in the opinion of the writer this injury is practically negligible.

The following list includes fourteen species of ants which were found to be actually nesting in the Diatræa borings. Frequently, particularly in the field, one or two worker ants would excitedly rush out of a boring as it was being cut open. These were not considered.

An interesting feature of this cane-nesting habit is the tendency to localization which it exhibits. Very frequently when one species of ant was found nesting in a boring, other nests of the same species were found in borings within a few yards. Considering *Camponotus planatus*, for instance, all the cases at Soledad were confined to one small field and most of them were within a yard or two of one another. The same ant was found nesting in borings at another central, but nowhere else in Soledad. The field notes of the writer bear frequent witness to this tendency of the ants of a certain area to adopt the habit.

Other insects were also met in Diatræa tunnels. Among them were two species of earwigs, a single cockroach nymph, wood-lice, several beetles of different families, and Collembola. As there was no way of telling without prolonged study whether their presence was merely accidental or whether they had any permanent connection with the boring or its previous occupant, they are not further considered here. The earwigs, however, may well turn out to be predators of the moth borer.

For the determination of the ants in the following list I am deeply indebted to Dr. W. M. Wheeler, Dean of the Bussey Institution, Harvard University.

**Pseudomyrmicinæ**

*Pseudomyrma elongata* Mayr var. *cubaënsis* Forel. This ant, which commonly nests in twigs and hollow stems, was found in one case occupying a Diatræa boring in sugar-cane.

**Myrmicinæ**

*Monomorium floricola* (Jerdon). One of the ants most commonly found nesting in Diatræa borings. The very small workers swarm in large numbers in the galleries. One colony was found occupying a partially rotted seed-piece.

*Monomorium carbonarium* F. Smith, subspecies *ebeninum* Forel. An occasional occupant of Diatræa borings.

*Tetramorium guineense* (Fabr.). Not very commonly met as a cane-nesting ant; only five colonies in moth-borer tunnels were recorded.

*Wasmannia auropunctata* (Roger). Three colonies of this small yellow ant were found in Diatræa borings.

*Pheidole megacephala* (Fabr.). In only one case was this ant found in a Diatræa boring.

*Pheidole flavens* Roger. This ant does not commonly nest in Diatræa borings at Soledad; only two such nests were found.

*Solenopsis geminata* (Fabr.). Found in only one case occupying a Diatræa boring.

**Dolichoderinæ**

*Tapinoma melanocephalum* (Fabr.). This tropicopolitan ant, very common in houses, also frequently uses Diatræa borings in cane for its nest. It was also found nesting between the stem and the adherent leaf-bases of the sugar-cane.

**Camponotinæ**

*Brachymyrmex heeri* Forel var. *obscurior* Forel. About four nests of this small ant were found in Diatræa borings, the colonies usually not so rich in individuals as some of the other small ants.

*Prenolepis* (*Nylanderia*) *steinheili* Forel. Probably the most common ant found in cane borings: the numbers forming a single colony are very large.

*Camponotus* (*Myrmoturba*) *santosi* Forel. This large ant rather frequently uses a Diatræa boring as a nesting site. The pupæ and larvæ are placed in neat groups along the tunnels to allow the

adults to pass. It was also found occasionally nesting on the outside of the cane, between leaf-base and stem.

*Camponotus* (*Pseudocolobopsis*) *ramulorum* Wheeler var. *mestrei* Wheeler. This ant very commonly nests between the stalk and the adherent leaf-bases, but in only two instances was found to be actually occupying Diatræa borings.

*Camponotus* (*Myrmobrachys*) *planatus* Roger. A very common red and black ant found in about six instances nesting in Diatræa borings.

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## PLATE I

SUGAR-CANE BORERS

1. Full-grown larva of *Diatræa saccharalis*, winter form. x2.
1*a*. Full-grown larva of *Diatræa saccharalis*, summer form. x2.
2. Pupa of *D. saccharalis*. x2.
3. Adult *Diatræa saccharalis* (Fabr.), female. x2.
4. Adult *Xyleborus sp.* (probably *perforans* Woll.). x10.
5. Full-grown larva of *Metamasius sericeus* (Oliv.). x2.
6. Cocoon of *M. sericeus*. x1.
7. Adult *Metamasius sericeus* (Oliv.), female. x2.

## PLATE II

BORINGS OF *DIATRÆA SACCHARALIS* IN SUGAR-CANE

Above: Boring in young cane causing a "dead heart." Notice the short, sinuous tunnel, the killing of the central shoot, and the development at the side of two axillary buds.

Below: Boring in mature cane. Notice the straight, clean tunnel, lined with red tissue (shown as a black line).

## PLATE III

BORINGS OF *METAMASIUS SERICEUS* IN SUGAR-CANE

Above: The boring far advanced. The almost complete destruction of the cane should be remarked, as well as the larva and cocoons of the weevil, and the large amount of debris clogging the stem.

Below: The beginning of weevil borer attack. The larva is shown *in situ*. The debris distinguishes it at once from Diatræa injury.

## PLATE IV

Above: Simple drying of cane, showing the angular central cracks.

Below: Termite injury to growing mature cane. Notice the numerous parallel passages with thin dividing walls.

