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OF THE

DEPARTMENT OF AGRICULTURE TRINIDAD AND TOBAGO.

Number One.

REPORT

ON THE

FROGHOPPER-BLIGHT OF SUGAR-CANE IN TRINIDAD

—BY—

C. B. WILLIAMS, M.A., F.E.S.
(Entomologist in Charge of Froghopper Investigations.)

January 1921. Trinidad, B.W.I.

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By C. B. Williams, M.A., F.E.S.,

(*Entomologist in charge of Froghopper Investigations.*)

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SECTION I.

INTRODUCTION.

TRINIDAD AND ITS SUGAR INDUSTRY.

THE Island of Trinidad is the most southerly of the West Indian Islands and is geographically and biologically practically a part of the South American Continent, from which at the narrowest part it is only separated by a strip of water about eight miles wide.

Its total area is 1,862 square miles and its population about 360,000. It is situated between 10° and 10° 50′ N. latitude and the climate is tropical. There are two distinct seasons, a dry season from January to the middle of May with an average of about 3 inches of rain per month, and a wet season from June to December with about eight inches per month (*see* Fig. 1). The total yearly rainfall is about sixty-four inches.

TRINIDAD RAINFALL. AVERAGE FOR FIFTY-THREE YEARS—1862–1914.

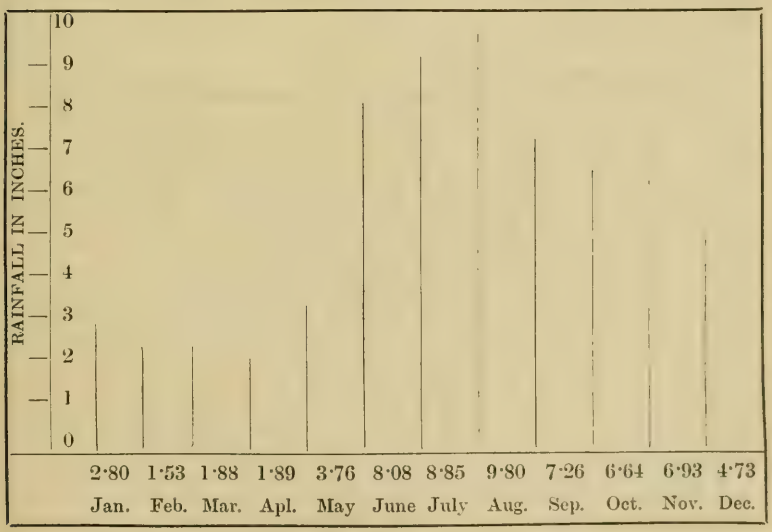

Fig. 1.

Fig. 1.—Monthly rainfall, Trinidad Botanic Gardens, average of fifty-three years.

The island is traversed by three parallel ranges of hills running approximately east and west. The first, which rises to over 3,000 feet, borders the northern coast; the second, rising only in one spot to 1,000 feet, runs slightly diagonally across the centre of the Island; and the third seldom rising above a few hundred feet, occupies a broad belt near the southern coast.

The chief sugar growing districts are the eastern ends of the two more or less flat stretches of land that are found between these ranges of mountains (*see* Fig 2). They may be divided for convenience into a

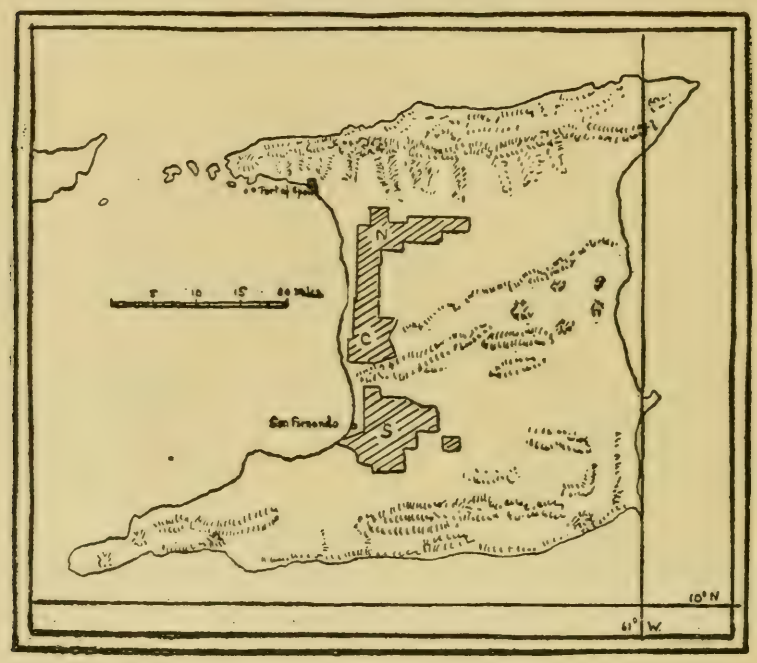

Fig. 2.

Fig. 2.—Map of the Island of Trinidad showing approximate position of the Mountain Ranges and the three chief sugar growing districts.

Northern section occupying the very flat low-lying areas on the banks of the River Caroni; a central section occupying the coast lands North and South of Couva, and in the Couva district running for some miles inland along the terminal spurs of the central hills; and a Southern section generally known as the "Naparimas," round San Fernando and Princes Town, in which the land is more undulating than in either of the two former areas, and the soil irregular but including some of the most fertile in the island.

The sugar cane is the second most important agricultural crop of the island (cacao being the first) and the export has varied during the last 20 years from 38,000 tons (of 2,240 lbs.) in 1905 (grown in 1904) to 71,000 tons in 1917 (grown in 1916). The total area under sugar-cane is roughly 50,000 acres or 78 square miles.

Fifty years ago a large number of small independent privately-owned estates, each with a small mill, occupied this area. Amalgamation into large estates and companies followed, as in other parts of the world, and there are now only fourteen factories of any size in the island. The greater part of the sugar cane cultivation is in the hands of these companies.

Hand in hand, however, with the fusion of estates and factories has gone, particularly in the last thirty years, the rise of a class of small cultivators, the "cane farmer," or peasant proprietor, who owns or rents a few acres of land on which he grows cane (usually together with ground provisions) and these canes are sold to the larger factories.

It is the official policy of several of the largest companies at the present time, to encourage this form of cultivation, and the number of cane farmers has risen from about six thousand in 1900 to over twenty thousand in 1918.

However desirable such multiplicity of small cultivators may be from a political, social or financial aspect, it must be recognised that it makes the organised control of diseases and pests of much greater difficulty, and has a considerable influence on the methods which it is possible to adopt for the reduction of disease.

The cane is planted usually in the second half of the wet season (August to November) and is not cut until the dry season of the second year following, having thus had about eighteen months growth. Canes are known up to their first cutting as "Plant Canes," which are distinguished as "Wet Season Plants" if originally planted during the wet weather or "Dry Season Plants" or "Crop Plants" if planted, as occasionally happens, during the dry season. These latter have only about twelve months growth before the first cutting. Subsequent cuttings take place every year and the canes are known as "1st Ratoons" or "2nd Ratoons" etc., according to the number of times they have been cut. Canes older than third ratoons are not commonly seen and are becoming each year less frequent.

All the cutting and grinding has to be done in the dry weather between January and the beginning of June, chiefly owing to the impossibility of cartage on the traces or field roads during the wet weather.

THE BLIGHT.

For many years the growing canes have been subject at irregular intervals to serious damage by a disease or complex of diseases known locally as "Blight." This consists, briefly, of a browning and drying up of the leaves of the cane and a decay of the root system, which results in more or less complete cessation of growth, an appearance throughout the field "as if scorched by fire," and a loss ranging from a slight check in growth to a complete destruction of the crop.

In practically every case of blight the insect *Tomaspis saccharina* (Hemiptera, Cercopidæ), known locally as the Sugar-cane Froghopper, is found in numbers in the damaged areas, both on the leaves in the winged adult stage, and on the roots where it lives in the young or nymph stage surrounded by its characteristic white froth (Plate III.)

In addition to the froghopper other diseases, chief of which are those caused by various species of root fungi, are frequently present in the damaged canes and have been sometimes considered as responsible for part at least of the destruction.

The loss varies greatly from year to year and is difficult to estimate with any exactness, particularly as it has been found, that many of the causes of the prevalence of blight are unfavourable conditions which would have themselves led to loss, even without the presence of the froghopper and its associated diseases.

Allowing for this, however, the loss in some years is sufficiently great to warrant the attention that it has attracted and to justify the continuance of effort towards its understanding and control.

Gough in 1910 (1911 C.p. 10 & 23) gave figures of the cost of production of cane per ton on healthy and blighted fields. These were—

Healthy field ...	...	$1.09 per ton.
Slightly blighted	...	$1.01–$1.49 per ton.
Badly blighted	...	$1.53–$3.50 ,,

This last section obviously does not include fields completely destroyed, as in these the whole expenditure is a dead loss. It is scarcely necessary to add that while the relative value of the figures remains, it is no longer possible to produce canes at the cost here given.

Urich (1913 C. p. 9) estimates the average damage from 1907 to 1912 as 10 per cent. of the crop, which at the then ruling prices was equal to a loss of about £55,000 per annum.

In 1916–17, a year almost free from blight, the export of sugar from the island was about 71,000 tons. In the following year it had fallen to 46,000 tons. Nearly 50 per cent. of this drop was due to disease of which the froghopper was the prime cause. The loss for that year was therefore about 12,000 tons of sugar worth £300,000 at the price then prevailing.

Further details of the loss will be found in Section III (p. 30) which deals with the history of the disease in Trinidad, but it will be seen from the figures already given that the planters of the island are faced with a disease which takes a considerable toll of their profits each year and which has moreover shown little sign of diminishing in intensity in recent years.

The damage during 1917 was unsurpassed by that in any year with the possible exception of 1912, and many estates were only saved from a serious loss on the year's working by the high price they were able to obtain for the sugar produced. Should prices again fall to anything in the neighbourhood of the pre-war figures, damage such as that in 1917 would make it almost impossible for smaller companies to carry on.

INVESTIGATIONS UP TO 1916.

In the course of my work and in the preparation of the following report I have made free use of the results of previous investigations, all of which will be acknowledged in their place. It might be convenient here, however, to summarise the work that had been done and the position in which I found it in 1916.

The earliest mention of damage at all resembling the present "Blight" is in a report dated 26th January 1863 by H. Cruger (see Bibliography at end, Cruger 1892). He describes the condition of the cane as being "alarming a few months ago" but says that since then "the canes have recovered nearly everywhere." He describes several insects attacking the canes but none of these could be identified with certainty as the froghopper. He mentions a "louse-like" insect on the roots, but the absence of any reference to the conspicuous froth makes it doubtful that this was the froghopper.

C. E. A. Francis made in 1878 a "Chemical Analysis of Blighted Sugar Cane and the soil in which they were grown" (Francis 1881). He found the cane ash deficient in silica and the soil deficient in lime as compared with several Antigua soils. Once more there is no definite indication of the cause of the blight.

In 1889 the froghopper was first discovered by J. H. Hart who described an outbreak of blight in the Chaguanas district and believed it to be due to the ravages of this insect. He also noticed the presence of root fungus (*Marasmius*) on the canes on some estates and said that "on these the attack of the froghoppers appeared to be more pronounced that on other fields where better health prevailed." He also mentioned a green mould growing on the insects, which has since been identified as the parasitic Green Muscardine fungus.

In 1906 attention was once more directed to the problem by a severe outbreak. Hart (1906) laid more stress on the part played by the root fungus, and Collens (1906 A and 1906 B) reported on two outbreaks in both of which root fungus and froghoppers were associated.

In 1907 O. W. Barrett, who was visiting the island to report on Cacao Cultivation, published two short notes on the sugar-cane blight (Barrett, 1907 A. & B.) In these he agreed that the froghopper injury to the roots must be considerable, but considered that the worst pest is the *Marasmius* root fungus which he believed responsible for over ninety per cent. of the damage in the Couva district in 1907.

The years 1906, 1907, and 1908 were all marked by severe outbreaks of blight, and, as a result of this, in 1909 the first steps to get regular investigation of the problem were taken by the recently formed Board of Agriculture, who appointed a Mycologist (Mr. J. B. Rorer) an Entomologist (Mr. F. W. Urich), and, in the following year, an Assistant Entomologist (Mr. P. L. Guppy) to investigate plant diseases in general and the froghopper blight in particular.

J. B. Rorer, who worked intermittently at the problem from 1909 to 1918, studied chiefly the possibility of controlling the froghopper by propagating artificially one of its fungus diseases, the Green Muscardine (*see* p. 82). He considered that the froghopper blight and root-disease were distinct but were sometimes associated and confused.

F. W. Urich who has given part of his time to the investigation from 1909 to the present date, produced in 1913 a comprehensive bulletin on the Froghopper, its life history and natural enemies, (Urich 1913 C) and gave various suggestions for its control. He believed in the possibility of reducing the numbers of froghoppers by agricultural methods and by encouraging the natural enemies already known in Trinidad, particularly that known as the Vermilion Egg-parasite (*see* p. 65).

P. L. Guppy was appointed Assistant Entomologist in February 1910. In this position he worked until March 1913, when he became assistant to J. C. Kershaw (*see* below). In November 1912 he discovered the Vermilion Egg-parasite (*see* p. 65) and in January 1913 the Trash-coloured Egg-parasite (*see* p. 65). After Mr. Kershaw's departure he continued to carry out recommendations in connection with the breeding of the Syrphid fly until June 1915.

In 1910 the services of Dr. L. D. Gough were obtained and he studied the problem for one season. In his report (Gough 1911C) he outlined the life history of the froghopper, advised the growing of the Green Muscardine fungus on a large scale to destroy the froghoppers, and further recommended spraying with kerosene emulsion to kill the adult insects. He was apparently the first to discover the parasitic Syrphid fly, the maggot of which feeds on the nymph of the froghopper.

In 1912 the damage to the sugar-cane was again so severe that the services of another entomologist, J. C. Kershaw, were obtained, and he studied the problem from December 1912 to December 1913. His results were published in a series of Circulars (*see* Bibliography at end)

and in his final report he emphasised the importance of control by natural enemies, and recommended among other things, that an attempt should be made to breed the Syrphid fly artificially on a large scale, and that, at the same time if possible, a search should be made abroad to find new enemies, which might be introduced into Trinidad. He made some careful anatomical studies of the Froghopper and was the first to show that the Tobago species was different from that in Trinidad.

THE SEARCH FOR PARASITES IN CENTRAL AMERICA.

May 1916–June 1917.

For eighteen months after the departure of Kershaw, Guppy attempted to breed the Syrphid fly on a large scale, but the work was found to be impracticable and was finally abandoned in 1915.

Attention was then directed towards the second of Kershaw's recommendations—that an efficient parasite be sought for outside Trinidad. In December 1915 it was decided to proceed with this, unfortunately, however, on a very limited scale, and in February 1916 I was appointed to carry out this work, with instructions to proceed to Trinidad, and from there to visit such neighbouring colonies and foreign countries as might be likely to contain fresh parasites of the froghopper.

As very little was known of the distribution in Central America of the various species of froghoppers and their parasites, and as conditions arising out of the European War had already begun to affect travelling, it was decided to commence work close at hand. Therefore, after a few weeks in Trinidad to familiarise myself with the conditions in the sugar fields there, I proceeded to Surinam (Dutch Guiana) where I was able to visit sugar fields for a few hours and to make a hurried study of a species of froghopper (*Tomaspis tristis*) reported as slightly injurious to sugar-cane in that country. A short report on that insect has already been published (Williams 1917, see also p. 46).

From Surinam I proceeded to British Guiana and spent there four months investigating chiefly two species of *Tomaspis*, one of which, *Tomaspis flavilatera*, Urich, was common in the canes in the coastal district of Demerara and has since proved itself capable of severe damage: the second species, at present unnamed, was abundant on a wild grass (*Imperata caudata*) in the rubber plantations at Issororo, North West District, and was studied chiefly on account of its very close resemblance to the Trinidad insect, from which it is only separated with difficulty. A report on the first of these two species has already appeared (Williams 1918 B.), the second portion is still awaiting an opportunity for identification of the insect itself and various insects associated with it.

From the point of view of the introduction of new enemies into Trinidad, the investigations in British Guiana had no practical result, as I found there nearly all the parasites and predators already known in Trinidad, although attacking different species of froghoppers. The work indicated that the distribution of the parasites was wider than that of their hosts and that in consequence it would be necessary to go further afield in order to find new enemies.

I returned to Trinidad in October 1916 and shortly afterwards paid a short visit to the island of Tobago, twenty-two miles North-east of Trinidad, to confirm the report that the froghopper found there was not the same as the Trinidad species.

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19.

This was found to be correct, but once more the few enemies found were the same as those already known in Trinidad. (*See* p. 43)

In December 1916 I visited the Island of Grenada about 90 miles North of Trinidad, to see some fields damaged by froghoppers, and found the Trinidad insect, *T. saccharina*, severely damaging canes in one or two small areas in the uplands of the island. A report on this outbreak has already appeared (Williams, 1918 A.) In a very hasty visit no insect parasites were seen and one parasitic fungus, the Green Muscardine, already known in Trinidad, was found to be present, but very scarce (*see* also p. 44).

In January 1917 I left Trinidad for Panama, visiting on the way La Guayra, Venezuela, where in a few hours ashore a species of froghopper, *Tomaspis propinqua*, Walk, was found on grass. This is closely related to, but distinct from the Trinidad insect.

In the Canal Zone, Panama, I found two froghoppers, *Tomaspis lepidior* and an undescribed species, both on grass and both related to the Trinidad insect, but as weather conditions were very dry and not favourable to the search for parasites, I left the Canal Zone and went to Bocas-del-Toro, on the Caribbean Coast, just at the border line of Panama and Costa Rica.

In this district I spent four and a half months and investigated the habits and parasites of ten species of the genus *Tomaspis*. Four of these were forest inhabiting insects, one fed on the roots of *Heliconia*, another on the attaching roots of an aroid creeper, and a third on the roots of a forest bush, and as these habits were so different from the Trinidad *T. saccharina* that it was improbable that their parasites would be of any practical value, little attention was paid to them. The remaining six species were grass feeders and two of them were closely related to *T. saccharina*. A close study was made of these with the result that once again nearly all the known Trinidad parasites were found, including the two specific ones, the Syrphid Fly (*Salpingogaster nigra*) which attacks the nymph, and the Vermilion Egg-parasite (*Oligosita girault*i). Once more the wide distribution of the parasites was emphasised, as opposed to that of the host insects, few of which seem to range over more than a few hundred miles. After three months work in this locality, a new egg-parasite was discovered, a Mymarid, *Anagrus* sp. Three specimens of this emerged from some froghopper eggs which had been submitted a month before to a miscellaneous collection of small Hymenoptera, obtained, by means of parasite boxes, from grass in which froghoppers had been abundant.

Unfortunately these three specimens emerged on one day during my absence on a short expedition to find new froghopper localities, and were all dead when I returned to my headquarters on the following day. The loss of these specimens was entirely due to an unfortunate attempt to carry out single-handed an investigation in which at the very least two people should have been engaged.

Six weeks more were spent in a search for further specimens in the locality which had produced the first three but without avail, and an examination of some thousands of small parasitic Hymenoptera already collected, revealed only two more specimens of this species of *Anagrus*. Not only, apparently, is it very rare in this locality, but it is so similar to another extremely abundant species of the same genus that it would

be scarcely possible to distinguish the two when alive. This abundant species would not touch the eggs of the froghopper and was probably a parasite of some species of leaf-hopper.

Under normal conditions I should have proceeded from Panama to British Honduras as had been arranged, but by this time travelling had become so difficult owing to the withdrawal of ships, that I reported that it would be almost impossible to transfer to Trinidad any parasites that I might discover there, until such a time as travelling facilities improved.

In view of this and of the indications obtained of the necessity of going still further afield in the search for parasites, it was decided to stop this work temporarily at least, and I returned to Trinidad, visiting on the way Carthagena, Columbia, where I found *Tomaspis lepidior*. previously seen in the Canal Zone, and the islands of Martinique and St. Lucia in the West Indies, in neither of which were any froghoppers found.

INVESTIGATIONS FROM AUGUST 1917 TO MARCH 1920.

On my return to Trinidad in July 1917, I was instructed by the Froghopper Committee to continue work in that island, to study the froghopper from a wide biological standpoint, and in particular to see if any reason could be found for the great increase of damage by the froghopper in recent years. It was desirable to find if this was connected in any way with the increased use of seedling canes less resistant that the original Bourbon cane, or if the increase in numbers of the froghoppers was due to the supposed reduction of their natural enemies by the spread the mongoose, first introduced into the island about 1870.

The present report gives as completely as possible the results of my experiments and investigations from August 1917 to March 1920. The greater part of this time was spent in Trinidad studying the agricultural aspect of the blight, but in December 1917 I was able to visit the island of St. Vincent for a few days, to see if the froghopper existed there but in the time that could be spared, no specimens were found (*see* p. 44).

In August 1918 I visited Barbados on sick leave and while there took the opportunity of discussing with Sir Francis Watts, Imperial Commissioner of Agriculture for the West Indies, some of the problems of soil chemistry involved in my investigations, and with Mr. W. Nowell, Mycologist to the Department, the question of the relation of root-fungus and froghoppers in the production of blight. As a result of this, Nowell visited Trinidad in December 1918 to January 1919 and again in October to November 1919 to co-operate with me. The results of his work have been published in two reports (*see* bibliography) and he did much to clear up the complexity of this branch of the work.

It is hoped to issue at a later date a full systematic account of the species of the genus *Tomaspis* met with during these investigations, and a classification of the genus based chiefly on a study of the habits and an examination of the structure of the genitalia.

ACKNOWLEDGMENTS.

In addition to acknowledging my indebtedness to the authors of the published records mentioned above or in the bibliography I wish to take this opportunity of expressing my thanks to a large number of gentlemen without whose assistance the completion of this work would have been impossible.

To the Managers of the sugar estates in Trinidad for their hospitality, patience and interest in my work; to the Staff of the Department of Agriculture in Trinidad, and in particular to Mr. F. W. Urich, whose assistance throughout has been invaluable; to the Department of Science and Agriculture in British Guiana, to whom, and to their Entomologist Mr. G. E. Bodkin in particular, I am indebted for assistance and facilities while in that country; to the Department of Agriculture in Surinam; to the Imperial Department of Agriculture for the West Indies, and to their Mycologist Mr. W. Nowell in particular; to the officials of the United Fruit Company for hospitality during my stay in Panama and Costa Rica; to the Imperial Bureau of Entomology in London for much help in identifying the various parasites found in the course of my work; and to a large number of individuals among whom I might mention Mr. J. R. Bovell, Director of Agriculture of Barbados, Mons. Bassieres, Director of Agriculture of Martinique, and Mr. H. W. B. Moore, Entomologist to Messrs. Curtis Campbell and Messrs. Booker Bros. British Guiana.

I have also to thank Mr. E. E. Fabien, Manager of Cedar Hill Estate, for the drawing of damaged cane leaves from which Plate II is reproduced, Mr. H. G. Osterstock, of the John Innes Horticultural Institution, London, for the drawings of adult froghoppers on Plate I, and Mr. W. Buthn of the Trinidad Board of Agriculture for the drawings of birds in figs. 12–16.

SECTION II.

THE NATURE OF THE "BLIGHT."

GENERAL SYMPTOMS.

The name "Blight" is sometimes used in Trinidad, as in other countries, to describe the insect, in this case the froghopper, supposed to be the cause of the damage. Thus one hears that "Blight was present, but no visible damage has been caused." In the present report, the word is used in its strict sense to mean the diseased condition produced in the cane.

Signs of the disease first appear in the cane fields six weeks to two months after the beginning of the wet season, seldom, if ever, before the middle of June and usually not until the middle of July. The first indication is a slight holding up of the growth of the canes, which cease to make their former good progress. A little later the tips of the leaves wilt slightly and unnaturally, especially during the hot part of the day, and narrow reddish-brown streaks begin to appear on their surface. A close examination at this time will reveal the nymph froghoppers in their froth on the roots (Plate III) and adults sitting during the day time in the axils of the upper leaves well hidden away. The streaks on the leaves increase in number and size, particularly on the outer leaves of the cane, and the whole plant appears from a distance to have a dead brown colour, frequently described as "as if damaged by fire." The diseased stools have nearly always a poor root system and are loose in the ground and easily pulled up, while the old leaf sheaths are frequently matted to the stem by various species of fungi. How far this condition can be considered as a consequence, or alternately, as a predisposing cause of infestation is discussed later.

The browning of the leaves is caused by the sucking of the adult froghopper, and the damage to the roots by the combined effect of the nymph and various fungi. The relative part played by each in the final damage to the cane is discussed in Section IX.

As the older leaves dry up and die the adult froghoppers crowd more and more into the remaining inner leaves, which in turn may be destroyed, and as a consequence all except the largest shoots of the tools die off and decay (Plates IV. to VI.)

Usually however, the first attack of the year does not reach this state of extreme severity and, as the brood passes the canes throw out fresh healthy leaves which gradually replace the damaged ones and normal growth is once more resumed.

After an interval of about two months a second attack may occur, usually, but not always, of greater severity, and after another period of recovery, a third attack may develop after about the same interval.

Recovery from all these depends chiefly on the original severity of the attack, on the general conditions of the cultivation, on the variety of the cane, and on the weather conditions prevailing at the time.

DAMAGE TO THE LEAVES.

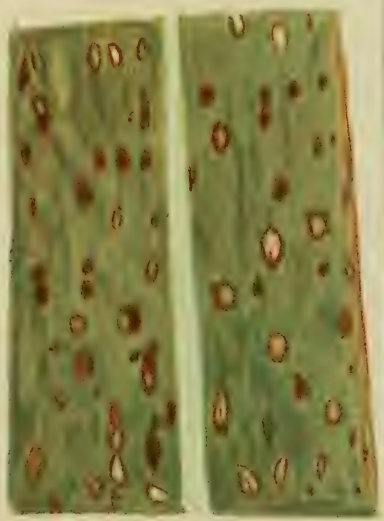
Apart from the slight wilting and curling which are usually the first signs of blight, the main damage to the leaves is caused by the spread of injury from the points at which the adult froghoppers have inserted their mouth tube to suck out the sap.

For convenience of reference I have divided the development of one of these areas of injury into four stages.

PLATE III.

Froghopper nymphs in froth at base of cane stool.

I



II

III

Stage I. (Plate II. fig. 1*a*). Within a day or two of the sucking of the adult froghopper at any point of the leaf the first indication of injury appears as a pale area surrounding the puncture and elongated slightly in the direction of the axis of the leaf. This decolourized area is more transparent than the rest of the leaf and is readily seen when the leaf is held up to the light.

It increases considerably in size particularly in the direction of the axis before the next stage is reached, and becomes a long narrow streak on the leaf, in the centre of which the original puncture is sometimes visible as a small brown spot. The elongation takes place both above and below the original puncture, but as a general rule is slightly more rapid towards the tip of the leaf than towards the base.

This first stage streak is seldom more than one-tenth of an inch wide and may reach three inches in length. A streak 0·5 of an inch long was 0·05 of an inch in width. Others from 2·5 to 3 inches long were about 0·1 of an inch in width.

Stage II. (Plate II fig. 1*b*). After a few days the centre of the pale streak becomes discoloured by a reddish brown pigment usually appearing first as a number of small points round the original puncture and producing a finely mottled effect. This discoloration spreads rapidly up and down the streak, which becomes red brown throughout, while only the newly invaded tissue round the edge remains pale.

Frequently the red pigment forms very narrow hair-like streaks which run for a considerable distance up and down the leaf along a vascular bundle.

The red colour usually begins to appear when the original streak, is about 1·5 to 2 inches long and, concurrent with its development the injury spreads both laterally and longitudinally, so that the second stage may reach 5 inches in length and about 0·175 or 0·2 inches in width.

Actual measurements of streaks of this stage are: 1·5 x 0·1 inch (red pigment just appearing); 2·5 x 0·1 (of this length 1 inch was a hair-like line projecting at the outer end); 2·5 x 0·175; 3 x 0·05; 3·5 x 0·15; 4·5 x 0·175 (2·5 of this was a red hair-like streak); 5 x 0·1, very long and narrow, red hair-like line distinct.

Stage III. (Plate II. fig. 1*c*). In this stage the destruction of the tissue round the point of injury begins to be complete, the centre of the red area dries out and becomes silvery brown in colour and opaque to transmitted light. This dead area spreads until it occupies the greater part of the streak, leaving only a narrow border of red edged with pale green where it is still encroaching on the undamaged tissue. The streak at this stage is usually more than two inches long and may reach a length of from four to six inches and a width of from 0·15 to 0·25 of an inch.

If the original punctures are close together the separate streaks join up into large dead areas on the leaf which I have found it convenient sometimes to record as stage IV, but which really only represents a number of overlapping streaks of Stage III.

The total destruction of leaf tissue resulting from a single puncture by a froghopper may thus exceed half a square inch, and as a stool of cane may have fifty or more adults, each of which will suck at several*

* Recent experiments show that on an average two streaks develop for each froghopper per night.

spots each night for several weeks, the accumulated injury is very considerable. A leaf often has as many as a hundred punctures and rough estimates in the field frequently indicate a destruction of ten or twenty per cent. of the leaf area, while in bad attacks 50 to 100 per cent. is the rule rather than the exception.*

The rate of spread of the injury from a puncture and the duration of the different stages is subject to very considerable variation and further investigation on this line might throw light on the cause of the spread. The increase in size is quite out of proportion to the original damage due to the puncturing of the leaf and removal of the sap, and must be due to the introduction of some poison, toxin or infection into the wound.

The first stage is noticeable about two days after the puncture by the insect and spreads slowly without any central discoloration for from five to eight days. In rare cases as long as 15 days has been passed without discoloration. A number of observations gives about seven days as the average duration of the stage.

The red discoloration of the second stage begins five to fifteen days (average seven), and lasts without the death of the centre till fifteen to twenty-six days (average nineteen days), after the original puncture.

The death of the centre part of the streak defining the third stage starts on the fifteenth to twenty-sixth day and continues to spread slowly until the death of the leaf a month or so later.

On an average the typical first stage is found after four days, the typical second stage after about two weeks, and the typical third stage after three to four weeks.

As the brood of adult froghoppers may only last two or three weeks it will be seen that the injury continues to increase after the adult froghoppers have disappeared.

In addition to the above symptoms the developing leaves in the terminal roll receive less nourishment from the damaged plant so that the new leaves are shorter and narrower than the leaves which would have been produced by the same plant in normal growth. By measuring the lengths of the successive leaves some time after an attack this check can easily be shown.

DAMAGE TO THE STEM.

The damage to the stem is entirely indirect and is due to the reduction of the food supply both from the injured roots and leaves, and also near the tip from the spreading of injury from the young leaves downwards.

The growing point of a cane badly damaged but not killed almost always shows a red discoloration when cut longitudinally. In a healthy cane this discoloration, probably due to oxidation, appears some minutes after the surface is cut, but in the diseased canes it is already there before cutting. It is most distinct at the nodes where it may take the form of narrow red streaks extending up and down the vascular bundles from each node, and it may spread some distance down from the growing point.

Another symptom sometimes present is the formation of small pockets of a gummy substance in the young internodes.

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* A cane leaf is about four feet long and two to two and a half inches in width, tapering towards the tip. The area of a healthy leaf is probably under 100 square inches.

In addition the young growing part of the cane still beneath the sheaths of the green leaves exhibits an unnatural brittleness and liability to break across in the internodes just above the level of the bud (eye) and the ring of undeveloped roots. This break occurs frequently in handling diseased canes for examination and also naturally in severe cases, and is probably the immediate cause of the complete death of the growing point frequently found in small and medium sized canes in a bad attack. In Plates IV and V several of the dead shoots will be seen to have broken off near the top in the manner indicated.

Length and width of internodes. The internodes or joints which are in the period of most rapid elongation are those bearing the outer green leaves and those from which the leaves have recently fallen. As a result of the great reduction of nutrition from roots and leaves during an attack this increase of length does not take place and the green leaves of the cane instead of separating from each other at the base, remain crowded together and form a more or less fan-like arrangement of leaves spreading at the tip, but close together at the base. This result is distinctly seen in the tall cane to the left in Plate V. The same reduction also occurs in the width of the internodes. This reduction in length and width is most clearly visible in canes of medium size as the largest canes have more reserve strength and show it less, while the smallest shoots are killed so rapidly that there is no opportunity for it to show (See Plate VI).

When the canes begin to recover the still young internodes increase in size but those which have matured and hardened during the attack remain short and considerably reduced in width.

These groups of short and narrow internodes remain visible on the cane and form a convenient and easily available record of past damage to the plant. Fig. 3 shows the successive lengths of the internodes in

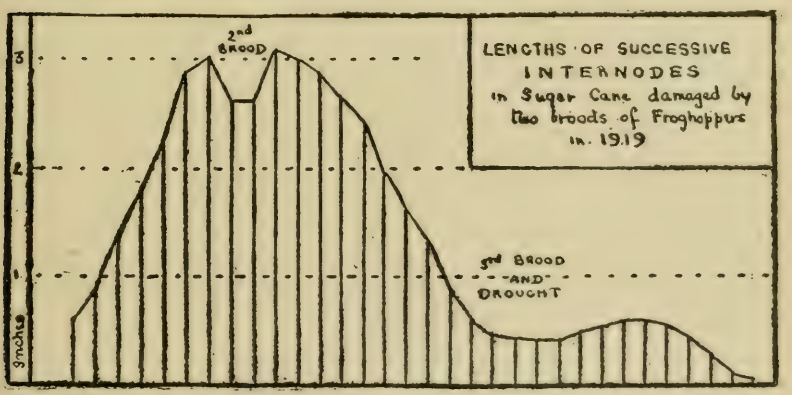

Fig. 3.

Fig. 3—Diagram of lengths of internodes in cane damaged by two broods of froghoppers in 1919.

December of a cane which had been damaged by froghoppers in both August and October. Each of these two checks is visible by the reduction in the internode length. The second check is more severe than the first, as it was in this case increased by the advent of drought at the same period as the second brood of froghoppers—the check thus representing the combined result of the two.

Shooting of the Eyes. When the growing point of the cane is injured in any way, or ceases to require nourishment, as after arrowing, the eyes or buds lower down usually start to grow. This is a frequent accompaniment of the froghopper blight. Shooting usually starts just below the level of the maximum shortening of the internodes and may spread through these to those above. This breaking of the buds only occurs in canes which have sufficient reserve strength to supply the necessary nutriment and so is usually seen only in the larger canes of the stool as in plate IV.

Adventitious Roots. Usually as a direct result of the damage to the root system and of the humidity produced about the stem by the matting of the leaf sheaths, the dormant roots on the lower parts of the cane start into growth underneath the sheaths in the attempt to get more moisture. At first this occurs only near the base of the plant but as these roots in turn become diseased, it proceeds higher and higher up the plant until developing roots may in extreme cases be found three feet or more above the base. This symptom, as with the breaking of the eyes, usually only occurs in the larger canes with more reserve food material and although frequently associated with froghopper attack. may be produced by many other causes.

DAMAGE TO THE ROOTS AND ROOT STOCK.

The root system of a severely blighted cane is almost always, but not invariably, poor and superficial. Further experiments are needed on the exact effect of the sucking of the nymph on the roots, but results obtained so far indicate that this alone does not produce such severe effects as are caused by the adult on the leaves. The problem is complicated by the fact that blighted canes are most commonly seen in heavy poor soils, which are themselves conducive to a poor root system; and further that both the unfavourable soil condition and the damage by the nymphs seem to assist the development of root fungi which invade the diseased roots and continue the destruction.

In addition to the weak superficial nature of the roots they are frequently blackened and dead throughout and even rotting and decayed and the whole stool can usually be pulled from the ground without great effort.

On the other hand blighted canes are found in some cases with apparently sound deep root systems. These are invariably in good well cultivated soils and such canes always recover with great rapidity after the passing of the brood of froghoppers.

The root stock, or that part of the cane below the ground is sometimes discoloured by a red staining such as is found in cases of root-disease, but as at present no cane has been found in this condition without root fungi also being present, it is probable that it is due to these and not to the uncomplicated attack by froghoppers.

EFFECT ON SAP OF CANE.

The greater part of the sugar in the juice of the cane is manufactured in the leaves of the plant. Severe injury to these leaves will therefore be expected to have its effect on the composition of the sap.

Further investigation is needed in this direction, but at present a few observations have been made which should be summarised here.

The adult is known to suck the sap from the plant and extract the sugar from it. All this is direct loss to the Planter. Gough (1911 C. p. 11) points out that the blighted canes when they come to the factory contain less moisture and hence often a higher percentage of sucrose than undamaged canes, but on the other hand the greater dryness of the cane renders extraction less effective.

I have been informed that the sucrose in blighted canes inverts more easily than in normal canes.

The juice of blighted canes is further considerably more acid than normal juice. This was first pointed out by Collens (1906 A & B.), and Carmody (1909 B. p. 110) states that "wherever froghoppers are unusually abundant the cane on closer examination is found to be diseased from other causes and the juice is abnormally acid." He then raises the question as to whether the acidity of the juice is due to the sucking of the froghopper or whether the froghopper is more attracted to canes which have already a juice made acid from other causes. Further discussion on this question will be found on p. 126.

Chemical change in the sap is also indicated by the spread of the red brown discoloration from the point of puncture of the leaves, and by its appearance in badly damaged canes on the upper part of the stem particularly in the growing point at the base of the young leaves.

FINAL CONDITION OF DAMAGED CANES.

On Plate IV is shown a very badly damaged stool of cane with the dead leaves removed, Plate V shows a larger stool somewhat less damaged and Plate VI shows the component parts of a damaged stool separated so that the effect on each shoot is more apparent.

It will be seen that the final condition of the stool is largely determined by the size and vigour af the shoots at the time of injury, or by the relative number of shoots of different sizes. The smallest shoots (Plate VI, C to G) are killed outright in spite of a relatively large root system; the medium sized shoots (B) are injured but may recover; while the largest shoots (A) are much less injured and retain sufficient vitality to throw out young shoots (*a*, *a*,) at the base, which will produce good canes if a sufficient growing period remains and good weather prevails.

It follows that, other things being equal, the larger and more vigorous the canes are in a field the less will be the probable damage.

If however conditions continue unfavourable and the severity of one or more broods is sufficiently great, the accentuation and accumulation of all the above symptoms may result in the complete destruction of the whole stool. All except the largest standing canes are killed, root fungus spreads with great rapidity on the already damaged stools, the new shoots fail to establish themselves and the plant, unable to stand the drain on its reserves, becomes a complete loss to the grower.

The ground between such stools soon ceases to be shaded and grass and weeds grow rapidly and assist in smothering and starving the cane plants, which are finally covered up by a growth of weeds and creepers.

RECOVERY.

If conditions become favourable and the original damage has not been too severe, a rapid recovery sets in after the passing of the flight of adult froghoppers.

The younger leaves as they unfold are no longer punctured and damaged, but remain healthy and green, and the stool and field gradually assume a healthier appearance as the proportion of green leaves increases.

At the edge of a damaged field recovery in this way is noticeable by the high level of the distinct line made by the brown leaves. The lower leaves are dead, the middle leaves are damaged only at the tips which hang down, and the youngest ones are green.

If the damage has originally proceeded to a stage when most of the younger shoots have been killed and only the older ones remain with normal growing points, the latter will recover as described above, but the field will be characterised by the number of small dead shoots round the base of the stool. (Plate IV.)

If the damage has been still more serious, so that the larger canes have had their growing points injured, the recovery will be very uneven and mostly by the shooting of the upper eyes in these canes, and by fresh healthy shoots breaking out from the old root stock and basal joints of the canes.

With the continuance of good conditions a remarkable recovery may take place, even in cases of severe damage, but the canes never make up what they have lost and the appearance of such a field is deceptive, as the new growth of leaves frequently serves to cover up a complete absence of cane development beneath.

The rate of return to normal growth depends on the original damage and on the ability of the cane to produce new leaves and shoots.

No special investigation has yet been made of the rate of root production, but in the absence of root disease this is probably rapid, and proceeds as usual in step with the development of leaf surface.

A number of observations have been made on the rate of production of new leaves and these show that a cane plant produces a new leaf every four to seven days according to conditions and the time of the year, and as a healthy plant should have 10 to 15 green leaves, it follows that two to three months are required for a plant to throw off all the damaged leaves and replace them by healthy ones.

In Fig. 4 an attempt has been made to measure the rate of recovery by estimating the percentage of efficiency (*i.e.* green assimilating tissue)

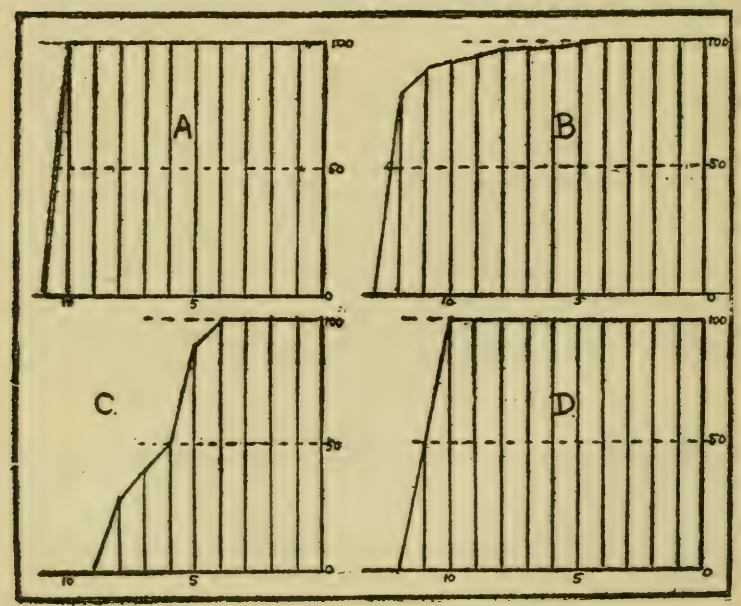

Fig. 4.