1

1A

2

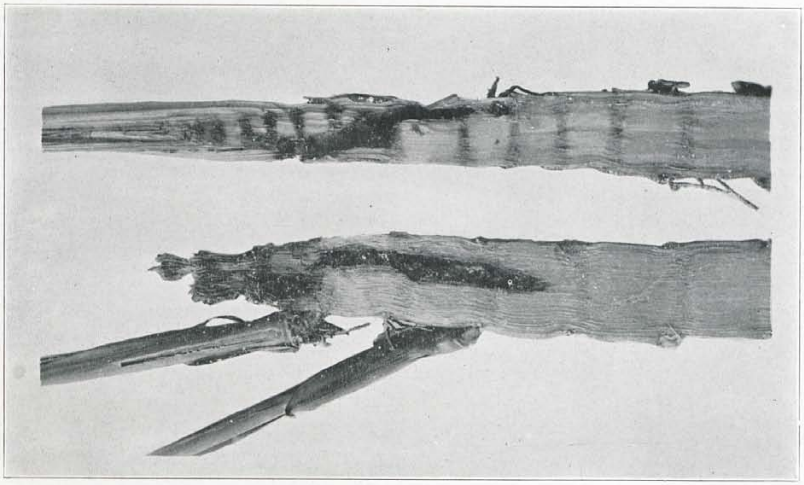
3

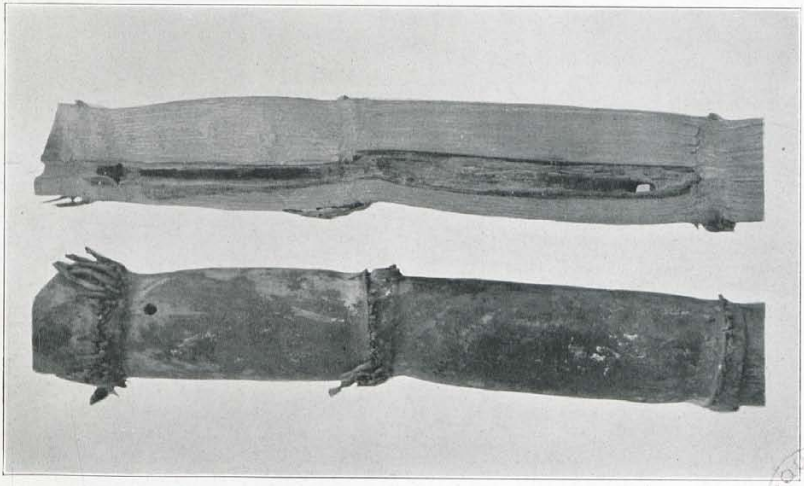
4

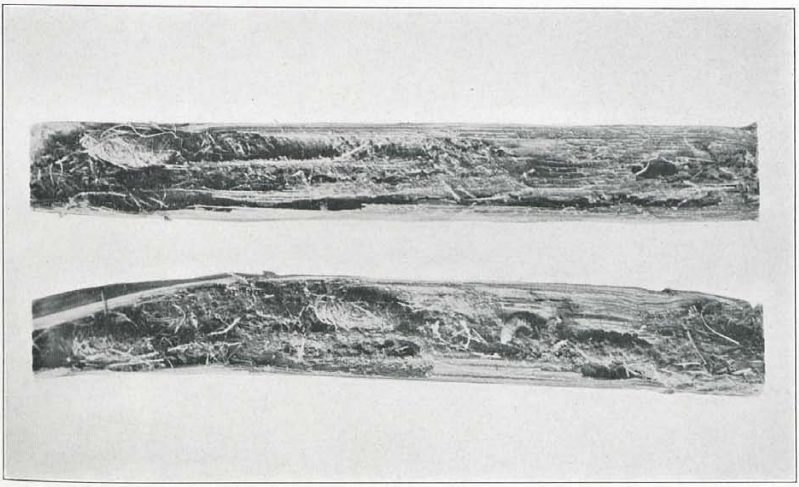
5

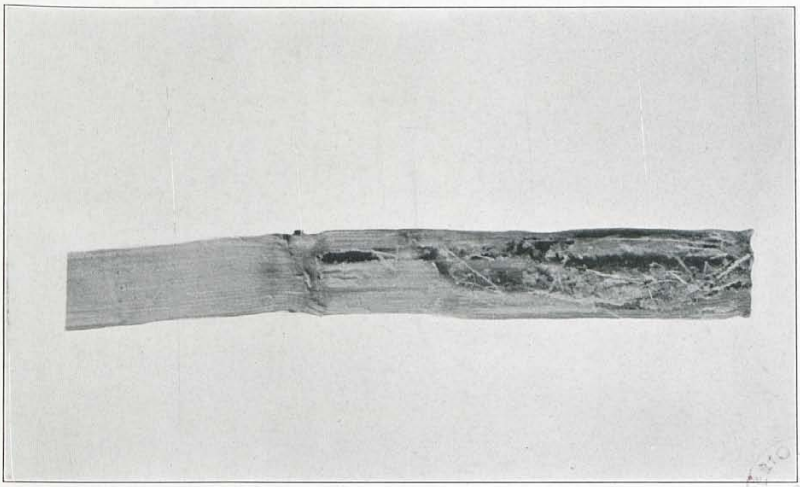
6

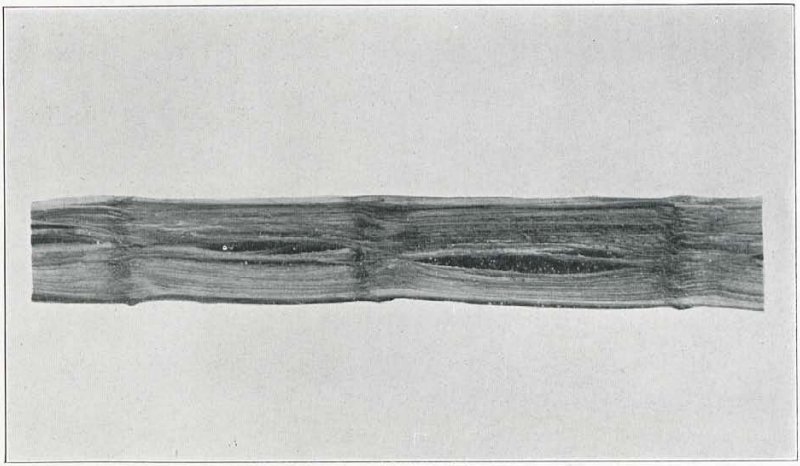
7

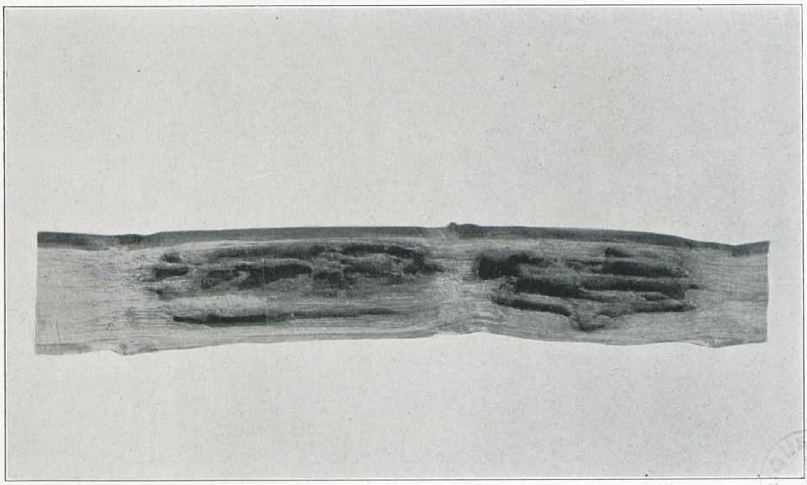












# DRY-SEASON STUDIES OF CANE HOMOPTERA AT SOLEDAD, CUBA, WITH A LIST OF THE COCCIDS OF THE DISTRICT

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II

# DRY-SEASON STUDIES OF CANE HOMOPTERA AT SOLEDAD, CUBA

# DRY-SEASON STUDIES OF CANE HOMOPTERA AT SOLEDAD, CUBA

## I. INTRODUCTION

THE Hemiptera or true bugs, distinguished from all other insects by their sucking mouth-parts and gradual metamorphosis, have long been recognized as including a large proportion of injurious species, but it is only comparatively recently that their importance as carriers of disease has been established, while their interrelations as vectors of virus diseases of plants form the newest chapter in applied entomology.

The leafhoppers, aphides, and scale-insects, or members of the suborder Homoptera, attacking sugar-cane, have sprung into prominence as carriers, possible, probable, or proved, of the mosaic disease of cane and other grasses. During February, March, and part of April, 1925, the writer was privileged, under an E. F. Atkins Harvard Fellowship, to spend some nine weeks at Soledad, Cuba, and to make a preliminary study of the aphis-leafhopper-mosaic situation as it appears in the driest season of the year.

Hearty acknowledgments are due to Mr. and Mrs. E. F. Atkins, to Dr. Barbour, and to the Soledad administration, for giving all possible facilities for the entomological work and for rendering the visit personally delightful. To Professor W. M. Wheeler and Professor C. T. Brues I am indebted for ready help and advice and for determinations of ants and of parasitic Hymenoptera respectively. To Dr. L. O. Howard and the specialists of his Bureau I owe the respective determinations credited personally to the latter in the text. For the identification of several of the ants and for much information in the field on Hymenoptera in general I am indebted to my companion in Cuba, Mr. George Salt. Dr. Weston very kindly lent me mosaic literature, and helped me in everything relating to this subject. Thanks are due finally to Professor B. L. Robinson and Mr. C. A. Weatherby, of the Gray Herbarium, for determining plant material, often of the most scanty nature.

An effort was made at Soledad to collect all the Hemiptera found at that season and to study their life-history as far as time would allow. The present report deals with the more immediately economically interesting of this material, with special reference to sugar-cane and its mosaic disease. It contains taxonomic and ethological observations on the species present at Soledad, limited by the short time available and by the dry weather. The writer has been cautious in drawing conclusions from such limited data, but has attempted to correlate his results with published work carried out elsewhere. The viewpoint has been essentially entomological, and an attempt has been made to clarify the taxonomy of the Homoptera dealt with in the bulky literature on West Indian cane insects. It has been necessary in pursuit of this aim to describe a new species, not hitherto properly characterized. This is relegated to an appendix. Other species referred to vaguely by economic workers have been identified with known species described from adjacent regions. The second appendix gives a list of the Coccids, or scale-insects, collected in the district, chiefly from cultivated or other useful plants. These insects were kindly determined by Mr. Harold Morrison, of the United States Bureau of Entomology.

## II. INSECT TRANSMISSION OF MOSAIC OF CANE

So much has been written of late years on mosaic diseases in general and on the form which attacks sugar-cane and other grasses in particular that an account of its pathology would be superfluous here. An excellent summary of our knowledge, with a useful bibliography, is given by East and Weston in the first volume of this series. Their work also obviates the necessity for a full bibliography, but the list at the end of the present report contains references to such purely entomological literature as was not included by East and Weston, and also to some of the work published since the appearance of their bulletin. Citations of the more important of the older literature on insect transmission of mosaic are also included. For a good account of the transmission of diseases in general by insects the reader

is referred to Rand and Pierce's excellent summary (1920). It is hoped that future workers will find this report useful as a guide to the Homopterous insects which occur commonly on cane at Soledad, and, secondly, to the literature published in other parts of the world on their taxonomy and natural history.

The question as to the infectious nature of mosaic disease of sugar-cane and related grasses — a question complicated by the fact that this, as other mosaic diseases, is caused by a filterable virus and not an obvious organism which can be isolated and studied — is entirely a phytopathological one and lies outside the province of the writer. By the plant-pathologists themselves mosaic appears accepted as highly infectious. Artificial inoculation has been achieved only under conditions so peculiar and rigorous as to preclude almost all possibility of field transmission other than by the agency of sucking insects. Thus the Homoptera were early suspected, although the first transmission experiments by Graywood Smyth in Porto Rico (1919) were performed on almost any insects — both biting and sucking species — which occurred on cane. These results were positive in the case of four very different insect species, namely, the West Indian cane leafhopper, the yellow cane aphis, and two species of scale-insects. The percentage of positive results was, however, so very small, and the conditions of the experiment so little rigorous, that the author himself did not regard them as conclusive, and later workers, who failed to confirm them, have practically unanimously rejected them.

Then Brandes (1920) showed that *Aphis maidis*, the corn aphis, — an insect very rare on cane and hitherto unsuspected, — could transmit the disease from sorghum to cane. Negative results were obtained with a leafhopper and a mealy-bug. Bruner carried out careful experiments in Cuba with most of the more probable of the cane Homoptera, but was successful only in the case of *Aphis maidis*. The work of Chardon and Veve in Porto Rico, of Kunkel in Hawaii, and of Ledeboer in Java all agreed in confirming the positive results of Brandes with *Aphis maidis*. Not a single species of the common cane

insects was shown conclusively to carry the disease. But Chardon and Veve demonstrated further (1922) that another aphid, *Carolinaia cyperi* Ainslie, which occurs normally only on coquí (*Cyperus rotundus*) in Porto Rican cane-fields, can transmit mosaic from this sedge to cane under certain conditions. These two authors made a great contribution to our knowledge of transmission when they showed that both *Aphis maidis* and *Carolinaia cyperi*, though both incapable of forming permanent colonies on cane, moved in large numbers to the latter when their wild hosts were weeded out from among the cane.

Finally Kunkel in Hawaii proved that the corn leafhopper, which practically never occurs on cane, can carry mosaic from maize to maize but not from this to cane.

There is thus the peculiar position that none of the common cane Homoptera have so far given positive results, while the only abundant insect which is proved to carry the disease to cane is extremely rare on the latter plant. Brandes states (1923, p. 281): "The fact also appears to be established that while *A. maidis* prefers other grasses to cane as a source of food, it frequently migrates to the cane in large numbers. Weeding of a cane-field is evidently a prime factor in bringing about this result, but the present writer has observed infestation of sugar-cane by *Aphis maidis* in Florida in fields which are never weeded. The conclusions of investigators who disclaim that any practical importance attaches to this insect as a vector of mosaic is based on negative evidence, and therefore cannot be held to controvert these facts in any way."

The other investigators referred to are Wolcott (1921) in Porto Rico and Bruner (1922) in Cuba, both of whom stressed the fact that the corn aphis does not normally occur on cane and cannot therefore be the chief agent in the field transmission of mosaic. But the observations on the spread of *Aphis maidis* on weeding seem to have gone far toward convincing these and other workers.