Fig. 4—Diagrams of efficiency of green leaves of damaged and undamaged canes. For explanation see text.

PLATE IV.
Stool very badly damaged by blight, dead leaves removed.

PLATE V.
Stool less damaged by blight.

PLATE VI.
Stool damaged by blight, dissected into component parts.

in each leaf from the centre roll outwards at various intervals after a froghopper outbreak. The height of the vertical lines represents the value to the plant of the successive leaves. A, shows a healthy plant in which there were ten leaves all of which were completely green. B, shows a plant one month after being slightly damaged by froghoppers. The five most recent leaves are quite healthy while the next seven all have their surface more or less reduced by the brown discoloration of the streaks, the greatest loss, however, not being beyond 20 per cent. C, shows a plant at the same period which had been originally much more seriously damaged and has only four young green leaves undamaged and the next six damaged up to as much as 80 per cent. of their surface. D, shows a plant three months after severe damage in which all but the outermost leaf have been replaced and are quite free from injury.

The production of new leaves has been estimated by several other methods with similar results.

As the time taken to produce a complete new set of leaves by a plant is greater than the average time between successive outbreaks (about two months) it follows that a plant damaged in one brood has not regained its normal vigour on the outbreak of the next attack, which will account for the greater severity of the damage in second and third attacks, even when the number of froghoppers present appears to be more or less similar.

VARIATION IN INTENSITY OF BLIGHT.

It has been pointed out that the blight occurs first about two months after the advent of the wet season, and then recurs periodically at intervals of about two months. These times correspond with the successive flights of the adult froghoppers, the life cycle of this insect occupying about two months. The greatest visible blight however, is not at the time of greatest abundance of adult froghoppers, but considerably after this. In the broods of 1919, when careful observations were made on this point, the interval was about two or three weeks. This is due, as has been mentioned above, to the time taken for the spread of injury from the original punctures on the leaves.

About the time of the second or third brood the short dry period known as the Indian summer occurs. If this is severe and long it may stop recovery and the canes gradually go from bad to worse. Further discussion on this point will be found on p. 96.

The distribution of damage in various years varies greatly. Sometimes the blight is not severe but widely distributed; at other times it is very severe in small well defined areas immediately surrounded by quite healthy canes. These patches are usually related to the contours of the ground, outcrops of different soil, different ages of canes, or different cultivation. In some cases the attack spreads into an otherwise healthy field from a diseased area alongside. A fuller discussion of these problems will be found in sections VIII and IX.

SIMILAR INJURIES FROM OTHER CAUSES.

Root Disease and froghopper injury are frequently intimately associated and the condition called "blight" is usually due to the combined effects of the two. The relative part played by each is discussed later.

At the same time there are quite distinct and recognizable differences between the uncomplicated forms of each. The most obvious of these, apart from the presence or absence of the insect, is the absence of any

definite streaks on the leaves in the case of root disease. There is only a severe wilting which may result finally in the death of the leaf. The visible presence of the fungus is not a proof that it is concerned in the injury as it may exist in quantities on the stool as a saprophyte, that is to say living on already dead tissue, and on the other hand it may be doing serious damage to the roots without any considerable surface development of mycelium.

In the canes damaged by root disease only, there is a very considerable shortening in the lengths of the internodes, similar to that caused by drought, but there is not the same narrowing of the joints that is conspicuous in the present blight.

Damage from root fungus does not usually spread over such large areas as froghopper blight and often appears on a few stools in a field. The froghopper may be abundant in small areas, but the smallest I have seen included at least twenty or thirty stools.

Another important difference is that root disease, while capable of rapid increase and decrease in a field, usually in correlation with weather conditions, has nothing of the definite periodic recurrence of the froghopper blight as found in Trinidad.

Sereh Disease. This disease is a serious trouble in the sugar growing districts of the East. In 1911 Dr. Gough suspected its presence in Trinidad and sent specimens to Dr. Went in Java. The latter found in the diseased canes nearly all the known symptoms of a mild attack of Sereh with the exception of the staining of the vascular bundles (which was however seen by Dr. Gough) and says "If all these canes had come from Java I would not have hesitated for a moment and would have declared them to be attacked by Sereh." As Sereh had never been recorded outside the East Indies he merely suggests that "Trinidad is suspect in regard to Sereh and it will be well for planters to keep a keen look out for any more serious signs of the disease." (*West Indian Bulletin* XII p. 558.)

On the other hand a Committee of the Board of Agriculture, who examined the suspected fields about a year later and found them no worse and probably better than the year before, was "not prepared to agree with Dr. Went's conclusions."

There is no doubt that the symptoms induced in the cane by froghopper attacks in Trinidad have a very close resemblance to those described for Sereh in the East. The shortening of the internodes, resulting in a fan-like arrangement of the leaves, the starving and final destruction of the growing point and the consequent death of the smaller shoots, the reduction in the size of the leaves, the appearance of red streaks at the internodes, the development of gum pockets in the young internodes, and the shooting of the eyes and the development of adventitious roots, all are common to both diseases. In fact the illustrations on Plates IV and V showing canes suffering from froghopper attack in Trinidad might well pass for illustrations of Sereh in Java.

At the same time the final symptom of Sereh, the persistence and continual increase of damage in infested stools from year to year, the character that makes it so much to be feared, is *not* found in Trinidad, nor on the other hand are the streaks on the leaves, so characteristic of froghopper attack found in cases of Sereh in the East.

Mr. Nowell and myself have come to the conclusion that the disease does not exist here, but that a series of similar symptoms are produced in the canes by a similar physiological disturbance, which however arises from a quite different cause.

Leaf Spots. Spots in the leaves of canes are produced in Trinidad by two fungus diseases, the Ring-spot disease (*Leptosphaeria sacchari*) and the Eye-spot disease (*Helminthosporium sacchari*). Both of these are readily distinguishable from the streaks caused by froghopper injury, by their size and shape. The spots produced by Ring-spot start as a small purplish red discoloration which later turns brown inside but spreads equally in all directions, remaining more or less ro und and very seldom reaching half an inch in length in the direction of the leaf axis (Plate II. Fig. 2). It is usually commonest in the outer half of the older leaves.

The "Eye-spot" streaks (Plate II. Fig. 3) are a dark brownish red in colour, elongated in the direction of the axis, usually small and closely crowded on the leaf, where they may join up to form larger irregular streaks. They also start almost from the first as a discoloured area. They may be found developing on leaves which have only just unrolled and in severe attacks cause a browning of all the leaves which at a distance resembles that produced by froghoppers, but is of a deeper reddish colour. Up to the present this disease has only been found on one cane, D. 109, in certain small areas, and seldom appears before the month of December when all froghopper injury has ceased in normal years.

Mosaic Disease or Mottle Leaf. A serious cane disease of unknown cause in Porto Rico, Louisiana and elsewhere, results in the more or less distinct mottling of the blade of the leaf with pale yellowish green spots. This disease has recently been discovered in Trinidad and steps are being taken to prevent its spread. There should however be no confusion between this and the froghopper blight as the leaf markings are quite different in colour (never darker than the healthy leaf) and in shape and distribution.

Mosaic Disease has been shown in the United States of America, to be transmitted from one plant to another by certain sucking insects. Experiments in Trinidad to test if the froghopper is a carrier have so far given negative results.

Insect Borers. Failure of the canes in Trinidad is frequently caused by the damage due to the Large Moth-borer (*Castnia licus*) and the Small Moth-borer (*Diatræa* spp.). The latter is the usual cause of "dead heart," which consists of the death of the centre green leaves of the cane owing to the destruction of the growing point by the caterpillar. The large borer, which is found at the base of the stem is frequently the cause of the failure of the smaller shoots in a stool and should always be sought for before such injury is ascribed to froghopper blight.

SECTION III.

THE HISTORY OF THE BLIGHT IN TRINIDAD.

In order to get a proper understanding of a disease that varies greatly in intensity in different years and localities it is important to have an accurate history of the past attacks. From such a record it may be possible to determine the cause of the prevalence of the disease, or, at least, suggested causes may be eliminated.

In the present case the records were originally collected to test the suggestion that the blight had arisen in the past fifteen years owing to the introduction of the mongoose, which question will be found discussed on page 87. They have also been used to trace a relation between the distribution of the rainfall and the extent of the blight. (*See* Williams 1919 E. and p. 96 of present report).

It has been difficult to get a history of the blight as few estates have kept accurate records, and little notice has been attracted except in the years of severe injury. The published literature has been searched and also the unpublished monthly reports of the Officers of the Board of Agriculture. Much information for the year 1912 was obtained from the replies to a circular sent out by the Department of Agriculture in that year, and for the year 1917 from the replies to a somewhat similar circular that I sent to the chief estates.

The dates given are the year in which the crops were growing, not the year in which they were cut.

1862.

Cruger, writing in 1863 (published 1892) says that in the previous year a blight attacked the sugar-canes. There was "alarming damage" about September or October, but the canes recovered by the end of the year. He also notes that the season was much drier than usual. There is no mention of any insect that could be identified as the froghopper, but the time of out-break of the disease and later recovery suggest identity with the present blight.

1869.

According to Urich (1913 C. p. 7) the local newspaper "Trinidad Chronicle" for 5th October 1869 says that "Canes in the Chaguanas district are attacked by a peculiar disease very like a blight."

Once more there is no mention of an insect, but the date corresponds to the time of greatest froghopper infestation.

1878.

In this year there seems once more to have been a severe outbreak of disease in the canes. L. A. A. de Verteuil writing to H. Prestoe (Government Botanist) on 17th November, 1878 says "The blight of which they have been talking for the last several years has kept one somewhat anxious. The blight begins to show itself in September, becomes worse during the blooming or arrowing season—in October and November—and then not only makes no further progress, but some of the canes which evidently had become blighted recover, and new sprouts make their appearance." (Hart 1894).

On 31st March 1879 Mr. Prestoe wrote in a letter that the disease was due to rotten roots and that "every cane stool that I examined in one field was infested with the fungus." (Hart 1893).

E. E. A. Francis in February 1879 reported on some blighted canes from Orange Grove Estate and the soil in which they were growing. He found the cane ash deficient in silica and the soil deficient in lime and in bad physical condition. (Francis 1881).

1873-1885.

According to Tripp (1908) Mr. Hart when speaking of the outbreak of blight in 1889 (q.v.) stated that the froghopper "had been in evidence intermittently for sixteen years previous."

Mr. J. P. Bain, a local Agriculturist, speaking in 1916 said that he remembered froghoppers doing damage thirty-five years before, and Mr. Sanderson, another old Planter, said in 1918 that he distinctly remembered the froth of the froghopper on the cane roots forty years previously.

1886.

Urich, discussing the outbreak of blight in 1906 (Urich 1906) said that he distinctly remembered an attack of blight in 1886.

1889.

This is the first year in which we have a record of the froghopper in association with blight. Hart (1890) reported on an outbreak in Chaguanas in November 1889. He noted that the effects of the insect are most severe after a long period of wet weather succeeded by a sudden drought. He mentioned that the roots were rotten but the cane itself was healthy and would probably recover with suitable weather, and a foot-note states that this actually did occur. The outbreak appears to resemble in every detail those occurring to-day.

Later Hart (1906) stated that the outbreak of froghoppers was followed in this year by an attack of *Trichosphaeria* or Rind-fungus.

1890-1892.

This period marks the beginning of the "breakdown" of the old Bourbon Cane. Various theories have been advanced as to the cause of the widespread failure. Blandford (1892) attributed it to shot-borer beetles and says that within the previous two years they had caused a loss on some estate of 30 per cent. of the crop.

It is now generally accepted however that the breakdown was due to the introduction of the fungus *Colletotrichum falcatum* causing the "Red Rot" of the stem. Nowell believes that this disease was introduced from the East.

1894.

On 14th August, 1894 a special Committee of the Agricultural Society "viewed with alarm the serious spread of insect and fungus pests among the canes," and suggested getting the services of an expert to investigate them. (Hart 1896).

1896.

Urich writing in 1906 said that an outbreak of blight in the Chaguanas district about ten or twelve years previous had attracted attention.

1900.

In August of this year there is the first mention of froghoppers in the canes in the letter book of the Manager of Tarouba and Harmony Hall Estate.

Collens (1906 A.) writing of Harmony Hall Estate says "in 1900 a similar disease attacked the canes—the same larvæ were present coincident with similar climatic conditions."

Gaul (1908) says that blight appeared in this year on several ratoon fields of Woodford-Dale Estate (now part of Cedar Hill). It was confined to the most impervious clay soils where the drainage was poor, and near abandoned lands. The damaged canes recovered later. (*See* p. 109 and fig. 27).

1901-2.

In this year Harmony Hall and Tarouba Estates, damaged by froghopper the year before, produced their record crop.

1904-5.

This was a year of very severe drought and the sugar crop of the island was the lowest for many years, only reaching 38,240 tons. There is however no record of blight.

The Recent Series of Outbreaks, 1906-1919.

1906 appears to be the first of a series of severe outbreaks which continued for many years with greater or less intensity. In view of the importance of the rainfall in connection with the outbreaks of blight, Table I has been prepared showing the main features of the season in each of these years. The total rainfall for the year is given as recorded at Brechin Castle Estate, as that is found to be more or less representative of the average rainfall in sugar districts. In Fig. 20 will be found a more complete statement of the annual rainfall on six estates (including Brechin Castle) during the same period.

The dates of the various broods in the years 1906-1919 will be found tabulated in fiig. 25 (p. 103) where their relation to the commencement of the dry season is discussed.

The figures given for the crop of the Island in Table I are obtained from the returns published by the Agricultural Society of Trinidad and Tobago and are in long tons of 2,240 lbs.

TABLE I.

RAINFALL IN SUGAR DISTRICTS, 1906–1919.

Year.	Dry Season Begins.	Dry Season.	Wet Season Begins.	Floods.	Droughts (Indian Summer).	Wet Season Ends.	Rainfall, Brechin Castle	Blight.	Crop in Tons.	Crop Year.
1906 ...	19th–20th December	Long and severe	8th–13th May ...	May wet, many days throughout year with over 2 in. rain	First half of September and end of October	13th–15th January	69·29 in.	Bad	50,564	1906– 7
1907 ...	12th–16th January	Short, not severe	Gradual, 10th May to 9th June	A few in June & July	October—7th November dry. Severe in places	20th–27th December	62·56 in.	Bad	48,933	1907– 8
1908 ...	20th–28th December	Somewhat severe in North	Gradual, end April to 21st May	Several floods in July December wet	September (especially end) and November dry.	Beginning to middle February	60·56 in.	Bad	52,972	1908– 9
1909 ...	1st–18th February	Very short ...	19th April to beginning June, gradual	Occasional floods in June, July and September	Very slight mid-September and mid-November	31st December–12th January	79·07 in.	Slight	51,950	1909–10
1910 ...	1st–12th January	February very wet, March wet	19th–24th May...	Occasional throughout the year	3rd to 20th September slight. End November slight. December dry	8th–28th December	70·60 in.	Slight	46,718	1910–11
1911 ...	9th–29th December	Very long and fairly severe	28th May – 2nd June	June very wet occasional floods later	Second half of Sept. First half Oct. fairly severe. End Oct. slight.	End November to 22nd Dec.	58·76 in.	Bad	40,936	1911–12
1912 ...	End November to 23rd December	Very long and very severe	17th–20th May..	Slight in June	End August to mid-September slight. October dry throughout.	19th–24th January	55·86 in.	Very Bad	42,331	1912–13

TABLE I.—Continued.

RAINFALL IN SUGAR DISTRICTS, 1906–1919.—*Continued.*

Year.	Dry Season Begins.	Dry Season.	Wet Season Begins	Floods.	Droughts (Indian Summer).	Wet Season Ends.	Rainfall, Brechin Castle	Blight.	Crop in Tons.	Crop Year.
1913 ..	19th–26th January	Severe, long and late	26th–28th May gradual	Occasional. End of August & September	July and August dry. Slight I.S. early October or early November	10th–24th December	57·52 in.	Slight	55,488	1913–14
1914 ...	11th–25th December	Long & severe	17th–26th May not sudden	Slight in September and November	July dry, August unusually dry, mid-October slightly dry.	6th - 9th January	51·13 in.	Slight	58,822	1914–15
1915 ...	6th–10th January	Short but severe, March very dry	25th April to end of May	Occasional, May, June, July & October	End of August to mid-October not severe. December dry in North.	22nd–26th January	60·29 in.	Slight	64,231	1915–16
1916 ...	23rd–30th January	Long, late and fairly severe	Gradual during May to mid-June	August 19th–24th and November 9th–12th	No distinct Indian Summer.	10th–22nd December	63·68 in.	Very Slight	70,891	1916–17
1917 ...	11th–23rd December	Long & severe	19th–22nd May, sudden	July wet. Slight floods in August and December	October dry especially beg. and end. Most severe in Couva district	23rd January to 4th February	63·41 in.	Very Bad	45,256	1917–18
1918 ...	24th January to 4th February	Not long, March dry, less severe in South	25th–27th May, sudden	Occasional ...	1st half September and October, both fairly severe	26th December to 2nd January	60·00 in.	Bad	47,850	1918–19
1919 ...	December 27th to 3rd January	Severe to middle of March	29th April to 12th May	Mid-June ; August 31st and December 15th	End September to mid-October, not very severe	19th December (end of Jany. again wet)	65·24 in.	Not Bad	58,416	1919–20

1906.

From the records obtainable the blight seems to have made its first appearance at the end of August and in September (second brood of adults) and broke out again in October (third brood).

The flat lands round the Guaracara River in the Naparimas, the Couva district, and the Northern Section were the worst infested. At Harmony Hall the Manager reported 30 acres badly blighted by the middle of September and in mid November "the canes have had a further check owing to bad weather."

In the Couva District the blight was prevalent throughout Waterloo Estate in September and there was a "slight recrudescence in old ratoons" in October. At Brechin Castle according to Mr. Arbuckle "When riding through the estate the froghoppers when worst (3rd brood) got entangled in the horses' manes by dozens" and 160 acres were lost completely. Forres Park Estate lost nearly 250 acres (Sargeant 1907).

At Caroni according to Gilbert (1909) a considerable acreage suffered very badly. "Some never recovered and the crop was almost entirely lost." At Orange Grove there was a severe outbreak and Urich (1906) mentioned the green muscardine as common here in mid-September.

According to Carmody (1909 B) the blight was spread over a larger area in 1906 than in 1907 and 1908. The crop grown this year was 12,000 tons below that of the previous year.

1907.

The blight appears to have been bad again this year although I have been able to collect few observations. Apparently it started with the first brood.

The crop in this year "suffered perhaps more severely than any previous one" (Tripp 1908).

In the Couva district, according to J. Black, it started at the end of June to July; in August "the froghopper pest seems to have absorbed all the vitality from the ratoons," but by November they had almost entirely disappeared (J. Knox).

Barrett (1907 A.) visited the Couva district on 18th and 19th July and reported froghoppers abundant, but believed root fungus to be responsible for 90 per cent. of the damage.

At Caroni, according to Gilbert (1908), it was again very bad, especially in the ratoon canes, though none actually dried up as in 1906.

1908.

Urich (1913 C.p.18) says that this year and 1912 were the most severe outbreaks that he had seen. Carmody (1909 B) says that the pest had been "increasing in numbers since 1906."

The damage was apparently much less in the Naparima district and Carmody (l.c.) states that the "most serious attacks since 1906 had been confined to the Caroni Basin, Couva, and Chaguanas." Waterloo and Exchange both reported blight as prevalent and canes damaged; but Brechin Castle produced one of the best yields per acre ever obtained, and three fields on this estate badly damaged in 1906 and 1907 were free in 1908.

In the Chaguanas district (Woodford Lodge) Urich (1913 C.p.18) records blight in October, November and December.

The infestation appears to have been greatest at Caroni. Gilbert (1908) says that it first appeared in early August in 1st ratoons. Between 25th and 29th August 600 acres were affected. It cleared up slightly at the end of September and then returned worse than ever.

Carmody (1909 B. p. 111) commenting on the above attack says "the virulence and concentration within a limited area of the froghopper attack at Caroni were as surprising as the unexpected abundance of the larvæ of *Castnia*, and strongly indicate the real cause of the attack."

1909.

There was a considerable reduction in the froghopper infestation this year and little damage appears to have been done. In spite of this the crop was slightly below that of the previous years. In this year Mr. Urich was appointed by the Board of Agriculture to investigate the pest.

The first brood of adults was very early and by the 22nd of June there was a blighted field at Woodford Lodge, and on July 2nd, there were traces of blight at Caroni. (Urich 1910 A. p. 19).

The second brood appears to have been at its height about 13th to 16th August and a few fields at Caroni were slightly blighted in September.

The third brood appeared in October and on 6th October at Caroni 28,875 adults were caught in 13 lamps (Urich 1910 A. p. 20). Canes were blighted at Orange Grove, Caroni and Woodford Lodge, but Waterloo reported that "Froghopper has been general, but not to the extent of producing blight, although it certainly retarded growth."

Urich reports adults fairly numerous in canes and grasses at Woodford Lodge on 15th January, so that a fourth brood seems to have occurred in this locality.

1910.

This year also was comparatively free from blight, particularly in the Couva district, but there is again a considerable drop in the total sugar crop, which is 5,000 tons below that of 1909–10.

The particulars below are mostly from Urich's monthly reports to the Board of Agriculture.

Slight blight appeared at Woodford Lodge in August, in two small fields in October, and in November and December in ratoon canes at Caroni and Woodford Lodge. Froghoppers were caught by thousands in light traps in December at Woodford Lodge, and continued on into January but "only in hundreds" where there had been thousands before. (Urich's report for February 1911.)

From this it seems probable that the three broods were at the end of July, the end of September, and the end of November, but this does not correspond with the diagram given by Urich (1913 C Plate VIII) of captures by six light traps at Woodford Lodge. This shows two periods of greatest abundance in September and January but does not correspond to his written reports. It may be that the light traps were out more frequently in some months than others.

The dry season of this year was unusually wet and this may have caused the broods to be more confused.

1911.

There was a marked increase of blight in this year, chiefly in the Couva district, and, as a result of the prolongation of the dry season, the broods were considerably later than in 1910. According to Guppy (Report to the Board of Agriculture November 1911) there were three

distinct broods. The first in July, which was fairly numerous, the second in September, very numerous, and the third in November which was excessively numerous.

In the Couva district the damage was considerable. Waterloo Estate reported in August that the froghopper had appeared "later than usual, but more virulent than ever." In September it was "strongly in evidence, but no actual blight." In October "worse than ever before on this estate. Several fields blighted and complete cessation of growth." In November it was worse again, but by December "The froghoppers and blight had disappeared entirely."

At Forres Park 15–20 acres were badly damaged, 10 acres less severely damaged, and some farmers canes blighted. At Brechin Castle the yield was the lowest for many years and the damage due to froghoppers was considerable.

At Woodford Lodge there was blight in August, September and October (Urich 1913 C. p. 18).

1912.

In this year occurred what is perhaps the worst outbreak yet experienced. Damage was severe almost over the whole area under sugar, the estates in the district round Princes Town being the only ones that escaped serious injury. Damage was widespread and severe on many estates in the Naparimas where it had never previously been recorded.

The dry season was very long and severe, lasting from the middle of December to the middle of May, and the crops were affected by this.

"The first two generations of the year were fairly well marked and in quick succession, but as the rainfall diminished the overlapping became more complicated owing to the retarded hatching of the eggs. The third generation dwindled away to nothing, and by the end of December froghoppers were in abeyance." (Urich 1913 C. p. 19).

The first brood was early (9–16 July according to Urich) and by mid-July slight blight had appeared in the Chaguanas district. (Urich *loc. cit.*)

The second brood was about the first week in September. Urich (Report to Board of Agriculture for September) says that the adults emerged in tremendous numbers from the beginning of September to the 14th, when they began to decrease.

This brood was disastrous in its effects. Estates throughout the Naparimas report fields suddenly destroyed. In the Couva district there was "complete stagnation" and "disheartening ravages" at Waterloo; "very large area affected" at Brechin Castle and "about 1,000 acres affected" at Esperanza.

At Chaguanas on 10th September the attack was the worst yet seen and 75 per cent. of the estate was damaged.

In the Northern Section the damage was if possible worse and Caroni reports (see Table II) 1,460 acres badly damaged.

The third brood occurred about the end of October or beginning of November and appears, for some unknown reason to have been small and inconspicuous. Blight was caused only in isolated areas, and nearly everywhere the canes recovered after the second brood.

In October of this year a circular was sent out to all the large estates of the Island asking for returns of the areas badly and slightly infested. These are shown in Table II with similar returns for the year 1917 (another bad year) for comparison.

The areas given are only estate canes and do not include those under small cultivators, who in 1913 produced about 25 per cent. of the canes of the Island.

It will be seen from this table that over 9,000 acres were infested out of a total under estate canes of about 25,000 acres.

1913.

The blight in this year was very much less than in 1912 and seems to have been serious only in the Couva district. The crop grown was 13,000 tons above that of the previous year.

In July Waterloo Estate reported "that adults were exceedingly numerous." In August there was "no extreme blight but stagnation." In September "considerable damage, but not so bad as last year." In October "the canes were beginning to recover," and by November the froghopper had practically disappeared.

TABLE II.

SUMMARY OF DAMAGE IN THE OUTBREAKS OF 1912 AND 1917.

ESTATE.	1912.		1917.		
	Severe.	Slight.	Severe.	Slight	Estimated Loss of Cane.
Northern Section.	Acres.	Acres.	Acres.	Acres.	Tons.
Caroni	1,460	397	260	770	5,000
Orange Grove	69	75	No figures		
Central Section.					
Woodford Lodge	603	208	243	229	6,750
Waterloo	164	763	487	440	12,000
Exchange Group	937	623	1,260	60	20,641
Brechin Castle	350	350	470	700	12,000
Esperanza	290	186	No figures		
Forres Park	15	30	No figures		1,500
Southern Section.					
Plein Palais...	41	73	(Included in Union Hall.)		
Harmony Hall and Tarouba ...	125	327	153	258	3,794
Reform	30	110	2	28	200
Williamsville	nil	15	2	3	10
Craignish	...	...	10	55	200
Hindustan	...	...	29	3	1,000
Malgretout Group	153	97	nil	nil	nil
Cedar Hill	40	190	27	108	2,000
Petit Morne	500	100	50	275	2,600
Union Hall	90	729	...	91	637
Picton and Wellington	171	192	10	70	1,300
Hermitage	70	50	308	217	3,500
La Fortunée...	35	83	203	119	3,500
	5,143	4,588	3,514	3,426	76,632
	For 19 Estates		For 18 Estates		For 19 Estates.

Bronté and Cupar Grange sent in no returns.

In August Urich reported that adults had been present in the cane fields since July, but only in small numbers and the first brood had done practically no injury to the canes. In September he reported that one estate had caught 295,000 of the "first brood" since July.

At Esperanza eight fields were badly damaged and 24 slightly injured (Urich, Bull. Dept. Agr. XII p. 203.)

The first brood seems to have been at the end of July and beginning of August, but there are no records that would locate the later broods.

Urich (Bull. Dept. Agr. XIII p. 102) says that the year was "not so bad as 1912 and this was in a large measure due to the latter part of 1912 having been comparatively more damp than the corresponding period of 1911."

1914.

There was little damage this year and the crop was again better.

According to Urich (Report for July) the first brood had issued and by mid-July most had laid eggs.

The results of light trap captures at La Fortunée show large captures throughout July and the beginning of August. At Waterloo in July they were "already strongly in evidence."

The latter broods were much smaller than in former years but "some damage and mild blight" was reported at Waterloo in September.

Otherwise very high crops and high returns per acre were reported throughout the Island.

1915.

In this year there seems to have been no damage except in the Couva district and the crop is again better than the previous year.

The first brood was early and by July they had "already appeared and part of one field showed blight" at Waterloo. By the end of August and September on this estate the second brood was in enormous numbers and several fields were badly damaged. The third brood does not appear to have been severe. Woodford Lodge records damage in one or two spots.

1916.

There were a few isolated patches of blight this year, but the crop grown was a record one for the island and produced 70,891 tons of sugar.

The pest was late in making its appearance, "nymphs in large numbers" were recorded in July at Waterloo, and the first brood appears to have emerged at the end of July and caused no damage.

At the end of September a number of fields commenced to show signs of blight at Waterloo and in October it was wide spread.

No other records of damage have been obtained and the third brood appears to have been of little consequence.

1917.

After a period of four years, during which conditions had been gradually improving, the year 1917 witnessed the return to an attack of extreme severity, surpassed perhaps only by that in 1912.

The areas damaged on the various estates are shown in Table II together with the estimated loss of canes.

The loss, which applies to the estates alone and not to small farmers, is equivalent to about 7,000 tons of sugar and at the price then prevalent the financial loss was much greater than in any previous year. The loss on farmer's canes would be at least half this figure, giving a total loss of about 11,000 tons of sugar. There was a drop in the total sugar crop of about 25,000 tons, but about half of this was due to other unfavourable conditions not dependent on the froghoppers.

The first brood was at its height about the third week in July; was very widely distributed and caused severe damage in the Couva district, at Woodford Lodge, and slight damage at Orange Grove, but no noticeable injury was recorded in the Naparimas.

The second brood was at its height about the middle of September and caused very great damage. In this month and October the blight spread rapidly in the sections already damaged and injury was reported throughout the Island.

In the Naparimas, Hindustan Estate reported worse damage than ever before. Craignish had severe injury. Cedar Hill reported damage on the red soils, blight was severe at Petit Morne, Picton and Hermitage and very severe on Harmony Hall. Reform, Williamsville and Malgretout on the contrary were very little damaged and Union Hall was only slightly affected and much less so than in the following year.

In the Central district Forres Park and Esperanza were much less damaged than the estates further North. At Perseverance on the other hand the damage was so severe that if it had been a separate small estate as of old, there would have been scarcely enough cane to work the factory.

In the North, Caroni was very severely damaged, but not quite so badly as in 1912, and Orange Grove had several fields badly damaged and a large area less affected.

By the end of September the second brood had passed and towards the end of October the canes began to recover considerably.

The third brood began to emerge at the end of October and in November, but was extremely small and did little damage. At La Fortunée, in the extreme South of the sugar district however, damage was caused in December by adults of either a late third or early fourth brood and in one field of young canes the adults persisted throughout the following dry season in gradually reducing numbers.

1918.

Damage was severe this year, but not so wide spread as in 1917. The most remarkable feature was the rapid recovery in many areas after the passing of the second brood.

The appearance of the broods as shown by captures in light traps at La Fortunée Estate is shown in Fig. 5; on most estates however the second brood was larger than here.

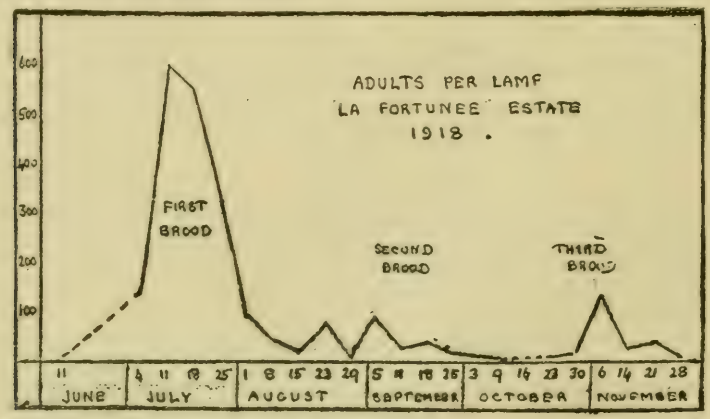

Fig. 5.

Fig. 5—Numbers of froghoppers caught by light traps, on one night per week, at La Fortunée Estate, 1918.

The first brood was at its height about the middle of July and by the end of July slight damage had been done in a few isolated spots (Harmony Hall, Plein Palais, Couva district). The brood was over by the end of July.

The second brood reached its maximum about the second week in September and caused sudden and wide-spread damage at Couva, Caroni and Harmony Hall and in isolated areas in the Naparimas. In September and the first half of October the canes were suffering throughout the Island for want of rain.

By the beginning of October the second brood of adults had passed, about the middle of the month the weather became much wetter, and, except in certain very badly damaged areas, a rapid recovery set in. The fields became greener and there was no further injury.

The third brood in November caused little damage except on one estate in the Naparimas, and throughout this month and December recovery was general.

1919.

This year was considerably more free from blight than either of the two previous years.

The broods were earlier (see Fig. 6) and the first brood was at its height at the end of June and beginning of July. Slight damage was recorded at Petit Morne, Woodford Lodge and Harmony Hall.

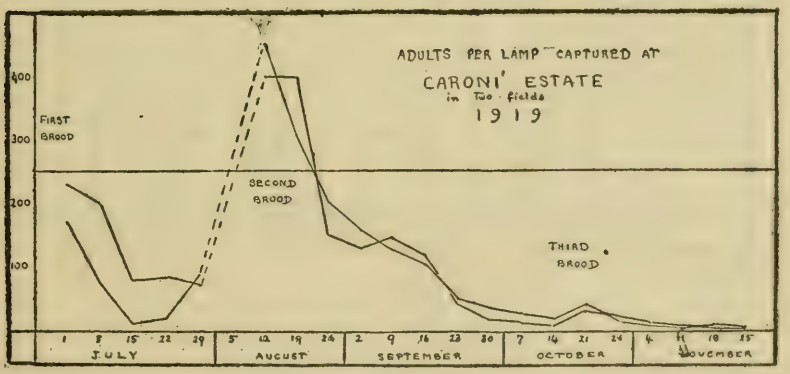

Fig. 6.

Fig. 6—Numbers of froghoppers caught by light traps, on one night per week, at Caroni Estate, 1919.

The second brood was at its height towards the end of August and was locally abundant. Couva district was almost free from damage, but isolated localities in the Naparimas were damaged and Caroni and Orange Grove in the North both had several fields blighted.

The third brood was at its height about the 16th–20th October and caused distinct blight in several areas chiefly in the Naparimas; Couva district being once more being almost free from injury, both in Farmers' and Estates' canes.

After this there was a general recovery with favourable growing weather in November and December.

DISCUSSION.

From an examination of the above records the following points of interest will be seen.

(1.) The dates of the broods vary a little each year and are related to the date of the commencement of the dry season (*see* fig. 25 and p. 102.)

(2.) The relative size of the broods varies from place to place and from year to year.

(3.) The second brood is usually the most injurious, while the third brood is often unexpectedly small.

(4.) There appears to be a recurrence of periods of severe damage at intervals of four or five years. The damage in the years 1906–1919 is shown diagramatically in Fig. 7, and this regular periodity is well marked. Whether it is accidental or significant cannot be determined

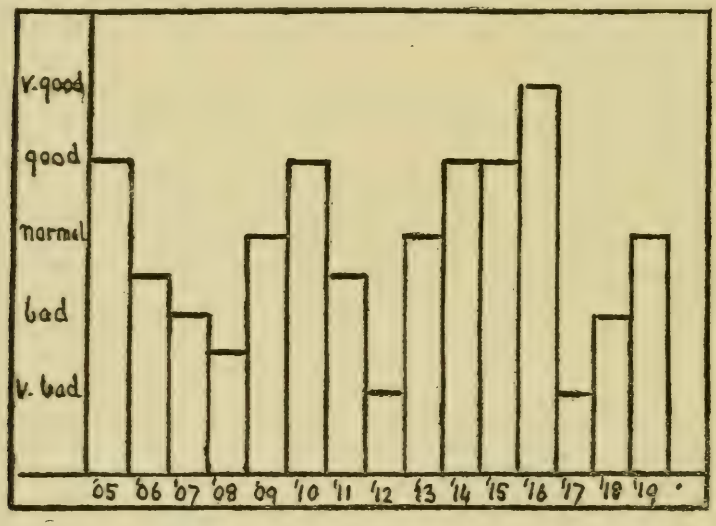

Fig. 7.

Fig. 7—Diagram of intensity of Blight during the years 1906–1919 showing the periodic nature of its occurrence.

without a longer series of records. Similar variations over long periods are known in other pests, but they are usually put down to the gradual increase of insect enemies. In this case this explanation does not seem to hold as each dry season most of the enemies are reduced and each wet season they increase rapidly in successive broods so that they are usually sufficient to control the third brood of froghoppers.

SECTION IV.

FROGHOPPERS IN OTHER COUNTRIES, AND LEGISLATION AGAINST FURTHER SPREAD.

In summarising the proofs of the responsibility of the froghopper for the condition in sugar-cane known as "blight" it is mentioned (p. 123) that similar damage is known in other countries in association with the same or other species of froghoppers.

In Central America records of damage are frequent and in nearly every case the injury is to a grass or cane crop and is caused by a froghopper of the genus *Tomaspis*, often closely related to the Trinidad *T. saccharina*. The only case known outside Trinidad in which the Trinidad insect itself has been found causing damage is in Grenada.

A summary is given below of the froghoppers of Central America recorded as causing damage, or in other ways important in the present investigation.

THE WEST INDIES.

TOBAGO.

Although only 22 miles from Trinidad in a direct line Tobago has its own peculiar species of froghopper, *Tomaspis carmodyi*, Kershaw (Plate I Figs. 7 & 8) and the Trinidad *T. saccharina* has not yet been found on the Island. The two are however closely related and difficult to distinguish, but differ in several small points, chief of which are the structure of the genitalia (*see* Kershaw 1913 D and F), the ground colour of the wings, and the range of variation in the markings.

T. carmodyi is darker than *T. saccharina*, less variable and does not have the light form with yellow at the base of the wings as in the variety *distanti* of *T. saccharina*.

On the other hand the two cross bands may be much reduced and the whole insect almost uniformally dark brown (Plate I Fig. 8), a variation not found in the Trinidad species.

All records of *T. saccharina* from Tobago up to the present have been mistaken identifications.

Although widely distributed in Tobago *T. carmodyi* has never been recorded as damaging grass or sugar-cane, and in this connection it might be pointed out that the little cane now grown in this island is mostly in mixed cultivation with other crops, particularly ground vegetables.

The rainfall is as a rule more evenly distributed during the year than in Trinidad, although the wet and dry seasons are still distinct.

I visited Tobago from the 9th to the 22nd November, 1916 and found the vermilion parasite (*Oligosita giraulti*) present, and in September 1917, P. L. Guppy found a maggot of the Syrphid Fly (*Salpingogaster igra*.) (*See* p. 67.)

The green muscardine fungus was not seen and has not yet been recorded.

GRENADA.

Grenada is about 90 miles North of Trinidad and froghoppers have only once been recorded as causing serious injury. This was at the end of 1916 (a year exceptionally free from damage in Trinidad). A report on this outbreak has already been published (Williams 1918 A).

The insect was found to be the same as the Trinidad species although previously recorded under a different name by Uhler (1895) and thought to be different.

The outbreak occurred on two estates "Mount Horne" and "Naingainfoix" in the East and centre of the island. The latter was not seen but the former showed most of the typical symptoms of a severe outbreak as seen in Trinidad. One of the fields was in plant canes after 8 years in pasture. Both localities were in the hills at an altitude of three to four hundred feet on a soil composed chiefly of volcanic ash, and all the damaged fields seen were on steep slopes.

No parasites were seen and the green muscardine fungus was only found on one adult.

Two or three pounds of the usual mixture of green muscardine spores and rice flour were distributed in the fields in the hope of starting an infection, and Mr. Berkely, the Manager of Mount Horne, informed me that a number of dead infected adults were found later on.

In the following year (1917) Hutson (1918) reported that there was "no extension of the infected area and the infestation has been less severe than last year."

In my report, (l.c.) the wide distribution of the insect in the island is considered as indicating that it is not a recent introduction. In the collection of the United States National Museum at Washington there are specimens from the following additional localities:—Mt. Gay, Balthazar, and Grande Ance.

ST. VINCENT.

There is a single specimen of the Trinidad froghopper *Tomaspis saccharina* in the collection of the British Museum of Natural History at South Kensington, London labelled St. Vincent. It was collected by H. H. Smith about 1890 and recorded by mistake by Uhler (1895) as *Tomaspis pictipennis*, a species originally described from Mexico which is not at present known to exist in the West Indies.

As it became necessary, for quarantine purposes, to find out if the insect still existed in any numbers in St. Vincent, I visited the island in December 1917 and spent three days searching suitable localities in the southern half of the island; but not a single specimen was found.

If still present in the island it must be very rare in the parts visited, and special quarantine regulations against the island based on the single specimen at present known would be, in the absence of any further evidence, undue interference with trade.

BARBADOS.

No froghopper has ever been found in this island and strict regulations have been made to prevent their importation (see p. 50). Local conditions of rainfall, soil, drainage and agriculture, however, make it improbable that the froghopper would ever be a serious pest, even if it should be accidentally introduced.

ST. LUCIA.

On the 21st July, 1917 I made a close search on grass in the vicinity of Castries and in the sugar cane fields of Cul-de-Sac Estate and found no froghoppers.

Mr. Brooks, the Agricultural Superintendent, who is familiar with the insect in Trinidad, has seen nothing of it in St. Lucia, nor has it been found by either Messrs. H. A. Ballou or J. C. Hutson in their entomological visits to the island.

The evidence is inconclusive, but it is very probable that the insect does not occur.

MARTINIQUE.

From July 15th to 20th 1917 I visited Martinique and made a close search for froghoppers both in cane and grass. The vicinity of Fort-de-France, the cane-fields in the district of Petit Bourg in the South of the island, and also round St. Pierre in the North were examined but nowhere were any found.

Mr. Bovell of the Department of Agriculture of Barbados, also visited the Petit Bourg district in May 1917 and during an investigation of root disease of sugar-cane, saw no trace of froghopper.

Mr. P. L. Guppy was also in the island in 1914 and Mr. J. B. Rorer in 1915 and neither saw any trace of the insect.

Neither the Director of Agriculture, M. Bassieres, nor his assistant, nor any planter to whom I spoke, had any knowledge of froth on the roots of the grass.