To sum up — the corn leafhopper can transmit mosaic from corn to corn; it does not occur on cane; *Aphis maidis* can carry

the disease from other grasses to cane and *Carolinaia* from sedge to cane. With regard to the relative importance at Soledad of this secondary infection by means of insects and the primary infection by means of seed pieces, East and Weston state (1925, p. 5): "While the sources of infection may at times be the wild grasses growing near the cane-fields the most important source presumably is diseased cane. . . . Seed pieces from diseased plants do not always give rise to visibly diseased shoots; but the correlation is very high." It remains for future workers to show whether and how this combination of causes can explain the mosaic situation at Soledad.

## III. THE MOSAIC SITUATION AT SOLEDAD

This has been so exhaustively treated by East and Weston that only the merest outline need be repeated here.

Mosaic is believed to be generally distributed, not only over all the estate, but throughout the whole Island of Cuba. In view of this wide distribution and of the tolerance shown to the disease by Cristalina — the dominant cane variety — the authors consider that mosaic has been disseminated through the island and associated with Cristalina for many years.

East and Weston are of the opinion that the damage done by the disease at Soledad is apparently not great, and they attribute this to the relative tolerance and to long association which has resulted in a state of balance between the injuriousness of the mosaic and the tolerance of the cane. More recently, however, Bruner (1925), by the study of carefully controlled experimental plots, has shown that in the Havana district, at least, there may be a loss of 48.2 per cent by weight of cane due solely to mosaic in Cristalina cane.

The question of possible vectors has not been hitherto dealt with at Soledad. Two insect species which have been elsewhere shown to transmit mosaic occur in the district, but have been found by the writer solely on maize and sorghum. These are *Aphis maidis* and *Peregrinus maidis* (the corn leafhopper). As indicated previously, the latter apparently carries the disease only from corn to corn. This leaves

only the aphis, which, in spite of prolonged searching, was never found on any of the weed grasses on the estate. Its favorite wild host-plant, Johnson grass (*Sorghum* [*Holcus*] *halepense*), is practically absent from the central. There is thus at the outset a much stronger probability at Soledad than elsewhere that *Aphis maidis* has little to do with secondary spread of mosaic under field conditions. Whether there is need for any other factor than diseased seed-pieces to explain most of the present distribution of mosaic at Soledad is to the writer open to question; but the evidence for the incrimination of other cane Homoptera will be discussed under each species in the list which follows.

## IV. THE FEEDING-HABITS OF HEMIPTERA IN GENERAL

Before passing to a detailed discussion of Soledad cane Homoptera it will be advisable to make a few remarks concerning the feeding-habits of Hemiptera in general. From the point of view of mosaic transmission it may be immaterial whether an insect spends its whole life-history on sugar-cane or merely wanders on to it for a few days. It is therefore of the utmost importance in the present study to discover why an insect chooses to feed on one plant rather than another. To an older generation the term "instinct" would explain all, and even now we must of course admit in the insect an inherited tendency to act upon certain stimuli. Our problem is to find what those stimuli are which determine food-plant preference. At the outset we are impressed with the existence of two sets of conditions — first, those which are inherent in the plant itself and are shared to a greater or less extent by the relatives of that plant, and which we may call botanical factors; and, second, those which depend primarily on external or purely physical conditions and may be termed environmental factors. The entomologist will at once recall instances in which the food-determining factors are predominantly or exclusively botanical. As examples we may cite the Pierid butterflies and Cruciferæ, certain *Vanessas* and Urticaceæ and *Dysdercus* and Malvaceæ. The appearance of taxonomic acumen with which insects will

choose for themselves, or for their morphologically often very dissimilar young, food-plants botanically related to their accustomed host has long excited interest and wonder and has been dealt with by Fabre in a very characteristic chapter on "l'instinct botanique." The modern view regards the preference as guided directly by the specific chemical — gustatory or olfactory — properties of the plants themselves.

But it has long been borne in upon the writer that the importance of environmental factors in the host-preferences of phytophagous insects is too little understood and too largely underestimated. In a study shortly to be published on the food-habits of the Hemiptera of New Zealand, it was found that, while cases analogous to that of the cabbage butterflies were plentiful and, in fact, the rule among the Heteroptera (phytophagous species only), they were rare in the Homoptera. The New Zealand fauna is so peculiar and apt to be a law unto itself that generalizations were considered risky. But later observations in North America, in Europe, and especially in Cuba have gone far to confirm the impressions gained in the antipodes, while the recorded data are apparently not opposed to the same conclusions. For example, Metcalf, discussing leafhoppers (1924), writes of "what seems to be a rather general rule among these insects, that is, that they live in a given habitat because they find there the complex of environmental conditions required and not alone because they find some particular food plants growing there." Thus there is, I believe, a marked but hitherto almost unnoticed difference in this respect between the two sub-orders Heteroptera and Homoptera. In the Heteroptera general plant-feeders are rare, though their scarcity is obscured by the individual frequency of such indiscriminate feeders as *Lygus pratensis* and certain Pentatomids. The pages of Butler's monumental work on the biology of British Hemiptera-Heteroptera (1923) abound in cases of restricted host range; while in reference to the species-rich and largely phytophagous family Miridæ (Capsidæ) Knight (1923, p. 422) states that "probably the greater number of species are limited to a single host-plant, or to a genus of plants, while a very few, such as

*Lygus pratensis* Linnæus and *Halticus citri* Ashmead, have a wide range of food-plants." In the Homoptera, on the other hand, the Cicadidæ and the Fulgoroidea are predominantly general feeders, a condition in this case probably correlated with the frequent difference in host and habitat between the nymphal stages and the adult. In the Cicadellids, Aphids, and Coccids, examples of very general plant-attachments are numerous. The Psyllidæ tend to be more specific, but perhaps the only Homopterous family which can compare with the Miridæ in this respect are the Membracidæ, of which Funkhouser remarks (1923, p. 167): "The various species of Membracidæ usually confine themselves to very definite host plants and are excellent botanists. In many cases the association between the insect and its host is so characteristic that a knowledge of the one is sufficient for the recognition of the other." The whole question, of course, may be obscured by the untrustworthy nature of so many published "host-records" based on the collecting of stray individuals.

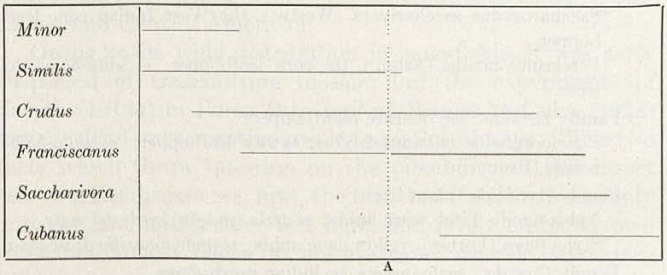
The bearing on the cane-leafhopper question of the principles involved in this somewhat lengthy discussion are obvious. The botanical factor in the food-plant preferences of insects is in one sense beyond the control of the cultivator — sugar-cane will always be a grass. But the environmental conditions — those under which the cane is growing — are amenable to alteration within certain wide limits. The botanical factor has intrigued the imagination of the observer and he has, too often with insufficient proof, assumed that sugar-cane as a grass was *ipso facto* liable especially to the attack of other grass-feeding insects. This does not follow, nor is it entirely true that cane may on the other hand be considered relatively safe from insects which commonly occur only on non-gramineous plants. Attack on cane can happen only under certain environmental conditions, and in the case of cane Homoptera it will be shown that these conditions, rather than the botanical relationship of cane to the other hosts, are often the deciding factors.

An environmental factor of the greatest importance at Soledad during the dry season was the degree of moisture. It

was found that the common Cuban cane leafhoppers could be arranged as follows in order of moisture requirement, beginning with those frequenting the wettest situations:

*Dræculacephala minor.*
*Kolla similis.*
*Myndus crudus.*
*Oliarus franciscanus.*
*Saccharosydne saccharivora.*
*Phaciocephalus cubanus.*

But since some species have a wider ethological range than others, and since there is overlapping throughout, the distribution of these species with reference to moisture may be better expressed in graphical form.




Moisture decreases from left to right and the condition of cane in the field with regard to this factor varies roughly from A to the extreme right.

## V. THE CANE HOMOPTERA OF SOLEDAD

### 1. List of Species

The nine species asterisked are the only ones which under dry-season conditions can properly be termed cane Homoptera at Soledad. The other species listed are either obviously relevant to the mosaic question or have been recorded from sugar-cane elsewhere and are common at Soledad on other hosts.

Conceivably the list would be materially increased by study in the wet season, with probably important results in the elucidation of the mosaic situation.

Order HEMIPTERA: True bugs

Sub-order **Homoptera:** Cicadas, leafhoppers, aphides, scale-insects, etc.

Family *Cicadellidæ:* leafhoppers in the strict sense

*Kolla similis (Walk.), common green leafhopper; *el salta-hojas verde de la caña.*

Draeculacephala minor (Walk.), sharp-headed green leafhopper; *el salta-hojas de cabeza puntiaguda* (Bruner).

Family *Cixiidæ:* cotton-tail planthoppers

*Oliarus franciscanus (Stål), black leafhopper; *el salta-hojas de rabo algodonoso* (Bruner).

*Myndus crudus Van Duzee, pallid cane leafhopper; *el salta-hojas chico de gramíneas* (Bruner).

Family *Delphacidæ:* spur-legged planthoppers

*Saccharosydne saccharivora (Westw.), the West Indian cane leafhopper.

Peregrinus maidis (Ashm.), the corn leafhopper; *el salta-hojas del maíz.*

Family *Derbidæ:* the delicate planthoppers

*Phaciocephalus cubanus Myers, tawny leafhopper; *el salta-hojas polilla* (Bruner).

Family *Aphididæ:* plant-lice

Aphis maidis Fitch, corn aphis; *el áfido (pulgón) verde del maíz.*

*Sipha flava (Forbes), yellow cane aphis; *el áfido amarillo de la caña.*

Family *Coccidæ:* scale-insects, including mealy-bugs

*Pseudococcus sacchari (Ckll.), pink cane mealy-bug; *la rosada chinche harinosa de la caña.*

*Ripersia n. sp., cane root mealy-bug.

*Targionia sacchari (Ckll.), cane stalk scale-insect.