It is improbable that any sugar-cane froghopper exists in Martinique.

DOMINICA.

The only known froghopper of the genus *Tomaspis* in the Lesser Antilles North of St. Vincent is *Tomaspis dominicana* (Plate I Fig. 14) described by Distant (1909 p. 187). It is about the same size as the Trinidad froghopper, but the wings, which are dark brown, are each marked with five reddish spots.

No locality or date is given in the original description but three specimens in the American Museum of Natural History, New York, are labelled Long Ditton and Roseau, 18th to 23rd June, 1911, and three specimens in the collection of the New United States National Museum in Washington are marked June–July 1913. About 20 specimens in the collection of the Imperial Department of Agriculture for the West Indies are marked June and July 1902 and October and November 1903.

Nothing is at present known of its habits and in its structure it does not very closely resemble *T. saccharina* or the other grass feeding froghoppers. It is possible that it may feed on some shrub as does *Tomaspis rubra* in Trinidad.

CUBA.

In 1916 about 700 acres of pasture lands covered with Paral grass (*Panicum numidianum*) at La Horqueta estate, eight leagues South-east of the city of Caminguey, were dried up and destroyed by a froghopper *Tomaspis* (*Monecphora*) *bicinctus*, locally known as the "salivita" (Plate I Fig. 18). P. Cardin (1917) reported on a visit to this estate, and from his account the following particulars are obtained.

The insect was first seen on September 1910 on sugar-cane in Perico, Matanzas. In September 1915 it was again found in abundance

on sugar-cane. In January 1916 it was reported in small numbers all over the Island by Loftin, and in April of the same year particularly on grass in Barancou.

The insect is most abundant in the wet months from July to November and particularly so from September to November. The eggs are laid in the soil and take 12 to 20 days to hatch. There are four nymph stages occupying 32 to 40 days and in the later moults the insect goes higher up the stem to the angle between the leaf and the stem.

In addition to sugar-cane and the above grass the insect has been found on Guinea-grass (*Panicum maximum*), Johnson grass (*Sorghum halepense*) and on *Andropogon muricatus*.

The damage to the pastures in the province of Camiguey in 1916 was estimated by Cardin as from $20,000 to $25,000, as even when the grass survived it was badly covered by weeds. The loss to the sugar-cane is stated to be not extensive or of long duration and can easily be arrested by removing the lower leaves and cleaning the field of grass.

As a method of control in the pastures a broad hopper-dozer is recommended, sixteen feet across and three feet high, drawn by two horses, one at each side, and painted inside with tar to which the insects will stick.

JAMAICA.

I have received specimens from Jamaica which appear to be *Tomaspis* (*Monecphora*) *bicinctus*, the same species that has been recorded as damaging cane and grass in Cuba, but up to the present there is no record of actual damage from the island.

Ritchie in his report for the year 1916–17 (Ritchie 1917) mentions a Cercopid (froghopper) damaging the developing buds, blossoms and berry-clusters of Pimento trees (*Pimenta officinalis*) in Jamaica but it is almost certainly not of the genus *Tomaspis* and is probably a *Clastoptera* sp.

Tomaspis jamaicensis is described from the island by Distant (1909 p. 197–8), and *Monecphora* (*Tomaspis*) *basalis* by Walker (List Homopt. Ins. Brit. Mus. III. (1851) p. 683.)

"ANTILLES."

Fabricius in 1794 (Ent. Syst. IV p. 48 (4)) describes a froghopper *Cercopis coccinea* from the "Central American Islands." It is said to be uniformly red without spots. In 1851 Walker (List Homopt. Ins. Brit. Mus. III p. 666) says that it belongs to the genus *Tomaspis*. Nothing further appears to be known of its habitat or habits.

CENTRAL AMERICA.

SURINAM (DUTCH GUIANA).

At the end of 1915 damage was caused to the cane on an estate in Surinam by a froghopper. Mr. J. W. Gonggrijp in a letter to Mr. F. W. Urich, Entomologist to the Board of Agriculture, Trinidad, said that "the fields attacked looked as if they had been burnt" and that the insect "had done a great deal of damage." Specimens sent proved to be a species different from the Trinidad froghopper, and have been identified by Mr. Urich as *Tomaspis tristis* (*see* Plate I Figs. 16 & 17).

On the 19th May* I passed through Surinam on my way to British Guiana and was able to spend a few hours at Marienburg Estate where

* In my report (Williams 1917) "June" is printed by mistake for "May."

the outbreak had occurred. A short report has already been published (Williams 1917). Very little damage was apparent at the time of my visit and the most interesting feature was that the froghopper differed considerably in habits from *T. saccharina*. The nymph stages in the froth were not on the roots but were all on the stalk of the cane above ground, usually under the leaf sheaths of the cane from three to four feet up from the ground. In this connection it is interesting to note that in *Tomaspis guppyi*, the only froghopper that we have in Trinidad that is structurally related to *T. tristis*, the few nymphs so far discovered have been above ground on the stalks of grass. (*See* p. 64.)

Tomaspis tristis is also known to occur in British Guiana but so far has not been reported from sugar-cane, nor has *T. guppyi* in Trinidad yet left its native host plants.

BRITISH GUIANA.

A froghopper, *Tomaspis flavilatera*, Urich (Plate I Fig. 5) had been known on sugar cane in British Guiana since about 1909. From that date to 1916 small areas of some of the estates on the East Coast of Demerara were frequently heavily infested, but no serious damage seems to have occurred and the insect ranked as a very minor pest of cane. Short notes had appeared by Bodkin and Moore (see bibliography) but it was not considered of sufficient importance to warrant any special investigation.

In 1916 I visited the country in a search for parasites and summarised the work up to that year and the results of my own investigations in a subsequent report (Williams 1918 B).

The insect resembles very closely in habits the Trinidad sugar-cane froghopper and both eggs and nymphs were found in similar situations. A curious difference in the habits of the adults was however that in British Guiana these spend the greater part of the day sitting on the short succulent grass which grows by the moist drains through the cane fields, and do not hide themselves in the axils of the leaves of the growing cane to anything like the same extent as the Trinidad insect does. Advantage was taken of this habit to reduce their numbers by catching the adults during the day with strong cloth nets which were swept along the drains by small boys. In this way several thousand could be caught in a day by one boy at a cost much below that of the previous method of hand collecting the nymphs. During September 1916 one estate caught 533,540 adults in this way at a cost of two cents (1d.) per hundred. Forty-six per cent. of the individuals captured by this method were found to be females.

In 1917 H. W. B. Moore (1918 p. 12) continued his investigations and made the important observation that the eggs were laid in the ground as well as in the dead trash. "In one case a piece of earth about $\frac{3}{4}$ of an inch long, $\frac{3}{8}$ in width and $\frac{1}{4}$ in. thick had stuck in it over 60 eggs."

The insect remained of very little consequence until May 1918 when it suddenly appeared in enormous numbers in three widely separated districts.

G. E. Bodkin (1918 A.) reported the great increase of the insect and warned planters to keep a strict watch for its appearance, and in a later report (1918 B.) he stated that the insect "has demonstrated that it is perfectly capable of doing immense damage." He was of the opinion that the sudden increase was due to abnormal climatic conditions, chiefly heavy downpours of rain which caused the soil to become water-logged and the canes to become backward and stunted. The froghopper then finished up the already weakened plant.

Moore in his Annual Report for 1918 (1919 p. 7–13) gave a fuller account of the outbreak and came to similar conclusions. He considered that the abnormally wet weather of the first six months of the year was the cause of the serious infestation. The soil became waterlogged, grasses and weeds grew apace, and could not be kept within bounds, and as a result of this the canes had already suffered before the froghoppers appeared. Moore made further observations on the eggs, which he recorded as abundant in the loose soil of worm castings, and also pointed out the close relation between the abundance of the insect, the severity of the damage, and the texture of the soil, the canes on heavy clay soils being in every case more damaged than those on the lighter soils.

No serious attack seems to have occurred in 1919 but the conditions in British Guiana at present resemble very closely indeed those prevailing in Trinidad about the year 1906 when the insect, after being of small consequence for many years, suddenly demonstrated its power; it is to be hoped that British Guiana will not experience a series of attacks similar to those which have occurred in Trinidad since that year.

COLOMBIA.

In 1913 Vargas Vergara published a short note on the damage done by *Tomaspis bogotensis* (*see* Plate I Fig. 10) in Colombia. He stated that for many years the pastures in the Tocaima and Casas Viejas region had suffered severely from the ravages of this insect, locally known as "el mion". Tocaima is about 30 miles W.S.W. of Bogota and is about 190 miles from the Pacific; Casas Viejas I have been unable to locate.

Since that date several inquiries have been received by Mr. Urich as to methods of control and the use of green muscardine, so that apparently the damage still continues.

PANAMA.

No froghopper of the genus *Tomaspis* appears to be of serious consequence in this country. In the collection of the U. S. National Museum of Washington are three specimens of *Tomaspis lepidior*, Fowler (Plate I Fig. 11) labelled "Panama, injuring grass. Dr. A. Precindo" and Urich (1913 C. p. 8) mentions that Mr. A. Busck found the same species on cane where it was well known to the natives.

Of more importance from an economic point of view is a froghopper of quite different habits and relationships, an undescribed species of the genus *Clastoptera* which I found in Panama and Costa Rica damaging the flowers of cacao (*Theobroma cacao*).

The insect is scarcely one third the size of *Tomaspis saccharina* and the nymphs live, several together, in masses of froth on the flower stalks of the cacao. The flower is killed and drops off, and in heavily infested trees as many as 75 per cent. of the flowers were destroyed in this way. It is only the fact that the cacao tree usually produces a large excess of flowers that prevents the insect being a serious danger in the localities where it occurs.

The cacao froghopper was also of particular interest as the froth was found to contain the larvæ of a fly (*Drosophila* sp.) not previously known as a froghopper parasite, (*see* p.). A fuller account of this insect is in preparation and will be published later.

BRITISH HONDURAS.

In 1883 in a report on "The Colony of British Honduras" p. 35–36, Sir Daniel Morris mentions a froghopper damaging the sugar-cane in that Colony. He describes the white froth on the cane roots which appears about the end of July and from which the mature insect emerges in August. "While affected in this manner the canes become stunted in growth but even afterwards with the mature insects they are not free from injury, as the fly attacks the leaves and causes them to be spotted and eventually to die off. The lower leaves appear to wither first, but the upper are soon attacked and sometimes so severely as to cause the whole to fall off, leaving nothing but the bare canes standing. Even among the canes not severely attacked the joints are short and poor. About the end of September and October the fly disappears. The canes after a time, relieved from the attacks of the fly, make very fair growth, their joints become long and full and they continue to develop until cutting time. The fly is more severe in damp and wet lands, in lower portions of fields, than in dry powdery lands."

Urich (1913 C. p. 8) suggests that the insect is probably *T. postica.* which is known from British Honduras and which has been recorded as damaging sugar cane in Mexico. (*See* below.)

Since the above was in print I have had the opportunity of examining specimens collected in British Honduras by Mr. W. R. Dunlop, according to whom the insect continues to do severe damage to sugar cane. The insect is not *Tomaspis postica* but is very close to *T. jugata* Fowler, known from Guatemala and also to *T. contigua* from Honduras.

MEXICO.

According to Urich (1913 C. p. 7) damage in the state of Vera Cruz, Mexico by the froghopper *Tomaspis postica* (Plate I Fig. 13) has been known since 1880. It usually injures the grass lands and pastures, but in 1903 it was found to attack sugar-cane also. In August and September the adult insects are in abundance, as well as later during the dry season in October and after, causing considerable damage to the pastures. It was controlled by burning the pastures in April and May.

Mr. Urich visited Mexico in 1911 and a short report was given to the Board of Agriculture at the meeting in January 1912 (*Bull. Dept. of Agr.*, Trinidad and Tobago Vol. XI. No. 71 p. 298). He stated that the froghopper was abundant on cane and grass in low lying damp ground. and was less numerous on porous friable soils. It was not so common as in Trinidad, which he considers as due to the absence of boucans (rows of unburied trash) in the fields.

No egg parasites were found, but a Reduviid bug (*Castolus plagiaticollis*) was found feeding on the adults. This was introduced into Trinidad but unfortunately did not survive (*see* p. 81). The green muscardine fungus was common on the adult froghoppers and in a later report Urich (1913 B. p. 249) further records a fungus of the genus *Empusa* which was also killing the adults.

U. S. A.

A froghopper, probably *Tomaspis* (*Monecphora*) *bicinctus*, has been found in the Louisiana district on sugar-cane but has never done any appreciable damage.

In the New York district, Timothy and other grasses have been damaged by two small froghoppers *Philaenus lineatus* and *P. spumarius*. Felt (31st Rept. State Entomologist, New York p. 87) recommends rotation of crop to prevent further damage.

DAMAGE IN OTHER CONTINENTS.

In England *Aphrophora sp.* has been recorded as damaging roses during June and July (*Gardener's Chronicle* LXV (1919) p. 122) and other species of the same genus occasionally damage pastures.

In India *Cosmocarta relata* is a serious local pest in Mysore and Coorg on Jak (*Artocarpus integrifolia*) (Fletcher, South Indian Insects p 495) and *Machærota planitae* makes calcareous tubes on cotton and frequently stunts its growth (*Review of Applied Entomology* IV. A. p. 225).

LEGISLATION AGAINST THE SPREAD OF THE FROGHOPPER IN THE WEST INDIES.

The only two islands in the West Indies that have brought in special quarantine regulations to prevent the introduction of the froghopper are Barbados and St. Lucia. The text of the orders in question is given in full below.

BARBADOS.

ORDER

Made by the Governor-in-Executive Committee under Sections 45 and 46 of the Trade Act 1910 (1910) 6, prohibiting the importation of Sugar-cane, etc., from South America, Central America, British Guiana, Trinidad, Tobago, Grenada and St. Croix, and prescribing the conditions under which plants, etc., may be imported from such countries :—

1.—(1) Sugar cane or any part thereof or any other plant of the order Gramineæ or any part thereof, or any growing plant of any other order, or any soil or earth or any goods, packages, articles, coverings or things in which the said sugar-cane or any part thereof or any other plant of the said order or any part thereof or any growing plant of any other order may be or may have been packed or otherwise contained shall not be imported or brought into this Island from the following places, viz :—South America, Central America, British Guiana, Trinidad Tobago, Grenada and St. Croix.

(2) Any plant of the order Gramineæ or any part thereof or any plant of any other order or any part thereof in which it is possible for any insect pest of the sugar cane to be introduced into the Island (used as food or bedding for any animal) on board any vessel arriving at Barbados, from any country mentioned in the preceding sub-section, shall before such vessel enters the careenage, be thrown over-board and the deck of such vessel be washed.

(3) Manufactured articles, dried seed or grain, dried stems or leaves of any plant of the order Gramineæ such as barley, guinea corn, maize, rice, rye, oats, wheat and hay or any other article which, in the opinion of the Superintendent of Agriculture is not likely to introduce the froghopper, (Tomaspis varia Fabr.), the giant moth borer, (Castnia licus, Drury) or any other insect pest of the sugar-cane shall be exempted from the operation of this order.

2. If the Superintendent of Agriculture is satisfied that there is an outbreak of any fungoid disease or any insect pest in any country, he may, if he think fit, fumigate or disinfect, or both fumigate and disinfect or order the destruction of any plant or part thereof or any article or thing in which it is possible for such fungoid disease or insect pest to be introduced into this Island. The destruction of any such plant or

part thereof, or any such article or thing, shall take place in the presence of and in accordance with the instructions given by the Superintendent of Agriculture or his Assistant. Should the importer decline or refuse to destroy any such plant or part thereof, or any such article or thing in the presence of, or in accordance with the instructions given by the Superintendent of Agriculture or his Assistant, the Superintendent of Agriculture shall have such plant or part thereof, or any such article or thing destroyed, and may recover the cost from the importer in a summary manner before a Police Magistrate.

3. This order shall not apply to any of the above-mentioned articles when imported by and for the Superintendent of Agriculture of Barbados, or the Imperial Commissioner of Agriculture for the West Indies for scientific purposes, with the previous consent of the Governor-in-Executive Committee; provided that the Superintendent of Agriculture of Barbados or the Imperial Commissioner of Agriculture for the West Indies so notifies the Comptroller of Customs or the Colonial Postmaster.

4. The order made by the Governor in Executive Committee, on the 23rd day of May 1912, is hereby repealed.

Made by the Governor in Executive Committee this 21st day of November, 1912.

J. A. BURDON,
Colonial Secretary.

ST. LUCIA,

A Proclamation

To prohibit the Importation of any plants, &c., belonging to the Natural Order Graminaceæ [*sic*] from certain places.

By His Honour Reginald Popham Lobb, Esquire, Companion of the Most Distinguished Order of St. Michael and St. George The Officer Administering the Government of the Island of Saint Lucia and its Dependencies, &c., &c., &c.

R. Popham Lobb,
Administrator (Acting).

By virtue of the power in me invested in that behalf by section three of the Plants Protection Ordinance, 1909, No. 12, and of all other powers enabling me in that behalf, I, Reginald Popham Lobb, The Officer Administering the Government of the Island of St. Lucia by and with the advice of the Executive Council of Saint Lucia, do hereby absolutely prohibit until further proclamation, the Importation into this Colony of any plants, cuttings, fruits or any parts thereof belonging to the Natural Order Graminaceæ that may have come either directly or indirectly from Trinidad or Grenada.

Provided that this prohibition shall not apply to any of such plants, cuttings, fruits or any parts thereof which are imported under licence given by the Governor and subject to the provisions and conditions of such licence.

And I do hereby order that this Proclamation shall come into force on the day of its first publication in the Saint Lucia *Gazette*.

Given under my hand and the Public Seal of the Island of Saint Lucia at the Government Office, in the said Island, this twentieth day of September, in the Year of Our Lord One thousand nine hundred and seventeen and in the eighth year of the Reign of His Majesty King George the Fifth.

By His Honour's Command,

B. P. E. BULSTRODE,
Chief Clerk, Government Office.

GOD SAVE THE KING.

NOTE.—The above Proclamation is issued to protect the St. Lucia sugar industry against the introduction of a small insect known as the Froghopper which is capable of doing very serious damage to sugar-cane cultivation.

The sugar-cane froghopper lives on almost any kind of wild grass as well as sugar-cane, and it has therefore been necessary to include the whole of the grass family known as Graminaceæ within this Proclamation.

The Graminaceæ is one of the most valuable and extensive Order of plants, and comprises between 3,000 and 4,000 species. To it belong the cereals and pasture grasses.

The importation therefore of such plants as sugar-cane, bamboo, wheat, barley, rye, Indian corn, millet, Guinea corn, rice, Job's tears, and all grasses, are prohibited except under the conditions of this Proclamation, from the places mentioned in the said Proclamation.

SECTION V.

THE TRINIDAD FROGHOPPER.

NOMENCLATURE AND SYSTEMATIC POSITION.

The Trinidad froghopper is a member of the family *Cercopidæ* of the Hemiptera-Homoptera. The family includes all the insects which are known typically throughout the world as "froghoppers," "froth-hoppers," "spittle insects," "frog-spit," and "cuckoo-spit," in each case the name being derived from the white froth which surrounds the young insect and its ignorantly supposed connection with the spittle of various animals.

The Trinidad species belongs to the genus *Tomaspis* which in its present accepted sense is confined to the American Continent, but related genera in Europe and Africa can scarcely be accurately distinguished.

It was first discovered by J. H. Hart in November 1889 and identified as a species of the genus *Thomaspis* [*sic.*] (Hart 1890 p. 126).

In 1895 P. R. Uhler named specimens of the same insect found in Grenada *Tomaspis pictipennis* Stal, an insect previously known only from Mexico.

In 1906 in an unsigned article in the "Agricultural News" p. 330 it is referred to as "*perhaps T. bicincta.*"

In 1909 Collens (1909 B.) reports that specimens sent to the Bureau of Entomology, Washington D.C. had been identified as *Tomaspis postica* Walker, an insect originally described from Mexico. In later references this name was sometimes written as *T. posticata.*

In 1909 Distant described the insect, from specimens sent to the British Museum, as *Tomaspis saccharina*, a new species found in Trinidad, Grenada and St. Vincent.

In 1911 specimens sent to Prof. E. D. Ball by Urich were identified as *Tomaspis varia* (Urich 1911 A.), an insect described from French Guiana by Fabricius in 1787 and never recorded since.

The present position is that we know the names *T. postica*, *T. pictipennis* and *T. bicincta* to be mistaken, and the use of the name *T. varia*, though possibly correct, implies that the same insect is found in French Guiana, which is not known and is, in view of recent work, improbable. Under the circumstances the name *T. saccharina* has been adopted as that liable to cause least confusion.

DISTRIBUTION AND ORIGIN.

Tomaspis saccharina is at present only known from the West Indian Islands of Trinidad, Grenada and St. Vincent. The record of the last locality is based on a single specimen in the British Museum.

The small island of Patos between Trinidad and the mainland of Venezuela was visited in June 1918 but no specimens were seen there. Gough (1911 C. p. 22) gives Tobago and Demerara as additional localities but both of these are mistaken records.

In Trinidad the insect is found throughout the island wherever the canes or grasses necessary for its food can be found, in the hills and on the plains, in the cultivated as well as the uncultivated districts, and in the cocoa districts as well as those given over to sugar-cane.

It is of some importance to decide whether the insect is native to these islands or is an introduced pest. Kershaw (1913 C. p. 8) considered that it was indigenous to Trinidad for the following reasons:—

"(1.) There are at least four species of the genus in the island.

"(2.) It prefers various native grasses as food plants to canes.

"(3.) It has at least two egg parasites and the nymphs are killed off to some extent by the larvæ of native Hover-flies (Syrphidæ.)

"(4.) There are very commonly one or two large parasitic worms in the abdominal cavity among the viscera of the adult froghopper, and these worms also occur in other *Homoptera* here."

On the other hand in a letter written in August 1916 Mr. Kershaw suggests that I should search for parasites in Argentina "because of rumours of much forage brought thence to Trinidad some 30–40 years ago," which would imply that he still thinks it possible that the insect might have been introduced with the grass from that country.

Urich (1910 C. p. 4) says that there is no doubt that it is indigenous to Trinidad, but gives no evidence in support.

If it should be an introduced pest it must have been here at least fifty years (*see* Section III.) but in addition to the arguments for its being native given by Kershaw* we now know that there are closely related species in the various surrounding countries. Tobago has *T. carmodyi*, British Guiana has a species very closely related to *T. carmodyi* in the North-West-District and *T. flavilatera* on the Demerara and Essequibo coasts. At La Guayra, Venezuela, I found yet another closely related species, *Tomaspis propinqua* Walker, and others occur at intervals of a few hundred miles along the coast.

It seems to be the rule rather than the exception in Central America for the species of the genus *Tomaspis* to have a range limited to a few hundred miles at most.

In view of these facts it is difficult to find any reason to suppose that *T. saccharina* is not native to its present habitat, and it is probable that it occurs in the neighbouring mainland, which, however, up to the present has not been visited.

On the other hand its occurrence in Grenada and St. Vincent is more probably due to accidental transmission in comparatively recent years.

ADULT—DESCRIPTION AND VARIATION.

Tomaspis saccharina Distant 1909. (Plate I, Figs. 1–4).

General appearance: Length 7–9 mm. ($\frac{1}{4}$–$\frac{1}{3}$ inch), width across folded wings 3·5–4·5 mm. ($\frac{1}{7}$–$\frac{1}{6}$ inch). Forewings dark brown with two narrow transverse bands of a lighter colour and sometimes parts of the base of the wing also light.

Head, pronotum and scutellum dark bronzy brown. Face and prothorax and a sublateral band on each side of the abdomen beneath, blackish brown. Legs dark blackish brown except at base of front and mid tibiae and base of femora of hind legs, which are lighter. Abdomen above and beneath red-brown in the male and brown in the female. Vertex broader than long, rounded in front, centrally carinate and longitudinally depressed on each side before the eyes. Face compressed centrally, longitudinally carinate, somewhat regularly rounded to clypeus. Eyes black. Tegmina less than three times longer than broad.

*I cannot quite agree with the word "prefers" in No. (2).

Variation. The markings of the wings are of two quite distinct types, a light form and a dark form, each of which is slightly different in each sex.

Dark Form. (Plate I, Fig. 3 female, Fig. 4 male) (Type form of Distant 1909). The ground colour of the wings is a dark chocolate brown, across which run two narrow pale brown bands. The front band, at about one-third the wing length from the base, is narrowest towards the hind margin of the wing and expands slightly towards the base of the wing near the costa, giving a curved appearance. The second band, at a little more than two-thirds the wing length from the base, is narrower, straighter and also slightly expanded on the costa. The outline of these two bands is more distinct in the male than in the female and the colour is paler cream in the former and a more yellowish brown in the latter. Beyond the outer band the wings are slightly more hyaline.

Light form. (Plate I, Fig. 1, female and Fig. 2, male) (Varieties A. & B. of Distant 1909 and Var. *distanti* and var. *tricolor* of Lallemand. 1912 p. 97.) The ground colour of the wing, and the outer band are similar to the previous form, but the whole basal third of the wing is light with the exception of an oblique brown streak which runs across it along the claval suture. The markings of the male are again more sharply defined and paler than those of the female. The internal light basal portion of the wing (*the clavus*) of the female of this variety is very distinctly darker than in the male.

Although each of these two forms is subject to slight variations, they are always readily distinguishable from each other and for some time I suspected that we had to deal with two related species. An examination of the genitalia however failed to show any constant difference, and as they were later found to interbreed quite readily they probably represent Mendelian varieties.

Both forms are found side by side, but the light variety is usually more abundant than the dark form. This excess is in most places slight (up to 30 per cent.) but in the district round Sangre Grande I have always found a very large excess of the light form, the dark one being quite uncommon. Table III shows the proportions in specimens captured at random by hand or light traps. There is no reason to suppose that one variety is more likely to be captured than the other.

TABLE III.

District.	*Light Form.*	*Dark Form.*
Northern Sugar Area...	57	59
Central Sugar Area	188	122
Southern Sugar Area	419	269
Sangre Grande	78	6

Observations of specimens seen pairing in the field showed in 20 cases both sexes of the same variety and in 16 cases opposite forms.

Occasionally a variety is found in which the eyes are bright red instead of the normal black. Without special search I have seen six such specimens in the course of three years. It is not an immature stage as the insect normally develops the full black of the eyes before leaving the last froth formed by the nymph.

A similar variety has also been seen in other species *e.g.*, T. *flavilatera*, *T. pubescens* and an unidentified related species in Panama.

PROPORTION OF SEXES IN THE FIELD.

The two sexes appear to be in more or less equal proportion in the field.

Urich (1913 C. p. 18) says that 51 per cent. of the adults in the fields during the day are males.

Gough (1911 C. p. 17) found a slight excess of females (2,098 males to 2,259 females) in adults captured by hand in the fields but points out that light traps had been recently used in the field which would reduce the number of males, and in addition the greater activity of the latter sex makes them less liable to capture by hand.

In adults caught in a net by sweeping the canes and grass at dusk I found only 31 per cent. of females but in this case the greater activity of the male has an opposite effect and makes them more liable to leap up into the passing net.

The proportion of the sexes actually in the field at any moment will also be influenced by the relative length of life of the two. Towards the end of the brood the longer living sex (in this case the female) will gradually predominate.

ANATOMY.

The only important studies on the anatomy of the froghopper have been made by Kershaw. He describes the breathing system of the nymph (1913 C.), the mouth apparatus of the adult (1913 H & 1914), the alimentary canal (1914), the reproductive system (1913 G.) and the male genitalia (1913 D.)

The salivary glands: In 1913 H he describes the mechanism of the sucking of the sap and also of the supply of saliva to the setæ which pierce the leaf. The salivary glands open by two flexible ducts into a syringe or pump, by means of which the saliva is forced out when required on to the setæ of the mouth, down which it flows into the wound in the plant. "It is supposed that the saliva flowing into the wound made by the setæ tips prevents the coagulation of the sap or aids its free flow. Be this as it may, the saliva is full of enzymes (ferments) and since it is sucked back into the stomach along with the plant sap, it aids in digestion."

Later (Kershaw 1914 p. 70) he says that the salivary glands differ slightly in the nymph and adult. They consist of a great length of coiled chitinous duct situated entirely within the head, which he believes to act as a reservoir; and twelve tubular glands, eleven of which are longer than the body and somewhat coiled or recurved in the abdomen among the fat body, the twelfth is shorter and thicker and lies partly within the head. The secretion of the glands appears to be neutral or faintly alkaline.

The above descriptions are quoted in view of the possible importance of the saliva in setting up the destruction of the leaf round the puncture of the adult by some toxic or enzyme effect.

The rest of the alimentary canal is described fully by Kershaw (1914) including a remarkable enfolding of a portion of the mid-gut and malpighian tubules by a lateral pouch at the juncture of the œsophagus and mid-gut, which he considers is an arrangement for getting rid more rapidly of innutritious liquid in the food in the œsophagus.

Reproductive System: In 1913 G. p. 95 and plate on p. 104 Kershaw describes the reproductive system of both sexes. In the female each ovary consists of about 20 egg tubes and each tube produces usually three eggs or a probable total of 120 eggs for each female. There are a pair of colleterial glands opening into the oviduct and a bursa-copulatrix.

In the male there is a single accessary gland attached to each duct.

HABITS OF ADULT.

The adult after emergence remains inside the froth chamber formed by the nymph for some hours until the chitin has hardened and the colour developed. Emergence has been noticed more frequently in the early morning, but this may be due to the fact that search has most frequently been made at that time.

Shortly after changing to the adult the insect voids a small quantity of white semi-solid excreta. Kershaw (1914 p. 68) had this analysed and found 36 per cent. water, 20 per cent. organic matter and 44 per cent. calcium potassium phosphate with minute trace of iron.

During the heat of the day the insect remains hidden away among the grasses or in the upper axils of the cane plants into which position it invariably gets by backing down the leaf, so as to be head upwards in its hiding place and, as a result, more free to escape by jumping if necessary. Apparently little or no feeding is done in this position.

In the late afternoon and early evening the adults gradually leave their hiding places and come out on to the leaves. This takes place earlier or later according to the condition of the day. On wet cloudy overcast days they begin to come up about 4.30 in the afternoon and have been seen in thousands sitting on the leaves by 5 p.m. On hot clear days they seldom start to move until 5.30 and are usually mostly out shortly after six. In this country the sun sets about 6.45 in July (first brood) and about 6.15 in October and November (last brood).

During the daytime adults can only be caught by hand individually from the axils of the leaves, but once they have come on to the leaves they can be caught by thousands with nets (*see* p. 146).

As soon as it becomes dusk the adults (males especially) begin to fly about. Nothing is known of the distance that they can fly, usually it appears to be small. In order to test the hour of the greatest flight five light traps were put out in a field on the 9th July 1918 and the insects caught were removed at the end of each hour. Fig. 8 shows the results, from which it will be seen that the greatest flight was in the first hour

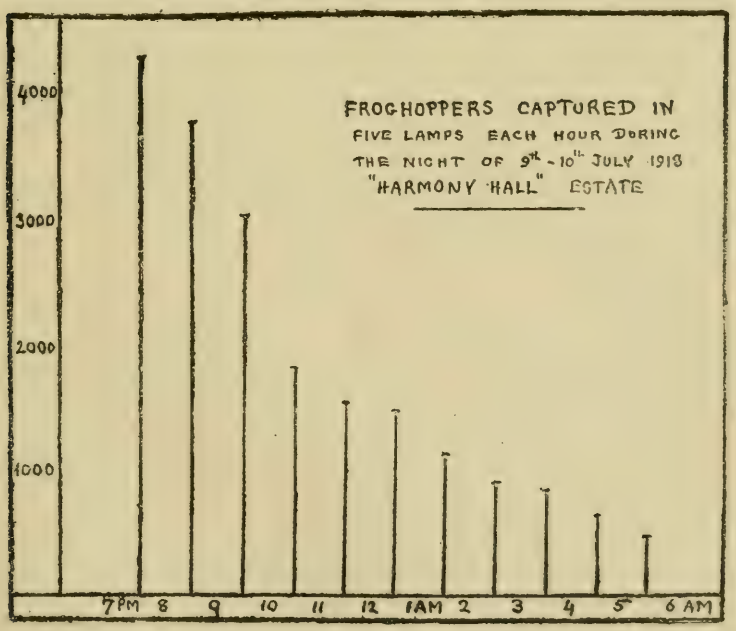

Fig. 8.

Fig. 8—Diagram to illustrate the activity of adult froghoppers during the night.

of darkness with a gradual and regular reduction throughout the night, and further that over half the total were caught in the first three hours.

In the early morning the reverse process takes place to that in the evening and by 7.30 a.m. to 9 a.m. according to the brightness of the day, all the adults have returned to their hiding places in the axils of the leaves.

Feeding takes place at night and the amount of sap sucked out by one insect is extremely large. During the whole time of feeding drops of liquid excreta are ejected from the anus at a rapid rate. According to McLeod (1908 p. 554) a drop of excreta is produced every 12–13 seconds. "A single insect under observation extracted and voided ½ drachm of clear liquid in one hour." With fifty froghoppers per stool each sucking for eight hours during the night about one and a quarter pints of sap would be removed from each stool during the night. This drain would last from two to four weeks in bad attacks.

Kershaw (1913 G. p. 100) notes that the excretion tested by two different methods showed no trace of sugar while sap extracted directly from the leaves was found to contain plenty. The absence of sugar in the excretion probably accounts for the fact that no "black blight" fungus growth appears on the infected plants as is the case with the cane-fly (*Delphax*).

At this point it might be mentioned that, in company with a planter, I tasted an adult froghopper, and we agreed that the taste resembled that of grass and was not unpleasant.

Pairing appears to take place at all times of the day and night. Urich considers (1913 C. p. 17) that the female pairs shortly after emergence and both Urich and Kershaw state that the males probably only pair once. More evidence is required on this point as, should it prove to be true, the use of light traps in the fields might be of greater consequence even if only males are destroyed thereby.

Egg laying takes place usually at night. In captivity the eggs may be laid in any material that can be pierced by the ovipositor of the female, as for example in damp blotting paper, but in the field the eggs are laid in two definite situations: (1) in the dead partly decaying moist leaf sheaths near the ground, or (2) in the ground itself.

The eggs are laid two or three at a time at short intervals and a total of from forty to one hundred can be laid by one female. Kershaw (1913 G. p. 95) from dissection considers that 120 is the maximum number that can be laid and thar they are matured in three batches.

THE EGG.

Description. The egg is about 0·75 mm. long by about 0·25 mm. wide (0·03 x 0·01 inches). Three times as long as wide and more pointed at the anterior end than at the posterior. For the first few days it is yellow in colour, but a dark longitudinal streak gradually develops at its anterior end leading from the tip to about half the length of the egg and broadest near the anterior end. This is the hatching lid which breaks away from the rest of the shell and allows the young insect to emerge.

Kershaw (1913 G. p. 96) has described in detail the internal structure of the egg and the position of the "egg burster" which is used by the young nymph to force up the hatching lid.

Position. In the dead leaf sheaths of the cane and grass the eggs are inserted head-end upwards and slightly projecting outward in a slit made by the ovipositor of the female in the tissue between two vascular bundles. The trash chosen by the female is nearly always that moist partly-decayed trash which is attached to the stem within a few inches of the ground. Eggs are also laid in a similar manner in the earth round the base of the stool. In British Guiana *T. flavilatera* has been found by Moore (1919 p. 9) to lay also in this situation, particularly, he believes, in the soft earth of worm casts.

Duration. The egg stage lasts for a minimum of about two weeks in favourable moist conditions, to a maximum of six months or more when the dry season intervenes.

There is some other factor concerned with the hatching which is not yet understood, as in many cases thousands of eggs laid by the third brood in October and November do not hatch to produce a fourth brood, even though two or three months of wet weather follow, but stay at an early stage of development during the remainder of the wet season and throughout the dry season and then produce the enormous first brood which sometimes occurs in certain localities. There is some evidence that this may happen even with eggs from the second brood.

In this connection Kershaw (1913 G. p. 99) gives some interesting but confusing results obtained by Guppy showing that eggs collected in December 1912 and kept dry for four months (till April 21st, 1913) did not hatch regularly on being moistened, but irregularly over an interval of from fourteen days to two months, and at the end of this period there were still two healthy eggs not yet hatched.

THE NYMPH.

Description and Moults. There has been some disagreement between investigators as to the number of moults of the nymph. Urich (1910 C. & 1913 C.) considers that there are three moults after hatching resulting in four nymph stages. Gough on the other hand (1911 C. p. 13–14) describes five nymphal stages and Kershaw (1913 G. p. 97) recognizes the same five stages but points out that the young nymph moults as it hatches from the egg leaving behind the first skin, so that there are six moults, the last of which produces the adult insect.

I have been unable to distinguish the last stage mentioned by Kershaw and Gough and consider that there are five moults including that in the egg, and the last one which produces the adult insect.

The four nymph stages after leaving the egg are shown in Fig. 9.

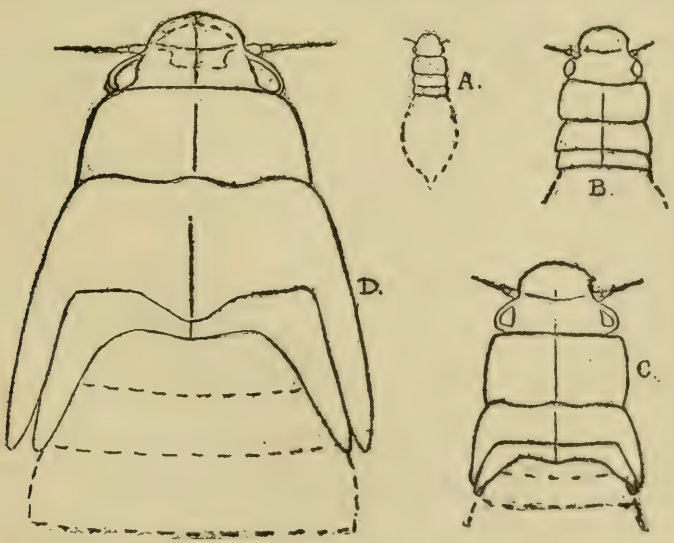

Fig. 9.

Fig. 9—The four nymph stages of the froghopper.

Stage I. (Fig. 9 A.) Total length 1–2 mm. Pale yellowish brown with a faint reddish mark on each side of the abdomen. No traces of wing rudiments on hind margin of either meso or meta-thorax. Antennæ five segmented, lengths of segments in millimetres:—1, 0·03; 2, 0·03; 3, 0·03; 4, 0·02; 5, 0·04; Total length of antenna 0·15 mm.

Stage II. (Fig. 9 B.) Total length 2·6–3·6 mm. Pale yellowish brown in colour. Hind angles of the meso and meta-thorax very slightly produced indicating the rudimentary wings. Antennæ six segmented. Length of segments in mm.:—1, 0·08; 2, 0·06; 3, 0·08; 4, 0·05; 5, 0·05; 6, 0·06; Total length of antenna 0·40 mm.

Stage III. (Fig. 9 C.) Total length 4–5·5 mm. Head and thorax pale brown distinctly darker than the rest of the body. Wing rudiments quite distinct but scarcely longer than wide at the base. Antennæ seven segmented. Lengths of segments in mm. 1, 0·13; 2, 0·11; 3, 0·15; 4, 0·09; 5, 0·08; 6, 0·07; 7, 0·08; Total length of antenna 0·72 mm.

Stage IV. (Fig. 9. D.) Length 6·5–8·0 mm. Head, thorax and wing rudiments brown, abdomen yellow. In nearly mature specimens the colour of the adult shows through in the legs, body and wings. Wing rudiments longer than broad at the base and reaching to the third abdominal segment. Antennæ eight segmented. Length of segments in mm. 1, 0·20; 2, 0·16; 3, 0·30; 4, 0·18; 5, 0·20; 6, 0·10; 7, 0·14; 8, 0·12. Total length of antenna about 1·38 mm.

HABITS OF NYMPH.

The nymphs suck the sap from the roots of the food plant at and below the surface of the ground. They may be quite exposed on the surface, (Plate III.) but more usually prefer the conditions and the soft roots developed under heaps of trash lying on the surface. In well broken soil the greater number seem to be at a depth of from two to four inches but many descend still lower than this and may be found occasionally as deep as eight or ten inches below the surface.

Above the ground they are sometimes found feeding on the adventitious roots of the cane beneath the leaf sheaths, and in such a position they have been seen over two feet from the ground. This refers to the feeding and developing nymph; when full fed, however, those below ground normally come up to some point a little above the surface where they make a final froth chamber in which to moult to the adult. In most cases there is no feeding when in this position and the froth must be made from reserve material.

These last moulting chambers are usually only a few inches above the surface on some grass blade or cane stalk, but they have been seen as high as three feet from the surface. After the adult leaves this chamber the froth dries and retains its shape for some days.

THE FROTH.

The froth round the nymph is one of the remarkable characteristics of the *Cercopidæ* or Froghoppers. It consists of a gummy liquid secreted by the alimentary canal, in which air bubbles are blown by the insect by means of its breathing system, which opens ventrally into a chamber formed beneath the abdomen by the overlapping sides of the latter.

The nymph may readily be watched protruding the end of the abdomen from the froth to take in a supply of air and then withdrawing it into the froth and forming a bubble beneath the surface.

The gummy substance which gives the excreta of the nymph its viscosity and tenacity is, according to Kershaw, a mucin or a mucinoid and is produced in his opinion by the anterior portion of the malpighian tubes (Kershaw 1913 C. p. 3). He states that "if part of a nymphal

tube is placed in alcohol the contained mucinoid shrinks and coagulates and can be dissected out as a very pale yellowish substance. If this coagulated material is then placed in water it quickly swells and becomes viscid, pale bluish, translucent and just as capable of being drawn out into viscid threads as the untreated material fresh from the tubes."