The identification of the Coccids has been confirmed by Mr. Harold Morrison, who examined all my material. The species of Homoptera in the above list will now be treated in turn, with reference to their occurrence and distribution at Soledad during the dry season and with references to the literature. Complete references to all work done on the species in Porto Rico will be found in Wolcott's admirable list (1924*a*). The same work ought to be confirmed for Cuban conditions by observations made over a complete year.

## 2. The Cicadellids

**Kolla similis** (Walk.), the common green leafhopper

This species has usually been treated in the literature as *Kolla* or *Tettigonia herbida* Walk.; but Walker's description of *similis* undoubtedly refers to the present insect, while *herbida* Walk. is a synonym of *Helochara communis* Fitch, as pointed out by Van Duzee, whose Catalogue may be consulted for full taxonomic references (1917, pp. 599–601). Olsen has suggested that it be removed to the genus *Cicadella* Latr., a genus from which in any case *Kolla* scarcely deserves separation.

*K. similis* is the medium-sized, very active leafhopper, with a rounded head and very vivid green coloration, so abundant in luxuriant stands of Pará grass (*Panicum barbinode*) and occasionally on young cane. Its distributional range is Antillean and Central American.

Owing to its wide distribution in cane-fields, it was early suspected of transmitting mosaic; but the experiments of Smyth (1919*a*) in Porto Rico and of Bruner in Cuba (1922) have yielded only negative results, and Smyth says: "The two facts which throw question on the possibility of this insect carrying the disease are, first, the fact that it occurs commonly only on cane under three feet high, and rarely on half-grown cane, but almost never on mature cane, whereas secondary infection may take place in cane of any age; and second, the fact that all experimental tests (and there have been more with this than with any other species) have failed to demonstrate its ability to carry the disease."

As early as 1912 Van Dine (p. 22) noted this leafhopper "common on young cane" in Porto Rico. The Porto Rican references are collated by Wolcott (1924, p. 60) with list of food-plants, which vary from grasses to carrots and beans. He records three species of Hymenopterous parasites.

The fullest account of the life-history and distribution is given by Wolcott (1921, pp. 22–28, figs. 8, 9). The eggs are deposited in the cane leaf "around the central whorl, appearing as thickened and more opaque portions of the leaf." The young

nymphs are yellowish, becoming greener, with olive-green and brown markings, in the later instars. In Porto Rico the period from egg-laying through the five nymphal stages to the adult was about forty days.

Wolcott found that *K. similis* "shows a decided preference for plant cane rather than ratoon cane of the same size." This was confirmed at Soledad.

The most interesting part of Wolcott's paper deals with the correlation between moisture conditions and the abundance of this leafhopper. At Soledad the time was not sufficient to confirm all these results so far as rainfall was concerned. Wolcott found distinctly the most leafhoppers on cane in the wettest month and the fewest in the driest month. All the writer can say with regard to Soledad is that during the driest eight weeks of the year — say from the middle of February to the middle of April, this leafhopper was extremely rare on cane. But the influence of moisture was confirmed in another way, and the confirmation receives value from the fact that the observations were made in ignorance of Wolcott's work. His paper did not become known to me until after my return to the United States.

Wolcott found that "the leafhoppers do not occur at all, or only in small numbers, in dry meadows . . . or in grass in a dry ditch in a cane field, even though the grass is green and thrifty, but on grass in a wet ditch, or in a wet depression in a field, or along a stream margin . . . they have invariably been found abundant." This was also strikingly the case at Soledad, but it will be noticed that, so far as the Porto Rican observations go, the insect is still attached to grasses, at least under field conditions. The interesting question arises, will still further decreased rainfall render the distribution of this leafhopper completely independent of the botanical factor and lead to complete dominance of the influence of moisture? The lowest rainfall under which Wolcott's observations were made in Porto Rico was 1.38 inches for April. In comparing Soledad results we must bear in mind East and Weston's (1925, p. 28) warning as to the uselessness of rainfall statistics. In their

opinion, "published tables of the total annual rainfall at a given station are of little value because of the essential importance of distribution throughout the year; and even the daily records of rainfall at particular points cannot be used for generalization because of the extraordinary variation in the daily record at places within a few hundred yards of each other." (This applies especially to Soledad.) Nevertheless, it is safe to state that within the area where observations were made by the writer there was a period of over a month in February-March when no rain fell at all. During this excessively dry period *Kolla similis* was found living in numbers on such unrelated plants as *Adiantum* sp., *Piaropus*, water-lilies, *Polygonum acre* HBK.. and various grasses — plants differing in most other respects, but growing under common conditions of the extremest moisture to be found during the drought. Here we have food-plant preference almost totally independent of the botanical element. It might be argued that at this time there was an element of Hobson's choice; but even at the height of the dry season there were other grasses supporting an abundant leafhopper fauna, but apparently not moist enough for *Kolla similis*.

But even taking into full account the very dry weather at the time, observations seem to show that *Kolla similis* is far less abundant on cane at Soledad than in Porto Rico. Only one specimen was ever found on mature cane, while the only infestation even moderately heavy was early in April on young cane planted in a low situation in the Botanical Garden and well watered. Incidentally, the Botanical Garden, with its wealth of species and abundance of artificial moisture during the dry season, provided the best lowland collecting of the district during our stay.

As elsewhere the favorite host of *Kolla similis* at Soledad is Pará grass (*Panicum barbinode*), but dense swarms were present also on *Polygonum acre*. Yet cane a few feet away from a hollow containing such myriads would be quite untouched and would, in fact, be often barren of leafhoppers of other species too. It seems reasonable to suppose that cane growing in a similar

hollow would be as badly infested as the Pará grass or the *Polygonum*.

Even in the middle of February, before the onset of the very dry weather, *Kolla similis* was swept in great abundance from *Commelina nudiflora* L. and other weeds on the edge of the cane. A week earlier it occurred on grasses and other herbage in the "guarda rayas," but was always quite absent in the rougher Guinea grass pasture (*Panicum maximum*). Repeated examinations and sweepings of young ratoon cane and of grown cane, both Cristalina and Uba, failed utterly to reveal its presence during March and early April, on these hosts. An advanced nymph was taken on Bermuda grass on April 1.

To sum up, *Kolla similis*, during the dry season is practically absent from cane at Soledad and is then confined to plants of various unrelated orders growing in moist or even wet situations. In the wet season it is probably more widely spread, as in Porto Rico, but even then it is not likely to be as plentiful on cane as in the latter island.

In connection with mosaic an interesting point remains. Mosaic has been shown especially in Porto Rico to spread with equal or even greater facility in cane growing on steep hills, from which *Kolla similis*, even under the heaviest rainfall, is practically entirely absent. (Wolcott, 1921, p. 28.) If these two facts be confirmed, together with the scarcity of *Kolla* on grown cane, they will go far to indicate the probability that this leafhopper is not concerned in the transmission of the disease. Finally, numerous experiments in transmission, with this species, have given only negative results, while its favorite wild host-plant, *Panicum barbinode*, is said by Brandes and Klaphaak (1923, p. 249) to be immune to mosaic, although Hansford (1923, p. 5) denies this for Jamaica and Hawaii.

**Dræculacephala minor** (Walk.), sharp-headed green leafhopper

This rather large, bright-green leafhopper, with yellowish, pointed, sharp-edged head, is easily recognized. The common and widespread *D. mollipes* (Say) in its typical form appears to be absent from the material collected at Soledad, but *D. minor*

is hardly more than a variety, as indeed it was long considered. *Mollipes* is recorded by Bruner (1922) from sugar-cane near Havana, but possibly his examples were referable to *D. minor*. In my very large but undoubtedly conspecific series there are no males of *mollipes*, but some of the females are practically indistinguishable from the latter species.

Of all the leafhoppers treated in this paper, *Dræculacephala minor* frequents, and indeed is restricted to, the dampest situations. It is true that *Kolla similis* occurred in stations as moist as any, but its range was much greater than that of *D. minor*, and it could sustain itself under conditions far too dry for the latter.

The nymph is a pale, elongate insect with four darker dorsal longitudinal stripes, and is probably indistinguishable from that of *D. mollipes* as described by Osborn (1912, p. 58). It occurs on the same hosts and in the same situations as the adult, but during the dry season is very much scarcer.

From what has been said of the moisture requirements of *D. minor* it will be no matter for surprise that this species was not found on cane at Soledad during the dry weather of the writer's sojourn. It is dealt with here, however, as one of those leafhoppers which would undoubtedly feed, and possibly breed, on cane, were the rainfall sufficiently high or the plants growing under otherwise moist conditions.

There was one damp hollow in the Botanical Garden filled with a dense lush growth of Pará grass where this leafhopper was present in clouds. In mid-February it was swept from the blue-flowered *Commelina nudiflora* L. and other weeds in a moist depression on the edge of the cane (Uba variety), but the latter was quite free from infestation even though much of it was young. Grasses and other herbage on the water's edge of creeks would usually yield numerous examples. A few specimens, including nymphs, were found on *Papyrus* overhanging the water in the Botanical Garden.

Bruner's experiments in mosaic transmission with the species referred to as *D. mollipes* by him, yielded only negative results (1922).

Before leaving the family Cicadellidae it will be of interest to note that several species have been implicated in the transmission of mosaic diseases of various kinds in other parts of the world, and this despite the fact that all experiments concerned with their relation to true sugar-cane or grass mosaic have yielded nothing but negative results. One of the most interesting cases of disease carriage by a member of this family (*sens. lat.*) concerns the small leafhopper, *Balclutha mbila* Naude, which transmits a virus disease of Uba cane in South Africa, known as "streak." Uba is generally accepted as immune to true mosaic, and in fact the control of this disease in South Africa consists largely in substituting this already widely grown variety for other more susceptible kinds. But maize, besides suffering from true grass mosaic, is also subject to the streak disease of Uba cane, and the leafhopper *B. mbila* is the sole known vector from corn to cane. The now notorious *Aphis maidis* has so far been shown incapable of carrying this new disease, while *Balclutha*, on the other hand, apparently cannot transmit true mosaic. Such a relatively recent discovery (see Storey, 1925) shows that we are barely on the threshold of a knowledge of the relations between insect vectors and virus diseases. So far as the former are concerned, it is apparent that in the end the fullest study will be required of all sucking insects liable to infest cane.

### 3. The Cixiids

**Oliarus franciscanus** (Stål), the black leafhopper

This is a medium-sized planthopper with a black body relieved by reddish on the ridges of the head and pronotum, and with more or less clear fore-wings traversed by darker veins. It is probably identical with the species mentioned by Bruner (as *Oliarus* sp.) as occurring on sugar-cane near Havana. I have no hesitation in identifying the Soledad examples with Stål's species, for full systematic references to which the reader is referred to Van Duzee's Catalogue (1917, p. 732).

In the family Cixiidæ very generally the young stages are

passed in a totally different habitat from that of the adult; and although the life-history of this species has not been studied, it is probably no exception to the rule. The nymphs of most species of *Oliarus* so far known live under stones or in crevices of the ground, obtaining their nourishment from roots. The only relatively complete study of the life-history of an *Oliarus* is that of Hacker (1925) on *Oliarus felis* Kirk., in Australia. Several species of the family were reared to maturity at Soledad, but *O. franciscanus* was not among them. In the absence of actual knowledge of the life-history it may be taken as practically certain that the nymph lives on the roots of plants.

The nymphs of *Oliarus*, in common with those of several other Cixiid genera, are provided with a wide tuft of long white cottony filaments of easily detachable waxy secretion at the end of the abdomen, while the crevices in which they live are often lined with similar material. The adults are often powdered with matter of the same nature, giving them a grayish appearance.

The adult of the present species is by no means confined to cane, but occurs on a variety of plants. The members of this genus more than most other Cixiids, except perhaps *Myndus*, frequent grasses and other low herbage, and *O. franciscanus* offers no exception to this habit. It was swept in considerable numbers from rough grasses and miscellaneous weeds in a guarda raya of a cane-field near the Harvard Laboratory, while odd specimens were taken from various shrubs in the Botanical Garden and elsewhere. In damper hollows of the cane-fields it occurred on a blue-flowered weed, *Commelina nudiflora* L. From the middle of February to the end of March it was taken, not plentifully but widely scattered, on Uba cane. The closest and most repeated examination of Cristalina cane failed to show any examples of *Oliarus*, but it is much to be doubted whether this common cane variety remains unattacked during the wet season. In the dry season Uba, by reason of its denser growth, supported considerably more leafhoppers in general than the Cristalina. If *O. franciscanus* really does not occur on the latter cane variety, it is ruled out

as a possible vector of mosaic, for Uba is generally accepted as immune to the disease.

Wolcott (1921, pp. 18, 19) has described as new a species, *Oliarus cinereus*, from cane in Porto Rico. Unfortunately this is not recognizable from his description, which omits specific characters. This species was tested by Tower (1922) as a possible vector of mosaic, but with negative results. Wolcott is surprised to find no eggs or nymphs on the cane, though this is the commonest host-plant. The explanation, of course, lies in the fact indicated above that the pre-adult stages in this genus are passed cryptozoically. The same remarks apply to the other Cixiid, *Bothriocera venosa* Fowl., mentioned on the same page (Wolcott, 1921).

**Myndus crudus** Van Duzee, pallid cane leafhopper

This is a smaller and more obscure Cixiid leafhopper than the preceding, which it resembles, however, in shape. The color is difficult to describe — very pallid, varying sometimes to a greenish and sometimes to a brownish tinge, with the eyes conspicuously darker and the wings practically colorless. It is with some hesitation that I refer it to Van Duzee's species described on very scanty material from Jamaica (1907, pp. 33, 34), but it is probably identical with the one recorded from cane near Havana by Bruner (1922) under the same name.

Exactly the same remarks regarding life-history apply to this species as to the preceding. Only the adult is known, and it subsists on a wide range of plant-hosts. Bruner's (1922, p. 15) supposition, "apparentemente se criá en pequeñas gramíneas," is almost certainly unfounded.

At Soledad this leafhopper was taken in some numbers from the damp hollow of Pará grass in the Botanical Garden, where it occurred with clouds of *Kolla similis* and *Dræculacephala minor*. It was found also on the miscellaneous weeds at the edge and in the *guarda rayas* of cane-fields, and in the grasses and other herbage of moist creek-beds. Occasional specimens were beaten from bushes, including guava (*Psidium*) and from the undergrowth in the small forest reserve near the

laboratory. It was quite abundant on the young growth springing from cut stumps of guasima trees (*Guazuma tomentosa*). On April 1, when all damp spots were supporting a concentrated leafhopper population, this species was very plentiful on *Panicum barbinode* on the edge of a pond.

On cane from February to April it was generally distributed but always scattered and never numerous.

### 4. The Delphacids

**Saccharosydne saccharivora** (Westw.), West Indian cane leafhopper
Synonyms: **Stenocranus saccharivorus, Delphax saccharivora**

The family Delphacidæ is notorious as containing one of the most redoubtable pests sugar-cane has yet suffered, namely, *Perkinsiella saccharicida* Kirk., which upon its introduction into the Hawaiian Islands, without the natural enemies which kept it in check in its native home, threatened the whole industry, but was finally controlled in one of the most instructive and successful experiments ever performed in entomology applied to agriculture.

The West Indian cane leafhopper, one of the first insects ever recorded as a special pest of cane, is an elongate, delicate green insect, with narrow, pointed head and transparent wings. The last feature will serve the layman to distinguish it from the Cicadellids, *Kolla similis* and *Draeculacephala minor*, with their somewhat similar color but stouter build and opaque fore-wings.

*Saccharosydne* occurred at Soledad fairly commonly in a thick growth of Uba cane which had remained uncut beyond the usual period. Nymphs largely grown were found on February 13, with the adults but far less abundantly. On the same date the species was swept from tall Cristalina cane, almost ready for cutting, near the Harvard Laboratory; but on this variety it was much scattered and less common than in the block of Uba cane. No other hosts were observed. Of all the Soledad cane leafhoppers this appeared the most restricted to sugar-cane. But the species was found in insufficient numbers

to enable a study to be made of its distribution. Possibly in the rainy season it increases considerably, but it does not appear to be a pest of much importance at Soledad.

Bruner (1922) finds it similarly negligible, presumably in the Havana district, and ascribes this to the activity of natural enemies, as also does Wolcott in Porto Rico. In the British West Indies, however, it has at times been a severe pest.

The experiments of Tower (1922) in Porto Rico and of Gowdey (1924) in Jamaica all failed to demonstrate its power to carry mosaic, while the positive results in Smyth's experiments were overwhelmingly scanty and have not been accepted.

A good account of the life-history and habits is given by Van Dine (1912) and by Wolcott (1921), based on observations made in Porto Rico. The eggs are embedded in the midrib of cane leaves, and are usually inserted from the under side of the leaf; they are parasitized by several Hymenopterous insects. The whole life-history is spent on the cane. This insect is heavily parasitized in Porto Rico, especially by the Strepsipteron, *Stenocranophilus quadratus* Pierce. At Soledad, of 18 adults and two nymphs swept at random from Uba cane, 16 of the adults were affected by this parasite, of which there were no fewer than 36 examples. This represents a very heavy rate of parasitism. These Strepsiptera are being studied by Mr. George Salt, who kindly determined my material.

For taxonomic references to the West Indian cane leafhopper see Van Duzee's Catalogue (1917, p. 763).

**Peregrinus maidis** (Ashm.), corn leafhopper

The corn leafhopper is a common North American insect closely attached to maize and sorghums, to which, at Soledad, it appeared indeed to be confined. It is a medium-sized leafhopper, much stouter in build than the West Indian cane leafhopper, and of a dark-brownish hue varied with lighter, the clear fore-wings marked on the distal halves with dark brown. It occurs in both long-winged and short-winged forms, the

latter appearing more numerous at Soledad in February than the long-winged.

In February this insect, both young and adults, formed tremendous colonies on the inside of the leaf bases and in the central shoots of the young maize plants. Here it was the central organism of a complex and very interesting biocoenose, comprising astonishingly numerous species of many diverse families of Hymenoptera and Diptera, attracted by the copious honey-dew secreted by the leafhopper, with various Coccinellids and their larvæ, Reduviid bugs and their nymphs, and other predaceous insects and Thomisid and Attid spiders preying on the leafhoppers themselves and on the guests at the honey-dew table. It was especially interesting to note that Thomisid spiders, which so often lurk in or near flowers for the purpose of capturing visitors to the latter, were here using the honey-dew deposits in exactly the same way. It was surprising what large Vespids these spiders could overcome. The beautiful red Reduviid, *Zelus rubidus* Lep. et Sev., seemed to find conditions very favorable in this association and was abundant in all stages from egg to adult. The predatory Pyrrhocorid, *Largus* (*Euryophthalmus*) *sellatus* Guér., with its metallic blue nymphs, was equally active and plentiful. Ants were running everywhere and living up to their reputation as general exploiters, lapping up the honey-dew and carrying away piecemeal the caps from the eggs of *Zelus rubidus*. But this is a digression, albeit on a subject which would furnish material for an extensive study.

The situation was a small field near the Harvard Laboratory, with young cane two to three feet high interspersed with maize. Apparently not the slightest straying occurred of *Peregrinus maidis* from corn to cane, even under these favorable conditions. The maize was strongly affected with mosaic; the cane relatively clean.

On sorghum in the Botanical Garden the corn leafhopper was found in fair numbers, but much less plentifully than on maize.

On March 24 a macropterous specimen, probably derived

from the small quantity of maize grown in the mine settlement, came to electric light at the Mina Carlota in the Trinidad Mountains.

As noted in Section II, this leafhopper has been proved to convey mosaic from maize to maize but not to cane. I am familiar with only one record of *P. maidis* on sugar-cane, and this concerned an isolated adult only (Wolcott, 1923, p. 273).