On the other hand Urich (1913 C, p. 28) quotes Gilbeau (American Naturalist 1908) as saying that the mucilaginous substance is secreted by hypodermal glands known as the "Glands of Batelli."

Some of the froth was submitted to the Government Laboratory by Mr. Kershaw in 1913 and Mr. Shrewsbury reported that "The froth held for four days finally, breaking down to about 0·1 cc. of a clear straw coloured liquid, with a decided earthy odour, which consisted mainly of a solution of sodium and potassium chlorides. A small amount of organic matter was also present, the nature of which has not so far been determined. There is no evidence of the presence of any protein. Numerously active moving protozoa were present in a minute amount of sediment left adhering to the side of the tube. These were mainly of two types, one oval and the other eel-shaped."

Kershaw (1914 p. 69) states that in addition there are "numbers of crystals, those of calcium oxalate are numerous, uric acid, leucine pellets and urates are also present."

The froth is of very considerable value to the nymph as a protection. Contained in its cavities is sufficient air to supply the nymph for some considerable time, which allows it to survive immersion or temporary water logging of the soil, and also makes it immune to destruction by poisonous gases as found by Carmody and Kershaw (Kershaw 1913 C). The covering also keeps the nymph moister in times of drought and excessive heat. It also acts as a protection against contact insecticides, which have to be of very great strength to kill the nymph unless the froth is first removed.

Perhaps the greatest value of the froth to the nymph is the protection it affords it from the thousands of predaceous insects, particularly ants, that are continually wandering over the ground in a tropical country.

On one occasion in British Guiana the ants during the night gained access to my laboratory table, entered my breeding cages and killed all adult froghoppers and other insects (including Syrphid flies) that I had there, but the froghopper nymphs remained untouched.

On another occasion in Panama I found a large army of hunting ants spread over a plot of grass which I knew to contain froghopper nymphs. After they had passed, I made close search and found not an insect living except the froghopper nymphs in their protecting froth.

FOOD PLANTS.

The froghopper attacks, so far as is known, any species of grass (Gramineæ) and has been found on related plants. Food plants actually recorded are :

Gramineæ
- Sugar cane (*Saccharum officinale.*)
- Indian corn (*Zea Mais.*)
- Rice. (*Oryza sativa.*)
- Savannah Grass. (*Paspalum conjugatum and P. compressum.*)
- Para Grass. (*Panicum muticum.*)
- Bamboo Grass.
- Bermuda Grass (*Cynodon dactylon.*)
- Kelly Grass (*Rottboellia exaltatus.*)

Cyperaceæ
- *Scleria melaleuca.*
- Razor Grass (*Scleria reflexa.*)

Cane is by far the most seriously damaged of these plants but reports of damage to corn, rice and other pastures have been made.

Rice. Damage has been reported once or twice on hill-rice or upland rice and in one case investigated the nymphs and adults were present on the rice in some numbers but the damage was almost negligible. The lowland or wet rice is never likely to be seriously damaged by froghoppers as the conditions at its roots are quite unsuited to the nymph.

Corn. Blight has been frequently reported on corn but in every case investigated the damage has been complicated by the presence of other insects, particularly the small moth-borer (*Diatroea spp.*). On a few occasions the froghopper has, however, been responsible for considerable damage.

Pastures. In other countries (*e.g.* Cuba, Colombia, etc.) pastures seem to suffer much more than canes from the attacks of froghoppers. In Trinidad the reverse is the case and on only one occasion, was any considerable damage done to pastures. This was at Harmony Hall Estate, in September 1918, on land that had recently been in cane and had been thrown out owing to the continual damage by froghoppers.

LIFE CYCLE.

The egg stage of the froghopper lasts from fourteen days upwards, the nymph stages occupy five to seven weeks and the adult may live as long as a month. Under normal wet season conditions a single complete cycle takes slightly under two months.

In the wetter parts of the country, in the mountains, forests and cacao districts, breeding goes on throughout the year and nymphs and adults may be found at any time. In the drier portions, in which the sugar districts are situated, there is an almost complete standstill during the four or five months of the dry season.

With the coming of the wet season about May or June the eggs, which have been held up by the dry weather, hatch out and the first nymphs are usually reported in the sugar districts a week or two after the first rains. These produce the first flight of adults at the end of June or during July, about seven weeks from the date of the first rains (*see* p. 103.)

Eggs from these produce a second flight of adults about two months later, varying in different years from the end of August to the beginning of October, and from these again a third brood in October to December and rarely a fourth in December or January. Each of these broods in succession is less definite in its limits owing to the varying dates at which eggs are laid by the females and individual variation in the length of the egg and nymph stages. At the same time the broods up to the third are almost always quite distinct and recognizable. Figs. 5 and 6. show these broods of adults in 1918 and 1919 as indicated by captures in light traps.

The fourth brood is very seldom of any considerable size even in years when there is quite sufficient wet weather after the third brood for it to develop, from which it must follow that many eggs laid by the third brood, and possibly in some cases by the second brood also, fail to hatch that year but hold over until the coming of the next wet season.

There has been some disagreement as to the manner in which the insect passes over the dry season but most authorities are now convinced that in Trinidad this is spent in the egg stage. At the same time there is no doubt that in the moister spots in the dry sugar districts the insect can continue to breed in small numbers, but these are never sufficient to account for the enormous numbers of insects which sometimes appear in the first brood.

Moore (1919 p. 12) is strongly of the opinion that in British Guiana, with their froghopper, the dry season is survived by a few individuals which continue breeding in the more favourable moist localities. It must however be remembered that conditions in the cane fields in British Guiana even at their driest season are never comparable with those of Trinidad. The dry seasons are shorter and less severe and the fields are low-lying and capable of being irrigated, and as a result it is seldom that there are not in every field moist spots in the drains where breeding can continue.

Kershaw (1913 D. p. 3) dissected a number of eggs during the dry season and found them all in the same stage of development; the primitive band had formed and invaginated, and the embryo had segmented but no appendages had been formed.

Although there is no doubt that the dry season in Trinidad is generally passed over in the egg stage, there are some exceptions, to one of which attention must be drawn here.

Throughout the whole of the dry season (January to April) of 1918, following the severe blight of 1917, adult froghoppers were found in considerable numbers in a field of young plant canes in the Naparimas. The numbers were not large, varying from two adults to every three plants in March to one adult to every seven plants at the end of April. During the months of March and April there was only 1·1 inches of rain on this estate. At the beginning of April adults were noticed pairing.

This continuation of normal activities of the adult throughout extremely dry weather is very unusual, and is recorded here chiefly in the hope of an explanation being forthcoming later.

OTHER FROGHOPPERS IN TRINIDAD.

There are four species of the genus *Tomaspis* known in Trinidad: *T. rubra*, *T. pubescens*, *T. guppyi*, and one unidentified. In addition two other genera, *Clastoptera* and *Cephisus* are also represented.

Tomaspis rubra (Plate 1, Fig. 19) is a species considerably larger than *T. saccharina*, dark brown with two transverse yellow bands. The same insect is recorded from the mainland and Grenada, but all the specimens seen from the mainland (Venezuela, British Guiana, Surinam) have the hind band as wide as the front one, whereas in the Trinidad and Grenada specimens the hind band is definitely narrower.

The insect feeds in the nymph stage on the roots of the Christmas-bush (*Eupatorium odoratum*) and according to Urich (1913 C. p. 29) the eggs are laid in the rootlets of the food plant. The insect is generally common in the cacao and bushy districts of the island, and is of no economic importance except in so far as it is sometimes mistaken for the sugar-cane froghopper.

Tomaspis pubescens Fabr. (Plate 1, Fig. 15) is about the same size as *T. saccharina* but greenish black in colour. The female is distinctly more pubescent than the male. Trinidad specimens are distinctly smaller than those from British Guiana and Surinam.

In habits it closely resembles the sugar-cane species. It feeds on various species of grass, but prefers very moist localities by the banks of streams in the wooded parts of the island. The froth formed by the nymph is much firmer and more glutinous than that of *T. saccharina*.

It is attacked by many of the parasites of the sugar-cane froghopper including the Syrphid fly, the vermilion parasite and the Mermis worm (*see* later). In British Guiana I found nymphs of this species on the roots of sugar-cane in some small cultivations in the forest but in Trinidad it has not been seen on cane. It has never been recorded as causing any injury and, in so far as it acts as an alternative host for parasites of the sugar-cane froghopper, and so tides them over periods when this is scarce, its presence is rather of value than the reverse.

Tomaspis guppyi, Urich. This species first described by Urich (1913 C. p. 30) is very closely related to *T. tristis*, known to damage sugar-cane in Surinam. In Trinidad however, *T. guppyi* has never been found on cane and is indeed extremely rare, being apparently confined to the south-western promontory in the district of Point Fortin, Erin, Chatham, and Palo Seco. It is a large species, dark brown in colour with six orange spots on each wing running across in two irregular bands. The two sexes are similar.

The first nymphs were discovered in January 1917 on the Erin-Point Fortin road. Only three were found and two were in froth masses on a coarse grass (*Panicum sp.*) six inches to a foot above the surface of the ground. The other was on a young bamboo shoot among the same grass. The habit of forming the froth above the ground is in close agreement with *T. tristis* in Surinam. The froth contained a large amount of solid matter and was rather calcareous in appearance, especially on the outer surface where it had dried a little.

One of the nymphs was almost full-grown and showed the markings of the wings of the adult. It emerged five days later.

Tomaspis sp. On 26th January, 1919 I found two nymphs of a froghopper on the clinging roots of an Aroid climber in the forest at an altitude of about 2,000 feet on Mt. Tucuche. It was not any of the known Trinidad species, but no adult was found and the nymphs died without emerging. Nymphs were found in similar situations in British Guiana and Panama and no doubt all three are related. The latter species will be described in a subsequent report.

Clastoptera sp. The Casuarina or "Whistling pine" trees in Trinidad are frequently heavily invested with the white liquid froth masses of a species of *Clastoptera*. Urich (1913 C. p. 29) identifies it as *Clastoptera laenata*, Fowler. The species is of particular interest as the froth masses frequently contain the larvæ of a fly *Drosophila paradoxa*, Lamb (1918) which destroys the nymph of the froghopper. No member of this group of flies, usually confined to decaying and fermenting vegetable matter, had previously been recorded as parasitic.

Although there is no possibility of transferring this parasite to the sugar-cane froghopper, it is of interest as indicating a possible new group of parasites which might be searched for elsewhere. The *Drosophila* is in turn parasitised by a Chalcid which has also been bred from the common *Drosophila* found in decaying bananas.

The Casuarina is an introduced tree in Trinidad, but the same froghopper is found on a number of local bushes, and also on *Hibiscus* and Pigeon pea.

Cephisus sp. Adults of a species of this genus (probably *C. siccifolia*) have been captured on several occasions in light traps in the sugar-cane fields in the Naparimas, and also at light in a house in San Fernando. Nothing is known of their habits in Trinidad, but in British Guiana I was informed that the nymphs were found on *Erythrina* (Immortelle). This tree is abundant in Trinidad, but is confined to the cacao districts, and the insects caught on the sugar estate in question probably had some other host plant.

SECTION VI.

THE NATURAL ENEMIES OF THE FROGHOPPER.

PARASITES OF THE EGG.

The Vermilion Parasite (*Oligosita giraulti*, Crawford).

This egg-parasite was first discovered by Guppy in December, 1912 and was described by J. C. Crawford (Canadian Entomologist XLV (1913) p. 311-312) from specimens sent by Urich.

It is a minute Chalcid about 0·6mm. (one-fortieth of an inch) in length, with the body bright vermilion-red except for a band round the base of the abdomen which is white.

This insect lays its eggs in the eggs of the froghopper and its grub feeds inside the froghopper egg on the contents, which suffice for the complete development of the parasite.

Its development is complete within about thirty days (Urich 1913 D.) and the female as soon as it has emerged can proceed to lay eggs without the necessity of pairing with a male. In fact in Trinidad the male has up to the present never been seen, but in Panama I obtained one or two specimens of it in a locality where females were very abundant.

The parasite appears to be able to carry on its life cycle throughout most of the year in localities which are drier than is necessary for the breeding of the froghopper, and specimens may be obtained in the dry season in spots where the froghopper has temporarily ceased to breed. It is on the other hand probably adversely affected by heavy rains.

There have been no observations on the percentage of parasitism in the field, but Kershaw under artificial conditions was only able to obtain an infestation of about five per cent.

It is very probable that it has some alternative host, as it exists commonly in localities where the froghopper is rare. I have been able to get adults to oviposit in eggs of leaf-hoppers (Jassidæ) but so far have not succeeded in breeding it through in these eggs.

It is common throughout Trinidad in all suitable localities and abroad I have found it in British Guiana, Tobago, Panama, and Costa Rica, parasitising various species of the genus *Tomaspis*.

In Panama it was very abundant, and, as mentioned above, males were found, but the discovery of it over such a wide range leaves no doubt that it is native to Trinidad and is not likely to increase naturally much above its present limits.

Urich (1913 A & D) has made attempts to introduce it into the sugar-cane fields by bringing grass from other localities where it is known to be common, but while the method is theoretically correct it has not been possible yet to demonstrate any practical result following from it.

The Trash-Coloured Parasite (*Paraphelinus tomaspidis*, Howard).

This parasite was also discovered by Guppy in January 1913 in the Princes Town district and was described by Howard in 1914 (Proc. Ent. Soc. Washington XVI (1914) p. 81–82). It is a uniformly brownish insect of about the same size as the vermilion parasite, and like it, lives during its larval life on the contents of a single insect egg.

Since Guppy found the original three specimens, all of which were females, this insect had never been bred again from froghopper eggs. I obtained one female by sweeping grass at St. Clair, Port-of-Spain, on 13th April, 1916 and two specimens, a male and a female, by sweeping grass in a trace among the canes on Caroni Estate on 2nd January 1917. The male had not previously been seen. There is considerable doubt as to whether or not it is a regular froghopper egg parasite. If the original record is correct it must destroy froghopper eggs occasionally, but it is probable that normally it is parasitic on the eggs of grass-hoppers, as the other species of the genus are known to be.

Paraphelinus xiphidii was described from Hawaii from the eggs of a grass-hopper *Xiphidium variepenne*, and species of the genus *Xiphidium* are abundant in the traces in Trinidad. These are probably the regular host of the Trash-coloured parasite. Waterston (*Bull. Ent. Research* VIII. p. 43–58) has given a full account of the genus *Paraphelinus* with a list of the known species and describes as new *P. perkinsi* that I found associated with froghoppers and *Xiphidium spp.* in British Guiana.

A species of the same genus as yet undetermined was also found in Tobago.

Panama Egg-Parasite (*Anagrus sp.*)

While in Panama I bred three specimens of an *Anagrus* (*Mymaridæ*) from the eggs of a froghopper closely related to the Trinidad species. Species of this genus occur in Trinidad but their separation is extremely difficult. Up to the present they have not been found attacking froghopper eggs here.

Thrips.

On two separate occasions I have found thrips of the genus *Haplothrips* destroying the eggs of froghoppers.

The first of these was in British Guiana in July and August 1916 when an adult thrips was reared from a larva found in a breeding tube containing only dead trash and froghopper eggs.

The second occasion was in Panama in June 1917 when under similar conditions an adult *Haplothrips sp.* was found in a tube that contained trash with froghopper eggs that had been in the tube a month. An examination showed all the eggs to be dead, dried up and half empty, just as if sucked, so that it is almost certain that the thrips in the larval or adult stage had been feeding on them.

The species of the genus *Haplothrips* are usually vegetable feeders but some have been recorded as predaceous in other parts of the world. It is probable that most species are omnivorous and can take either animal or vegetable food as the occasion arises.

Several species are abundant in the grass in the traces in Trinidad in the localities infested by *T. saccharina* and may exert a small controlling effect, but up to the present I have not found them on the cane in the field.

Ants.

Urich (1913 C. p. 26) expresses a belief that the eggs are carried off by ants of the genus *Monomorium.*

Fungus.

Kershaw (1913 I. p. 9) mentions that there is a fungus that completely fills up some froghopper eggs, but he is doubtful if it kills then or only attacks them when dead.

PARASITES OF THE NYMPH.

Birds.

A full account of the bird enemies of the froghopper will be given when dealing with the enemies of the adult on p. 70.

Of the seventeen birds there recorded as feeding on the adult only three have been proved to eat nymphs. These are :—

ICTERIDÆ.

(1.) Trinidad Boat-tail (*Quisqualus lugubris.*)
(2.) Golden Head (*Agelaius icterocephalus.*)

MNIOTILTIDÆ.

(3.) Manicou Bird (*Geothlypis aequinoctialis.*)

Other birds doubtless also take them occasionally, but the froth in which the nymphs are enclosed must serve as a partial protection.

The Boat-tails have a habit of following the ploughs and diggers in the field, in the manner of crows in England, and obtain many nymphs in this way.

THE SYRPHID FLY. (*Salpingogaster nigra*, Schiner).

This fly, the maggot of which is parasitic on the nymphs of the froghoppers, was first noted by Gough in 1910 (1911 C. p. 18) and first bred to the adult stage by Urich (1912 D.)

The adult fly (Fig. 11.) is about two-thirds of an inch (14-16 mm.) in length and nearly one inch (20-22 mm.) across the open wings. It is blackish brown in colour except for a narrow band behind the thorax, two spots on the side of the abdomen, and the bases of the tibiæ of the legs, which are yellow. The front border of each wing is suffused with dark brown.

The abdomen is long and joined to the thorax by a long stalk (petiole) which gives the fly a close resemblance to some species of wasps.

The most complete record of the life history has been given by Guppy (1913). According to his account, the egg is about ·75mm. long elongated and shining white in colour. It is laid in the froth. The egg stage lasts about two to two and a half days.

The footless maggot which hatches out destroys the froghopper nymph by piercing its integument and sucking out the contents. This stage lasts about nine days. According to Guppy one maggot destroys about 30-40 froghopper nymphs during its development.

Fig. 10.

Fig. 10—The Syrphid fly ; pupa.

The maggot is frequently seen in the froth of the froghopper and is confused with the nymph by overseers and boys collecting and destroying the latter. This should never occur as, apart from the absence of legs, it is quite a different shape, long pointed cylindrical; of a different colour, semi-transparent shining white; and has a characteristic habit of drawing in and out the front end of the body.

The pupa (Fig. 10) is dull brown in colour with four dark markings on the dorsal surface which are irregularly V-shaped, and a rather darker lateral streak edging the lighter ventral surface. It is about 1·0 cm. in length by 0·4 cm. in breadth and is invariably situated head downwards attached to some grass stem or twig near the ground.

A pupa that I found on 18th June 1916 emerged on 27th June, which indicates a pupal stage of at least nine days. Another which pupated on 4th March 1917 emerged on the 14th of the same month, which gives a duration of ten days. The complete life cycle is passed through in 20 to 22 days.

The adults fly chiefly in shady places and are to be found throughout the year in the traces through the forests and cacao plantations in the moister parts of the Island. In flight they hang down their legs in a manner which gives them a still closer resemblance to the wasps which they mimic in form. According to Guppy (1914 B. p. 10) they feed on the pollen of a small white flower, but will readily eat sugar and water

Fig. 11.

Fig. 11—The Syrphid fly; adult.

in captivity. The males seem to be more abundant in the field than the females. Kershaw dissected an adult and found about 350 eggs in the ovaries. Guppy (unpublished report for October 1914) states that he obtained an average of 150 eggs each from four females in captivity between 1st and 15th October, and later (unpublished report for

November 1914) he obtained 210 eggs from one female in sixteen days, 142 of which were laid in the first ten days. Guppy also found that eggs from unfertilised females did not hatch.

In the moister parts of the island the insect breeds throughout the year, but in the cane fields it is seldom, if ever, seen before the beginning of the wet season, and usually does not become common until the second or third brood of froghoppers are in the nymphal stage (August to October). The first adult was seen in the cane fields in 1918 on 17th June and in 1919 on 1st July. By October and November it is usually possible in thickly infested fields to find a Syrphid maggot on almost every stool, and on one occasion in November 1918 I found four maggots in fifty froth masses examined.

It is not known how or in what stage they survive the dry season in these localities or to what extent restocking takes place each year by migrations from the moister districts.

Up to the present the Syrphid fly has been found on *T. saccharina* in Trinidad, *T. pubescens* in Trinidad and British Guiana, *T. flavilatera* in British Guiana, *T. carmodyi* in Tobago, on another unidentified species of *Tomaspis* in the North-West District of British Guiana, and on two unidentified species in Costa Rica.

In addition to these localities where the host is known, it is recorded from Mexico, Guatemala, Panama, and Brazil, which indicates a very wide range in which it probably parasitises many other species of the genus *Tomaspis*.

It is in its turn destroyed by enemies, the chief of which are apparently spiders. Guppy in Tobago found a larva which pupated and from the pupa three *Oligochaete* worms emerged. I submitted one of those to Mr. P. S. Welch of the University of Michigan and he identified it as an immature specimen of one of the *Enchytraeidæ* (*Oligochaeta*). He suggested that as no similar worms have ever been recorded as parasitic on insects their position as parasites of *Salpingogaster* should be questioned until further corroborating evidence is obtained.

In view of the value of the Syrphid fly as a froghopper control, and of its scarcity in the cane fields during the earlier broods of the froghopper, Kershaw recommended an attempt to breed it through the dry season in large numbers so that specimens could be liberated early in the wet season in the localities likely to be infested with froghoppers. During 1913 and 1914 Guppy attempted to carry out this suggestion. In October 1914 he distributed 400 eggs, in November 500, and 200 in December. During the dry season however the difficulties were so great, with the funds and assistance available, that the work was finally abandoned. He has given (1914 B.) an account of these experiments, in which he mentions the impossibility of obtaining sufficient froghopper nymphs during the dry weather to keep alive more than a very limited number of Syrphid maggots, and also the difficulty of saving the adult flies from the persistent attacks of spiders.

The method, even if it were possible and successful from an economic point of view, suffers from the disadvantage that it would have to be repeated every dry season.

Ants.

It has been mentioned above (p. 60) that the froth of the nymph protects it almost entirely from the numerous species of hunting-ants which infest the ground in the cane fields.

Toad-Bugs. *Galgupidæ.*

Urich (1913 C. p. 25) noted that in captivity some Toad-bugs killed froghopper nymphs which were given to them free from froth. In the field it is very probable that their covering will protect the nymphs from these predators as well as from the ants.

Fossorial Wasps.

A very close search has been made for species of mud wasps or burrowing wasps that might store their nests with the froghopper nymphs. They are known to do this in Europe with the nymphs of another genus of froghoppers, but so far in Trinidad and Central America none have been found.

The Mermis Worm.

This is a long narrow hair-like worm which is sometimes found coiled up in the abdomen of the nymph froghopper, occasionally also in the adult. Kershaw, who is the first to report it (1913 C. p. 8) says that two may be present in the same insect.

A single worm may reach three inches in length when uncoiled and when large is distinctly visible through the skin of the abdomen of the nymph which is usually swollen.

Nothing is known of its life history after it leaves the body of the froghopper. It is not sufficiently common to exert any check and I have only met with it on two occasions (1) Union Trace, near Mayaro, in the forest district in a nymph of *T. pubescens* 27th March, 1916 and (2) in nymphs and adults of *T. saccharina* at Craignish Sugar Estate in August 1918. Urich (1913 C. p. 26) records it also in nymphs of *T. rubra*.

Similar worms are known in many other insects including mantis, beetles, grasshoppers and flies, occasionally in abundance as in one recorded case where 60 per cent. of a swarm of grasshoppers in Mass., U.S.A. were infested.

According to N. A. Cobb they may remain in the ground after emergence from the insect host for as long as two years before becoming adult. They are often parthenogenetic and the female may lay as many as several million eggs.

The Green Muscardine Fungus.

This fungus grows readily on nymph froghoppers in captivity and is occasionally found on them in the wild state. It is however of very much greater importance as a parasite on the adult and will be discussed more fully under that heading.

ENEMIES OF THE ADULT FROGHOPPERS.

Birds.

Kershaw (1913 B.) mentions having found froghoppers in the stomach of a Tick bird (*Crotophaga ani*) and Urich (1913 C. p. 24) lists in addition the Scissors-tail Fly-catcher.

As a result of a number of stomach examinations, I have found seventeen birds which feed on froghoppers (Table IV) and there are still a few which are suspected of eating them, but up to the present have not been proved to do so.

TABLE IV.

List of Trinidad Birds Proved by Dissection to eat Froghoppers.

Fam. Mniotiltidæ (Wood Warblers).
(1.) *Geothlypis aequinoctialis*, The "Manicou" Bird.
Fam. Hirundinidæ (Swallows).
(2.) *Atticora cyanoleuca*, White Breasted Swallow.
Fam. Fringillidæ (Finches or Grass-Birds).
(3.) *Volatinia jacarina*, Small Black Finch.
Fam. Icteridæ (American Orioles).
(4.) *Icterus xanthornis*, Common Corn-Bird.
(5.) *Molothrus atronitens*, Lazy Bird.
(6.) *Agelaius icterocephalus*, Golden-Head.
(7.) *Leistes guianensis*, Red Breast.
(8.) *Quisqualus lugubris*, Boat-Tail.
Fam. Tyrannidæ (Tyrant Fly-Catchers).
(9.) *Fluvicola pica*, Washerwoman.
(10.) *Arundinicola leucocephala*, White-headed Widow.
(11.) *Elainea pagana*, White-crested Fly-catcher.
(12.) *Myiarchus tyrannulus*, Foolish Fly-catcher.
(13.) *Tyrannus melancholicus*, Grey headed Keskadee.
(14.) *Milvulvus tyrannus*, Scissors-tail Fly-catcher.
Fam. Dendrocolaptidæ (Wood Creepers).
(15.) *Synallaxis cinnamomea*, Marsh Giouiti.
Fam. Caprimulgidæ (Night-jars).
(16.) *Podager nacunda*, Nacunda Night-hawk.
Fam. Cuculidæ (Cuckoos).
(17.) *Crotophaga ani*, Common Tick-Bird.

(1.) *Geothlypis aequinoctialis*, Gmel. The "Manicou" Bird. This is not common on the sugar estates. I have only seen three specimens, one at La Fortunée, 18th July, 1918 and two at Harmony Hall 10th October, 1919, all of which had in their stomachs remains of adult froghoppers, and one of the latter had in addition the remains of a nymph.

Other food included a caterpillar, small beetles, grasshoppers and winged ants.

The bird is olive green above, yellow beneath, with the top of the head grey and a black band across the front of the head and eyes resembling a mask.

I have not found it nesting.

(2.) *Atticora cyanoleuca.* White-breasted Swallow.

Several species of swallows are commonly seen flying over the cane fields, and no doubt most eat froghoppers occasionally. This however is the only species in which remains have so far been found. Other food included ants, beetles, small flies, and the remains of a soldier-bug (Reduviid.)

According to Leotaud (1866 p. 90) this swallow remains in Trinidad throughout the year.

(3.) *Volatinia jacarina.* The Small Black-Finch or Black Dancing Grass-bird. This is one of the commonest small birds in the cane fields, of a shining blue-black in colour and easily recognised by its habit of perching on a small bush or twig and suddenly rising in the air a few feet to perform dance-like gyrations in the air before returning to the same perch.

Unlike most other finches in Trinidad this bird feeds to a considerable extent on an insect diet, although still remaining chiefly vegetarian. One shot at Caroni Estate on 28th September, 1917 contained only seeds and beetle's wings. Another shot at Harmony Hall on the 27th October, 1917 contained one froghopper and seeds, a third shot at Williamsville Estate on 11th June, 1918 contained several froghoppers, the remains of a small beetle and some seeds, while a fourth shot at the same time contained also froghoppers, beetles and seeds.

It nests on or within a few inches of the ground usually in a tuft of grass or low bush. Nests have been found in August and November.

(4.) *Icterus xanthornis.* The Common Corn-Bird, Yellow Corn-Bird, Yellow Plantain Bird or Carouge.

This golden bird with black head, neck, wings, and tail is one of the most conspicuous birds on the sugar estates.

One shot at Harmony Hall on 20th October, 1917 contained one froghopper, a beetle, two caterpillars, and some vegetable remains. Another shot at La Fortunée, 11th July, 1918, contained a froghopper, 2 moths (one probably the large moth-borer of sugar-cane) and some small beetles.

This bird builds a stocking-like nest about one foot in length which is a conspicuous object hanging from the top of a tall tree or clump of bamboos. In the sugar districts these nests are usually solitary and twenty feet or more above the ground, but on one occasion I found one on a low bush, in the middle of a cane field, that was not more than seven feet from the ground.

The birds appear to nest throughout the wet season and one pair may produce more than one brood during that time.

According to Leotaud it feeds on seeds, berries and insects.

(5.) *Molothrus atronitens.* Lazy Bird.

This bird is occasionally seen on sugar estates. It is shining blue-black in colour and in habits (whence it derives its popular name) it resembles the cuckoo in England, as it lays its eggs in the nests of other birds, chiefly those of the house wren.

The stomach of one shot at Harmony Hall on 1st July, 1919 contained three froghoppers, one small weevil, one small plant-eating beetle, and some broken seeds resembling corn, the latter forming the chief contents of the stomach.

(6.) *Agelaius icterocephalus.* Golden-head, or Rice-Bird.

This bird is usually seen in the neighbourhood of water and is often common round the ponds in the cane fields. It is black or dark brown with a golden yellow head.

It occasionally eats froghoppers along with general insect diet. One shot at Williamsville on 13th August, 1918 contained beetles, (including *Metamasius*), moths and some doubtful vegetable remains; one shot at La Fortunée 12th September, 1918 contained some small beetles and three seeds; while a third shot at Harmony Hall on 30th June, 1919 contained about 20 adult froghoppers and one nymph, a small brown

beetle and traces of vegetable matter. It nests in the reeds and grasses growing in the shallow water round the edges of ponds. Nests have been found in July and August.

(7.) *Leistes guianensis.* Soldier Bird or Red-Breast.

This bird is confined to the savannahs and pasture lands. It is blackish brown with a brilliant red breast.

One shot at Craignish on 18th June, 1918 contained the remains of a froghopper, a grasshopper, a caterpillar, and a beetle; another shot at Harmony Hall, 2nd June, 1919, contained no froghoppers but numerous remains of small beetles (including two weevils) and about ten small Hemiptera.

It nests in a tuft of grass on or within a few inches of the ground and is often seen in large flocks in the pastures. Nests have been found in August and have been reported by Dr. Shannon in December.

(8.) *Quisqualus lugubris.* Boat-tail, Golden-eye, 'Barbados' Black-Bird or Pen-Bird. (Fig. 12).

Fig. 12.

Fig. 12—The Trinidad Boat-tail (*Quisqualus lugubris*). About two-fifths natural size.

This is one of the most abundant birds in the neighbourhood of the buildings and pens of a sugar estate. It is shining black with the iris of the eye golden yellow. When in flight and occasionally at other times, the tail feathers are arranged in the form of a V, from which it derives its popular name of "Boat-tail."

It feeds on a variety of insects and other small fry. One shot at Harmony Hall 20th October 1917 contained a froghopper, some beetles, many small insects and the remains of a small lizard. Another shot at Caroni, 30th October 1917, contained twenty or thirty froghoppers and a few beetles; while a third shot at Wellington Estate on 9th July 1918, contained 8 adult and 2 nymph froghoppers, 3 spiders, 5 white-ants (Termites), a grasshopper and a cockroach.

It nests in trees, usually well out of reach, and is particularly fond of tall palm trees (Palmiste) or the wild pines (Bromeliads) growing on other large trees.

(9.) *Fluvicola pica.* Washerwoman or Widow. (Fig. 13.)

This black and white bird is generally common throughout the sugar districts.

One shot on 30th October 1917 at Caroni Estate contained the remains of about ten adult froghoppers and some small beetles.

It makes a covered nest with the opening at one side in low bushes, tall trees and on telegraph posts. It nests through the greater part of the wet season and rears I believe more than one brood in the same nest.

Fig. 13.

Fig. 13—The Washer-woman (*Fluvicola pica*). About half natural size.

(10.) *Arundinicola leucocephala.* The white-headed Widow. (Fig. 14.)

This bird is in habits closely similar to the last. One cock shot at Brechin Castle on 19th November 1917, contained two froghoppers and other insect remains, chiefly beetles.

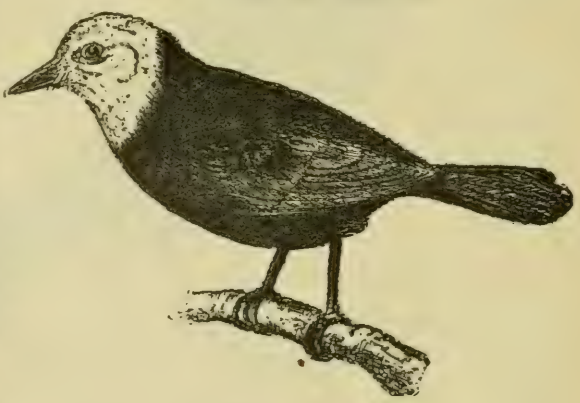

Fig. 14.

Fig. 14—The White-headed Widow (*Arundinicola leucocephala.*) About half natural size.

A hen shot at the same time contained one froghopper and miscellaneous insect remains, mostly beetles. A third shot at Williamsville on 11th June 1918. contained several froghoppers and small beetles.

The nest is almost indistinguishable from that of the previous species and is found in similar situations throughout the wet season.

(11.) *Elainea pagana*, White-crested Fly-catcher or Tillon.

This bird is not uncommon in the sugar districts and is fond of settling on telegraph wires and projecting branches of trees.

One shot at Harmony Hall on 26th July 1919, contained five or six froghoppers, one small beetle and three seeds.

According to Chapman (Bull. Amer. Mus. Nat. Hist. VI. 1894 p. 38) it feeds as much on fruits as on insects.

I have no record of its nesting, but according to Chapman (l.c.) a female was laying in April.

(12.) *Myiarchus tyrannulus.* Foolish Fly-catcher, or Black-billed Petchary.

One of these was shot at La Fortunée Estate on 11th July 1918 and contained one froghopper and two small red and green fruits.

I have no other certain record of it in the cane fields. According to Leotaud it is fairly common.

(13.) *Tyrannus melancholicus.* Grey-headed Keskadee.

This is one of the commonest birds in the sugar districts and is frequently seen seated on the telegraph posts or wires along the road or on the topmost branch of some small bush. It differs from its town relative the Common Keskadee in the grey instead of black head, in the absence of the white streak over the eye, and in its quieter habits. It does not utter the loud "Keskadee" of its relative.

One shot at Caroni on 28th September 1917, contained the remains of a number of dung beetles (*Scarabæidæ*), two weevils, a Chrysomelid beetle, one moth and one butterfly. Another shot at Caroni on 30th October 1917 contained several small beetles, including one Scarabæid and one weevil, and four adult froghoppers.

This bird is one of the chief enemies of the Large Moth-borer (*Castnia licus*) in the cane fields and on one occasion one was seen to catch and eat a dragon fly.

It nests in bushes and trees usually over ten feet from the ground, but occasionally less. It has been seen nesting in May, June and July.

(14.) *Milvulus tyrannus.* Scissors-tail Fly-catcher, or Swallow-tail Fly-catcher (Fig 15.)

During the wet season this is one of the most abundant birds in the cane fields and is without doubt the most important bird enemy of the froghopper.

In colour it is black and white with a slight yellow crest in the male, and the long outer tail feathers of this sex make it a conspicuous object.

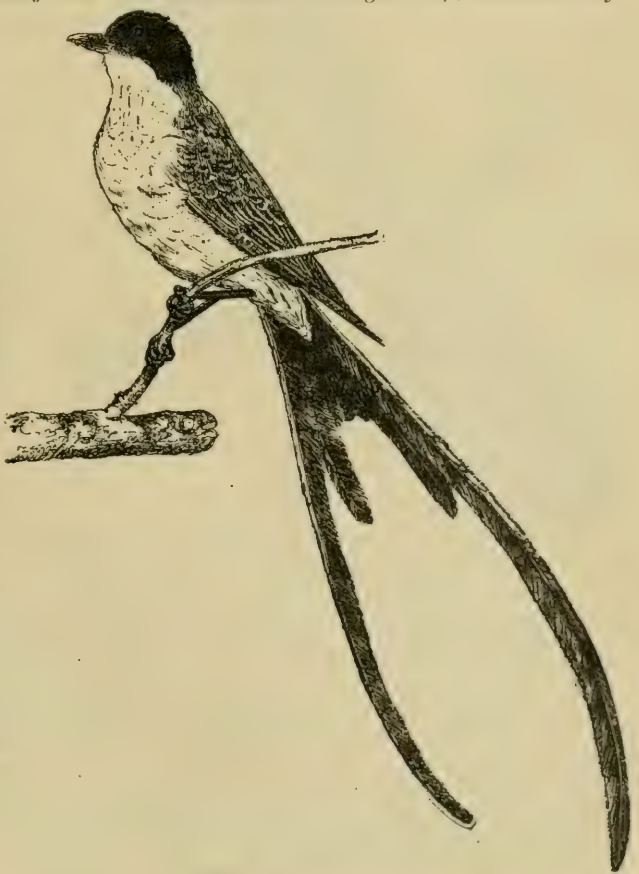

Fig. 15.

Fig. 15.—The Scissors-tail Fly-Catcher (*Milvulus tyrannus*). About half natural size.

It is a migrant and does not breed in Trinidad. Normally it arrives here from the mainland of S. America in June and leaves in October. The birds seem to congregate in the fields which are infested with froghoppers and are in this way particularly valuable in destroying the first brood.

In 1918 the first individuals began to appear towards the end of May and nearly all had departed by the end of October. In 1919 the first were seen on 15th June; by the 27th June they were present in thousands. By the beginning of October they had begun to leave, but stragglers were seen up to the 24th November.

It is interesting that a field of young plant canes in the Naparimas had, quite abnormally, adult froghoppers present in it throughout the dry season of 1918, and in March of that year four Scissors-tail Fly-catchers appeared in it for about two weeks and were busily engaged in eating the froghoppers.

One bird shot on 4th July, 1918 at La Fortunée Estate contained seven adult froghoppers, several small *Elaterid* beetles, other small beetles, four winged-ants, and pieces of a small millipede.

One shot on 12th August, 1920 contained seeds in addition to insects.

(15.) *Synallaxis cinnamomea.* Marsh Giouiti, Marsh Rootie, or Kri-kri-kri.

This and several related species of *Synallaxis* are not uncommon in the cane fields.

They have active wren or tit-like habits and their sharp grating cry has given rise to the local name of "kri-kri-kri".

A pair were shot at La Fortunée on 4th July, 1918. One contained two froghoppers, two spiders, several small beetles, and various insect remains too small to identify. The other one contained one froghopper, one ant, one red-mite (*Trombidium sp.*) and various small beetles and insects.

It nests in bushes and low trees, seldom above ten feet from the ground and occasionally quite low down, only two or three feet from it.

Its large retort-shaped nest, made of interwoven twigs, is a conspicuous object but well protected against intruders.

This species or related ones have been found nesting in February, June, July, September and October.

(16.) *Podager nacunda.* Nacunda Night-jar or Night-hawk.

This is a fairly large species of Night-jar with a conspicuous white bar across each wing, white beneath and a white collar.

According to Leotaud it is probably a migrant, remaining from July to October. I have seen it in the cane fields at the end of June and in July and again in October 1919. It starts flying early in the evening almost as soon as the sun has set.

One shot at Harmony Hall on 29th June 1919 at 6.45 p.m. (sun set about 6.30) had already in its stomach 26 adult froghoppers, one *Metamasius* weevil, one Scarabæid beetle, one Elaterid beetle and two winged ants.

The birds rest on the ground during the day and a flock of about six which I observed kept close together usually near one particular spot. On one occasion (4th July 1919) when the flock was disturbed during the day time, a close examination was made to see if they were nesting. No eggs were found, but on the spots where they had been lying were

several droppings containing many insect remains. These were examined and found to contain large numbers of beetles and other insects, but no froghoppers.

It is possible that the froghoppers are chiefly eaten during the early part of the night when they fly most (*see* p. 57), and that these droppings represented the remains of the food taken later.

(17.) *Crotophaga ani.* Common Tick-bird. Merle corbeau. (Fig. 16.)

This bird is frequently seen in the cane fields, particularly in the neighbourhood of small copses, but it is said by planters not to be so common as formerly.

Fig. 16.

Fig. 16.—The Tick-bird (*Crotophaga ani*). About two-fifths natural size.

Kershaw examined the stomach of one bird and found four froghoppers, other insects and some seeds of a weed. One that I shot at Caroni on 4th October 1917 contained several beetles (including *Cassidae* and *Chrysomelidæ*) several large bugs (*Coreidæ*), and four spiny caterpillars; another shot on 6th November 1917 at Caroni among canes badly infested with hundreds of froghoppers, contained a large grasshopper, a large spider, a large black *Coreid* bug, a small green *Pentatomid* bug, several small grasshoppers and only one froghopper; a third shot in the Oropuche Lagoon on the 12th October, 1919 contained one large red-bodied grasshopper.

Mr. T. I. Potter tells me that he has seen one of these birds kill a smaller bird just escaped from captivity.

The stomach contents indicate that, while capable of eating froghoppers, the Tick Bird prefers larger prey, particularly grasshoppers. This conclusion is confirmed by dissections made in the cane fields in Porto Rico. Wetmore (Birds of Porto Rico, Board of Commissioners of Agriculture, Porto Rico. Insular Experimental Station Bull. 15 (1916) p. 60) found after an examination of 41 stomachs that 91·3 per cent. of

the food was animal and *Orthoptera* (grasshoppers and crickets) formed over 40 per cent. In spite of the popular name of the bird *no* cattle ticks were found in all these stomachs.

The bird nests in large bushes and trees and frequently also in the clumps of prickly "Black Roseau." The nest is usually over ten feet above the ground and several birds may lay in one nest. Nests containing eggs have been found in February, July, August and September.