A fine study has been made of the life-history of *Peregrinus maidis* in Hawaii by Fullaway (1919). The eggs are deposited chiefly in the midrib, on the upper surface of the leaf, and are packed several together in cavities cut for the purpose by the ovipositor of the female. The nymphal instars, of which there are the usual five, differ in appearance from the adult chiefly in size and the absence of wings. Under Hawaiian conditions, in summer at sea-level, the life-cycle required about a month for its completion.

A number of natural enemies are described by Fullaway in detail.

Before leaving the great grass- and sedge-feeding family of the Delphacidæ it should be mentioned that a large number of species occurs in all suitably moist situations in the Soledad district. A very large proportion of these are small and obscure forms belonging to the large genus, *Delphacodes* Fieb. (*Liburnia* Stål). Some time must elapse before the taxonomic affinities of this group can be elucidated, but abundant material consisting of several thousands of examples obtained by sweeping at Soledad is available for this revisory work. Until this is accomplished, it will be sufficient to note here that the insects of this and related genera are very rarely found on sugar-cane, but prefer low grasses in moist situations. The little black *Delphacodes teapæ* (Fowl.), which has been recorded from cane in Porto Rico by Wolcott (1921), was very plentiful at Soledad, especially on a shady lawn at the Botanical Garden, but was never taken on cane. On the other hand, one specimen each of two new species of *Delphacodes* was swept from the cane at the edge of a field. In the light of our present scanty knowledge it seems unwise to attach any im-

portance to these two apparently random occurrences, but the work on *Aphis maidis* has shown that even casual records should not be neglected.

### 5. The Derbids

**Phaciocephalus cubanus** Myers (see Appendix I)
Tawny leafhopper

A rather small, but delicate long-winged planthopper, with the head and visible portion of the thorax bright reddish-brown, and the fore-wings a more olivaceous brown, the whole insect, wings included, often powdered with bluish pruinose material like the bloom on a ripe plum.

This leafhopper, so far as we know, is confined to Cuba. It is closely related to *P. uhleri* (Ball) of North America, but is quite distinct specifically, and has therefore been described as new. The diagnosis has been relegated to an appendix. Apparently the same species is recorded from cane near Havana by Bruner (1922, p. 16) as *Phaciocephalus* sp., "el salta-hojas polilla." He says: "Esta especie es uno de los pocos salta-hojas observado en considerables numeros en caña completamente desarrollada; no abunda pero usualmente se pueden encontra algunos; hasta ahora no hemos observado que se crie en la caña. Sospechamos a este insecto como un transmisor posible de 'mosaico,' especialmente entre plantas de caña grande. En Agosto de 1921, cuando mas se propagaba la enfermedad en nuestros campos, notamos especialmente numerosa esta especie. Hemos preparado experimentos para determinar su relación con el 'mosaico' de la caña." All these statements of Bruner concerning habits I was able to confirm at Soledad.

The life-history is quite unknown, but the nymphs are almost certain to be cryptozoic and probably bear no relation to cane. Muir (in Kirkaldy and Muir, 1913, p. 28) states with reference to the family Derbidæ in general: "Although the adults of some species collect in such numbers in cane fields, . . . yet they never do any considerable damage; this must be

attributed to the habit of the young of not feeding on sugar cane, for if they did, their number, which is much greater than that of the adults, would cause considerable damage." The same remarks apply to *Oliarus* and *Myndus*, of the Cixiidæ.

At Soledad during the dry season the conditions on full-grown cane were apparently almost optimum for *P. cubanus*, since, in spite of its wide host-range, it was more frequent on cane than elsewhere. Tall cane, as Bruner states, is preferred. It was the one insect which one could be almost sure of finding on almost any grown cane. It was slightly more abundant in Uba than in Cristalina cane, but very widely and evenly distributed in both varieties, even under the driest conditions.

Sweeping of rough grass and weeds in guarda rayas, of Guinea grass (*Panicum maximum*) in the potreros, and of bushes and shrubs in the Botanical Garden and elsewhere, usually produced examples of this species. It is probably the commonest, and certainly the most widespread, of the cane leafhoppers at Soledad.

### 6. The Aphides, or Plant-lice

#### **Aphis maidis** Fitch, the Corn Aphis

Aphides are preëminently insects of the temperate zones. Their place is taken in the tropics largely by Psyllids and Coccids. Ordinarily they are among the most difficult insects in the world to identify, but among the few species found at Soledad *A. maidis* is easily recognized by its deep green color marked with black.

This aphis, now so well known as practically the only insect shown to carry mosaic from other grasses to sugar-cane, is, at least in the dry season, exceedingly rare at Soledad. Such scarcity may be explained in part possibly by the abundance of Coccinellids, especially *Cycloneda limbifer* Casey [1] — a factor which helps to account for the rarity of the yellow cane aphis also, and perhaps throws light on the paucity of the corn aphis in maize fields, where at least one host-plant is numerous. In

[1] Kindly determined by Mr. H. S. Barber, U. S. Bureau of Entomology.

the latter connection it would be interesting to know whether there is any direct competition on maize between the corn leafhopper and this aphis. The part of the plant affected and the age of the host seem much the same in both cases, while a shoot heavily infested with the leafhopper, which was much the commoner at Soledad, apparently has little room left for aphis. Yet mixed colonies were found. The percentage of parasitism in the corn aphis was, as described below, very high. But probably the chief explanation of the scarcity of *Aphis maidis* at Soledad lies in the almost complete absence of Johnson grass (*Sorghum* [*Holcus*] *halepense*) as a weed there. In many other parts of Cuba and elsewhere this is one of the commonest weeds of cane-fields, where it forms the chief host of the corn aphis. Finally, it must be borne in mind that the observations on this insect, as on all the others considered in the present report, were made only during the dry season and should be checked at other times of the year. But the factors for scarcity mentioned above would be operative at all seasons.

*Aphis maidis* was found in only two spots at Soledad, and required much searching even there. One was in the maize field so heavily infested with *Peregrinus* as described in the account of that insect, and was discovered in the middle of February, when one corn-plant was found infested. On a minimum estimate, based on the number of already dead and swollen brown parasitized examples, the percentage of parasitism among these aphides was about 50. Mr. George Salt reared two species of parasitic Hymenoptera from this material. One, a Braconid, *Aphidius testaceipes* (Cress.),[1] was a direct parasite, or rather parasitoid, of *Aphis maidis* itself, and responsible for the brown, swollen appearance, and the other a Chalcidoid,[2] *Pachyneuron siphonophorae* (Ashm.), almost certainly a hyperparasite attacking the *Aphidius* and therefore to be considered an injurious insect.

*Aphidius testaceipes* belongs to a genus which specializes in aphides as hosts. Its larva develops in the body of the aphid,

[1] Kindly determined by Professor C. T. Brues. Synonyms are *Trioxys testaceipes* Cresson, and *Lysiphlebus tritici* Ashm.

[2] Kindly determined by Mr. Gahan, U. S. Bureau of Entomology.

and the perfect insect emerges from the swollen skin by a circular opening to which is often still attached, like an open lid, the piece of excised cuticle. The best accounts of the life-history and habits of *A. testaceipes* occur in Hunter (1909), and Webster and Phillips (1912), in both of which papers it was studied as an enemy of the spring grain aphis, *Toxoptera graminum* (Rond.). In Hunter's publication is an account by P. A. Glenn (pp. 165–200) of the influence of climatic conditions on the development and distribution of *Aphidius* (*Lysiphlebus tritici*). Webster and Phillips give a long list (pp. 115–117) of other aphides, including *A. maidis*, all of which are attacked by this same very active and prolific parasite.

The self-colored red ladybird [1] and its elongate blackish grub were both actively engaged, in some numbers, devouring the corn aphis. Probably the larger red and black species [2] attacks it, too.

In the same maize-field, by March 9, the only plan s remaining still young and green enough for the aphis were infested heavily by corn leafhopper, and no more aphis was to be found.

The other infestation of *Aphis maidis* at Soledad was on sorghum in the Botanical Garden, where it was quite plentiful on March 17, but considerably decreased in numbers on the 29th, while on the 31st it was practically gone — possibly hastened by a very heavy rain during the night.

It is interesting to note that, although East and Weston (1925, p. 26) found elephant grass (*Pennisetum purpureum*) with mosaic at La Vega, Soledad, the plot of this grass at the Botanical Garden failed to reveal the presence of *Aphis maidis* after repeated search.

The implication of *Aphis maidis* as the chief carrier of mosaic has been described in the opening section of this report. It is significant to note that the important rôle thus assigned to this insect by Brandes was greeted with scepticism by experienced sugar-cane entomologists in nearly every country con-

[1] *Cycloneda limbifer* Casey. Kindly determined by Mr. H. S. Barber.
[2] *Chilocorus cacti* (L.). Kindly determined by Mr. Barber.

cerned. Most of them insisted that *A. maidis* was very rarely, if ever, found on cane, and never plentifully enough to be a probable vector under field conditions. Two circumstances led to the very general breaking-down of this scepticism — firstly, the long succession of negative results in experiments with most of the common cane Homoptera and the confirmation of Brandes's work with the corn aphis, and secondly, the discovery by Kunkel, and by Chardon and Veve, that weeding of a cane field caused a rapid extension of mosaic infection due to the colonization of the cane by *Aphis maidis* from the dying weed grasses. But it still remains very difficult to understand how an insect so rare on cane can be the sole vector (with the possible exception of the still rarer *Carolinaia*) of such a widespread disease as mosaic. As late as 1924 Gowdey in Jamaica, after securing only negative results in experiments on transmission with *Kolla similis* (*herbida*), *Saccharosydne saccharivora*, and *Peregrinus maidis*, considered that these are nevertheless the most probable vectors, since no aphid occurs in sufficient numbers on sugar-cane in Jamaica to be seriously implicated.

As pointed out previously, the corn aphis explanation for secondary infection in the field at Soledad is rendered much less plausible than elsewhere by the practical absence of its chief weed host, *Sorghum halepense*. Nevertheless, *Aphis maidis* is present at Soledad and may be more widely distributed on the estate during the wet season. Moreover, the power of spread of aphides is very great. Thus Kunkel states with reference to the present species (1924, p. 130): "Experiments have shown this insect to be more active than was at first supposed. Young seedlings of Sudan grass, one of its favorite hosts, were grown in pots in insect-proof cages, and after reaching a height of approximately one foot, were exposed for different periods of time on a grass lawn about fifty yards from aphid-infested corn and Sudan grass plants. It was found that an exposure of one day was usually sufficient to bring about an infestation of most of the seedlings by the winged form of the corn aphid." It must, of course, be remembered that it is not necessary for infection that the aphis estab-

lish colonies on the cane. It can transmit mosaic even if it sustains itself on cane only a few days and then dies out.

A curious feature of the *Aphis maidis* question is that the chief wild host, at least in Cuba, Johnson grass (*Sorghum* [*Holcus*] *halepense*), is shown by Brandes and Klaphaak to be itself immune to mosaic. Various other wild grasses have been recorded as hosts by Porto Rican workers and others, and probably exist also in Cuba. If it should be established, however, that *Aphis maidis* can use only cultivated sorghums and maize as its source of infection, then the possibility of its acting as the chief agent in the secondary spread of mosaic under field conditions becomes incredibly remote.

**Sipha flava** (Forbes). Syn. **S. maydis** (Bruner) nec Passerini, the yellow cane aphis

This is the common yellow aphis of cane, distinguished easily from the preceding species by its more or less uniform yellow color and by its station on the older leaves of cane itself. *A. maidis* confines its attention to the central shoot of the host-plant, whether that be cane or corn. This difference in the point attacked has been suggested as perhaps the chief reason why the yellow cane aphis apparently does not transmit mosaic. A vector must attack the shoot and not the older leaves. No transmission experiments with this species have been successful save the inconclusive early one of Smyth (1919*a*).

The yellow aphis was rare at Soledad during the dry season, but was evenly if extremely sparsely distributed on old cane, both Uba and Cristalina; much rarer on the latter. The red or orange coloring of old leaves caused by the attack of this insect was frequent enough to suggest a greater abundance of the aphis earlier in the season.

Both the common ladybirds, *Cycloneda limbifer* and *Chilocorus cacti*, occurred on cane with the yellow aphis, but were not actually observed to feed on it. The little Anthocorid bug, *Triphleps insidiosus* (Say), a well-known predaceous species, was also not uncommon.

Menéndez Ramos (1925) has recently reported *Sipha flava* as a serious pest of Uba cane in Porto Rico. He states that it is very common in all cane-fields, and in some isolated cases he knows "fields of the Uba variety where hundreds of hills have been destroyed by an extraordinary invasion of this insect." But he notices that natural enemies, including spiders, larvæ of Syrphid or hover-flies, and ladybirds soon restore the balance. Such unusual outbreaks can occur only when conditions are especially favorable for the aphides. In Cuba generally, as stated by Bruner, the yellow cane aphis "no es dañino en el campo."

An account of the habits in Porto Rico is given by Wolcott (1921, pp. 33, 34). With reference to the synonymy, Mr. P. W. Mason, of the U. S. Bureau of Entomology, writes (6 Nov., 1925) that *S. flava* (Forbes), described from American material, and *S. maydis* Pass., based on European examples are considered distinct by Mordwilko. The descriptions clearly justify this in the opinion of the writer.

### 7. The Coccids

**Pseudococcus sacchari** (Ckll.), the pink cane mealy-bug

This is the common pink, short mealy-bug of cane, found under the leaf-sheath, often closely flattened against the stem, in a very large percentage of stalks examined in the field. There has apparently been confusion in economic literature dealing with cane mealy-bugs in the West Indies. There is a second species common on cane but only once found at Soledad — a much more slender, grayish species, which is the *Ps. calceolariæ* (Mask.) of authors. These two kinds are easily distinguished by shape and color with the naked eye. Yet Smyth referred to the two (1919 a, p. 92) as "almost indistinguishable except under the microscope." On a later page he calls *Ps. calceolariæ* the "pink sugar-cane mealy-bug" and *Ps. sacchari* the "gray" one, thus exactly reversing the facts of the case. This is repeated by Bruner (1922, p. 16), while Wolcott does not separate the two species at all (1921). The earliest record

I can find of the confusion is in Cardin (1915, p. 115), where he referes to *Ps. sacchari* as the *chinche harinosa gris* and to the other species as the *chinche harinosa rosada.*

The pink mealy-bug is very plentiful at Soledad, on both Uba and Cristalina cane. Mr. Salt states that in his moth-borer survey reported upon in this volume, he found the heaviest infestation of mealy-bug in low-lying country where *Diatræa* also was at its maximum.

Almost every colony of pink mealy-bug beneath a leaf-sheath forms an interesting association. Several instars are present together and are accompanied by numbers of a small Anthocorid bug, *Lasiochilus pallidulus* Reut. Their relation to the Coccids is unknown, but most members of the family are predaceous. The mealy-bugs themselves are attended by several species of ants, notably *Prenolepis steinheili* Forel and *Brachymyrmex heeri obscurior* Forel, which feed on their secretions. Often the leaf-sheath shows a gaping rent over the place where a thriving mealy-bug colony resided. One would suspect birds, but I believe rodents have also been incriminated.

This species is essentially confined to the actual stem. The roots themselves are attacked by another form, a species of *Ripersia.* But Van Dine (1913, p. 255) states with reference to *Ps. sacchari:* "The most serious injury noted has been to the roots of young cane beneath the surface of the ground. The mealy-bug appears to be taken into the cane fields on the seed cane and to develop below the ground about the young and tender roots until the cane stalk has formed sufficient internodes above the ground for the pest to find shelter, at the nodes, beneath the leaf-sheaths."

Hatching, almost certainly of this species, was observed in a block of Uba cane at Limones, Soledad, on April 2, during very dry weather. There was a fine dust of extremely minute freshly hatched young, over the surface of the cane leaves. The insects were not distributed evenly over the field, but were concentrated into numerous separate centres, though the cane itself was continuous.

Fungus parasites of the cane mealy-bugs are known, but they have not so far shown themselves capable of economic use in field practice. The well-known Australian, mealy-bug-devouring ladybird, *Cryptolæmus montrouzieri* Muls., has been introduced into Porto Rico to combat the species attacking sugar-cane, but so far without much success. The closely appressed leaf-sheaths of the cane shield the insect very effectually from the attacks of natural enemies.

The mealy-bugs do not seem very probable vectors of mosaic. Smyth did obtain one apparently successful result in a mosaic transmission experiment, but questions its validity himself. Elmer (1922) has shown that a *Pseudococcus* can transmit the mosaic of Cucurbitaceæ, Solanaceæ and Leguminosæ.

It is extraordinary that the other common cane mealy-bug, *Pseudococcus calceolariæ* (Mask.) of authors, was not found by the writer at Soledad, save in one isolated instance and that on adventitious roots of cane from the main stem just before ground level. Morrison (1925) has recently shown that this should be known as *Pseudococcus boninsis* Kuwana.

**Ripersia** n. sp. Morrison, cane root mealy-bug

This is a purely subterranean species, of less powdered appearance and more globular shape than the preceding forms. At Soledad it is extremely rare. In spite of the fact that I examined numerous cane roots in company with Dr. J. A. Faris, who was working on "root-rot" at the time, only one lot of this species was found, at least on cane. These were on the true roots of a large healthy hill of Cristalina cane near the Harvard Laboratory, and were at a considerable depth below the surface of the ground. Large ants of the species *Odontomachus haematoda insularis pallens* Wheeler were in close attendance.

Several examples of the same Coccid were found on the rootlets of mixed scrubby bushes near the track at the Hanabanilla Falls, near Cumanayagua, at a very considerable distance from any sugar-cane or cultivated crop. This occurrence would lead one to suspect that the species is perhaps an endemic one, only secondarily attached to cane.

**Targionia sacchari** (Ckll.), the cane-stalk scale-insect
Syn. **Aspidiotus sacchari**

Dr. J. A. Faris found this small white circular scale quite thickly on the lowest part of the stem, among adventitious rootlets, of a specimen of "botanical cane," that is, a new variety planted for the first time under field conditions. He kindly handed these examples, which were taken at Guabairo, Soledad, to me, and they remain all I saw. But it may be commoner than this indicates, since it is easily overlooked.

Wolcott (1921, p. 35) found it in Porto Rico "living at the base of high cane stalks, most often where the leaf-sheaths are bound to the cane by the mycelium of the root-disease fungi . . . but only .15 per cent of all stalks examined were infested."

## VI. SUMMARY AND CONCLUSIONS

1. Some eight weeks in February, March, and April were spent at Soledad itself, partly in observations on sugar-cane Homoptera. These observations apply to dry-season conditions and were made purely from an entomological point of view.
2. A summary of present knowledge of cane mosaic transmission by insects shows that the corn leafhopper is a vector from maize to maize and *Aphis maidis* from other grasses to cane. A second aphis, *Carolinaia cyperi*, carries the disease from sedge to cane in Porto Rico. None of these occur normally on cane, but the two latter have been shown to migrate to the cane when their weed host-plants are eliminated.
3. Not one of the common cane insects has yet been shown to carry mosaic.
4. The question of insect vectors has not hitherto received much attention at Soledad. Two insects, the corn leafhopper and the corn aphis, both vectors elsewhere under experimental conditions, occur at Soledad on corn and sorghum, but not on cane.

5. *Aphis maidis* is very rare at Soledad. This rarity may perhaps be explained partly by the abundance of ladybirds and partly by the absence of its chief wild host, Johnson grass, as a common cane-field weed.

6. The feeding habits of Hemiptera, or true bugs, in general, are discussed and it is suggested that there is a marked difference between the two suborders in the part played in plant-host preferences by botanical as compared with environmental factors.

7. Attack on cane can happen only under certain environmental conditions, and in the case of cane Homoptera at least, these conditions, rather than the botanical relationship of cane to other hosts, are often the deciding factor.

8. Five species of leafhoppers, one Aphis and three Coccids, are listed as definitely associated with cane at Soledad, and at the same time it is suggested that work in the wet season would very materially increase the number. Species are also listed which are recorded elsewhere as common on sugar-cane, but which are found at Soledad on other hosts.