In addition to the above, several other birds in the sugar districts are believed to eat froghoppers, but up to the present have not been proved to do so. The most important are:—

HIRUNDINIDÆ.

Chelidon erythrogaster. Red-bellied Swallow.
Stelgidopteryx uropygialis. Yellow-bellied Swallow.

TANAGRIDÆ.

Tachyphonus rufus. Parson.

TYRANNIDÆ.

Pitangus sulphuratus. Common Keskadee.

CAPRIMULGIDÆ.

Chordeiles acutipennis. Long-winged Night-hawk.
Nyctidromus albicollis. Common Night-hawk.

These will be further investigated as occasion arises.

LIZARDS.

There is no doubt that lizards destroy large numbers of froghoppers and in certain conditions are among the most important enemies. Lizards are however not very common in the cane fields in Trinidad, and, according to the general opinion of planters, much less so than formerly.

Kershaw (1913 I p. 10) says "I have never found lizards abundant in the cane fields in any other countries even when very numerous in grass and waste land adjoining." With this I can agree, with the qualification that in Trinidad they seem to be even less plentiful than elsewhere.

The general reason given for the scarcity of lizards in Trinidad is the introduction of the mongoose, and while this may be so, it must be remembered that many agricultural practices, particularly burning the trash and good continual cultivation, will have as great if not a greater effect on their numbers.

Waterloo Estate, after a campaign against mongoose in 1917, imported, with the assistance of Mr. Urich, about 1,500 lizards, but no definite results could be seen as, although there was a large reduction in the froghopper infestation in the next two years, there was also a distinct change in the agricultural methods in use on the estate, and in addition the reduction of froghoppers was general throughout the district and not confined to the area where the lizards were released or even to the estate in question.

It has also to be remembered that lizards, while eating froghoppers, will also destroy many other insects and spiders that would in turn eat froghoppers.

An accurate investigation of the food of lizards in the cane fields is much needed and will be started as soon as possible. Pending this I am inclined to think that the importance of lizards as a control has been over estimated.

According to Urich the commonest lizard of the cane fields is *Ameiva surinamensis.*

Frogs and Toads.

The comparative scarcity of these animals in the cane fields has also been put down to the introduction of the mongoose. Although this may be partially true (*see* p. 88) once more the effects of agricultural processes must not be overlooked, and in the case of these animals the most important factor is increased drainage which reduces their breeding places.

In some moister localities they are still common and frequently visit the light traps to catch the adult froghoppers attracted thereto.

As with the lizards an accurate investigation of their food is needed before definite conclusions can be drawn.

Grasshoppers.

There are several species of predaceous grasshoppers in Trinidad that eat froghoppers and other insects. These belong to two genera *Xiphidium* (*Conocephalus*) and *Pflugis*.

Xiphidium (*Conocephalus*) is represented in Trinidad, according to the latest revision of Rehn & Hebard (Trans. Am. Ent. Soc. XII. p. 225) by the two species, *saltator* and *versicolor*.

The former of these is the most abundant and is often in very large numbers in the traces through the cane fields, but much less common among the canes themselves.

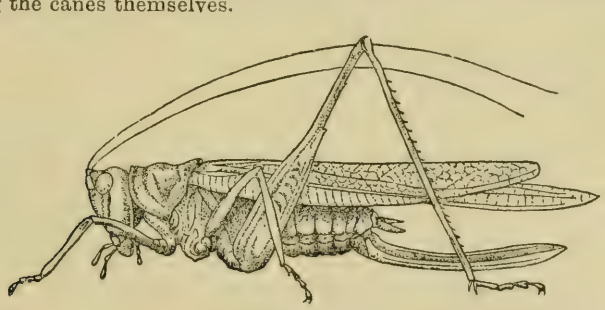

Fig. 17.

Fig. 17—A predaceous Grasshopper (*Xiphidium saltator*).

It is a medium-sized long horned grasshopper, green with a brown streak along the back. The ovipositor of the female is long and projects beyond the wings which are frequently reduced in length (Fig. 17.)

In addition to froghoppers it eats many other insects including caterpillars, small Hymenoptera, and smaller specimens of its own species. It also takes vegetable food. In British Guiana a closely related species was found to eat the developing flowers of rice, and in Hawaii *X. variepenne* is partly vegetarian although also a valuable destroyer of the injurious leafhopper. Closely related species are abundant throughout Central America but always seem to prefer grass to sugar cane as a place to live.

Although most active during the day the adults are frequently found in light traps put out in the cane fields during the night.

The eggs of this grashopper are laid four or five together in slits in the dead leaf sheaths of grass and canes, but are easily distinguished from those of froghoppers by their much larger size and cylindrical shape. The eggs of *X. variepenne* in Hawaii are parasitised by *Paraphelinus xiphidii* and the eggs of the Trinidad species are probably

an alternative host (if not the regular host) of *Paraphelinus tomaspidis*, the Trash-coloured Egg-parasite, supposed to destroy the eggs of the froghopper.

The adult *Xiphidium* are caught and stored up as food by the burrowing wasp *Sphex ichneumonicus*.

Pflugis is represented in Trinidad by *P. mantispa* an active green grasshopper, smaller and more slender than *Xiphidium*, which however also prefers the grass and bush to the canefields. It is nothing like so common as *Xiphidium* and is of comparatively little importance as a check to the froghopper.

Related species of the genus are widely distributed throughout Central America.

Ants.

As has been mentioned above, the froth covering of the nymphs makes them almost immune to the attacks of hunting ants.

The adult however, in spite of its ability to jump and fly, frequently falls a prey to the various predaceous ants that are found in the cane fields.

The following species of ants have been found preying on adult froghoppers :—

Anochetus inermis, André, in Trinidad (Urich 1913 C. p. 26.)
Solenopsis geminata in Trinidad (Urich 1913 C. p. 26.)
Solenopsis tenuis in Trinidad.
Pseudomyrma elegans in British Guiana.
Monomorium sp. in Trinidad.
Ectatomma ruidium, Roger, in Panama.
Monomorium carbonarium F. sub sp. *ebenium*, Forel, in Panama.

I am indebted to Messrs. C. T. Bruce and W. C. Crawley for the identifications.

In addition to destroying adult froghoppers these ants kill many other useful and injurious insects in the field and some also carry away froghoppers infested with green muscardine, thereby preventing its spread. Froghoppers are particularly liable to be destroyed by ants when affected with fungus diseases, which make them lethargic for some time before killing them outright.

Fireflies (Lampyridæ).

On one occasion it was reported to me by a planter that he had seen a candle-fly" on his table the previous evening eating an adult froghopper which had been attracted in to the light.

On another occasion I was given the larva of a similar species which had been found in the froth of a nymph froghopper. Unfortunately the larva was dead before I received it.

These Lampyrids and their larvæ are known to be predaceous and are common in the cane districts, but it cannot be said to what extent they are a serious enemy of the froghopper.

The firefly or candle-fly referred to here is the small soft bodied beetle with the single light beneath the end of the body, and not the large hard click-beetle, locally known as "La Belle" which has two green lights in front and a yellow one beneath.

Phoridæ (Diptera).

Kershaw (1913 I p. 10) reports finding some small flies of the genus *Phora* emerging from dead froghopper adults, but was not able to determine whether or not they had attacked the adults before death.

On two occasions I have found similar flies associated with froghoppers. Once in British Guiana when they were found in captivity destroying dead nymphs of a *Clastoptera* sp., and the second occasion was in Panama when they were found emerging from dead adult froghoppers of the genus *Tomaspis*. On neither of these occasions was it possible to say that the froghoppers had not been dead before being infested.

Phoridæ are known as parasites, but further investigation is needed before it can be said if the above is of this nature.

Soldier Bugs (Reduviidæ).

These insects are general predators and many of them occur among the grasses and canes where froghoppers are found. Their value as enemies of the froghopper is difficult to estimate in view of their wide range of food.

Several species are not common in Trinidad and the following have been found in the cane fields:—

Sirthenea stria. F.
Rasahus hamatus. F.
Narvesus carolinensis. Stal.
Saica recurvata. F.

Numerous other species are found in other countries associated with froghoppers. The most important are the following:—

Heza peramata, a large species found in British Guiana hiding in the axils of cane leaves and destroying adults of *Tomaspis flavilatera*.

Zelus mimus, a smaller species common along the edges of the drains through the cane fields in British Guiana where it was on several occasions seen to eat froghoppers.

Castolus plagiaticollis. The Mexican Bug. (Fig. 18.)

When on a visit to Mexico in September 1911 Mr. F. W. Urich sent to Trinidad eggs of this bug which was found preying freely on froghoppers in Mexico.

Fig. 18.

Fig. 18—The Mexican Bug (*Castolus plagiaticollis*), (From F. W. Urich).

The eggs were hatched out by Mr. Guppy and the insect kept breeding in captivity until March 1914 (Urich, Bull. Dept. Agric. XIII. p. 102.)

At intervals several thousand were released in the fields but conditions were apparently unfavourable as none was ever recovered. Urich suggests that they were killed by spiders.

In Mexico the eggs were destroyed by a species of *Telenomus* (Urich 1913 B. p. 247.)

Repipta taurus. This small red Reduviid was very common in the Bocas-del-Toro district of Panama in the first half of 1917 and was frequently seen feeding on adults of *Tomaspis*.

At one time I intended sending specimens to Trinidad but lack of communication made it impossible at the time and the few specimens I brought back with me died on the journey.

The eggs of this bug are erect, almost cylindrical, flattened at the sides, very slightly narrowed towards the upper end and then expanded at the cap. They are about 1·2 mm. in height by 0·44 mm. in width. Colour dark red brown with a narrow white rim at the margin of the cap. The upper end (the cap) is covered with a pale brown mealy secretion which is produced to a slight point in the middle. The eggs are joined together and to the substratum by a colourless gum. The exposed sides of the egg are minutely punctate. They are laid in two closely approximated rows, the eggs in one row alternating with those in the other.

They are laid on grass stems and twigs and hatch in about sixteen days.

Some experiments were made on the effect of cold on the eggs with a view to the possibility of sending them to Trinidad in cold storage. Eggs laid between 14th and 24th May were put into a domestic ice chest on the latter date and kept there till 4th June (11 days). They were then removed to normal temperature and hatched on 16th June. They thus took about 26 days to hatch, of which 11 days were in cold storage.

The adults eat many other insects besides froghoppers and are also to certain extent cannibal. They are capable of giving a severe prick with their proboscis and one that pierced my finger produced intense pain, worse but less lasting than a wasp sting, and the mark of the injury persisted for over ten days.

Zelus rubidus was a larger bronze and yellow Reduviid not uncommon in the Bocas-del-Toro district of Panama, and several times seen to feed on *Tomaspis* sp.

Spiders.

A certain number of froghoppers are caught in the bush in the webs of the orb-weaving spiders but these are not common in the cane field. The most important group of spider enemies are the *Attidæ* or jumping spiders which are much more abundant among the canes and are frequently seen with adult froghoppers in their jaws.

The only specimen so far identified was a *Scopocira* sp. from Panama.

The spiders are in their turn destroyed by ants and fossorial wasps, and are also killed in large numbers when a field is burnt.

Red Mites (*Acari.*)

Froghoppers and other insects (grasshoppers, mosquitoes, flies, etc.) are frequently found with small red mites attached to their bodies, wings and legs. One or two up to as many as seven or eight may be attached to a single insect.

In Trinidad they appear to be most common towards the end of the wet season and I have found them also on other species of froghoppers in British Guiana and Panama.

Nothing is known of their history, and it is doubtful if they have any serious effect on their host.

Urich (1913 C. p. 23) gives their name as *Rhyncholophus* sp.

The Green Muscardine Fungus.

(*Metarrhizium Anisopliæ*, Sorokin.)

This fungus which is one of the most important natural enemies of the froghopper was noticed by Hart in 1889 at the time of his first discovery of the insect. It was mentioned again in 1906 by Urich and Collens in connection with the outbreaks in that year, and has since continued each year to be more or less effective as a check on the froghoppers, particularly on the later broods.

The fungus, which is one of the *Entomophthoraceæ*, attacks the living froghoppers by hyphæ from a germinating spore entering the body apparently either through a spiracle or through the thinner parts of the skin. The mycelium gradually fills up the body and the insect becomes lethargic and dies. The mycelium then appears on the outside of the body piercing at first chiefly through the thin connective tissue between the abdominal segments, and fastens the insect to the substratum. In the exposed places the fungus begins to produce its characteristic dull olive-green cylindrical spores, which are formed in chains on the ends of special erect hyphæ and are from 0·0045–0·0070mm. in length and 0·0023–0·0025 mm. broad.

From the time of original infection of the adult to the time of its death may be from two to six days and spores usually begin to appear about two or four days after this. The insect when killed by this fungus usually has the hind legs stretched out behind and crossing over one another and is either in the axil of a leaf, or attached to the surface of a leaf (usually on the upper surface) near its base (cp. symptoms of Empusa fungus below).

The fungus is very much more abundant on adult froghoppers than on the nymphs and indeed in the fields I have found it extremely rare on the latter. Many thousands of infected adults have been seen in the last four years, but less than one dozen infected nymphs.

Gough (1911 B.) says he has not seen naturally infected nymphs and he had great difficulty in infecting them artificially, chiefly he believed owing to the protective froth, but Rorer found that they could be infected as well as the adults.

Among the adults a very large proportion of the infected specimens are females. The following figures show this.

Locality.	*Males.*	*Females.*
(Urich B. D. A. XI. p. 360)	9	38
Brechin Castle 19. XI. '18	3	16
Caroni 29. X. '18	3	7
Reform 18. IX. '18	9	20
Total	24	81

This may be due to the greater activity of the males causing the spores of the fungus to be shaken off more readily.

It has also been observed that the infected females have usually not laid their eggs, a fact which considerably increases the practical value of the fungus. On the other hand the specimens dead and dying from the fungus fall an easy prey to predaceous ants and are often carried away by them before they have time to disseminate their spores.

The fungus usually appears in the fields in small quantities on the adults of the first brood. The first specimen seen in the field in 1918 was on 12th June and in 1919 on 27th June. On the second and third broods however it is usually widespread and occasionally is responsible for the death of the greater part of the brood. Its increase appears to depend chiefly on the moisture present in the fields, and in periods of drought (*e.g.* the "Indian Summer", which sometimes comes in September and October) it does not spread. This is possibly one of the ways in which the rainfall brings about its important effect on the prevalence of blight in the different seasons. (*see* p. 96)

The Green Muscardine fungus is not confined to Trinidad, but is known throughout the world on many different hosts.

Stevenson (1918) gives its natural distribution as Russia, France, United States, Mexico, Trinidad, Hawaii, Porto Rico, Samoa, Philippine Islands, Java, and Queensland, and says that it has been introduced into Mauritius, Cuba and Argentine.

To the natural distribution I can add British Guiana, Panama and Grenada, and to the countries of introduction, Barbados and Colombia should be added. From the high degree of humidity in the fields of British Guiana it might have been expected to be common there, but only a single infected specimen was seen during my visit in 1910. It is possible that it is reduced by the continual heavy trade wind blowing inland from the sea.

It is also known to attack a large number of other insects, *Coleoptera* (including Rhinoceros beetles attacking palms, and hard-back beetles), *Lepidoptera* (including the grubs of the small Sugar-cane Moth-borers), *Orthoptera* (including earwigs and cockroaches), *Diptera* (a species of *Stomoxys* is recorded by Kershaw) and *Hemiptera* (Reduviids, leaf-hoppers and froghoppers).

Urich (Bull. Dept. Agr. XI. p. 344) says that it did not attack the Mexican bug (Reduviid) that he found feeding on froghoppers in Mexico, but I found a Reduviid in Panama killed by it.

From the Trinidad point of view the most important of these alternative hosts are the caterpillars of the small Moth-borers of Sugar-cane (*Diatraea* spp.) and the hard-back beetles.

Practical Use of the Fungus. The fungus under favourable conditions destroys such a large proportion of the froghoppers that attention was at an early stage drawn to the possibility of producing it artificially on a large scale and introducing it into the cane fields in time for the early broods.

It was previously known by experiments in Europe that, unlike most entomogenous fungi, it would grow well on artificial media, and Rorer in 1909 and Gough in 1910 took up the problem of producing it in quantity. They both found that it produced abundant spores on potatoes, yams, peas, rice, various artificial culture media such as bouillon-agar, and horse-dung agar and also on cylinders of sugar-cane. On the latter, however, Gough (1911 C. p. 19) found that it grew but produced no spores.

In 1918 I attempted to cultivate it on "filter-press cake", which is a residue obtained in the manufacture of sugar, but found that on this also it would grow slowly but produced no spores.

Experiments along these lines resulted in the making of large cabinets about six feet high by about three feet square, designed by Rorer, in which were a dozen or more trays of cooked rice which could be sterilised and innoculated with the green muscardine fungus. It is not the purpose of the present report to describe these in full (for this *see* Rorer 1913 A. & B.). From one of them about 30 lbs. of a mixture of rice flour and spores could be produced and this was spread by various methods in the field.

The Usine St. Madeleine had in 1916 twelve of these cabinets in operation and produced 1,230 lbs. of the spore mixture which they sold to their subsidiary estates at 31 cents per lb.

Distribution in the Field. The simplest, most laborious and least wasteful method consists of catching adult froghoppers in tubes containing spores and then allowing them to escape after sufficient time for infection. The second method emphasized by Gough, consists of putting small pieces of infected rice or potato in the upper axils of the leaves of the canes in such a position that they would probably come into contact with the adults.

The most wasteful method, and at the same time that requiring least labour and so applicable to a large area, consists in blowing the mixture of spores and rice flour over the infested fields in the late afternoon or evening by some form of hand or rotary blower. This method was developed by Rorer, who at the end of 1912 dusted about 508 acres on one estate with about 636 lbs. of mixed rice flour and spores at a cost of about 25–28 cents (1/--1/2d.) per lb. for the mixture, or about 40c. per acre (these prices could not now be repeated).

In this connection it might be mentioned that if the distributor of the spores gets much of the mixture in his face it may set up a form of hay-fever which is extremely unpleasant. I myself was incapacitated for two days by this after shaking a bag of spores over about two acres of a cane field.

Yet another method of distributing the spores experimented with by Gough and Rorer and later by myself consists in attracting the adults during the night by means of lights to trays containing the spores with which they become covered. For further particulars of this method see under "light traps" (p. 146.)

The final test of these various methods adopted to spread the infestation of the green muscardine fungus, must always be the result obtained, and in this connection it must be admitted that it is extremely difficult, if not impossible, to estimate accurately the effect of such treatments. There is nearly always a considerable natural infestation in a field and it is difficult to separate this from the results of artificial introductions.

Under suitable conditions there is little doubt that appreciable results can be obtained but should the conditions alter, as for example when the weather turns dry, the whole expense of the treatment may be lost.

Rorer and Urich in 1912 distributed spores on a field at Orange Grove and found later an average of 92 dead adults per stool. (Urich, *Bull. Dept. Agr.* XI. 71 p. 360).

At Golconda Estate in 1918 we were able to produce an infection of the first brood which was light but at the same time considerably greater than most first brood infections. On the other hand in July 1918 I distributed spores in a field at Williamsville Estate where only one or two dead adults could be found, and three weeks later a close search failed to reveal a single infected specimen. Conditions were somehow unfavourable, and not only did the artificial infection fail, but even the natural infection that was starting passed away.

Some estates distributed spores regularly for several years. Others have never made any attempt to supplement the natural infection. Estates in both groups have suffered severely and other estates in both groups have escaped.

The method is so dependant on external conditions that it becomes a form of gamble. The outlay is however small* and could easily be covered by most estates by the saving of a few tons of sugar. The method is also technically difficult, the wrong fungus may be grown in the cabinets by accident, particularly if sterilization of the cabinets has been faulty, while distribution in a high wind or in fields already heavily infected naturally, will result in a loss of the material prepared.

I believe that further investigation could be profitably made on the use of green muscardine fungus, but the method can never be made to appeal to those who are looking for a certain cure with next to no expenditure of time and trouble.

*The Usine Ste. Madeleine in 1918 spent just over two thousand dollars on the production of green muscardine fungus.

The Empusa Fungus.

This fungus, a species of a well known group of insect parasites, is very much scarcer in the fields of Trinidad than is the green muscardine.

The insect, when attacked by it, usually remains attached to the leaf blade high up on the upper or under side well away from the base of the leaf. This would indicate that the death of the insect occurred at night time when it was out sucking and that it was more sudden and less preceded by lethargy than when caused by the green muscardine. The insect when dead is also in a more natural position than with the latter fungus and the hind legs are not stretched out behind.

The appearance of the fungus shortly after the death of the froghopper is a soft moist jelly-like mass of fungus mycelium between the body of the insect and the leaf. At this stage the spores are shot off and then the fungus dries up leaving the dead adult attached to the leaf by a brown net-like palisade of dried hyphæ.

Nowell examined the fungus in its moist stage and found the characteristic spores of *Empusa* and also a number of minute motile bodies probably *Protozoa*.

The first reference to the fungus is by Urich (1913 C. p. 27) who says "it was active last year [1912] and in several districts quite a large number of adult froghoppers were killed by it. It was particularly prevalent in the Princes Town and Naparima districts."

Mr. E. E. Fabien, Manager of Cedar Hill Estate says that in October 1912 a large number of the froghoppers on that estate were destroyed by it, and J. McPherson, Manager of Ben Lomond Estate, wrote at the end of 1912 in an unpublished circular "since the beginning of November 1912, while we were getting showers of rain daily, a natural fungus was very prevalent and destroyed large numbers of froghoppers. When the fungus attacks them, they leave the heart of the cane and walk up into the sun at the top of the leaves where they remain until they die."

Since 1916 I have found it in the cane fields on various occasions which are as follows:—

Records of Empusa Fungus.

Date.	*Locality.*	*Notes.*
9. X. 16	Harmony Hall	fairly common.
25. X. 17	Cedar Hill	4 specimens.
26. X. 17	Harmony Hall	5 specimens.
16. XI. 17	Orange Grove	5 specimens.
22. XI. 17	Orange Grove	3 specimens.
1. II. 18	La Fortunée	1 specimen.
19. XI. 18	Golconda	5 specimens.
31. XII. 18	La Fortunée	2 specimens.
6. I. 19	Golconda	2 specimens.
20. I. 19	Tarouba	2 specimens.
28. X. 19	Golconda	2 specimens.
4. XI. 19	Golconda	2 specimens.
5. XI. 19	Corinth	1 specimen.
End Nov. & beg. Dec. 1920	Naparimas	widespread.

The last record refers to a very sudden epidemic which occurred on the unusually late third brood in 1920 after a wet November. Several thousand dead specimens were seen on four or five different estates but the greatest outbreak was at Cupar Grange. Of eighty-three specimens collected at the latter locality 58 were males and 25 females; this excess of males is the opposite of what is found with the green muscardine fungus.

It will be seen that the fungus has never been found before October but may persist for a short time into January.

The rate of infection of adults as indicated by laboratory experiments is extremely rapid. Healthy specimens were confined in a cage with diseased ones on 4th November, 1919 and one was dead and showing distinct signs of *Empusa* fungus thirty six hours afterwards on the 6th November.

Unfortunately this *Empusa*, unlike the green muscardine, can only be cultivated with very great difficulty off the host insect, and even in this it is exceptional as most other species of *Empusa* cannot be artificially cultivated at all.

Acting on some suggestions of Mr. Rorer I made an attempt in 1917 to cultivate the fungus and carry it over the dry season in order to distribute it in the beginning of the following wet season.

On 17th November, 1917 I inoculated from an infected insect two culture tubes of agar and six potato tubes. By the 3rd December (sixteen days) one of the potato cultures had a thick mycelium growth and was shooting off spores on to the side of the tube. By 15th December several other of the potato cultures were producing spores, but those on the agar had failed to do so.

Transfer cultures were taken on fresh potato tubes from these spores, but they gradually died off and failed to produce a further supply of spores. It is probable, that in order to carry on the culture, alternate generations at least would have to be grown on the insect to keep up the vigour of the strain.

The fungus, or a similar one, has been recorded in Mexico on froghoppers by Urich (1913 B. p. 247). In Trinidad nothing further is known of its habits or any other hosts.

HYPERPARASITES.

Under this heading will be considered those animals which prey on the enemies of the froghopper, and by reducing their numbers allow the froghopper to multiply.

The Mongoose.

Since its introduction into the West Indies about 50 years ago the mongoose has been a subject of debate and dispute.

It was originally imported without the slightest attempt to get first an accurate estimate of its food, and after being greatly praised for years for its effective destruction of rats, it has gradually become the scapegoat which receives the blame for every outbreak of every pest in the West Indies, among which must be included the froghopper at present under consideration.

As mentioned on p. 18. I was in 1917 instructed by the Froghopper Committee to find out if possible to what extent the mongoose was responsible for the recent outbreaks of froghoppers.

In order to do this, two lines of work were necessary (1) to get an accurate history of the outbreaks of froghopper blight in Trinidad and (2) to get an accurate knowledge of the food of the mongoose.

The history of the blight so far as can be ascertained has been given in Section III.

The investigation of the food of the mongoose was started in 1917 and carried on for a year, the results being published in a separate report (Williams 1919 A.)

With these facts we can proceed with the original inquiry.

According to Urich (1914 D.) the mongoose was first introduced into Trinidad about the year 1870 to some estate in the Naparimas. The animals arrived in a ship from India and some escaped in Port-of-Spain. Other importations took place during the next twenty years or so, but it was not until 1898 that any adverse opinion was expressed as to its desirability. In this year the Trinidad Field Naturalists Club resolved that its importation should be prohibited.

Urich, writing in 1914 (1914 D. p. 6) says "There is no authentic record of how many animals reached the Naparimas, but evidently the mongoose did not survive there as up to now comparatively few have been reported from that district." This is also confirmed by figures given of the numbers destroyed in the Northern and Southern sections of the island. From 1902–1913 a Government reward was given for dead mongoose and over 30,000 were destroyed in the island north of Couva, while forty-three were destroyed in the Naparimas and none further South (*Proc. Agr. Soc. Trinidad & Tobago*, XIII. p. 131.)

The mongoose has been abundant in the Northern district for about 20 years, in the Central district for about 10 years, and has only recently become common in the Southern section.

In order to show more accurately the variety and proportion of the food of the mongoose, the tables showing the total contents of 180 mongoose stomachs is reproduced here from my previous report and also the final balance sheet, where the foods of no practical importance are eliminated. In this table all the useful animals destroyed are printed in CAPITALS and all the injurious ones in *italics*.

TABLE V. –The Contents of 180 Mongoose Stomachs.

VERTEBRATES	*Common Rat*	26
	Spiny Rat	2
	MISCELLANEOUS BIRDS	14
	DOMESTIC FOWL	10
	FOWL EGGS	2
	LIZARDS	17
	Snakes	18
	FROGS	14
	TOADS	14
	Fish	6
INSECTS	*Grasshoppers*	535
	Mole Crickets	2
	Crickets	3
	Cockroaches	54
	Stick Insects	1
	Moths	3
	Caterpillars	2
	Fly-grubs	27
	Plant Bugs	2
	Lamellicorn Beetles	43
	Lamellicorn Grubs	7
	CARABID GRUBS	44
	Weevils, adults	7
	Weevils, grubs	7
	Miscellaneous Beetles	46
	Ants	3
OTHER ARTHROPODS	SPIDERS	44
	Scorpion	1
	Centipedes	14
	Millipede	1
	Tick	1
	Crab	3
VEGETABLE MATTER	Half a dozen fruits. One feed of yam. A little coconut.	

TABLE VI.—BALANCE SHEET.

Credit.	Debit.
28 Rats.	26 Birds.
	17 Lizards.
About 600 injurious insects.	29 Frogs and Toads.
	44 Useful insects.
3 Crabs.	44 Spiders.

The evidence incriminating the mongoose is as follows :—

(*a*) The froghopper blight in Trinidad has been apparently more abundant in the last fifteen years, within the time that the mongoose has been to any extent widespread in the island.

(*b*) There is a general opinion among all the older planters in the colony that wild birds and lizards are much less common nowadays in the cane districts than formerly, and as many of them eat froghoppers, their reduction would allow the froghoppers to increase.

(*c*) The mongoose is known to destroy lizards, frogs, toads and birds.

(*d*) In most countries where the mongoose has been introduced it has acquired a reputation for destroying birds and lizards and causing outbreaks of insect pests.

On the other side the following observations can be made.

(*a*) Although outbreaks of blight have apparently been commoner within the last fifteen years, we have accounts of blight of a similar nature many years before the mongoose was introduced, and outbreaks definitely known to be due to the froghopper so soon (1889) after the introduction of the mongoose that its influence cannot have been concerned. Further the outbreaks of blight even in the last twenty years have not been correlated with the spread or numbers of the mongoose. In 1906 there were serious outbreaks in the Naparimas, although the mongoose was still rare in that district.

(*b*) Many other causes during the past fifty years have tended towards a reduction of animal life in the cane fields. Increased population, spread of cultivation and destruction of forest areas are not the least of these. Better drainage has reduced the number of breeding places for toads and frogs, better cultivation and the reduction of abandoned land destroy breeding places for birds and lizards, and last, but not least, the practice of burning the canes before cutting and of burning the trash after cutting, fortunately less frequent now than formerly, both destroy a considerable proportion of the animal life in the cane fields.

If it is held that injurious as well as useful animals and insects are thus destroyed it must be pointed out that the injurious insects breed more rapidly than birds, lizards and toads and hence recover more quickly and cause damage before their slower breeding enemies have again become efficient.

(*c*) Although, as shown by Table V and my previous report the mongoose destroys birds, a large proportion of these are domestic fowls, which do not concern the present enquiry, and of the others many are not insect-eating.

Several planters have remarked to me on the great reduction in ground-doves as a proof of the ravages of the mongoose, but this bird does not eat froghoppers, and in my own experience it is one of the commonest birds in the Caroni district, where the mongoose abounds, and though large flocks of them are to be seen on the ground there, thirty-six mongoose stomachs from this estate did not contain the traces of a single bird.

The mongoose cannot climb and has to confine its attention to birds which nest or feed on the ground, and it will be seen from the account of the bird enemies of the froghopper (p. 70) that the chief of these are not ground-nesting birds. The most important of all—the Scissors-tail Fly-catcher—does not breed in Trinidad, while the others mostly nest in bushes and trees well away from the ground. The only two which nest within reach of the mongoose are the Black-finch and the Red-breast, both of which are of little importance, and yet at the same time cannot be considered rare in the cane districts. In addition the mongoose eats rats which are able to climb and destroy the eggs and young of many tree-nesting birds (*see* below).

The destruction of lizards and toads is a more serious charge and it is hoped to start an investigation of the food of these in the coming year.

At the same time attention must be drawn to the figures given in Table IV of my report on the food of the mongoose (Williams 1919 A. p. 184). The number of lizards, snakes, frogs and toads found in thirty-six stomachs at Caroni, a locality for many years heavily infested with mongoose was in each case greater than the number found in forty stomachs from the Southern district, where the mongoose has only recently become numerous. Although the excess is not great, yet it is entirely contradictory to what would be expected if the mongoose had been the chief factor in the supposed reduction of these animals in recent years.

(*d.*) Trinidad, and other countries to which the mongoose has been introduced, are by no means the only places in the world which have suffered from insect pests of recent years, nor are they the only countries which complain of a reduction of natural wild life.

As a result of these considerations one is forced to the conclusion that *the mongoose although doubtless undesirable, and possibly to a very limited extent contributory to recent outbreaks of pests, is not the one cause, nor is it even one of the most important causes, of the outbreaks of froghopper blight in Trinidad.*

Two points of interest in connection with the mongoose have been settled since my report in 1919. The centipede which was found represented in fourteen stomachs was identified by the Imperial Bureau of Entomology as *Scolopendra angulata*, Newport.

I submitted to the same Bureau some preserved skins of mongoose, with the idea that their destruction might be encouraged and made more profitable if a market could be found for the skins. The reply, which was as follows, is not encouraging.

"I submitted the skins of the mongoose to the Imperial Institute and asked them to make enquiries as to their market value. They have written to me to say that the replies they have received are very unpromising and indicate that the skins have no commercial value. One firm stated that they would come into competition with ordinary squirrel skins, etc., and might possibly be valued at ½d. (1 cent) each."

Rats.

On several occasions rats have been found to destroy the nests and eggs of birds, and in this habit they have the advantage over the mongoose in that they can climb trees and reach the nests of tree and bush-living species.

On one occasion the nest of a tick-bird was found with a rat in it and the eggs broken. This nest was about seven feet from the ground.

On another occasion a rat fled from the nest of a giouti on our approach and on examination this nest was found to be damaged and the eggs broken.

Birds.

In addition to the good that insectivorous birds do by eating the adult and nymph froghoppers, it must be recognised that by destroying the enemies of froghoppers they may to a certain extent cancel out their previous value. Thus the tick-bird (*Crotophaga ani*) has been found to eat spiders, grasshoppers (including *Xiphidium*) and preying mantids.

The boat-tail (*Quisqualus lugubris*) eats lizards which would in turn eat the froghoppers. The grey-headed keskadee has been observed eating dragonflies, and the common keskadee has several times been reported killing lizards. In fact, with regard to the latter bird, Mr. Urich has put down the comparative abundance of tree lizards in Grenada to the absence of our common keskadee.

Lizards.

Even the lizards are not above reproach in the matter of their food. On more than one occasion they have been seen to eat jumping spiders, and dragonflies have been found in the stomach of a large species. A more accurate investigation of the food of lizards is needed.

Snakes.

Urich (1913 C. p. 24) reports that the snake *Scytale coronatum* eats lizards, but that it is not very common on the sugar estates and he thinks that it is disappearing.

Grasshoppers. (*Xiphidium.*)

In captivity young *Xiphidium* have been found to eat miscellaneous small *Hymenoptera* including the vermilion parasite. In the field their diet is probably somewhat similar.

Ants.

Ants, like all general predators, do not distinguish between insects that are, to the agriculturist, useful or injurious. They have been observed killing jumping spiders (*Attidæ*) and young *Xiphidium*.

Fossorial Wasps. (*Sphegidæ.*)

Sphex ichneumonicus makes burrows in the soil in various parts of Trinidad and British Guiana, particularly where the soil is light and sandy, and stores them with the adults and nymphs of the grasshopper *Xiphidium*. Other wasps make mud nests and store them with spiders.

They are in turn preyed on by other parasitic wasps and I have seen hunting ants removing the grasshoppers from the burrow of the *Sphex*.

Spiders.

These have also to be sometimes included among the hyper-parasites. They have been said to be responsible for the failure of Urich's "Mexican Bug" to establish itself here, and Guppy found that in captivity they destroyed his Syrphid flies to such an extent that breeding these on a large scale was impossible.

Oligochaete Worm.

Under "The Syrphid Fly" p. 69 will be found particulars of a worm believed to be parasitic in the pupa of this fly. It was found in Tobago by P. L. Guppy.

Gibellula Fungus.

This is an entomogenous fungus which destroys spiders. On several occasions I have found it on jumping spiders in the cane fields. The spider dies attached to the leaf and is covered with a mass of fungus hyphæ which are raised into vertical projections bearing spores.

THE PARASITE COMPLEX.

In the above pages an outline has been given of the various parasites and hyper-parasites with which the froghopper is associated in the cane fields. In Fig. 19 an attempt has been made to show in diagramatic form the way in which all these animals and fungi are inter-related. In the centre the froghopper is shown and in the first ring round it are all its natural enemies grouped according as they feed on the egg, nymph or adult. In the outermost ring are the hyper-parasites or enemies of the enemies, and in the intermediate ring are shown other hosts or foods of the parasites and hyper-parasites. The arrows indicate that the animal at the feather of the arrow destroys the animal at the tip.

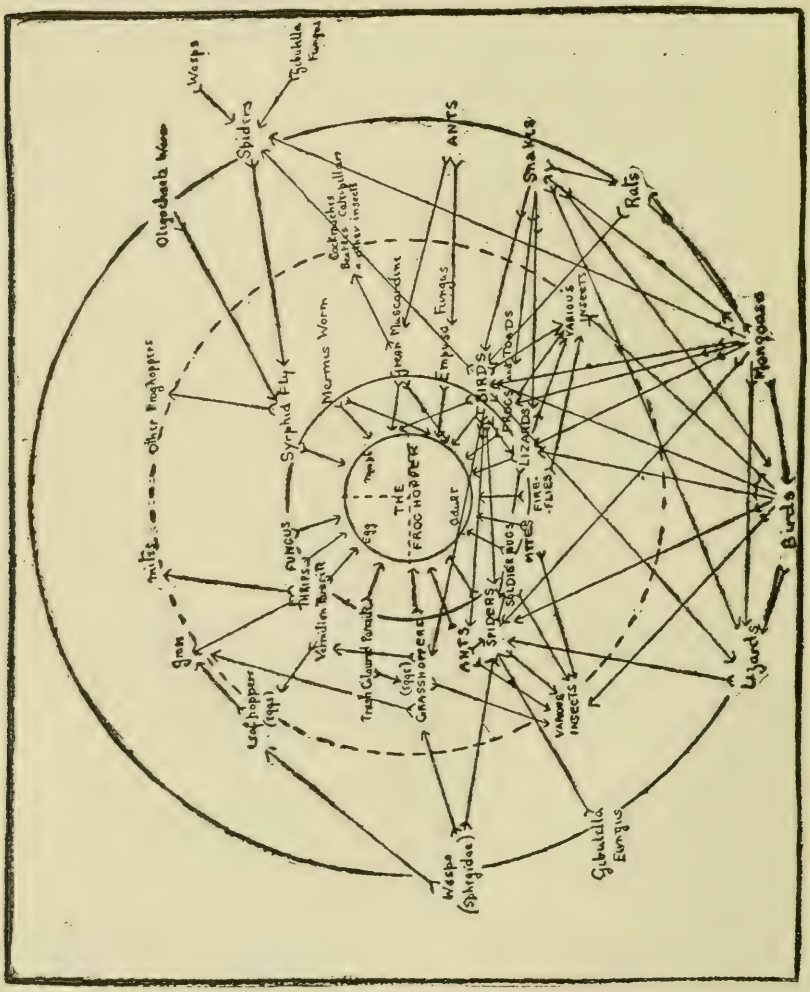

Fig. 19.

Fig. 19—Diagram illustrating the Parasite Complex centring round the froghopper.

A careful study of this diagram will show the extraordinary complexity of the relationships and the great difficulty of deciding whether any particular animal is valuable or undesirable.

Thus it will be seen that birds eat froghoppers, but they also eat lizards, which in turn eat froghoppers. The mongoose eats birds, which eat froghoppers, and as such it is undesirable. But the mongoose also eats rats, which eat birds, which eat lizards, which eat spiders, which eat Syrphid flies, which eat froghoppers. What conclusion can be drawn from this ?

It is hoped that an examination of this diagram will disillusion those who speak of the "Introduction of New Enemies" as if it were a remedy the obviousness of which was only exceeded by its simplicity and certainty of success.

SECTION VII.

THE ROOT DISEASE OF SUGAR CANE.

It is not the purpose of the present report to give a complete account of the root-fungi of sugar-cane. Such a work is best done by an experienced mycologist. Only a sufficient outline will be given here to enable the planter to recognise the chief root-fungi, in order that he can realise for himself the part they play in the production of blight.

For most of the technical information in this Section I am indebted to the writings of Nowell, Johnston, Bancroft, South, and others mentioned in the bibliography at the end.

FUNGI CONCERNED.

We have apparently two distinct groups of fungi attacking the roots of cane in Trinidad (1) The *Marasmius* type and (2) the *Odontia-Himantia* type.

Quite recently Carpenter (1919) has described a root fungus *Pythium* sp. causing a form of root disease in canes in Hawaii but no search has yet been made here for this fungus.

Marasmius type. The most obvious visible sign of the presence of this fungus is the matting of the leaf sheaths, particularly near the base of the stem, by a white, dried-paste-like mycelium (Plate VII). This is the vegetative part of the fungus and grows in living or decaying tissue according to conditions. The spores of these fungi are produced on small mushrooms or toadstools (Plate VIII) which are however not frequently found. The various species concerned differ in small details such as the size of the mushroom, the number of rays beneath the top and the colour of the stalk, but all are apparently more or less similar in effect.

The *Odontia* fungus in its vegetative stage also mats down the basal leaf-sheaths of the cane, but on pulling them apart a feathery fungus is seen (Plate IX) which when examined with the microscope is found to contain numerous minute stellate crystals. This form is found between the matted sheaths only, in positions hidden from the light, and has been known as *Himantia stellifera*.

On the outside of sheaths infested with this fungus is found a closely felted granular surfaced fungus in which numerous spores are produced (Plate X). Two closely similar species of this type have been described as *Odontia Sacchari* and *O. saccharicola*. It is the opinion of Nowell, Johnston and Stevenson that this is the fruiting or spore producing stage of the previous feathery *Himantia* fungus. From my own experience in the field I can testify to the constant association of the two forms, often in such close proximity as to leave almost no doubt as to their identity. On Plate X a few strands of the *Himantia* type will be seen near the top where the surface sheath has been removed exposing the fungus that has developed in the darkness.

DISCUSSION AND SYMPTOMS.

The recognition in the field of these two types of fungus is a comparatively easy matter, but the determination of the amount of damage done is extremely difficult. The fungi are "facultative parasites," that is to say they can exist quite readily on dead and decaying matter (*saprophytically*) but under certain conditions they become parasitic, invade the still living tissue and destroy it. When parasitic, these fungi grow in the roots and root-stock of the canes, cause the death and decay of the smaller roots and the staining of the tissue of the larger roots and root-stock.

A cane with its roots damaged by such an attack ceases to grow, and even in moist weather shows symptoms of a shortage of water. The leaves curl inwards at the edges and wilt and become paler in colour. The internodes of the upper part of the cane do not elongate, the leaves remain crowded together, and adventitious roots are thrown out at the base of the cane underneath the matted leaf sheaths in an attempt to obtain the required moisture. If conditions remain favourable to the fungus these small roots become in turn infected and the stool may die out completely.

Only rarely does the infection spread above ground to any extent inside the cane and commonly when conditions become favourable quite healthy shoots are put out by diseased root-stocks.

The disease may attack a few isolated stools in a field, or the greater part of a field, but outside Trinidad it does not appear to destroy such large areas as is found to be the case with the blight in this island.

The conditions which determine the extent of parasitism of the fungus are not well understood. The amount of visible fungus present in the fields is no measure of the amount of damage. The injury always shows most severely in dry weather, particularly when this occurs at an unusual time of the year. Thus it is more conspicuous after severe dry spells in September to November in Trinidad than in the normal dry season.

The disease is known in all the chief sugar-growing districts of the world (W. Indies, Louisiana, Java, Hawaii, Queensland, S. Africa etc.) and it is usually found that any condition which adversely affects the vitality of the cane will reduce its resistance to the fungus. Thus previous insect or fungus injury, starvation due to poor soil, heavy badly-aerated or waterlogged soil, and also acidity due to injudicious use of chemical fertilizers in soils deficient in lime, are all found to increase the damage done by these species of fungi.

There is great need of more critical experiments on this subject. Johnstone and Hartman (1919) have studied the influence of soil acidity, moisture and soil temperatures on a fungus *Thielavia basicola* which

PLATE VII.

Mycelium of *Marasmius* Root-fungus.

PLATE VIII.
Fruiting Stage of *Marasmius* Root-fungus.

PLATE IX.
Mycelium of *Himantia* Root-fungus.

PLATE X.

Fruiting stage of *Odontia* Root-fungus.

causes the "root-rot" of tobacco in certain parts of the United States. After carefully planned experiments in which they were able to vary the conditions one at a time they found that the most important factor was the temperature of the soil, and that at 20° C. (68° F.) the fungus is an active parasite and rapidly destroys the roots of the tobacco plant while at 30° C. (86° F.) it has little or no influence and the plant grows vigorously. A series of experiments of this nature could not fail to throw important light on the problems in connection with the root disease of sugar cane.

ROOT DISEASE IN TRINIDAD.

In Trinidad the two types of root fungus are to be found throughout the sugar districts, one or other, and occasionally both, being present in almost every field in small quantities. On the whole the *Odontia* type is more abundant than the *Marasmius*. The former can be found in the fruiting stage at almost any time in the wet season, but the fructifications of the latter are not common. They have however been found as early as the 10th June, and as late as the 30th December, and probably occur at all times in the wet season under suitable local conditions, which appear to be provided by a saturated atmosphere after comparatively dry weather.

There are at least two species of *Marasmius* on sugar-cane in Trinidad in one of which the stalk of the mushroom is white and in the other purple-black.

Root fungi have been seen attacking plant-canes just sprouting and occasionally damage well-grown plant-canes, but it is on ratoon canes that they are most abundant and that the injury is most severe.

The difference between uncomplicated root fungus attack and the Trinidad blight, and the possible association between the two are discussed in Section IX.

SECTION VIII.

THE FACTORS INFLUENCING THE PREVALENCE OF BLIGHT.

From year to year and from week to week—from district to district and from field to field, the blight varies in intensity. It is the purpose of the present section to discuss the influence of the factors of the environment that vary with time and locality and so produce these local differences in the extent and severity of the injury.

These factors may be conveniently grouped under four sub-headings :—

(1) *The physical environment*, or those factors such as rainfall, temperature, soil and contours of the land over which man has little or no control.

(2) *The agricultural processes* such as drainage, tillage, rotation, manuring, etc., by utilising which the planter can make the best of his given physical environment.

(3) *The characteristics of the cane* itself which vary in different varieties and produce greater or lesser resistance to injury.

(4) *The direct effect of the numbers of froghoppers* present and the effects of root fungus and other diseases on the cane in weakening resistance to further attacks or preventing the recovery from past injury.

The methods by which these various influences may be utilised to prevent or control blight will be discussed in Section X. Here we are concerned chiefly with the degree of relation between the environment and the damage.

RAINFALL.

The quantity and distribution of the rainfall during the year is probably the most important single factor in the environment of the froghopper.

From the very first the connection between rainfall and blight has been noticed, and Cruger in 1863 considered the blight as due to "a want of rain at a certain period." Other observers have at intervals recorded their opinions, some believing that an excess of rain favoured blight, others that it was due to a deficiency, and others again that rainfall had no effect.

In 1919 I made a special study of the rainfall in relation to blight by comparing it in good and bad years and on good and bad estates. It was shown first that there is no relation between the total annual rainfall and blight (*see* Fig. 20), but that there is evidence that the distribution of the rainfall has a distinct effect.

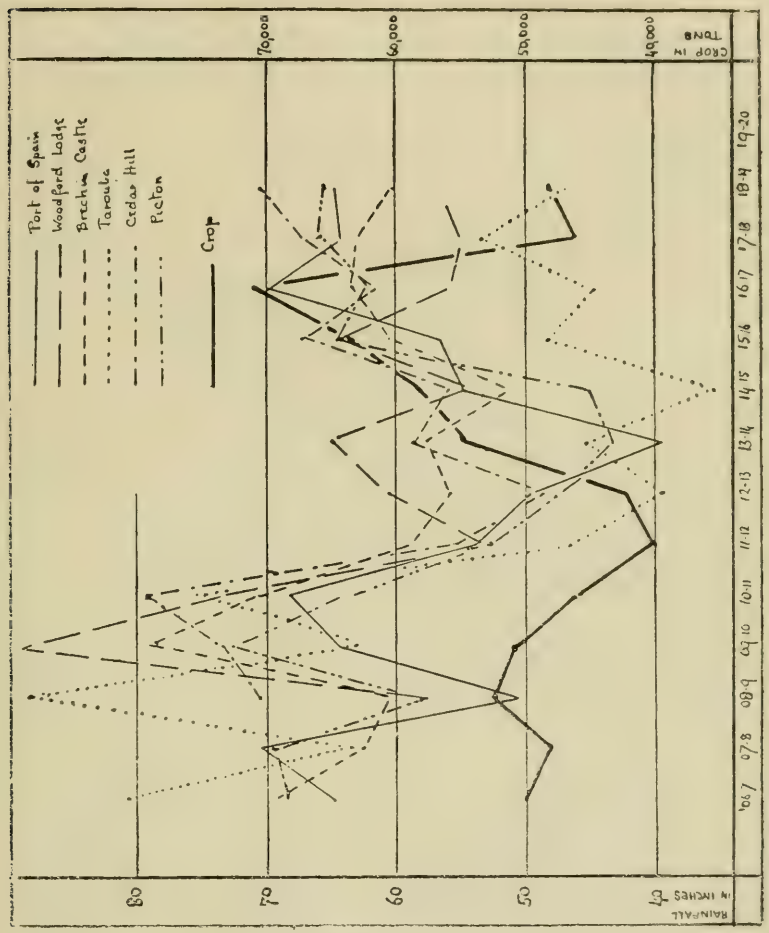

Fig. 20.

Fig. 20– Annual Rainfall on six Trinidad sugar estates 1907 to 1918 with the total crop for the corresponding period. Note the absence of relation between the two.

The conclusions reached were summarised as follows, (Williams 1919 E. p. 167):

"(1) Alternation of wet and dry periods during the growth of the cane is an important factor in determining the prevalence of blight.

"(2) A long dry season followed by unusually heavy rains in June or July is frequently connected with wide-spread blight.

"(3) The most important climatic condition however appears to be the severity of the 'Indian Summer', a dry period in September or October. A severe Indian Summer is a general condition both of localities damaged by blight in one year and of years of wide-spread blight in one locality."

The evidence of these conclusions is given in full in the above report, but for convenience four of the diagrams are reproduced here.

Figs. 21 and 22 show the rainfall on a single sugar estate during five years free from blight and six years of widespread injury respectively. Figs. 23 and 24 show on the other hand the rainfall in one year on three estates free from blight and four estates where damage was more or less severe.

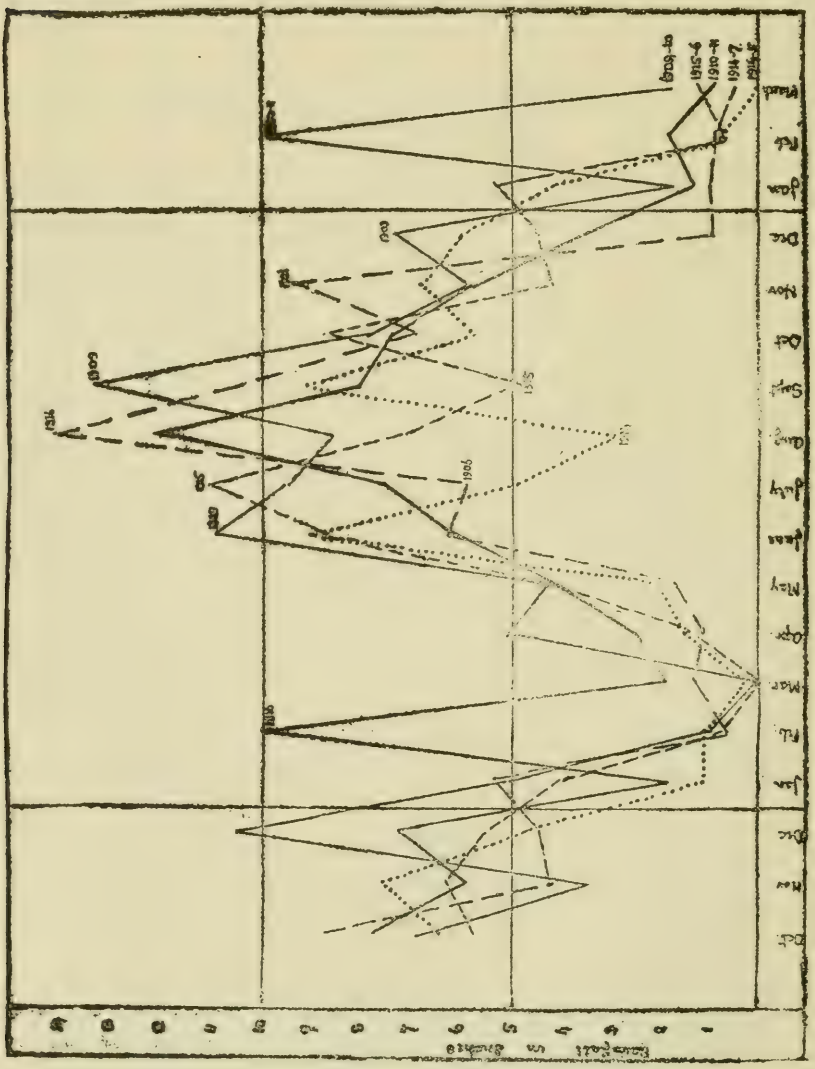

Fig. 21.

Fig. 21.—Monthly rainfall on a Trinidad sugar estate during five years remarkably free from blight. Note regularity of rainfall as compared with Fig. 22.

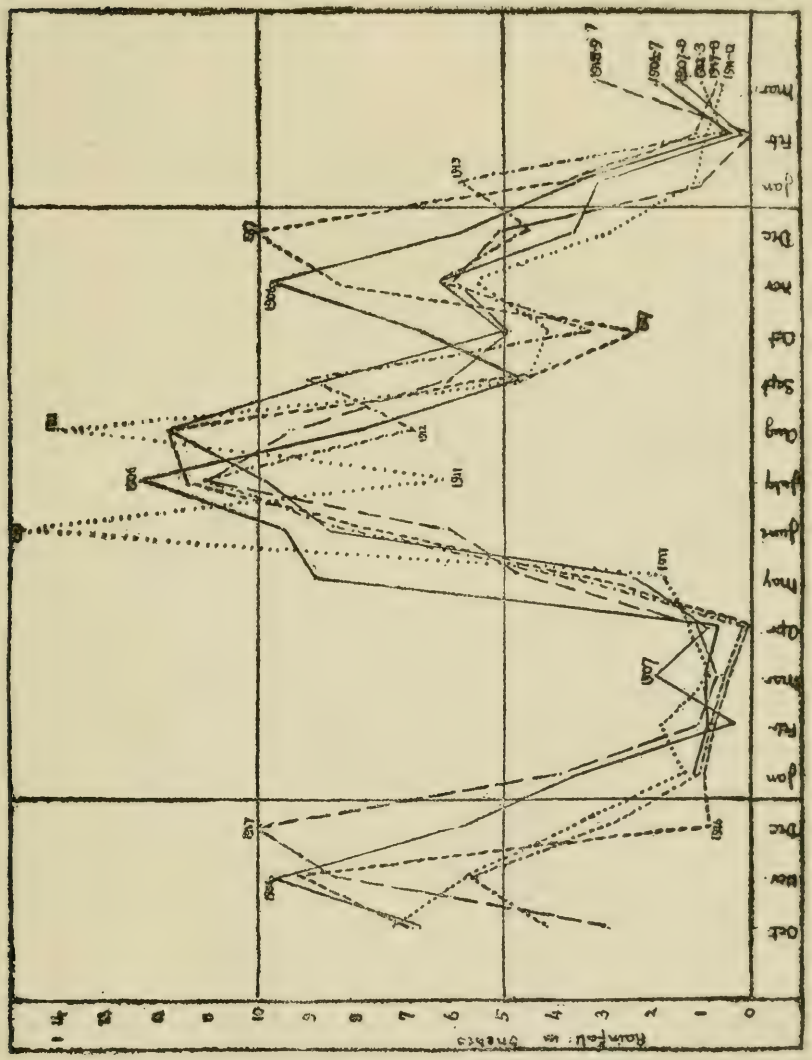

Fig. 22.

Fig. 22.—Monthly rainfall on the same estate during six years of widespread blight Note the marked drop in all cases in September or October at the "Indian Summer" (c.p. Fig. 21).

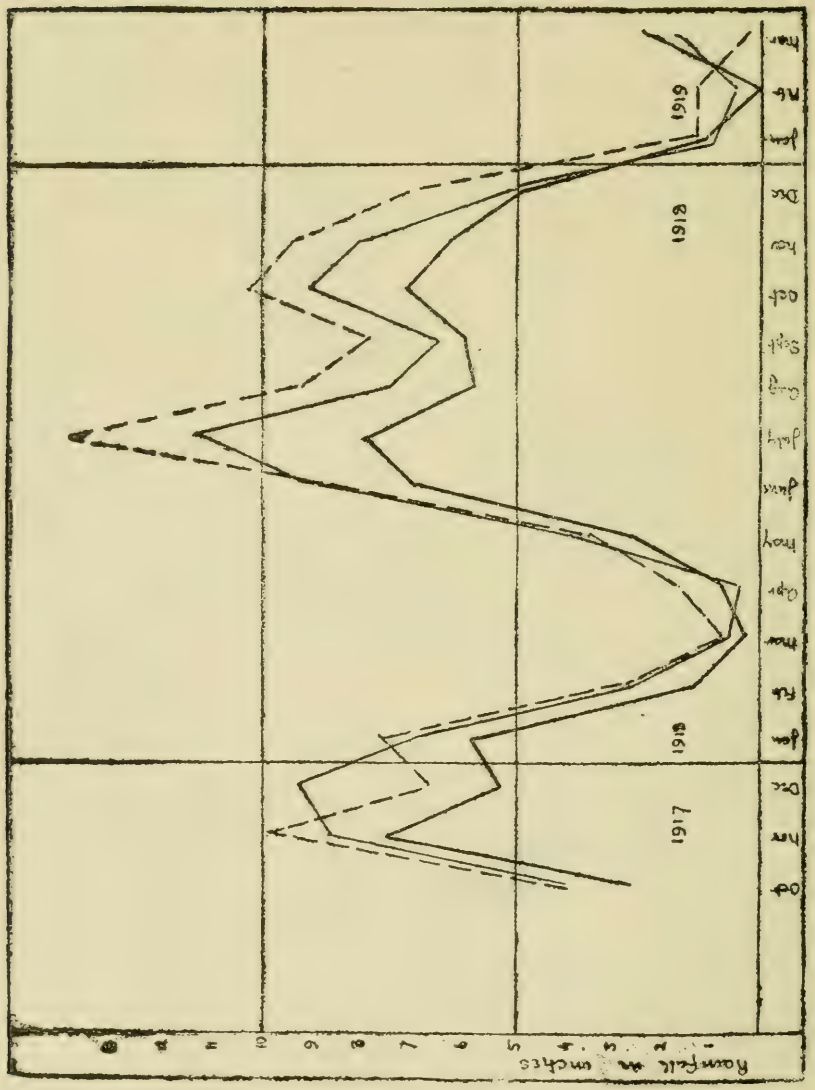

Fig. 23.

Fig. 23.—Monthly rainfall during 1918–1919 on three estates where no damage was reported (c.p. Fig. 24).

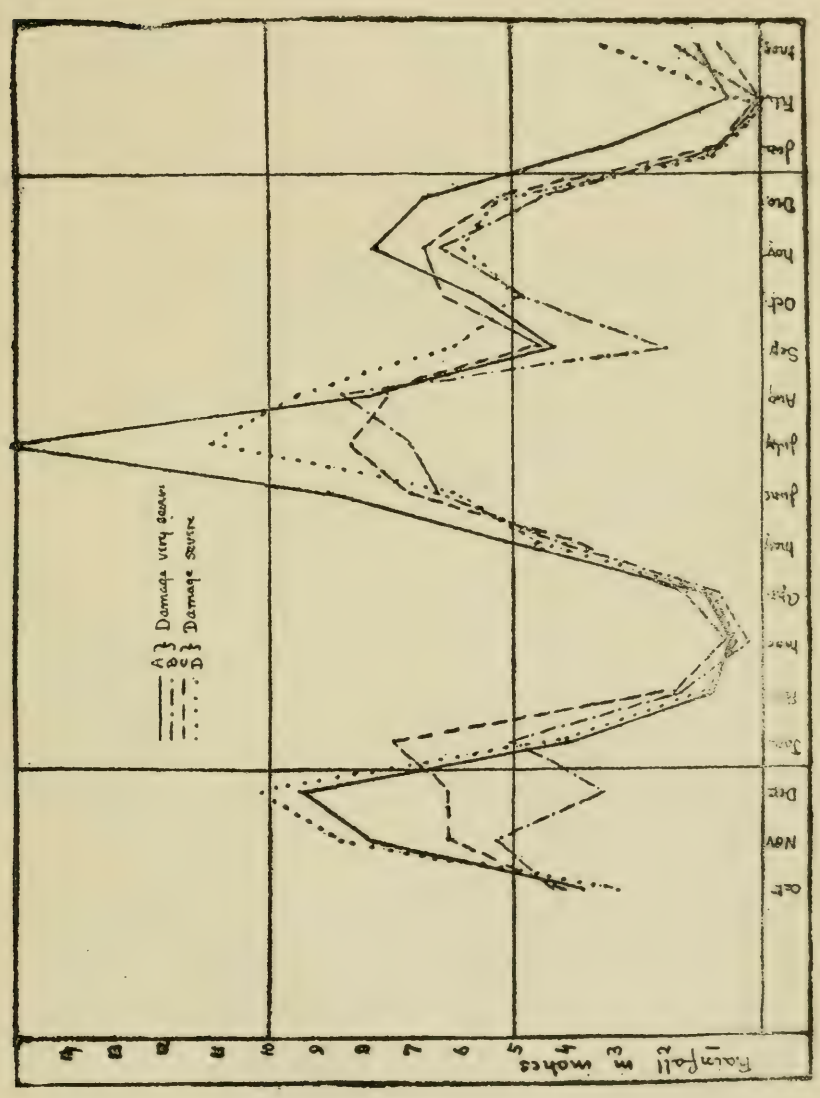

Fig. 24.

Fig. 24.—Monthly rainfall during the same period on four estates when the damage was more or less severe. Note again the more severe "Indian Summer" drought in September (c.p. Fig. 23).

In each case the importance of the dry Indian Summer is emphasised, and in the first two figures there is some evidence of the influence of a longer dry season and wetter June and July in producing blight.

The beneficial influence of a more regular supply of moisture is well shown by certain observations. Thus in the Princes Town district the rainfall appears to be more regular, and less subject to droughts than the rest of the sugar-cane areas, and it is this district that suffers least from blight. Another still more striking case is in a field on Hermitage Estate which is regularly damaged by blight, but, apparently owing to the gradual seepage, the canes immediately round a pond at the top of a ridge and in a line down the slope below it are always much less damaged than those on either side.

Similar conclusions have been arrived at in British Guiana by Bodkin and Moore, both of whom believe that the severe outbreak of blight in that country in 1918 was brought about, or at least influenced by abnormal weather conditions, the most important of which was unusually wet weather at the beginning of the year, which produced a waterlogged condition of the soil and backward cane plants.

The total effect of the rainfall can be brought about in several different ways, chief of which are:—

(1.) Direct effect on the froghoppers.
(2.) Indirect effect on the froghopper through its enemies.
(3.) Direct effect on the canes.
(4.) Indirect effect on the canes through root fungi.

(1.) *Direct effect on the froghopper.*

The froghopper cannot continue its cycle without a certain amount of moisture, and except in wooded country (forest and cacao districts), along the banks of streams, and occasionally in field drains, the conditions in the normal dry season in Trinidad are below the minimum moisture required for breeding. The insect as a result spends this part of the year chiefly in the egg stage, which has been shown experimentally by Guppy to be capable of resisting at least six months desiccation.

The first rains of the wet season are the signal for the hatching of the eggs and resumption of activity, and as these occur more or less simultaneously over the island the dates of the broods of the froghoppers bear a constant relation to the first rains.

In Fig. 25 is tabulated all the information that can be obtained for the fourteen years 1906–1919 with regard to the beginning of the wet season and the occurrence of the broods. In 1908, 1909, 1915, and 1919 the wet season started at the end of April and the beginning of May. In all these years (except in 1908, for which we have no records), the first brood had begun to appear before the end of June and the second brood before the end of August. In 1911 and 1913 on the other hand the wet season did not start till the last week in May and in both these years the first brood was at the end of July and lasted into August.

The beginning of the wet season is sometimes well marked and sometimes gradual, the latter usually when it has started early. Allowing as far as possible for this lack of definition it may be stated with some degree of accuracy that the first brood is at its height 53–61 (with an average of 57) days after the first rains.

It is more difficult to estimate the maximum of the second brood, but it seems to occur a few days under two months (about 58 days) after the first, with the third brood at a similar interval later again.

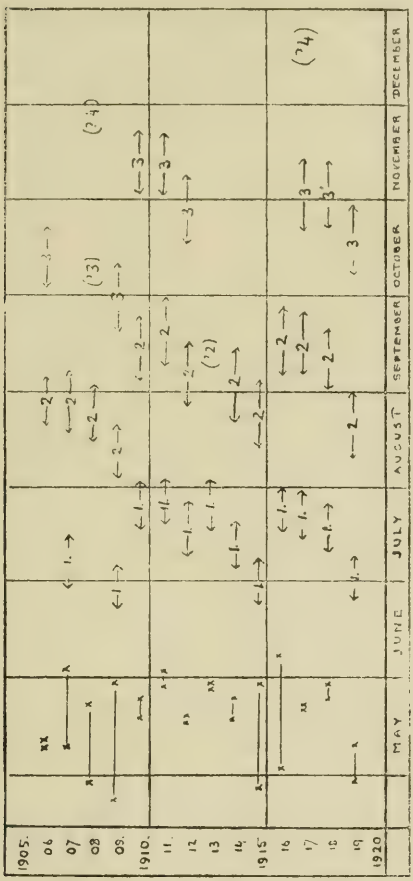

Fig. 25.

Fig. 25—Diagram showing the relation between the commencement of the wet season and the dates of the principal broods of froghoppers from 1906–1919. The lines between the crosses represent the commencement of the wet season. The lines between the arrow heads the time of the successive broods of adults.

Doubtful fourth broods have been recorded in 1908 and 1917 and may occur in isolated localities more frequently.

(2) *Effect on the Enemies of the Froghopper.*

From the captures of adult vermilion parasites during the dry season, it would appear that this insect can continue breeding at a much lower degree of moisture than that required by the froghopper; it is also very probable that sudden heavy downpours have an adverse effect on it as on most small parasites.

During the dry season the Syrphid fly disappears in the cane districts, but this may be a direct result of the absence of froghopper nymphs. On the other hand the maggot of the Syrphid fly has to travel along the ground from one mass of froth to another and under dry conditions this would not be easy.

The close similarity between the periods, confirms Kershaw's observation that the egg æstivates at a very early period in its development.

The ability to foretell the dates of the broods is of great practical importance, and will be considerably more so if any direct method should be adopted of combating the pest in the field.

Ordinary variations in the rainfall during the wet season do not appear to have any particular effect on the adult or nymph froghopper, the latter being particularly well protected by its frothy covering from temporary extremes of moisture and drought.

The continuation of the rainfall late in the year does not have the same effect in producing late broods that might be expected. For some unknown reason most of the eggs laid by the third brood do not seem to hatch until after the dry season.

Urich however (Bull. Dept. Agr. XIII. 1914, p. 102) says that "the comparatively damp period at the end of 1912 [as compared with 1911] caused many eggs that would have æstivated to hatch out and the nymphs either did not complete their transformations or were attacked by natural enemies."

Fredholm (1912 B. p. 416) discussing the serious drought at the beginning of 1912, and the outbreak of blight which followed it, writes "That there is a connection between these two occurrences there is not the slightest doubt in my mind.... The frequent and widespread forest and field fires of the drought may be contributory reasons for the increase of the froghopper. Many of the natural enemies, which under normal conditions would tend to keep this pest down, must have perished in the field fires. Vast numbers of snakes, lizards, toads and frogs must have perished in the field fires. The eggs of the two first mentioned must have been destroyed by tens of thousands. Ponds and marshes drying up would entail the destruction of nearly all the eggs of the latter and their tadpoles."

It is however probably on the Green Muscardine fungus that the dry weather has the most important effect. This fungus can only grow well in a moist atmosphere. Attempts to produce artificial infection of adult froghoppers during the dry season failed until the cage was surrounded by damp cloth to produce a moisture-laden atmosphere. Dry weather at the time of the second brood of froghoppers will prevent the rapid spread of this disease, (which under favourable conditions may destroy the greater part of the brood), and as a result the following third brood will be much more serious. Very heavy downpours may also produce a similar effect by washing to the ground many spores that might otherwise have come into contact with the adult froghoppers.

We know that both dry weather and heavy downpours are correlated with blight and this is undoubtedly one of the ways in which the effect is produced.

Dry weather has probably a similar effect on the *Empusa* fungus, but this is usually so rare that its reduction would be little felt.

(3) *Direct effect on the Cane.*

Dry weather during the growing season reduces the vitality of the cane, checks growth, and puts it in a condition in which it is more likely to succumb to injury, or if the injury is already present it prevents recovery. This is one of the effects of the severe Indian Summer.

Further experiments are needed to see if the spread of the leaf injury from the point of puncture of the froghopper is more rapid in dry weather than in wet. A few observations I have made seem to indicate this, but no opportunity has yet occurred to follow up the investigation.

(4) *Indirect effect on the Cane.*

Severe injury by root fungi is in many countries correlated with unusually dry weather. The main physiological effect of the presence of root fungi is to increase the severity of the injury that would be caused by the lack of water.

The importance of rainfall in connection with root disease is well illustrated in Barbados, where in the dryer areas only a single crop can be obtained from one planting, whereas two or even three can be cut further inland where the rainfall is higher. This is largely due to the rapid increase of root fungus in the dryer areas when any attempt is made to grow ratoon canes.

In all questions of rainfall in connection with agriculture it must be remembered that it is the available moisture rather than the total precipitation that is important. The former depends on the state of the soil and drainage, both of which will be discussed below. In addition the rainfall is not the only source of moisture, as in many parts of Trinidad in the dry season there are heavy dews and ground mists each night, which condense on leaves of the plants and supply them with much of the moisture necessary for growth at this time of the year.

Rainfall records have been kept at about a hundred stations in Trinidad for many years, but up to the present no attempt has been made to study the records or to produce rainfall maps. In view of the importance of an accurate survey of the rainfall in the study of agriculture, plant diseases, and. last but not least, the water supply of towns, it is to be hoped that funds will be made available for such work without delay.

CONTOUR.

There appear to be certain districts in the Island more liable to frog-hopper attack and others less liable. The low-lying parts of Harmony Hall Estate in the Naparimas, the Waterloo group of estates in the Couva district, and the estates in the Northern Section are particularly liable to attack, while those in the Princes Town district are particularly free. Some of these differences are due to differences in the soil, others to differences in the rainfall (*e.g.* Princes Town district) but as a general rule it seems that the low-lying flat districts are more liable to attacks than the hilly parts.

In individual fields a similar effect is sometimes seen between the part of a field on the top of a slope and that at the foot, but the difference is not always in the same direction and in some fields it is the upper part that is damaged and in others the lower part. A close examination almost always reveals some change in the soil which will account for the difference in infestation. Some examples of each are given below.

Damage Worse at top of Slope.

Brechin Castle. Mr. Arbuckle says that some years ago he had a field with a small hill in it and that the top of the hill was destroyed while the lower surroundings were untouched.

Tarouba. Field E. "better at N.W. corner at top of slope *where soil is distinctly better*". (20. i. 19.)

Union Hall. Field 6 N. damaged at top of slope, 10. ix. 19. Visible difference in soil, *which is heavier red clay at top.*

Corinth. Field 6. 10. ix. 19, "Worst part of field is on slope, especially near the top."

Wellington. Field 43. 16. viii. 18 "Damage chiefly at top of hill *where soil is red.*"

Hermitage (19. xii. 17) "In several spots damage is at top of hill and not lower down."

La Fortunée. Field 6, 16 & 17 BS. Damage much worse at top of hill in 1918. *Analysis showed much poorer soil.* (*see* p. 110).

La Fortunée. Field 33 & 48 BS. Worse at top of hill than at bottom, 11. ix. 17.

Tarouba. Field 33. Fewer nymphs at bottom of hill where canes are larger *and soil darker.* (1. vii. 18.)

Analysis showed a richer soil at the foot of the slope.

Damage Worse at Bottom of Slope.

La Fortunée. Field 45 B. V. "Best at top of field and along ridges *where soil is better.* (27. vi. 18.)"

Tarouba. Field 3 St. John. "Damaged at foot of hill and not on the hill (1. xi. 19) *Soil better on slope.*"

Orange Grove. South end of field 21-23 worse than North end and former is lower part of slight slope.

It appears from the above that changes in the soil are usually of sufficient importance to outweigh any advantage or disadvantage that the contours of the field may give in the way of drainage. The question will be discussed further under the heading of soil and drainage.

THE SOIL.

In 1850 Messrs. Wall and Sawkins published a report on the geology of Trinidad and described with considerable accuracy the main types of soil of the cultivated parts of Trinidad.

In 1880 L. A. Sehault wrote a paper on "Our Arable Lands" based largely on the work of Wall and Sawkins, but treating the problem more in its agricultural aspect. For the following notes on the types of soil met with in the sugar districts I am indebted very largely to the above works, but have made alterations and corrections from my own experience in the fields and with the assistance of several geologists now working in Trinidad.

Fig. 26 shows the sugar districts of Trinidad with the distribution of the soils based on the map given by Wall and Sawkins in 1860. It is diagramatic and shows only the approximate outlines of the formations.

This is particularly so in the Naparimas where they are so confused that changes occur from field to field.

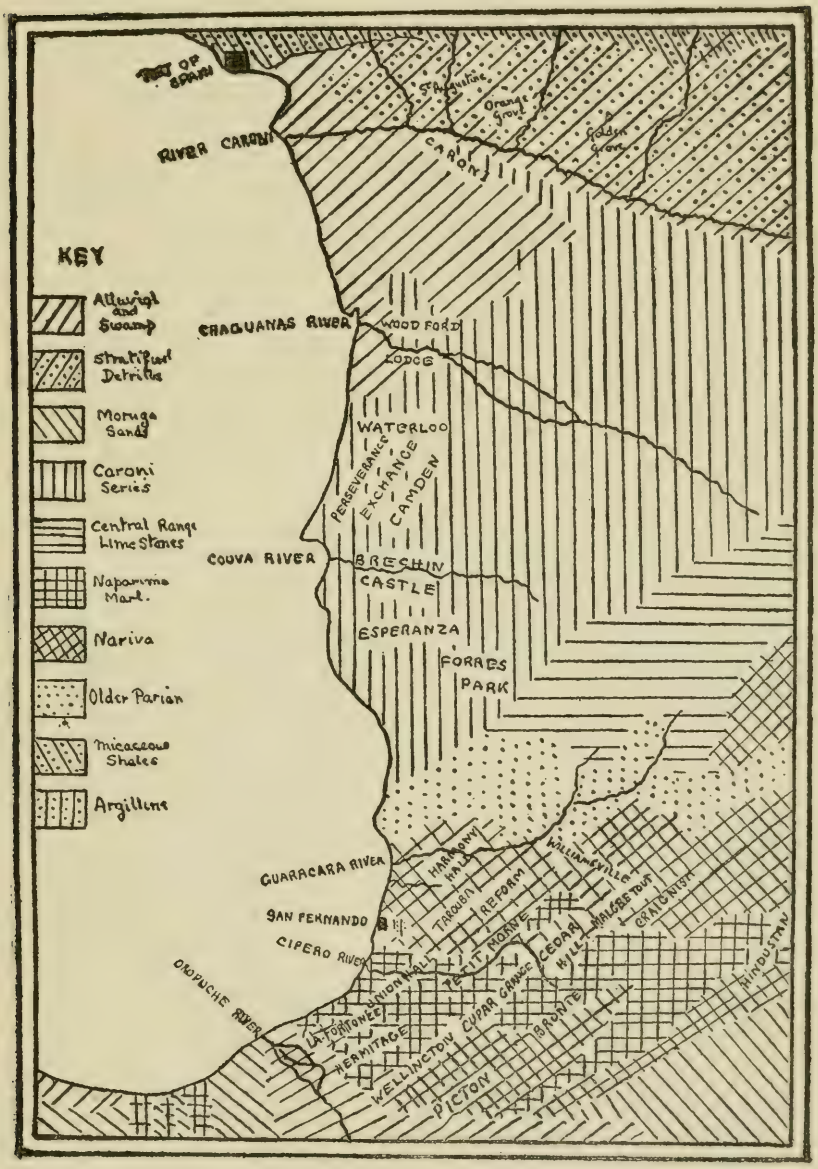

Fig. 26.

Fig. 26.—Map of Sugar districts of Trinidad showing approximate boundaries of the different soil types (After Wall and Sawkins).

The chief types of soils are as follows :—

(1) *The soils of the Northern Range Mountains*, derived from the decomposition of the old rocks below, which are chiefly micaceous shales with occasional patches of crystalline limestone. These are mostly hilly lands under forest or cacao and there are no sugar estates in this area. They are marked on the map as 'micaceous shales.'

(2) *The alluvial soils on the northern side of the Caroni River* between it and the foothills of the Northern Range, and in the valleys of the Northern Range, derived from the detritus (washings) from the Northern Range. They are lighter than most of the Trinidad soils, often with a cheesy consistency, but are usually deficient in lime.

The estates in this formation are Golden Grove, Valsayn and St. Augustine (Government Experimental Station) and parts of Caroni. They are marked on the map as "stratified detritus."

(3) *The argillaceous (clay) lands of the Caroni.* These are heavy alluvial lands on the Southern banks of the Caroni River. They are difficult to work, are low-lying and tend to be moist and swampy.

This formation includes the greater part of Caroni Estate. It is marked on the map as "alluvial and swamp."

(4) The soils classified by Wall and Sawkins as the *Caroni or Carbonaceous series* stretch from Woodford Lodge along the coast to Esperanza and inland from this line across the island.

They are usually poor soils, except where good agriculture has given them a high humus content, and, except near the coast, are rather sandy. This formation is however very variable from an agricultural point of view, and some of the lands in the valleys of the low hills behind Couva give excellent crops.

The estates on this formation are Woodford Lodge, Waterloo, Exchange and Camden, the Brechin Castle Group, Esperanza, and parts of Forres Park. Some parts of the latter estate are almost pure sand.

(5) *The calcareous clays and sands of the Tamana series*, are chiefly along the northern slope of the Central Range. These soils include some of the best cacao lands, and part of the black soils on Forres Park and the back lands of Esperanza may belong here. They are marked on the map as "Central Range limestone."

(6) *Older Parian sands and shales along the Southern side of the Central Range* running running inland from Pointe-à-Pierre.

Portions of Plein Palais, Reform and Williamsville estates may belong to this formation. The soils are lighter than the Naparima clays that border them on the south, but they are not rich and are according to Seheult deficient in lime.

(7) *The Nariva Series, or Red Soils of the Naparimas.* These rather heavy soils make up the bulk of the undulating lands of the Southern Sugar district, where they are intermingled with the black lands of the next group. Nearly every estate in the Naparimas has fields of this type, easily distinguishable by their red colour. Harmony Hall, Reform and Williamsville are almost entirely made up of this soil and on others it is predominant. It is deficient in lime, difficult to work in wet weather, and dries hard and cracks in the dry season. In dry years, it produces very good crops.

(8) *The Naparima Marls or Black Soils of the Naparimas* are derived from a white infusorial marl. These soils include some of the best sugar lands in the country and usually, but not always, contain a good percentage of lime. They are easier to work than the red clay soils and produce larger crops with less effort, particularly in wet years when the red soils suffer from lack of drainage. They are however, rather heavy soils, and sometimes suffer from being too shallow, the white subsoil being occasionally exposed even in shallow field drains. Such thin soil fields should be submitted to a course of gradually deepening mechanical cultivation through many years.

The greater bulk of the soils of Trinidad are noticeable for the almost complete absence of small stones, which tends to increase the difficulty of drainage and aeration. In the Naparimas, where soil changes occur rapidly it is unfortunate that in many cases the boundaries of the fields do not follow the boundaries of the soils, so that fields often contain two distinct types of soils which require different treatment, a condition which adds greatly to the difficulty of adopting extensive cultivation by animals or tractors.

Influence of Soil on Blight.

In the flat parts of the Northern and Central sugar districts the soil is usually more or less uniform over large areas, and one finds also that the blight is often uniformly spread over whole fields or even larger areas if otherwise similar. In the Naparimas on the other hand the soil is more irregular and the blight more patchy. It was noticed many years ago that injury was always more severe on the red soils than on the black. Sometimes a red soil field is badly damaged alongside a black-soil field which is untouched. At other times part of a field is damaged and this is found to be a different and poorer type of soil.

A few examples might be given here.

(1) A field on La Fortunée Estate was very severely damaged in 1918 by froghoppers, but it was noticed that a band of canes across the field was much greener and less injured. A year later when the field was ploughed up, this was found to correspond to a belt of black soil across the field, the rest of which was red soil.

(2) The "Government Pond" field at Hermitage Estate has for three years in succession been damaged on one part only. The limits of the damage (with the exception of the canes immediately below the pond which are affected by seepage) correspond exactly to an outcrop of a heavy clay.

(3) On another field (36 D.) at La Fortunée Estate in 1918, on a slight ridge, the eastern slope was a black soil, and the canes on it were healthy and contained scarcely any froghoppers. The western slope was a red clay and here the canes were severely damaged and froghoppers abundant.

(4) A very striking case is shown in the accompanying map of Cedar Hill Estate (Fig. 27). On this estate the black soils are in a band across the middle of the estate, while the northern and southern ends are both red clays. Records kept of the fields damaged in 1900, 1912, and 1919 show that they were all without exception on the red soils.

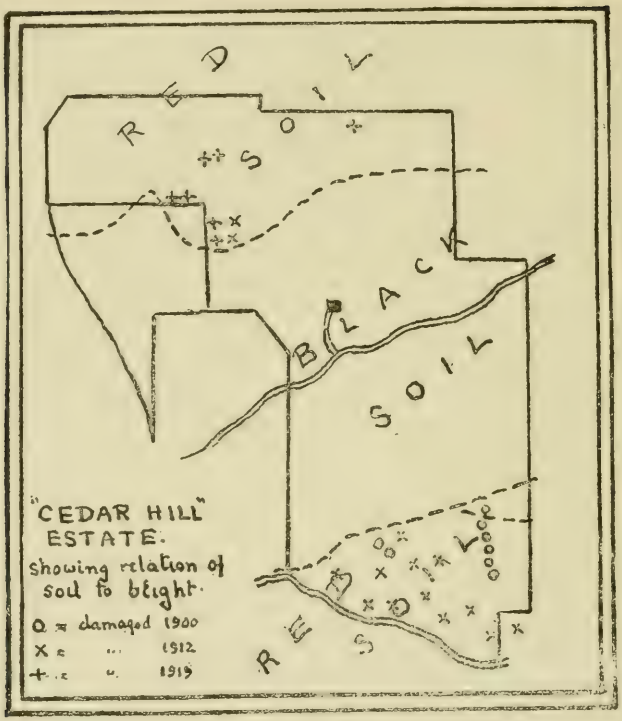

Fig. 27.

Fig. 27—Map of Cedar Hill estate shewing the distribution of blight in 1900, 1912 and 1919 in relation to soil.

In 1917 a few spots of damage appeared in farmer's canes near this estate on black soils, but this is the only case where the Manager had seen damage on these soils.

Many other examples will be found above (p. 105) in connection with the influence of the contour of the ground, where it is shown that the type of the soil is of greater importance and overshadows any small influence that may be due to situation.

In 1919 a number of damaged fields on Hermitage and Golconda estates were observed to be roughly in a straight line running East and West. This is the direction of the geological strike in this district and when the positions were shown to a local geologist he stated that the damaged fields corresponded very closely with the outcrop of a certain type of clay as indicated by his geological maps.

Chemical Composition of Soils.