9. The common green leafhopper, *Kolla similis*, was almost absent from cane at Soledad in the dry season. Its plant preferences in the dry weather were determined apparently solely by the environmental factor of moisture.

10. The sharp-headed green leafhopper, *Dræculacephala minor*, was not found on cane at Soledad.

11. The two Cixiids, *Oliarus franciscanus* and *Myndus crudus*, both occur on cane but not in great numbers. Both have numerous other host-plants.

12. The West Indian cane leafhopper was too rare to supply material for very extended observations.

13. The Derbid leafhopper, *Phaciocephalus cubanus*, is described as a new species. It is the commonest and most widespread leafhopper on cane at Soledad, but occurred on numerous other hosts.

14. *Aphis maidis* was found only on maize and sorghum. It was parasitized at the rate of at least 50 per cent by the Braconid, *Aphidius testaceipes*, but the latter was in its turn attacked by a Chalcidoid.
15. The yellow cane Aphis, *Sipha flava*, was not common.
16. The pink cane mealy-bug was plentiful at Soledad.
17. There has been confusion in the economic entomological literature of the West Indies between the two common cane mealy-bugs. An effort has been made to clear this.
18. The cane root mealy-bug, *Ripersia*, was rare at Soledad.

# APPENDIX I

Description of **Phaciocephalus cubanus,** n. sp.

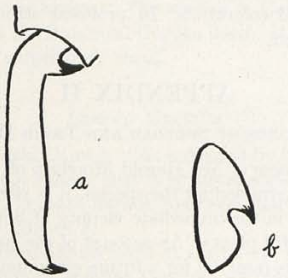
A small tawny species closely related to *P. uhleri* (Ball) 1902.

*Male,* length 2.3 mm., tegmen 3.3 mm., total length to tip of tegmen, 4 mm.

Vertex wider at base than long, with elevated sides and coarse granulations; apex narrower than base; base angularly emarginate. Face very narrow, frons with highly raised edges making it trough-like in appearance save at apex, where it expands and slightly flattens to join the generally wider clypeus.

Pronotum with distinct median longitudinal ridge, and two mediolateral ones. The three mesonotal carinæ very distinct.

Tegmina with about twelve large and conspicuous granules on basal half of 2nd Anal (Tillyard modification of the Comstock-Needham system)




PHACIOCEPHALUS CUBANUS, n. sp.
Right genital style of male;
*a*. Ventral view. *b*. Caudal view.

vein. Nearly as many similar granules more widely spaced along subcosta, commencing some distance from base.

Last ventral segment produced in a triangular point with sweeping, incurved sides and a wide base. Genital styles on their inner ventral sides, each with an inwardly directed slightly curved spine near base; distal of this spine the inner ventral edge is nearly straight. The two spines almost meet in mid-ventral line. One recurved spine at tip of each style. (See figs. *a*, *b*.)

Head and body reddish-brown, brighter on mesonotum. Beneath light brownish, the genitalia tinged with fuscous. Tegmina brownish amber, with the granules of subcosta and of 2nd A fuscous, as well as commissural

margin. Apical margin of tegmen with thickened slightly serrate actual edge crimson. Stigmatic region whitish; hind-wings infuscated, the veins darker.

*Female*, length 2.8 mm., tegmen 3.9 mm., total length to tip of tegmen, 4.5 mm. Rather more fuscous in color than the male. Pregenital plate as viewed from below almost square.

*Holotype*, male, from sugar-cane, Soledad, Cuba, Feb. 13, 1925.

*Allotype*, female, sugar-cane, Soledad, Cuba, Feb. 13, 1925.

Both are deposited in the Museum of Comparative Zoölogy, Cambridge, Mass.

Described from a large series collected on cane and other hosts at Soledad, from February to April.

Both sexes are often covered in life with grayish pruinosity, giving, in combination with the reddish body color, a purplish tinge.

The species is nearest to *P. uhleri*, to which it runs in Metcalf's (1923) and in McAtee's keys (1924), and to which it is very closely related, but differing in shape of male styles, in shape of female pregenital plate, in size, markings, and general coloration. In pronotal structure it is practically identical with *P. uhleri*.

## APPENDIX II

### List of Coccids of Soledad and Their Host-plants

Through the kindness of Mr. Harold Morrison of the U. S. Bureau of Entomology, who determined all the species, it is possible to give a list of the Coccids collected in the immediate vicinity of Soledad, chiefly on cultivated and other useful plants. An account of the species obtained in the Trinidad Mountains is reserved for a future communication.

At least to one accustomed to collecting in New Zealand, the very great scarcity of scale-insects in general at Soledad was so surprising as to require some explanation. The paucity of Coccids in the large Botanical Garden, with its great range of Cuban and foreign hosts, was especially extraordinary, since such places are usually rich collecting-grounds for the coccidologist. Yet in the Soledad Garden, with its more than two thousand species of plants, one searched assiduously tree after tree without finding a scale. Only an odd citrus tree or other species here and there bore a moderate number. Mr. R. M. Grey, the Superintendent, states that a close watch is kept for infestation, and treatment promptly administered. Probably most of the foreign plants arrive as seeds. But this cannot explain all. Possibly the great isolation of the garden, not only from the city of Cienfuegos but also from the tiny Soledad settlement itself, has been a contributing factor. An oleander near the mill was rather thickly infested with *Saissetia oleæ*, while those at the garden were without scales—a remarkable

condition for such a susceptible tree. In the orange orchard at the batey the unusual scarcity of black scale may have been due to the abundance of the little black ladybird, *Egius platycephalus* Muls.[1]

There is some slight evidence that Coccids other than cane mealy-bugs are somewhat uncommon elsewhere in Cuba. Thus Tower (1911, p. 34), describing a visit to Cuba, remarks that "not very much scale was observed [in orange orchards] as the groves visited were protected by the beneficial fungi, which were in great abundance. Cuba apparently has not as strong trade winds as Porto Rico, and for this reason alone the scale would not be as bad. Another reason why Cuba does not have a great amount of scale is that many of her groves were originally planted in strips cleared in the forests." Most of these remarks of Tower refer to the purple scale, *Lepidosaphes becki* (Newm.).

In the list which follows I am indebted for some of the plant names either directly to Mr. R. M. Grey, or to the labels in the Botanical Garden, of which he is in charge. I take this opportunity of thanking Mr. Grey for his never-failing readiness to impart information from his very wide knowledge of tropical natural history. The species of Coccids asterisked were taken at least once in the Botanical Garden itself. It will be seen that the list of such species is surprisingly small.

## List of Coccids

***Pseudococcus comstocki** (Kuw.). "As indicated by Green in *Ent. Month. Mag.* [but] I do not believe that it is this species." H. Morrison.

On stem of banana, beneath fibrous layer, February 9.

On fruit of banana, March 3.

On undetermined Leguminous plant at the batey, February 14.

On underground stem of another Leguminous plant, *Calopogonium* sp., attended by the large ant, *Odontomachus hæmatoda insularis* Guer. var. *pallens* Wheeler, April 2.

***Pseudococcus maritimus** (Ehr.).

On *Acalypha Wilkesiana* J. Muell., March 6, assiduously attended by the ant, *Monomorium floricola* (Jerdon).

**Pseudococcus nipae** (Mask.).

On undetermined plant, May 24, coll. G. Salt.

On golden areca, *Chrysalidocarpus lutescens* Wendl., assiduously attended by the ant, *Pheidole megacephala* (Fabr.), at the batey, February 20, coll. Mrs. E. F. Atkins, Jr.

On undetermined plant at the batey, February 14.

[1] Kindly determined by Mr. H. S. Barber, U. S. Bureau of Entomology.

**Pseudococcus sacchari** (Ckll.) [or **Trionymus,** H. Morrison].
Plentiful on sugar-cane.

**Pseudococcus boninsis** Kuwana.
One occurrence on cane. This is the species commonly referred to as *Pseudococcus calceolariae* (Mask.), February 27.

**Pseudococcus** sp.
On *Cyperus ferax* Rich. in cane-field, February 13.

**Ripersia** n. sp.
On roots of Cristalina sugar-cane, February 27. An account of this species will be found in the text.
On roots of unknown plant, Hanabanilla Falls, near Cumanayagua, April 7.

**Toumeyella** sp. (610).
On edge of scar on trunk of undetermined tree, attended by ants, *Camponotus. ramulorum* var. *mestrei* Wheeler, which had nest on the trunk a little lower down, March 4.

**Toumeyella** sp. (609). "Apparently, and possibly undescribed, but the genus is in a very difficult condition and the material submitted is hardly adequate for determination." H. Morrison.
On zarza, *Pisonia aculeata* L., attended by the ant, *Camponotus planatus* Roger, March 4.

***Coccus viridis** (Green).
On undetermined plant at the batey, February 14.
On *Citrus* sp., March.

**Coccus mangiferae** (Green).
On mango, February 15.

**Saissetia hemisphaerica** (Targ.).
On cycad, February, coll. Mrs. E. F. Atkins.
On *Tabernaemontana citrifolia* Jacq., attended by the ants *Camponotus planatus* Roger and *Solenopsis geminata* (Fabr.) March 2.

**Saissetia oleae** (Bern.).
On oleander at the batey, February 15.

**Howardia biclavis** Comst. and

**Pseudaonidia (Selenaspidus) articulatus** (Morg.).
On undetermined plant at the batey, February 14.

**Chionaspis citri** Comst.
On *Citrus* sp. at the batey, February 14.

***Hemichionaspis minor** (Mask.) of authors.
On *Acalypha Wilkesiana* J. Muell., March 27.

**Aulacaspis pentagona** (Targ.).
On *Piper umbellatum* L. in the forest reserve ("seborucal"), April 1.

***Lepidosaphes becki** (Newm.) and

***Parlatoria pergandei** Comst.
On *Citrus* sp., April 12.

**Aspidiotus lataniae** Sign.
On oleander at the batey, February 15.

**Targionia sacchari** (Ckll.).
On sugar-cane, March 3, coll. J. A. Faris.

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