Carmody in 1909 (A) published an analysis of a soil at Caroni strongly affected by blight and noted that the percentage of magnesia exceeded that of lime. A. Urich in 1909 gives details of another analysis of a soil from Caroni in which he also found a higher percentage of magnesium than of lime, but came to the conclusion that there was nothing in the composition of the soil to explain the prevalence of blight "unless it be the extraordinary impermeability."

In 1918 I made an attempt to find the chemical differences between the damaged and undamaged soils in the Naparimas. Messrs. Tennants were good enough to allow their Chemist to analyse the soils of ten

fields on Hermitage and La Fortunée Estates, three of which were quite free from blight and the remaining seven attacked to a greater or less degree. The results of this analysis so far as they appear to be of any significance are shown diagramatically in Figs. 28 and 29. The fields are arranged from left to right, approximately in order of the severity of the damage.

A was a black soil field on Hermitage Estate "one of the best fields on the estate—gave 38¾ tons of cane per acre last year."

B was one of the best fields on La Fortunée Estate alongside the Oropuche Lagoon.

C was the lower part of a field at La Fortunée Estate, which gave a very good crop except for a patch at the top of a rise in the field (*see E*). The soil was visibly darker and less heavy at the bottom of the field where this sample was taken.

D was a field on La Fortunée Estate when the soil was a rather heavy clay and the plants were poor in condition and slightly blighted during 1918.

E was the top of the hill mentioned above (*see C*) where the soil was heavier and the canes were distinctly blighted.

F was a field of medium heavy red clay on Hermitage Estate where the canes were distinctly blighted late in 1917 as second ratoons.

G was a heavy soil field on Hermitage Estate where the canes were badly damaged at the end of 1917.

H was taken from two badly damaged spots in the "Government Pond" field in Hermitage Estate referred to above (*see* p.) as an outcrop of heavy clay soil in an otherwise good field.

I was a field at La Fortunée Estate, in which the young plants were severely damaged by froghoppers during the dry season of 1918. In view of more recent experience this field should have been put nearer to the "good" end of the scale. This is interesting when the acidity of the soil is taken into consideration (*see* below).

K was a very heavy red clay soil field on Hermitage Estate, in which the canes were completely destroyed by froghoppers in 1917. The subsoil is a heavy sticky yellow clay.

Fig. 28 shews the percentage of the three valuable constituents of the soil, Calcium oxide, Carbon dioxide, and Nitrogen (indicating organic matter) in these ten samples.

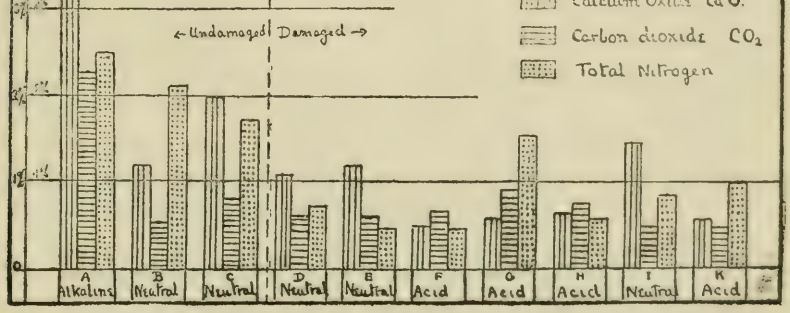

Fig. 28.

Fig. 28—Diagram of valuable chemical constituents in soil of ten fields arranged from left to right in approximate order of liability to blight.

It will be seen that the three good fields have each a higher nitrogen percentage than any of the damaged fields. Two of them have a higher calcium oxide percentage and the same two have also a higher carbon dioxide percentage than any of the damaged fields.

The result of testing the reaction of the soil to litmus is still more striking and the best soil of all is the only one that is alkaline. Both the other good soils are neutral and all the acid soils are badly damaged. Since the diagram was prepared further experience with field I has shown it to be less damaged than first indicated, and it would be best placed between *E*, and *F*. This would leave the four acid fields as the four worst attacked and still further emphasize the gradation of the lime content.

In Fig. 29 is shown the percentage on the same fields of SO_3 which is an undesirable acid constituent and is increased by large applications of sulphate of ammonia as manure. It will be seen that the worst field of all has by far the highest SO_3 content but that after this, the good soils have as high or higher than most of the bad. However, the influence of the sulphuric acid is neutralised by the presence of lime, and we have previously found that the good soils had sufficient lime to do this, while most of the bad soils had not.

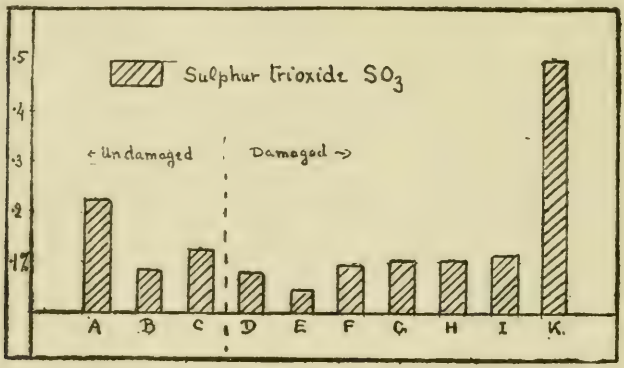

Fig. 29.

Fig. 29—Diagram of SO_3 percentage in the soil of the same fields.

The other constituents of the soil, Iron, Aluminum, Magnesium and Phosphates were estimated, but no significant differences could be noticed. The high magnesia-lime ratio suggested by Carmody did not exist in these soils.

The soil from six fields from the estates of the Usine Ste. Madeleine were analysed by the Chemist of this Company, with results on the whole confirming those given above.

Mr. Carlee, General Manager of the Waterloo Group of Estates, which have suffered almost more severely than any others from blight informed me that his Chemist found that all their soils were acid.

Discussion. It will be seen that there is a distinct evidence that the froghopper breeds with greater freedom and that the blight is worse on heavy sour soils than on light, well aerated, well limed soils.

Sometimes a soil that is chemically suitable gets into a bad condition owing to lack of cultivation. On one estate with a light soil the froghopper attack in 1919 was confined to an area where the soil was compact and very badly in need of cultivation.

Soils in such a condition are not suitable for the growth of the soil bacteria which cause decay, and until they are properly turned over and cultivated, cane trash or even pen manure may be seen in compact masses in the ground, not decaying to form the humus that is so essential for the improvement of the soil and the supply of organic plant food.

It is not only in Trinidad that the close relation between soil conditions and froghopper blight has been noticed.

In his report on the Blight in Mexico Urich (Bull. Dept. Agr. XI. No. 71, p. 298) says "on the plantation where I was the froghoppers occurred under exactly the same conditions as here [Trinidad] viz:—on low-lying damp ground they were numerous on cane and grass, becoming less on porous and friable soils."

In the outbreak in British Guiana in 1918 both Bodkin and Moore emphasised the importance of soil conditions. Bodkin (1918 B.) mentioned the water logged condition of the soil aggravated by the injurious effect of the use of nitrate of soda, and Moore (1919) says "When the soil was stiff the insects tended to be more numerous." "At Plantation Ogle .... the canes showed distinct evidence that they had been contending against an excessively moist, cold, stiff clay, and it was these soil conditions which primarily induced the froghopper attack."

TEMPERATURE.

The daily and annual variation of temperature in Trinidad is not great, nor have we any evidence that it in any way affects the prevalence of blight. Attention is drawn to it here chiefly in view of the recent work of Johnston and Hartman (1919) on the root rot of tobacco, where soil temperature had been found to be the most important factor in the environment (*see* p. 94). If temperature had any similar effect on the root disease of sugar-cane in Trinidad, it would assume a much greater importance. Further work in this direction is desirable.

DRAINAGE.

In view of what has been said above of the influence of rainfall and soil conditions on the prevalence of blight, it will be expected that drainage is an important factor.

Drainage in Trinidad has to serve the double purpose of (1) rapidly removing surface water in heavy downpours, (2) slowly removing the percolating moisture so as to aerate the soil.

In one field in the Naparimas, where froghoppers had been persistent for many years, the beds and the sides of the drains on part of it were forked in September 1918 to allow the moisture to percolate better into the drains. In the following year the froghoppers and consequent blight were much less serious on the part that had been forked than on the unforked part. This case is confused by the effect that the forking would have on the aeration of the soil, but there is little doubt that both contributed to the final beneficial result.

Until the last ten years or so all the cane plants in Trinidad were set in rows across the beds so that drainage was rapid. With the introduction of implemental tillage large areas are gradually being relaid with long beds in which the rows of cane are parallel to the drains. Drainage, unless helped by well planned tillage, is not so good on beds so laid out, and it may be necessary on some lands to reduce the distance between the drains.

MANURING.

The manures in general use in Trinidad for sugar-cane are as follows :—

Natural Manures. (1) Pen Manure.
(2) Sheep manure from Venezuela.
(3) Lagoon mud.

Chemical manures. (4) Sulphate of Ammonia.
(5) Nitrate of soda.
(6) Lime.
(7) Nitrolim.

It is by the judicious use of manures that the planter can alter the condition of the soil so as to produce conditions which have been shown to be unfavourable to the froghopper and to the spread of blight.

By far the most important is the ordinary pen-manure formed by the droppings of the animals on bedding which usually consists of cane trash.

The scarcity and increase in cost of manual labour is bringing about a rapid increase in implemental tillage, and a consequent increase in the stock kept for haulage purposes. There is however still room for much improvement and it should be the aim of every estate to have every acre of the land heavily pen manured once in every replanting of the sugar cane.

The amount usually put in is from 10 to 25 tons per acre. I have seen on one estate 100 tons per acre put on a small field as an experiment but there is little doubt that the manure used for this application would have been better applied to a larger area.

Sheep manure has been used on one estate to a considerable extent and it is worthy of note that this estate has suffered little from blight. The manure is imported from Venezuela.

Lagoon mud is used with good results by some estates bordering on the Oropuche Lagoon, and fields treated with 10 to 20 tons of this per acre are considerably improved and do not appear to suffer so severely from blight.

The use of artificial manures is a more difficult problem, nitrate of soda is known to have a bad deflocculating effect on clay soils, and the continual use of sulphate of ammonia in soils deficient in lime, as are most of the Trinidad soils, becomes more and more injurious.

As a stimulant to the canes to counteract blight they are probably best used well before the advent of blight on fields where it is expected to occur, in order to get the canes into a vigorous resistant state. They are apparently of little value if applied to an already blighted field and still less so if the blight is accompanied by drought, in which case the whole effect of the manure is lost.

Continual applications of artificial manures must be counteracted by applications of lime. This is already done by many estates, but seldom to the necessary extent. The analysis given above for damaged and undamaged soils show the importance of soil acidity in connection with blight, and heavy applications of lime are necessary to eliminate this.

The effect of such applications to lands subject to blight must not be expected immediately nor will they be for ever after free from injury, but with proper agriculture there should be a gradual return to soil conditions under which damage is less likely to occur.

In 1912 a number of experiments were made with nitrolim which is an artificially prepared manure containing both lime and nitrogen. The experiments were chiefly designed to test its destructive effect on the froghopper and not its general manurial effect on the condition of the soil. They will be referred to again later under Control Methods (p. 142).

AGE OF CANE.

The age of the canes in a field can be considered from the number of years that the stool has been in the ground, or the number of months that the shoots have been above ground.

In the first case we are concerned with the difference in resistance to blight of "plant canes" in their first year, and first and second ratoons. There is no doubt of the greater immunity of the first year canes.

In 1912, a year of severe blight, a number of estates gave the returns of acreage damaged. From these returns the following particulars are obtained.

For ten estates in 1912.

Area under plant canes.....2,980 acres.
Plant canes damaged.....1,093 „ = 37 per cent.

Area under first ratoons.....3,405 acres.
First Ratoons damaged.....1,789 „ = 52 per cent.

Area under older ratoons.....3,144 acres.
Older Ratoons damaged.....1,482 „ = 47 per cent.

In 1917 a similar return was given by many estates, but the 1st and 2nd ratoons were not given separately.

For thirteen estates in 1917.

Area under plant canes.....3,861 acres.
Plant canes damaged.....1,712 „ = 44 per cent.

Area under ratoon canes.....6,677 acres.
Ratoon canes damaged.....4,311 „ = 64 per cent.

It will be seen that in these two bad years the plant canes are about 50 per cent. less liable to damage than the ratoon canes.

It is however a distinct feature of the blight that it is less selective when it is severe than when it is slight, so that in the years when the outbreaks are only slight there is a very much greater relative freedom from attack in plant canes. In 1919, when the area under plant canes was probably greater than ever before, only a few small spots were attacked, much less than one-tenth of the area damaged under ratoon canes.

In the figures for 1912 it will be noticed that the older ratoons are slightly less attacked than the first ratoons. The difference in the numbers is small and from other experience I do not think significant, as fields of second ratoons which are doing poorly are frequently abandoned altogether and not included in the returns, while third ratoons and older are only kept in cultivation on the better soils.

Occasionally a field of canes is badly damaged as plants and yet gives an excellent crop of ratoons. This merely indicates that conditions in the field have in some way changed and does not in any way effect the truth of the statement that, other things being equal, the younger canes are less liable to damage than the older.

In the above the word "plant-canes" means the well grown canes eight months or more from the date of planting, but occasionally the young, just sprouting canes are damaged late in the year. Several examples of this could be given, and they seem usually to be caused by planting the young cuttings in a field from which the old stools have not been removed and the froghoppers are able to carry over without being destroyed as would occur under a proper system of rotation.

Reference has already been made to one unusual case in which adult froghoppers were found throughout the whole dry season of 1918 in a field of young plant canes.

Among the ratoon canes there is a difference in age of the shoots above ground according to whether the field is cut early or late in crop time. On a field cut at the beginning of crop in February the ratoon shoots have three or four months longer to grow than in a field cut at the end of crop. Growth is of course slow at this period of the year, but considerable gain in yield is made by the earlier cut fields. Accurate data on the subject are much needed.

It might be expected that the ratoons that were earliest cut and that had longest growth would be less damaged by froghoppers owing to their larger size. However, the only two cases in which uncomplicated evidence on this question is available seem to indicate the reverse.

At Harmony Hall Estate in 1919 there were two contiguous fields of Uba cane, all second ratoons and all previously similarly treated, with the soil very uniform throughout.

A corner of one field was accidentally burnt and cut on 1st April (1). The rest of this field was cut in the middle of May (2). The field alongside was cut in the middle of June (3).

The first brood of froghoppers appeared at the beginning of July. was large and did distinct damage on 1, was medium and did slight damage on 2 and was very small and did no visible damage on 3. The largest growth was most damaged and the smallest growth least so.

The first plot may have been affected by the burning, but between the other two there was no known difference in previous treatment except the date of cutting.

Another case was seen at Orange Grove in 1919 when two fields of second ratoons, mixed varieties, in similar soil were side by side. The canes cut at the end of February and beginning of March were larger but much more severely blighted than those in the field cut at the beginning of May. Another field of the same canes alongside, but cut towards the end of May was still smaller and almost free from damage, but in this case the field was first ratoons, although otherwise similar.

These two are the only cases in which all other factors can be eliminated and if significant it would appear that the covering up of the ground by canes throughout the greater part of the dry season produces conditions not favourable to the froghopper, or perhaps more favourable to the survival of its egg parasites. (*see* p 103).

ROTATION.

In the greater part of the sugar area of Trinidad either no rotation at all is in practice, the fields being replanted with canes as soon as the old ratoons are worn out, or a very primitive and inefficient rotation is made by abandoning the land, for a longer or shorter series of years between successive cane plantings, to whatever plants and bush are able to take possession.

The break may be anything from one to as many as ten years in length according to the amount of land available, and the character of the vegetation varies slightly according to the length of time that it remains untouched. There is usually a thick growth of grasses, mixed in the first year or two with shoots from the old cane stools, and a higher bush growth of Black Sage (*Cordia cylindrostachya*), Christmas Bush (*Eupatorium odoratum*), guava, etc.

Neither of these systems has anything to recommend it from the point of view of the control of blight. When the field is replanted immediately it is almost invariably done by putting the fresh cuttings in between the old plants which remain there with their froghoppers, moth-borers and root-fungi as a source of infection within a few inches of every young stool. Later they may be dug up and turned over but this, as often as not, only serves to bring the root-fungus infection still closer to the young plant.

If the land is abandoned for a series of years conditions are not much better. The old stools are not dug out and on them root-fungi persist for more than a year, while the grasses which grow up between them serve as an excellent breeding ground for the froghopper and a source of infection not only to that field when it is replanted but also to neighbouring fields which may have been more carefully cultivated.

In addition the undisturbed and undrained condition of the soil has an accumulative injurious effect on the soil which we have found to be so important in connection with the survival of the froghopper.

Many examples could be given of severe blight in fields which had been abandoned for years. Thus at Union Hall Estate in 1919 a field was severely damaged that had been abandoned as part of a burial ground for twenty years previously. At Hermitage in 1917 a field was damaged that had been ten years abandoned, and two fields damaged at Caroni in 1906 are mentioned as having been out of cultivation for ten years. It will also be remembered that one of the fields damaged at Grenada (p. 44) had been out of cultivation for eight years.

Other cases are known of the spread of blight from abandoned fields into healthy ones. Thus in one of the earliest attacks of blight on Cedar Hill Estate in 1900 the Manager noted that all the damaged fields were alongside an area of abandoned land, and at Petit Morne in 1919 a field of plant canes was attacked along one edge bordering on an abandoned farmer's plot, under conditions that left no doubt that the blight had spread from this spot.

Under estate cultivation, a manager has only himself to blame when conditions like these arise, but, under the present adopted policy of encouraging a multiplicity of small owners, cases of spread of disease from one land to another will cause much more dispute and trouble.

With a proper break in the cultivation, with all fields not under cane completely cleared and planted in some other crops for at least six months and preferably for eighteen months, it is impossible for an

attack to result from insects passing on in the same field, and the reduction of waste land will reduce the number of centres of indirect infection.

Further discussion and some suggested types of rotation will be found on p. 134 in the Section dealing with the Control of the Blight.

TILLAGE.

It follows from the relation already discussed between the condition of the soil and the prevalence of blight that any process that will bring the soil to a more open, lighter, and looser state will have an effect in removing the blight.

In the past most of the preparation of the land and tillage has been done by hand labour with forks. These are being now gradually replaced by ploughs and cultivators drawn by cattle and mules, and there is little doubt that the near future will see a considerable increase in the use of tractors.

The beneficial effect of cultivation has been seen in many cases. Thus two fields of young plants side by side on Tarouba Estate in 1918 were both the same age, but differed only in that the Manager had been able to give one of them a more complete cultivation than the other. In the less cultivated field, not only was the soil in a visibly poorer tilth and the young canes much weaker, but froghoppers were at least ten times more abundant.

A still more striking case was at Harmony Hall where in September 1918 half of the field badly damaged by froghoppers was forked throughout between the rows and down the edges of the drains No particular effect was noted that year, but the following July the first brood of froghoppers was at least twice as abundant on the unforked part of the field as on the forked part, and the leaf damage was much more obvious. There was in fact a distinct line across the field separating the badly damaged area from the slightly damaged area, and this line corresponded to the division of the forked area from the unforked.

A curious and unexpected fact, which is as yet unexplained, is that the canes on the unforked half although more damaged were, until the advent of the blight, distinctly larger than those on the forked half.

It will of course be realised in view of the many other factors influencing the abundance of the froghopper, that sometimes a field will be blighted in spite of the best tillage, but this is no proof that the cultivation has been injurious.

In a few cases however, the sudden apppearance of blight has been put down by Managers as being directly due to implemental tillage, and in particular following on the use of the sub-soil plough. It is possible that in some soils with a sour undisturbed sub-soil the use of deep implements might have a temporary injurious effect, but in most cases it is probable that the canes would have been blighted in any case, particularly when it is recollected that the leaf injury to the cane continues to increase for about three weeks or more after the height of the brood of froghoppers and the ploughs are often sent through when the field begins to look poor.

It is not the purpose of the present report to discuss the relative advantage of animals versus tractors in agriculture, but it might be mentioned that, from the point of view of froghopper control, more pen

manure is required to improve the soil conditions of the poor soils and clays, and the larger the extent to which animals are used the more of this will be available.

There is scarcely any operation that cannot be performed by animals. Light ploughs pulled by mules can pass between the cane rows and I have seen on the lands of the Usine Ste. Madeleine a plough with twenty-two oxen tearing up the old cane stools in heavy land. Except where speed is required or very large areas have to be covered, these methods could nearly always be adopted.

DEPTH OF PLANTING.

On several occasions it has been suggested to me that the depth at which the original cuttings are planted might influence the amount of blight by producing a shallower or deeper root system more or less exposed to the sucking of the nymph.

Moore in British Guiana (1919 p. 13) says "plant as deeply as possible, as with old ratoons when the stools get high out of the ground the root system is specially liable to attack—and so with shallow planting."

I have at present no evidence that the depth of planting affects either the depth of the root system or the amount of blight and as in Trinidad the depth of planting is governed almost entirely by the time of the year and the heaviness or depth of the soil it would be difficult to alter it except within very small limits even if it were proved to have an effect.

DISTANCE OF PLANTING.

There is at present no evidence that the distance that the canes are planted in any way effects the blight. The Trinidad planter, faced with a shortage of labour, has to choose between the reduction of weeding by close planting and the facilities for rapid inter-row cultivation in wide planting.

VARIETY OF CANE.

In 1919 (D.) I made a report on the relative resistance to blight of the various varieties of cane grown in Trinidad, and came to the conclusion that no variety was immune, but that a few were more resistant than others.

During the past year no observations have been made which in any way affect that statement. Some of the varieties that had not up to then been attacked owing to their recent introduction and small distribution have this year shown that they also are not immune.

Thus the recently introduced B.A. 6032, a very valuable variety, has this year been severely damaged by blight on one estate.

A few observations of relative condition of different varieties in the same field might be added to those already given (*loc. cit.* p. 82).

Hills Seedling (No. 1.) was less damaged than B. 1753 at Union Hall.

Uba was less damaged than Hill No. 12 at Golconda.

Hilis Seedling (No. 1) was less damaged than B. 156 at Hermitage.

D. 109 was less damaged than D. 347 at Tarouba.

D. 109 was less damaged than D. 347 at Harmony Hall.

The two most resistant varieties at present known are Uba and Badilla, both of which are said to be deep-rooted, but it is not known whether this is the cause of the resistance or not.

In 1918 a number of stools at St. Augustine were cut through vertically to get an indication of the depth of the root system and the Badilla was not noticeably deeper than the other varieties.

I was informed by one planter that the recent outbreaks of blight were due to the replacing of the old deep-rooting Bourbon cane by shallower rooted seedlings. But Mr. J. R. Bovell assured me that the old Bourbon cane was shallow rooted and my own observations on stools cut across confirm the latter opinion.

The depth of rooting is so much influenced by the condition and depth of the soil that it is doubtful whether in most cases the inherent character of the variety has much opportunity to show itself.

It is possible that relative resistance is due to a difference in the rate of the spread of injury from the point of puncture of the leaves by the adult. Observations on this point will be made during the coming year.

NUMBERS OF FROGHOPPERS PRESENT.

We have discussed above the relation that the various factors of the environment bear to the number of froghoppers present or to the total amount of "blight" or damage.

Owing to the varying condition of the resistance of the cane it will be found that the same number of froghoppers do not always cause the same amount of damage. Thus fields are found severely damaged by an infestation of froghoppers that would in other fields have caused a much less serious injury.

The total number of froghoppers in an infested field may reach as high as one hundred per stool, which is almost three hundred thousand per acre. Rorer (1912) records 500–1,000 eggs per stool "by actual counts," but I have never found adults or nymphs in this quantity.

In 1906 according to Mr. J. Arbuckle the adults were so numerous that they became entangled in the horses' manes when the overseers were riding round the estate, and at Caroni in 1917 they got into the mouths and eyes of the boys attempting to distribute sulphate of ammonia through the fields.

The largest number I have ever caught by light traps was 20,000 in five lamps in one night at Harmony Hall Estate on 9th July, 1918. As a general rule 20 froghoppers per stool on well grown canes means visible signs of blight and with 50 to one hundred the blight will be severe.

Unless the field has been closely watched for some time the number of froghoppers seen is very misleading as the attention of the agriculturist is only drawn to the fields when the damage begins to be serious and in many cases this may be a week or two after the height of the brood.

ROOT FUNGI.

The effect of root fungus on the cane is outlined in Section VII and in Section IX will be discussed the possible part that it plays in the final condition of the cane. It is here introduced as one of the almost constant features of the blighted fields.

Very occasionally fields, usually of plant canes, are found blighted without obvious signs of one of the root fungi, but more usually they are common on almost every stool and in some cases, particularly in certain years, (*e.g.* 1918) they are so widespread as to be almost sufficient to account for the production of blight without any other cause.

OTHER INSECTS.

Carmody in 1909 (p. 111) says that in 1908 at Caroni the large moth borer (*Castnia licus*) was very common, and he believed it to be partly responsible for the outbreak of blight.

In 1918 and 1919 this insect was again common, particularly in blighted fields, but whether this was accidental or not is impossible to say.

The caterpillars of the small moth borer (*Diatræa spp.*) are also common in the cane fields in Trinidad and do more injury than is usually attributed to them. They are frequently found in blighted fields but the probable position with regard to both these borers is that they weaken the cane and make it less able to withstand the blight, but do not in any way render the cane actually more attractive to the frog-hopper.

PREVIOUS DAMAGE AND SOURCE OF PLANTS.

There are certain districts and fields in the island that have shown themselves to be more liable than others to blight, but at the same time a field badly damaged one year may be quite free in the following year. This is no doubt due to the fact that some of the environmental factors are more or less constant (soil, drainage, contour) while others change from year to year (rainfall, age of cane, agricultural processes).

One field at Golconda Estate was severely damaged as plant canes in 1917, almost free from damage as first ratoons in 1918 and again badly damaged as second ratoons in 1919.

At Esperanza six out of eight fields badly damaged in 1913 had been previously damaged in 1912. Five new fields were slightly damaged in 1913 and they were all near fields affected in 1912 (Urich Bull. Dept. Agric. XII p. 203.)

On the Government Pond field at Hermitage blight has occurred for three successive years in the same part of the field.

At Caroni the fields affected in 1918 were in the same area as those damaged in 1917.

At Brechin Castle a field was badly damaged in 1906 and has never since had any injury whatever.

Many other examples could be given, but the conclusion is that on the whole damage is more likely to occur in fields that have been recently damaged than in others (allowing for the beneficial effect of replanting fields that have been in old ratoons).

In the same way plants taken from a damaged field are more likely to carry with them eggs of the froghopper and traces of root fungi than those from healthy fields, and as far as possible only the latter should be used.

SECTION IX.

THEORIES OF DAMAGE AND GENERAL PROBLEMS.

In previous Sections we have given an account of the froghopper and its habits; its natural enemies; the root fungus; the effect of froghopper and root fungus injury on the cane; and the way in which this is influenced by the environment of the cane field. In the present section an attempt will be made to discuss some of the general problems arising out of these facts.

THE CAUSE OF THE BLIGHT.

The most important of these problems is the determination of the relative importance of the different factors concerned in the production of blight and the way in which they are related to each other.

For many years there has been discussion on the parts played by root disease and froghopper, and this question has been examined and summarised in several recent reports by Mr. Nowell and myself (*see* Williams 1919, Nowell 1919 and 1920, and Nowell and Williams 1920).

We are concerned with the adult and nymph froghoppers, root fungi, some other insects and diseases, and a variety of external conditions.

These factors may be inter-related in many ways to produce the final visible effect.

The damage may arise:—

(1) Through the sucking of the froghopper, adult or nymph.

(2) Through the destruction of the roots by root fungi.

(3) The previous attacks of froghopper may weaken the canes and produce outbreaks of root disease.

(4) An outbreak of root disease may render the canes more attractive to froghoppers.

(5) The environmental conditions may act directly on the froghopper or indirectly on it through its natural enemies.

(6) They may act directly on root fungus.

(7) They may act directly on the cane rendering it less able to resist injury.

The Part Played by the Froghopper.

There is now no doubt that the sucking of the froghopper is by far the most important immediate cause of blight. The chief evidence for this is as follows:—

(*a*) The constant presence of the froghopper in blighted fields in numbers which, in the early stages of damage at least, bear an approximate relation to the amount of damage.

(*b*) The constant presence in blighted canes of discoloured streaks on the leaves, which have been shown experimentally to be produced by the sucking of the adult froghopper.

(*c*) The occasional occurrence of severe blight in fields, usually of plant canes, in which root fungi and other pests and diseases are almost absent and the abundant froghopper is the only apparent cause.

(*d*) The first occurrence of blight in the wet season is about the time of the first brood of froghoppers and is early in those years in which the froghopper broods are early and late when they are late.

(*e*) The periodicity of the blight, which recurs, at least up to September or October, at intervals exactly corresponding with the time between the successive froghopper broods.

(*f*) The occurrence of similar blight in sugar-cane and other grasses in other countries in association with various species of froghoppers.

Adult or Nymph.

The froghopper damages the canes at two stages of its life in two different ways, the nymph sucks only at the roots, the adult only at the leaves. The nymph lives for about six weeks but is at first very small. The adults live two to five weeks and suck large quantities of sap every night. It is important to decide if one of these is more injurious than the other.

The evidence that the nymph is the cause of damage is at present very indefinite, but experiments are being planned by which it may be possible to test the question more accurately.

Heriot (1908) produced artificially blighted Para-grass in three weeks by placing nymph froghoppers on it, but it appears that the adults were also kept on the plants when they hatched out, so that the experiment is inconclusive.

On the other hand in July 1919 I put a large number of nymphs on the roots of a healthy stool of cane and failed to produce any symptoms of blight.

Gough (1911 C. p. 10) says "Nymphs are more numerous during blight, adults during recovery", but with this, after longer experience than he was able to get, I cannot agree. The severe blight visible on a field during the nymph stage is that caused by the previous brood of adults.

The evidence incriminating the adult is much more conclusive.

(*a*) The visible browning and streaking of the leaves, which causes the canes to look "as if scorched by fire" is the direct result of the puncture of the adult on the leaves.

(*b*) The staining of the growing point and death of the top of the cane is more likely to result from injury to the leaves than to the roots.

(*c*) The damage never becomes serious until some time after the adults have appeared. The field is often "held back", which may be due to the nymphs, but the results are never disastrous until the leaf injury has developed.

(*d*) The appearance of fresh green healthy shoots and leaves, on plants not too severely damaged, immediately the blight has passed and the conditions become favourable is an indication that the root system is not permanently injured.

(*e*) The sprouting of the upper eyes in blighted canes is an indication of vigour which is being impaired by want of leaves.

(*f*) The occasional appearance of blight on the edge of a healthy field which has been infested with adult froghoppers from fields or abandoned land alongside indicates that the presence of nymphs is not essential for the production of blight.

(*g*) In Surinam severe injury has been caused by a froghopper which does not touch the roots of the cane in the nymph stage (*see* p. 46).

(*h*) In July 1919 I produced typical signs of blight in a healthy cane stool, which had never had nymph froghoppers on it, by caging over it a number of adults. On the other hand Urich (1913 C. p. 10) says that he put 100 adults a day on a cane plant and failed to produce signs of blight.

It had been noticed that both drought and root fungus, which affect the plant through the roots, produce a shortening of the internodes of the cane without any particular narrowing, in fact such short internodes (*e.g.* those produced during the dry season) are frequently almost as thick as the longer internodes of the same cane. In "blight" on the other hand one of the most typical symptoms is the *narrowing* of the diseased canes, particularly when growth has just been resumed after an attack.

On 30th October, 1919, as the outcome of a discussion with Mr. Nowell as to the causes of certain symptoms, we removed the greater part of the leaf blades from three otherwise quite healthy cane stools free from froghoppers. One stool was left to grow. The others were trimmed again seven and ten days later.

The experiment was to test if the narrowing of the canes was due to leaf injury, as opposed to the shortening produced by root failure.

Plate XI shows typical canes from the stools at the end of January 1920. A. shows three canes from an untouched control plant. B. shows three canes from the stool from which the leaves were removed twice at an interval of seven days, and C. shows three from the stool kept trimmed for ten days. The stool with the leaves removed once was unfortunately later infested with borer and the results were unreliable.

The narrowing of the canes is conspicuous and conclusive. In addition several other points of great interest were brought to light.

(1) The average weight of the main shoots on the control plant was 3 lbs. 10 ozs. The average weights of the main shoots of the two trimmed plants were 2 lbs. 2 ozs. and 1 lb. 15 ozs. respectively. The complete removal of the leaves from the cane had resulted in a reduction three months later of about 50 per cent. of its possible weight.

(2) The untrimmed plants had several young and healthy shoots of various ages. In the trimmed plants the youngest shoots were killed and the medium sized ones were very severely injured, as is found in froghopper blight.

(3) The root systems of the trimmed plants, although not directly injured became poorer and much smaller than those of the untrimmed plants. The stools were looser in the ground and more easily pulled out, exactly as is seen in typical blight. We thus have experimental evidence that injury to the leaves can affect the root system in the manner found in froghopper blight.

(4) Several of the smaller shoots of the trimmed plants showed a tendency to break across just above the upper nodes as is found in typical cases of blight.

In view of these experiments, which will be repeated more fully this coming year, I think that the evidence is strongly in favour of the view that the chief direct damage to the sugar cane is caused by the destruction of leaf tissue following the sucking of the adult.

Possible Infection or Toxin.

We have seen that the destruction of leaf tissue by the puncturing of the leaves by the adult froghopper continues to increase for several weeks after the original injury is inflicted. This is unusual and is worthy of more complete investigation. There is no doubt that this one fact makes the froghopper at least ten times more destructive than it would otherwise be.

It is a very strong indication that some form of poison or toxin is introduced into the plant at the time of puncture. Kershaw (1913 H.) describes the salivary glands of the froghopper and explains how the

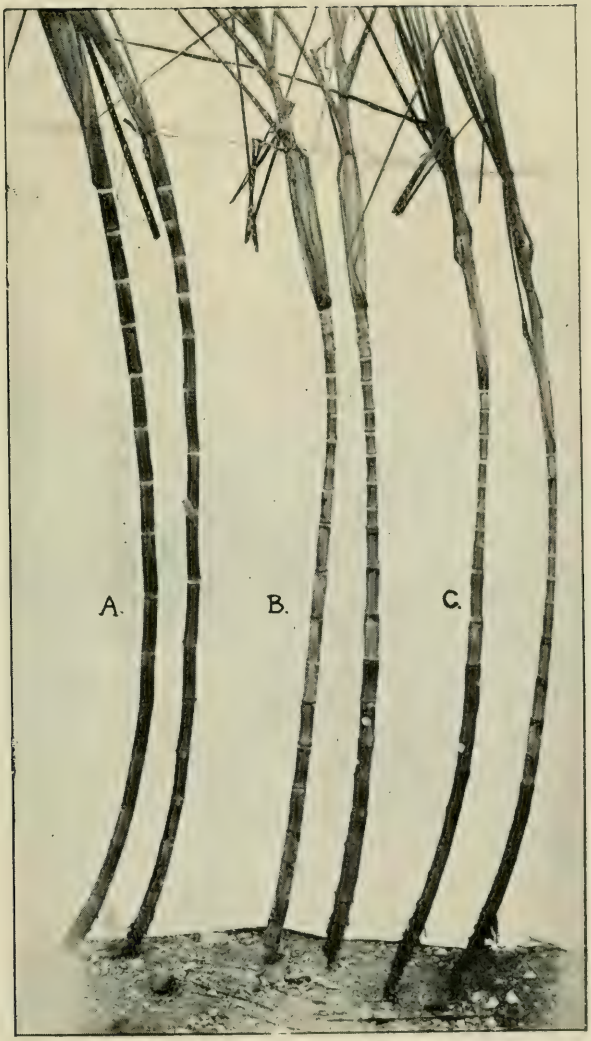

PLATE XI.

Canes damaged by artificial removal of leaves (*b* and *c*) with undamaged canes (*a*) for comparison

saliva is pumped into the wound. He says that it is full of enzymes, which aid digestion, and also prevent the coagulation of the sap. (More probably the original effect is to facilitate the extraction of the sap by action on the protoplasm which lines the cell walls). He also mentions (1914 p. 70) that the glands differ somewhat in the nymph and adult. If such a structural difference were reflected in the composition of the saliva, it might account for the greater destructiveness of the adult.

There is also to be considered the possibility that some infection is introduced into the wound. This is known to be the case with some insects (*e.g.* the leaf-hopper which transmits "curly leaf" of sugar-beet, and various insects suspected of transmitting "mosaic disease" of sugar cane), and in the present case local infection may be set up in the neighbourhood of the puncture by a similar process. Further investigation along these lines is needed though there is at present no evidence supporting such a view.

The Part Played by the Root Disease.

The evidence that root-fungi play a material part in the production of blight is as follows :—

(*a*) The almost invariable presence of root-fungi in blighted fields, usually in greater quantities in severely blighted fields.

(*b*) The close dependence of the blight on weather conditions, particularly drought, which is known in many other countries to be correlated with severe root disease attacks.

(*c*) Although the blight is periodic up to September or October, after this month in bad years the fields frequently continue to get worse, or at least fail to improve even after the froghoppers have disappeared. There must be some other cause holding them back, and of these the most apparent is the diseased condition of the roots and the visible presence of root-fungi in large quantities.

(*d*) In some fields the damage appears to be greater than the number of froghoppers present would be likely to cause, but great care has to be used in estimating this, as the planter does not usually draw attention to a field until the damage is severe and this may be when the number of froghoppers has already greatly diminished.

(*e*) When there is noroot disease present, recovery is very much more rapid than when it is widespread.

Relation between Root Disease and Froghopper.

From the evidence given above it will be seen that typical blight can exist without root disease, but not without froghopper, and further that the chief evidence of the destruction by root-fungi is in connection with the later broods.

From these and many other observations in the field one is led to the conclusion that the *attacks of the froghopper are the prime cause of the blight, but that they produce in the cane a weakened condition that results in the rapid spread of root-fungi, which in turn become destructive, and in some years and localities may finally cause greater injury than that originally caused by the froghopper.*

Greater Attractiveness of Diseased Canes.

Scattered throughout the writings on the blight one finds continua references to the possibility that the canes diseased or damaged by other causes are more attractive to the froghoppers than are healthy canes; and that when froghoppers are found in numbers in a blighted field, it is possible that the infestation is the result and not the cause of the trouble.

Carmody (1909 p. 111) commenting on an outbreak at Caroni in 1908 says "the virulence and concentration within a limited area of the froghopper attack at Caroni were as surprising as the unexpected abundance of the larvæ of Castnia and strongly indicate the real cause of the attack."

In blighted canes the juice has been found to be acid. It is well known that many insects are only attracted to plants when some such fermentation of the sap has taken place and Carmody (l. c.) suggests that this occurs with the froghopper.

Both Collens and Hart suggest that froghoppers are more attracted to canes already suffering from root disease.

I have often observed in the field the froghoppers more abundant on fields or parts of fields where the canes are in poor condition or more diseased, but a careful examination of each case has so far failed to prove that the condition of the cane attracted the froghopper. In every case it has been found more reasonable to explain the result by the ascertained fact that the conditions of environment which produce stunted and diseased canes are the same which allow the froghopper to multiply to the greatest extent. This question is discussed below.

DIRECT AND INDIRECT EFFECT OF ENVIRONMENT.

A careful study of Section VIII brings to light a fact of great significance.

The evidence on the influence of conditions on the blight indicates that nearly all these act directly or indirectly through *the amount of moisture present round the leaves and roots of the cane.*

With the rainfall this is directly apparent, as also with the influence of drainage. With the soil it is found that acid soils are more frequently attacked, but this acidity is probably more an indication of the physical condition that has brought it about: all the acid soils were heavier and more impervious than the alkaline or neutral undamaged soils.

Again it is found that the date of cutting of the crop has an effect on the numbers of the froghopper. After cutting the crop from a field, however, that field is more exposed and hence dryer than while the crop stands. It is also possible that the deposition of dew on standing canes is much heavier than on fields in which the canes have been cut.

The influence of the seepage of water from the pond in the field at Hermitage already referred to must also be recollected.

The known facts on the effect of moisture on blight can be summarised as follows:—

(*a*) *Extreme dryness* such as that experienced in unusually dry dry-seasons, or in fields from which the standing canes have been removed early, or where the soil is in poor physical condition so that percolation from beneath does not take place freely, *is followed by an increased amount of blight.*

(*b*) *Medium dryness*, such as that in dry-seasons which are not severe, and particularly in fields where the canes are standing, or the soil is in good physical condition, or where unusual percolation takes place (*e.g.* Hermitage pond) *reduces amount of blight.*

(*c*) *Slight dryness* during wet season, as at the Indian Summer, *increases the amount of blight.*

(*d*) *Normal regular moisture* of wet season, *reduces the amount of blight.*

(*e*) *Extreme moisture* in wet season especially on heavy soils, *increases the amount of blight.*

These facts appear at first to be extremely contradictory, but an examination of Table VII showing the known effect of different grades of moisture on the froghopper itself and on its parasites, on root disease and on cane, will provide, I think, a reasonable explanation of these observed results.

TABLE VII.

Effect of grades of humidity on members of the Froghopper-Blight Complex.

	Humidity.	Sugar-Cane.	Froghopper.	Root-Fungus	Green Muscardine.	Vermilion Parasite.	Syrphid-Fly.	Expected Combined Effect.
V.	Excessive Moisture in Wet Season	Growth checked	Breeding	Increases	?	Probably reduced	?	Increased Damage
IV.	Normal Wet Season Moisture	Rapid growth	Breeding rapidly	Diminishes	Increases rapidly	Increases	Increases	Reduced Damage
III.	Dry Weather in Wet Season	Stops growth, Vitality reduced	Breeding	Increases	Diminishes rapidly	Increases	? Decreases	Increased Damage
II.	Normal Dry Season	Growth checked	Dormant in egg stage	?	Dormant	Continues to breed	Dormant	Reduced Damage
I.	Very Dry Dry Season	Injured	Dormant in egg stage	Increases	Dormant	Dormant	Dormant	Damage not Reduced

It will be seen that with extreme drought the froghopper is dormant, but so also are all its enemies. With a slightly increased supply of moisture, the vermilion parasites will start to breed and so reduce the number of eggs passing over the dry season. With dry weather in the wet season, the froghopper increases rapidly while only the vermilion parasite acts as a check.

With moister weather the Green Muscardine and Syrphid Fly assist the Vermilion parasites and the blight decreases, while greater moisture again (*e.g.* heavy floods) has an injurious effect on the cane, on the Vermilion Parasites, and probably also on the Green Muscardine without affecting the froghopper which once more forges ahead.

The results following from this suggested explanation are identical with those found by experience to occur. It is also possible, however, that infestation is in some way directly related to the condition of the cane as shown in the first column.

PERIODICITY AND RELATIVE SIZE OF BROODS.

Reference has been made to the way in which in some years the third brood of froghoppers is almost non-existent even after a serious second brood. The same uncertainty exists with the other broods also. Fig. 30 shows some of the typical variations in relative size of the three conspicuous broods that have been observed.

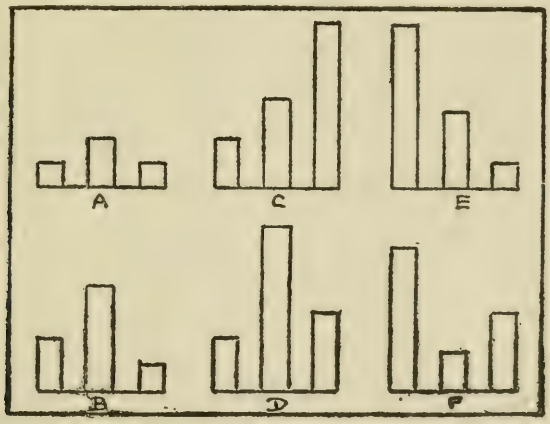

Fig. 30.

Fig. 30—General types of succession of the three chief froghopper broods in different localities or in different years.

A and B are two variations which occur in good years in both of which the first brood is small, the second a little larger and the third again smaller. The year 1916 is a typical example of the first type and the previous year 1915 and the results observed at Caroni in 1919 (*see* Fig. 6) are examples of the second.

C and D are typical successions in bad years. The year 1911 and Caroni in 1908 are examples of the first, and certain fields (of B 347) at Harmony Hall in 1919 of the second. The years 1912 and 1917 are like D, except that the first brood was apparently larger than the third.

E and F are unusual types in which the first brood is larger than any of the others. E has occurred for two successive years (1918 and 1919) under my observation in the same area of Uba cane at Harmony Hall Estate. F is illustrated by the captures at La Fortunée Estate in 1918 (*see* Fig. 5).

The periodicity of the bad outbreaks, which appear to recur at intervals of four or five years (*see* p. 42) is also at present without explanation. Four or five years is approximately the agricultural cycle for cane-growing (planting to planting) and bad lands damaged in old ratoons will be in the same unresistant condition after an interval of four or five years. Although this will undoubtedly have its influence, it does not explain all the facts, as for example the widespread nature of the blight in bad years, when its selective capacity is much less apparent, and good fields and bad fields, plants and ratoons are affected.

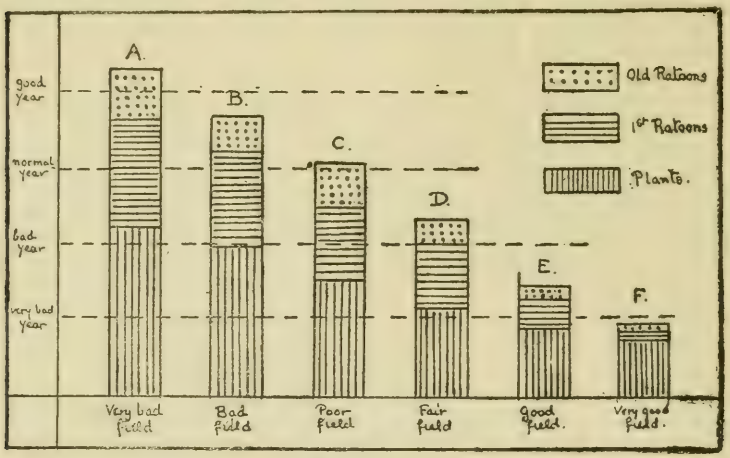

Fig. 31.

Fig. 31—Diagram to explain liability of various fields to blight in different years. For explanation see text.

Fig. 31 presents a diagrammatic scheme of the way in which this selection varies in different years. The total height of vertical columns represents the liability to damage of the various types of fields at various periods of growth. The horizontal lines show the severity of blight in that year, any column above this line indicating that the type in question is damaged.

We see that in very good years only very bad fields are attacked as old ratoons, in bad years all fields below the average are attacked even in some cases as plants and only the best fields escape, while in very bad years even good fields may be blighted. This scheme refers only to attacks developing in the field and not to damage caused by a froghopper invasion from neighbouring lands, which may obviously occur in the best fields in the best years.

CAUSE OF RECENT PREVALENCE OF BLIGHT.

It will be seen from the history of the blight in Trinidad given in Section III that it has apparently been more severe and of more frequent occurrence in the last fifteen years than formerly, although serious attacks did previously occur at longer intervals.

In considering possible causes it must be remembered that Trinidad is not alone in this condition. Demerara has just suffered a very severe attack from a froghopper previously unrecorded as a serious pest, and other countries (Cuba, Colombia, etc.) will be found mentioned in Section IV as having suffered more severely of recent years.

It is thus probable that some general influences are at work in addition to special causes that apply to Trinidad.

Two suggested causes are referred to on p. 18. These are the introduction of the mongoose and the introduction of seedling canes.

(*a*) The mongoose has been fully discussed in Section VI p. 87 and the conclusion arrived at was that, although undesirable, it could not be considered as one of the important causes of the recent spread.

(*b*) The question of the resistance of varieties is dealt with on p. 119 of the present report and more fully in a previous report (Williams 1919 D.) devoted to this subject. There is no evidence to show that the old Bourbon cane is more resistant to froghopper than many of the seedlings now in cultivation. Some of the latter are indeed distinctly more resistant than the Bourbon.

Other factors that have to be taken into consideration are as follows:

(*c*) The injurious effect of continual use of artificial manures (sulphate of ammonia and nitrate of soda) on soils which are deficient in lime, as are most Trinidad soils.

It is probable that the acid condition of so many of the soils in the old sugar districts of the island has been aggravated by this practice, and the resulting poor condition has been favourable to the multiplication of the froghoppers.

(*d*) The working out of the land by continual cane cultivation, frequent burning of trash and insufficient use of pen manure has had an injurious effect on the physical condition of the soil with similar results.

(*e*) The spread of cultivation has had an injurious effect on the lizards, birds and other animals which tend to keep down pests, and at the same time the larger areas under one crop make the continuance of pests which feed on that crop simpler and more certain.

(*f*) The rise of the study of economic entomology, and the greater interest taken by planters in diseases has resulted in more accurate recording and more careful search for their causes, since they are no longer looked upon merely as "acts of God."

The general increase of insect pests in many tropical countries of recent years is part of the wider influence of the spread of civilisation, population, communication and cultivation in places that have not worked out for themselves reliable rotational methods of agriculture to combat the disadvantages inherent in man's artificial method of planting the same crop on large areas of land at frequent intervals.

SECTION X.

METHODS OF CONTROL.

The control of nearly every disease or pest can be considered from two different points of view. First with the idea of preventing the occurrence of the outbreaks, and secondly with the idea of reducing the numbers of the pest when it has appeared, or lessening the damage that it can do.

Of recent years the method of prevention has been gradually assuming more importance, even in temperate climates where intensive cultivation is practised and numerous facilities for control are easily available. Under the present extensive system of tropical agriculture it becomes still more necessary to adopt methods of prevention, even if these may take many years to produce results, rather than to wait for the disastrous outbreaks which may occur over such wide areas and with such intensity as to render their cure almost impossible.

Even in those cases where methods are known to deal with the insect when it becomes abundant, it has to be remembered that until the frequency of the attacks can be reduced by preventative measures, the cost of the destruction will continue to be a charge on the estate year after year, whenever conditions are favourable for the multiplication of the pest.

The sugar-cane is a particularly difficult plant to deal with, under conditions at present existing in Trinidad, with respect to direct destruction of the froghoppers, and it is probable that control will be finally obtained by agricultural methods, which will bring about conditions in the fields unfavourable to their rapid increase.

An outline of such methods is given below, followed by a brief account of the various attempts at cure which have been tried at various times.

INDIRECT METHODS. PREVENTION.

In Section VIII the various factors of the environment have been taken one by one and their influence on the prevalence of blight discussed. In Section IX the important conclusion is reached that nearly all these factors seem to have their effect by altering the moisture of the soil and the humidity of the air just above it.

To what extent can this relation be taken advantage of in devising methods of prevention?

It is immediately obvious that any agricultural process which will get the soil into a condition so that it is less subject to extremes of moisture, will lessen the liability of the canes on that soil to froghopper attack.

Extremes of dryness and water-logging are encouraged by an agriculturally bad physical condition of the soil, and many processes are known to the experienced planter whereby this evil state can be remedied.

Soil Improvement.

Drainage. From what has been said on p. 113 it will be apparent that good drainage is an essential condition of freedom from blight. The drainage system of many of the estates in Trinidad is at present

in a state of transition, as large areas are being relaid out so as to obtain the longest possible furrow to allow implemental tillage with animals or tractors. This has in some cases upset the old drainage of the field and has produced bad results, which should however wear off in the course of a year or two if the new system of drains has been well designed.

On the heavier flat lands the drains should be as close together as is economically possible, as it is often possible to see a distinct difference in growth between plants in the centre row of the beds and those in the outside row.

On most estates at the time of replanting the field, it is not the custom to redrain until some time after the cuttings have been planted. On a few estates, however, I have noticed the fields in preparation for planting redrained at the first opportunity, so that the soil is well drained at the beginning of the crop. This method should be adopted wherever possible.

Considerable reduction in damage has been noticed where the edges of the drains have been occasionally loosened to allow of the free percolation of the soil water into them. This should be done if there is any reason to suppose that the sides of the drains have become impervious.

Manuring. On p. 114 the effects of manures are discussed and it is a reasonable deduction that soils liable to damage should be given the largest possible applications of pen manure to improve their physical condition, and that artificial manures should, on the contrary, be used with caution and their effect counteracted at intervals with heavy applications of lime.

Almost every field in Trinidad which is subject to frequent recurrence of blight, would be improved by applications of manurial lime or ground limestone.

Larger quantities of stock are needed on many estates in order to supply the necessary pen manure, but in view of the labour shortage and rapidly increasing use of implements drawn by cattle and mules, an increase in the number of animals on most estates would be valued from other aspects and should be part of a general policy of sugar-cane agriculture.

From the point of view of the prevention of disease, I should prefer to see the increased stock distributed as widely as possible over the various estates rather than accumulated in special stock farms. This, however, is a question which the managers will have to decide from a wider aspect.

The remarks above, with regard to manuring, apply to fields constantly attacked by froghoppers. In very bad years as has been pointed out, even fields with good soil may be damaged, and artificial manures can still be used with good effect both before an expected attack and perhaps after the attack to hasten recovery.

It has been pointed out above that the evidence is that an application of sulphate of ammonia during an attack is wasted, particularly if the attack corresponds with the period of the "Indian Summer."

Tillage. The influence of tillage has already been discussed fully on p. 118. Little more can be added here. Every opportunity should be taken to improve the condition of the soil by careful tillage, but the shallow soils, with sour sub-soils, which are frequently found in the low-lying sugar areas require careful treatment so as not to bring to the surface too

much sub-soil at any one time. Implemental tillage should not be used when the soil is too wet, as in this condition more harm than good can be done.

In this connection attention might be drawn to the unfortunate conditions existing in a few localities in Trinidad, where the boundaries of the fields bear no relation to the changes of soil. As a result one field may contain two entirely different soils which require entirely different treatment and cultivation. Sometimes the soil changes are so irregular that this cannot be avoided, but wherever possible in relaying out fields their boundaries should be made to correspond as closely as possible to the visible soil changes, so that tillage may have more uniform effect.

Selection of Varieties.

The question of relative resistance of varieties has already been fully discussed in a separate report (Williams 1919 D.) and summarised on p. 119 of the present report. There are no immune varieties, but some are apparently a little more resistant than others. The best of these are "Uba" and "Badilla," but neither is generally acceptable to the planter. Both require very heavy pressure in the mill, and "Uba" is difficult to cut in the field, while "Badilla" is very slow in its growth.

Recently some seedlings from "Badilla" have been obtained which show great promise, but at present it is not possible to say if they retain the resistant properties of the parent cane.

Among the other varieties there is so little difference in resistance and so much depends on soil and other estate conditions, that the planter will probably be best guided in his choice of varieties by other circumstances than the prevention of disease.

Reduction of Ratooning.

The relative liability of plant and ratoon canes to attack is discussed on p. 115. It follows that the less the relative proportion of ratoon canes to plant canes on an estate, the greater the freedom from attack.

This policy is being gradually adopted on one or two estates. On the fields which have shown themselves particularly liable to attack only plant canes and first ratoons are allowed to grow.

It is more expensive to grow canes in this way instead of allowing them to produce second or third ratoons, but against this has to be put the greater freedom from froghopper blight and root disease, rapid improvement of the soil by more frequent cultivation (especially if some rotation crop is introduced, *see* below), and the higher average yield per acre, which reduces the overhead charges.

The method is to be strongly recommended from an entomological point of view, particularly in the low-lying districts where improvement of soil and drainage is a difficult matter. It is for the planter to decide which fields require such treatment and which are sufficiently good to stand continued ratooning without deterioration.

Rotation.

In every country in the world agriculturists are driven sooner or later to a rotation crop. In temperate climates, where conditions are severe and agriculture old-established these rotations have developed to an axiom of agriculture and good systems are already worked out. In tropical countries where growth is easier and, as a general rule, agriculture is a more recently organised industry, rotation is still a matter of trial and experiment and even in some cases only of anticipation.

In Trinidad until recent years canes were grown on land as long as possible and then the land was abandoned and allowed to grow up in grass or bush without interference. This is an inefficient form of rotation and as an indication of the uncertainty of its effect it may be mentioned that some estates put down their freedom from blight to the large area of abandoned land, while others attribute it to their having no abandoned land whatever. The apparent contradiction is largely explained by the type of the soil that is abandoned.

In other countries where sugar-cane is grown, rotation cycles have been practised for many years. Thus in Java where lands can be irrigated one rotation in use is between cane and rice.

Months—J. F. M. A. M. J. Jy. A. S. O. N. D.

1st Year || < ... ..Plant Canes.....
2nd Year...Plant canes .....> <.....Ratoon...
3rd Year...Canes..... .....> <.....Rice.....
4th Year...Rice, second growth.....> <.....Rice...
.....> ||Canes again.

Another rotation in the same country is as follows, introducing a greater variety of crops, but only a single cutting of canes.

Months—J. F. M. A. M. J. Jy. A. S. O. N. D.

1st Year || <..... .....Cane.....
2nd Year .....> <Beans or Maize>
3rd Year... <Rice....> ... <.. Fallow, Beans or Indigo.....>
<Rice.....> ||Canes again.

In Louisiana a crop of cow peas or maize or both is grown after two or three cuttings of cane.

In Barbados two systems are in vogue on land that will not produce ratoon crops, known respectively as "Halving" or "Thirding."

In the former, half the area under cane is cut each year.

Months—J. F. M. A. M. J. Jy. A. S. O. N. D.

1st Year || <.....Plant
2nd Year...Canes.....
.. ..> <Corn crop or fallow...> ||Canes again.

In the second system used on the poorer soils, only one-third of the land is cut each year and there is a break of eighteen months between each cane crop.

Months—J. F. M. A. M. J. Jy. A. S. O. N. D.

1st Year || <.....
2nd Year.....Plant canes.....
3rd Year.....> <.....Cotton, Cassava.....
Corn or Sweet potatoes.....> ||Cane again.

Trinidad will be forced in the near future to adopt some system of rotation to a much greater extent than at present.

The properties of an alternative crop should be as near as possible to the specifications given below.

(1) It should be botanically as different as possible from Sugar Cane—*i.e.* not a member of the order *Gramineae*, or any related order, in order to eliminate common pests and diseases.

(2) It should produce a marketable commodity or at least a stock food for use on the estate.

(3) It should require good and deep cultivation so as to leave the soil in an improved condition for the next cane crop.

(4) It should require labour at times when this is not required for other purposes, so as to ensure regular employment of hands.

(5) It should not be too exhausting to the soil.

(6) It should, if possible, be a leguminous plant as these add nitrogen salts to the soil, and so improve it and save money in the supply of artificial manures.

(7) It should leave behind a good supply of trash or haulm to be ploughed in to improve the texture of the soil and increase its humus content, both of which are particularly needed in most of the Trinidad soils.

The following crops have been tried or recommended for rotation purposes in Trinidad.

Grass Crops.	*Leguminosae.*	*Other Crops.*
Pasture	Alfalfa	Yams.
Corn	Bengal Beans	Cassava.
Guinea Grass	Pigeon Peas	Sweet Potatoes.
Rice	Cow Peas	Cotton.
	Sword Beans	Castor Oil.
	Lima Beans	Banana.
	Velvet Beans	
	Soy Beans	
	Woolly Pyrol	

Abandoned Lands. The oldest form of rotation known here consisted of growing cane until the crops became poor and then abandoning the land to a mixed growth of grass, cane stumps and bush, (Guava, Black Sage (*Cordia cylindrostachya*), etc.). This was done more frequently according to the amount of land available. I am informed that on one estate a regular sequence of three years canes and seven years abandoned land was kept up for a long period.

This method is a poor, uncertain, and wasteful form of rotation. The old cane stools left in the ground harbour the froghoppers, moth borers, and root fungi of canes for many months and make it a breeding ground from which they can spread to other fields. The grass which grows between the stools also encourages the froghopper, while the abandoned undrained condition of the field has often an accumulative injurious effect on the tilth and physical condition of the soil, which we have found to be so important in connection with the survival of the froghopper.

Pasture. The remarks under abandoned land apply partly to pasture in that it harbours insect pests but in Trinidad at least, the froghoppers do not seem to thrive in the close cropped grass, and the more efficient destruction of cane stools makes the field a less dangerous source of other diseases.

Corn. As a preventative of insect pests corn is a very bad rotation crop for Trinidad, as it is a host plant for both the froghopper and the small moth borer. It is also capable of being infested with Mosaic Disease. At the same time it is a valuable crop and might be grown as part of a rotation on lands which do not suffer severely from insect damage.

Leguminous Crops. Alfalfa was tried at Caroni Estate, but, according to Mr. Gilbert, it would not stand the damp climate and was in addition badly damaged by a weevil.

Bengal Beans have been tried at Caroni and elsewhere. As they are poisonous they are grown only as a green manure to be ploughed in to improve the tilth and humus content of the soil. An illustration of Bengal Beans being used as a cover crop for sugar is given by Urich (1913 C. plate VI.). Gough (1911 C. p. 37) notes that they were a great success at Caroni in 1910, but failed completely at Chaguanas where they were sown without previous preparation of the soil.

Cow Peas have been tried on a larger scale than any other leguminous plant and Waterloo Estate in 1918 had 1,400 acres of land under this plant, afterwards to be planted in cane. According to Mr. Carlee they cover the ground quicker and better than the Sword Bean. When possible they are grown to seed, the seed picked and the haulm fed to the cattle and returned to the ground as pen manure. If this cannot be done they are ploughed in as green dressing.

Sword Beans. The common species in use here is *Canavalia ensiformis*, which in addition to being a good cover crop and stock feed is to a small extent edible by man. It is widely used in other parts of the West Indies. Another species, *Canavalia gladiata*, is of more vigorous growth, and has been grown successfully by Mr. Connell at Esperanza Estate and Dr. Shannon at Harmony Hall.

Pigeon Peas have been tried on several estates, but unless thickly planted are not such a good cover crop as the lower growing species. On the other hand the more woody stalks of this plant when ploughed in should help considerably in improving the drainage and aeration of the soil. On some estates they were grown on ths bodies of the fields with the idea of preventing the spread of the froghopper, but there is no evidence of any results being obtained in this way.

Woolly Pyrol was particularly recommended by Gough (1911 C. p. 34) as a suitable cover crop for cane land, and Urich in 1913 mentions that it has given good results, but it does not seem to have come much into use in the last ten years.

Non-leguminous Plants. Yams are one of the best non-leguminous crops that can be grown on cane lands. They give a large yield of a marketable food, necessitate deep tillage of the ground, and provide a haulm to be ploughed in.

In 1917 the Usine St. Madeleine planted a five acre field with yams immediately after the cane was cut (about April). The yams were removed in February 1918 and the field planted with crop plants a month or two later. The canes grew rapidly as a result of the excellent condition of the soil and were bigger at the end of the year than many wet season plants, while the proceeds of the sale of the yams more than paid for the whole cultivation of the field from the time the canes were removed to the time when they were growing again.

Sweet Potatoes are also a good non-leguminous rotation crop and in many cases the cane plants may be planted between the sweet potato plants so as to lose no time.

Cassava, Cotton and *Bananas* are other plants which might be experimented with on a larger scale to find suitable conditions under which they could be grown.

The following rotations are suggested as those most likely to improve the condition of the soil and render the canes less liable to attack by froghoppers or other insects and fungi.

(I.) *Catch-crop rotation for good lands.*

Month. J. F. M. A. M. J. Jy. A. S. O. N. D.

Ratoon canes cut —> <—Land ploughed —> <— Peas, beans or sweet potatoes —> || <—Plant canes.

The canes should be planted between the sweet potatoes.

(II.) *Short rotation for fairly good lands not particularly liable to froghopper and root disease.*

Month. J. F. M. A. M. J. Jy. A. S. O. N. D.

Ratoon canes —> <—Land ploughed —> <————Yams, or beans followed by sweet potatoes.

——> || <—Crop plant canes.

In this no cane crop is lost.

(III.) *Long rotation for poor lands.*

Month. J. F. M. A. M. J. Jy. A. S. O. N. D.

Ratoon canes cut —> <——— Yams or cassava———

——— —> <—Cow peas or sword beans ploughed in as stock food. —> || <—Canes planted again.

In this rotation one crop of cane is lost in each cycle.

The number of ratoons cut would depend on the condition of the field and the crops produced, but it would be well to abandon second ratoons on poor lands until they have been worked up into better condition even if there is no immediate indication of blight.

In all discussion of rotations in Trinidad the final solution will depend largely on the labour supply, but in order to keep the poorer land under cultivation, some form of rotation will have to be adopted and it is for the planter to experiment on methods of implemental cultivation etc., whereby the result may be obtained with the least possible outlay.

DIRECT CONTROL METHODS.

Destruction of Froghopper Eggs.

The eggs of the froghopper are in the semi-decayed moist leaf sheaths of the cane near the ground, in the corresponding parts of the grasses that grow in the cane fields, and in the ground itself. Up to the

present no method, except perhaps spraying, has been suggested for destroying those eggs in the ground. Those in the cane and grass sheaths can be destroyed by the processes of trashing and weeding.

Trashing (Stripping): Trashing in Trinidad consists of the removal of the dead leaves of the cane by hand from the growing plant, and must not be confused with the process of spreading the trash round the young plant in the dry season for which process the word "trashing" is used in Barbados.

The dead leaves when stripped from the plant are either left in heaps (boucans) between the rows of canes, or removed from the fields and used as bedding for the stock.

The value of trashing as a control method for destroying froghopper eggs depends on two important facts. First the operation must be performed at the time when the eggs are in the trash, and secondly that the trash must be removed from the fields.

The first condition necessitates that the trashing should be done shortly after a brood of adults (except in the case of the last brood). A careful watch should be kept, with the use of light traps if possible, for the height of the brood and the trashing should be done about ten days later. It is probably the neglect of this fact or that has produced the contradictory results so far obtained. A delay of little more than a week may allow the hatching of the eggs and only the empty shells are then removed.

If the trash is left in rows or small heaps among the canes little or no result is obtained, as these rows produce almost ideal conditions for the hatching of the eggs and the development of the young nymphs. The trash must either be placed in large heaps at the edge of the field, or be removed to the stock pens as bedding.

The eggs that remain in the trash during the dry season can be removed in the same way by collecting the trash from the fields after the cane is cut and piling into large stacks for removal to the pens later as required for bedding. This is already done on one or two estates in Trinidad and, though expensive, is worthy of extended trial, particularly in fields liable to froghopper attack.

The question was raised as to whether eggs removed in the trash in this way could survive while the trash was in the pens and be returned to the fields with the pen manure, which would thus be a source of danger.

Experiments have shown that this can not happen. Trash containing some hundreds of eggs was buried among the bedding in a cattle pen on Cedar Hill Estate and two months later was removed. None of the eggs subsequently hatched when kept in suitable conditions. The temperature in the manure heap in the vicinity of the eggs was over 125° F. (51° C.) and it is almost certain that none could survive such a temperature.

Occasionally fields are reported to have been severely damaged shortly after trashing. The probable explanation is that the trashing has been done too severely, that the damage is due to the previous brood of adults which naturally is not influenced by this process, or that it has been done during a spell of dry weather when the canes are suffering from a want of moisture and are sending out adventitious roots beneath the trash, in the attempt to get more water. The sudden exposure of these roots to the direct heat and dryness of the day has an injurious effect on the canes.

Weeding. Much the same remarks apply to weeding as to trashing and the contradictory results obtained by different planters are probably due to similar reasons.

Some planters make a point of giving special weeding to fields showing signs of attack, while others say that such labour is wasted.

If weeding is done during the flight of adults or while the insect is in the nymph stage, little good can be expected, in fact the insects will be left in the field and will feed on the canes in greater numbers than before. If it is done at the time that the majority of insects are in the egg stage, good results should be obtained, but it must be emphasised that these results will not be apparent until the next brood of froghoppers two months, or, if the dry season intervenes, six or eight months later.

Weeding and trashing, when carried out in a field actually suffering from blight, are liable to cause considerable damage by the number of canes accidentally broken owing to their abnormal brittleness near the growing point.

Weeding is probably of less importance than trashing and no immediate results can be obtained from either.

Burning.—The question of burning the trash on cane fields before or after cutting has been the subject of much controversy. It has important effects both on the animal life in the cane field and the physical condition of the soil.

Considering first the effect on the froghopper there is no doubt that a number of eggs will be destroyed, limited however by several factors:—(1) The eggs are chiefly near the ground where the trash is moister and less likely to be destroyed (2) Burning is often carried on at night to prevent too severe scorching and this means that still more eggs will escape. (3) The eggs in the soil will probably escape.

On the other hand many egg parasites will be destroyed in addition to the lizards, toads, spiders and other parasites and hyper-parasites shown in Fig. .

The field evidence to decide whether the good or the harm done is the greater is contradictory. Some fields have been burned regularly and still have not suffered severely from blight. Mr. C. Connell of Esperanza Estate reported in 1912 that fields burnt had suffered less than fields not burnt.

On the other hand I found in 1919 the blight definitely worse in a corner of a field that had been accidentally burnt at Harmony Hall than on the rest of the field that was not burnt. Mr. Halliday at Picton in 1912 reports that the fields where the trash was burnt were the worst attacked fields on the Estate.

It is possible that the immediate effect depends largely on the original proportion of the froghoppers and their enemies.

Burning during the wet season will have still less effect in the destruction of the eggs, and nymphs have been seen making fresh froth masses on the surface of the ground within twenty-four hours of the burning of a field.

In addition there is evidence that the burning of trash has, in Porto Rico and Louisiana at least, a distinctly bad effect on the prevalence of the small moth-borer of sugar-cane, probably by the destruction of its parasites (*see* Wolcott, Annual Rept. Porto Rico, Insular Expt. Station 1917-1918 p. 43; and Loftin and Holloway, U.S. Department of Agriculture Bulletin 746 p. 55). The latter authors give figures indicating 67 per cent. infestation of small moth-borers in a field previously burnt as compared with 15·5 per cent. in an unburnt field. In view of the presence of the small moth-borer in Trinidad this effect must not be forgotten.

Finally we have the fact that in the burning of the trash a large amount of vegetable matter is destroyed which would otherwise decay to humus in the soil and so improve its physical conditions. On soils rich in humus and well aerated this loss would not be so important, but in Trinidad there are few soils of this nature and one of the prime needs of the blighted areas is, as has already been shown, a better physical condition of the soil.

From these considerations it is reasonable to conclude that, for the control of blight, the less burning of trash that is carried out the better will be the results, particularly in the future when the accumulated humus begins to have effect.

Spraying. Gough (1910 B. p. 176) suggests spraying the bases of the cane stems with tobacco juice just after the first flight of adults to destroy the eggs. I dipped a number of pieces of trash containing eggs 3–5 days old, in a solution of 1 in 240 Black Leaf 40 (Nicotine) for three minutes, the pieces being subsequently dried on blotting paper. Several eggs survived this treatment and hatched within the next few weeks.

The results of experiments with Mr. Glasgow's preparation containing corrosive sublimate will be summarised later in connection with the destruction of the nymph (p. 142).

Destruction of the Nymph.

Weeding. The remarks already made in dealing with the destruction of the eggs apply here also.

In dealing with abandoned lands which are believed to be a source of danger as breeding places, it is important that they should be brushed (cut over) while the froghopper is in the egg or young nymph stage, as if the adults have begun to emerge they will have all the more inducement to spread into the surrounding fields. Abandoned fields so brushed should be put into some form of cultivation or ploughed up as soon as possible.

Flooding. In British Guiana, where the greater part of the sugar lands are below the level of the irrigation canals, fields are sometimes flooded in order to destroy the nymphs (Williams 1918 B. p. 165). This method can never be adopted in Trinidad as there are nowhere the facilities for rapid drainage that is an essential part of such a method.

Use of Chemicals and Sprays. A large number of chemicals have been at times experimented with and so far none has proved successful. Gough (1911 C. p. 26) discusses the use of quick lime, lime wash, lime sulphur, kerosene emulsion, kerosene lysol emulsion, rosin wash, cyanide of potassium, and copper sulphate. His conclusions are that the only ones worthy of further trial are the kerosene emulsion and the kerosene-lysol emulsion.

I have reports from planters of experiments with Cooper's cattle dip, "milk-oil," Bordeaux mixture, salt and lime, carbon bi-sulphide, tobacco dust and nicotine solution. All of these were found of no practical value.

The frothy covering of the nymph protects it from most sprays unless they are of unusual strength, and experiments in which the nymphs are removed from their froth are misleading unless followed by others with the nymphs in their natural state.

I have experimented with various strengths of nicotine (Black Leaf 40) solution, and found that at certain concentrations, particularly when small traces of soap and ammonia are present, it will kill nearly all the nymphs with which it comes into contact, but the cost of the solution at the concentration required was almost prohibitive.

Gough recommends the use of kerosene emulsion for destroying the adults, but, I am not aware that any extended trials have been made of this method, which might be practicable on a small scale.

Carmody and others in 1912 experimented with Nitrolim, an artificial manure containing nitrogen and lime. About two ounces were applied to each stool particularly on the visible nymphs, and in some cases the results were said to be satisfactory. The advantage of this method is that the material applied is a manure and thus no extra expense is involved. Its disadvantage is that probably only the nymphs actually touched by the powder will be killed. The chemical has been unobtainable during the last few years, and I have unable to test it.

In 1918 Mr. Glasgow of Orange Grove Estate reported that he had a secret liquid that would destroy all the froghopper nymphs and eggs, but my tests of it and the results of his field demonstrations were not satisfactory (*see* Williams 1919 B.). In the following year Mr. Glasgow patented his liquid, in which the active substance is corrosive sublimate with hydrochloric acid and common salt. I made a few laboratory experiments, and found that it was of no value in destroying nymphs but eggs dipped in it for one minute failed to hatch.

All these methods of spraying liquids round the stools suffer from the common disadvantage of the cost of application and the labour required when all available hands are needed for other work.

A number of experiments were made with spraying machines at St. Augustine with the assistance of Mr. J. B. Rorer, and we came to the conclusion that an average of half a minute per stool is required and that the plants cannot be properly sprayed at a higher rate than twelve plants to the gallon of liquid.

With six men spraying, two at the central pump for filling and mixing the liquid, and one man with cart bringing water, about two acres per day can be done. This would cost about $2 per acre for labour in addition to the cost of 200 gallons of liquid (allowing 2,400 stools per acre).

The ground cannot be covered with sufficient rapidity, and the cost, particularly if more than one application is necessary, is too great.

The use of small cups for pouring the liquid round the stools from buckets, as used by Mr. Glasgow, is less expensive, but also less efficient.

It must also not be forgotten that the sprays will almost certainly destroy the grubs of the Syrphid fly and so reduce one of the natural checks on the froghopper's increase.

Stamping out of Nymphs. On some estates children armed with short sticks are sent through the infested fields to crush every visible froth mass with the end of the stick. The method is not expensive, but only froth masses on the surface are destroyed and in these friend and foe alike are killed.

It is doubtful if the method would be of any value in the case of a severe widespread outbreak, owing to the labour required.

Hand Collecting. Still more laborious is the method of sending children through the fields to collect the nymphs from the froth masses

About 5c. per hundred nymphs is paid and a child will collect 400–600 per day. According to Kershaw (1913 I. p. 6) 700,000 were collected in this way at Brechin Castle Estate on 31 acres at a cost of $11 per acre. The same method was in use in British Guiana (*see* Williams 1918 B. p. 170–171).

It is a much slower method than crushing the nymphs, but has the advantage that some check is kept on the activities of the gang. Unless the children are carefully instructed they will destroy Syrphid grubs as well as nymph froghoppers.

Destruction of the Adult Froghoppers.

Hand Collecting. Both in Trinidad and in British Guiana children have been employed at various times to collect and destroy the adult froghoppers by hand. This is an extremely slow process and even when they are abundant, it is seldom that more than six or seven hundred are collected as the result of a day's work by one boy, whereas this number can be caught in a few minutes by the use of nets (*see* below).

The sexes caught are in more or less equal proportions, a slightly greater number of females is sometimes found, owing to the activity of the males giving them more chance to escape.

In some cases the insects thus caught are infected with green muscardine fungus and allowed to escape to infect others.

In other cases instead of collecting the adults, the growing point of the cane is squeezed with the hand to destroy the insects sheltering in the axils of the leaves (Carlee 1912 A. p. 271).

Spraying. Spraying for adults with kerosene emulsion has been recommended by Gough (1911 A. and 1911 C. p. 28) and has already been discussed above (p. 142). It is worthy of more extended trial and might be of value in small localised outbreaks.

Light Traps. The adult froghoppers can be caught in great numbers by means of light traps. On one occasion I captured 20,000 in five traps in one night, and at Caroni in 1915 with 100 lamps the captures reached 250,000 per night during the broods.

The form of trap generally in use is shown in fig. 32 and consists of a kerosene oil (paraffin) lantern, locally known as a hurricane lamp, placed in the middle of a round tin pan of about twelve inches in diameter, in which there is about half an inch of water with a little kerosene oil on the top.

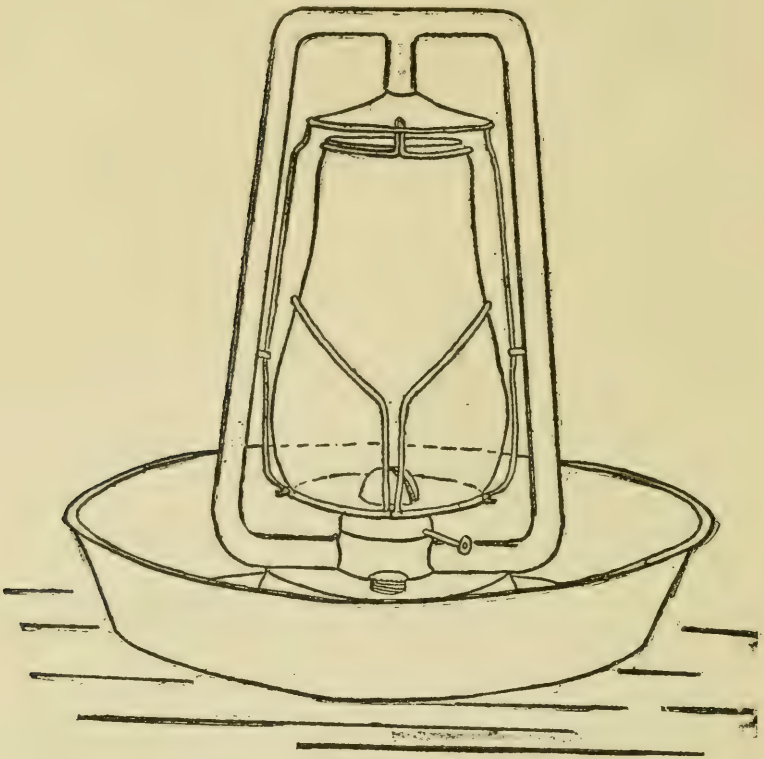

Fig. 32.

Fig. 32—Simple form of light trap for attracting adult froghoppers.

The method suffers from the great disadvantage that practically all the specimens caught are males. Gough (1910 A. p. 306) has given counts of over ten thousand individuals caught in light traps showing about 1½ per cent. females, (11,257 males to 175 females). My own records and those of other observers entirely confirm these results. In many cases the proportion is even lower than this and as a result the use of light traps is of comparatively little use as a control method.

Intensity of Light. Investigations have been made by different workers on the relative attracting powers of different intensities of light.

Urich with a Kitson kerosene-vapour lamp of 1,000 candle power found that the increased attraction was slight and in some cases the more powerful lamp attracted fewer froghoppers. In three evenings the powerful lamp attracted 163 insects while one oil lamp attracted 241 individuals on the following three nights, while during August 1910 the Kitson lamp attracted 7,447 froghoppers and three hurricane lamps attracted 3,929, which is more in favour of the powerful light (Urich 1910 A. p. 20).

In British Guiana I experimented with an acetylene lamp of about 100 candle power and caught 651 individuals (1·2 per cent. females) while an oil lamp in the next bed caught 525 (1·2 per cent. females) of *Tomaspis flavilatera*.

In Trinidad at Brechin Castle in September 1917 I tested the same acetylene lamp and on one night obtained 2,170 insects as compared with 1,008 with an oil lamp some distance away; and on the next night it captured 1,132 when two oil lamps one on each side captured an average of 1,110.

It appears that there is no great increase of captures by using lights of greater intensity and the percentage of females captured remains the same.

Colour of Lights. To test if lights of different colours were more attractive to females I put out oil lamps with white, green and red shades at Brechin Castle Estate in September 1917.

The results were as follows:—

Colour.	*Average Catch.*	*Per cent. of Females.*
White	1,228	about 1 per cent.
Red	146	0 „
Green	443	0 „

It will be seen that the percentage of females is not increased while the total attractiveness is reduced, more so in the case of the red than the green.

Height and Position of Lamps. To test the best height at which to place the lamps and whether they are best in the canes or in the traces, experiments were carried out at Golconda Estate in September 1918.

The lamps were tested (1) on the ground, (2) about 18 inches from the ground, (3) about four feet from the ground.

The results obtained were as follows:—

1st Night.

	In trace	*In canes*	*Total*	
High	30	220	250	
Medium	166	446	612	
Total	196	666	862	in 4 lamps

2nd Night.

	In trace	*In canes*	*Total*	
High	6	55	61	
Medium	380	430	810	
Low	145	852	977	
Total	531	1,317	1,848	in 6 lamps

It will be seen that in all cases the lamps at 18 inches above the ground are much more efficient than those at four feet, while the total captures at ground level were greater than those at 18 inches, although the results are less conclusive as in one case the total was lower for the lamp on the ground.

With regard to the position it appears that the lamps in the canes caught many more than those in the traces, but the canes had suffered severely from froghoppers and were small and open while the traces had ploughed land at one side.

Time of Greatest Captures. On p. 57 and in fig. 8 is shown the numbers of froghoppers caught during each hour of the night. It will be seen that the greatest number are caught during the early part of the night and more than fifty per cent. of the total are attracted before 10 p.m.

Other Insects Destroyed. A number of experiments have been made to find what other insects are destroyed by the use of light traps. The list is a large one and includes both useful and injurious. Some of the principal are as follows :—

Useful.	*Neutral.*	*Injurious.*
Mantidæ	...Crickets	...Hard-back beetles.
Candle-flies (Lampyridæ)	...Cockroaches	...Mole-crickets.
Xiphidium (grasshoppers)	..Crane flies	...Small moth borer (Diatraea)
Soldier bugs (Reduviidæ)	...Beetles	...Leaf eating grasshoppers.
Ichneumon flies	...Ants	...Termites.

Use of Lamps for spread of Green Muscardine Fungus. Owing to the small proportion of females attracted light traps are of little use as a direct control method. It has however frequently been suggested that they could be used in order to infect the adults with the green muscardine fungus.

Rorer (1910 B. p. 478) first suggested the use of a trap round the lamps and that the froghoppers so caught could be infected and released the next day. Gough (1911 C. p. 38) suggested that if the spores were in the trays round the lamps infection would take place without the additional expense of a trap.

Rorer's trap consisted of a zinc funnel beneath the lamp down which the insects slipped into a box below. I have tested this and several other types of traps, and while occasionally quite successful and one of the best methods of distributing the fungus, it is uncertain and suffers from the defects which are discussed more fully on p. 85.

Use of Lamps for indicating broods. A few light traps on an estate put out about once a week, and in which the total captures are counted, are of great value in determining the occurrence and dates of the broods, and when the damage may be expected to increase and when recovery may set in.

The diagrams in figs. 5 and 6 show results obtained in this way.

Use of Nets. In British Guiana in 1916 I found that the adult froghoppers could be caught in large numbers by sweeping the grass and canes at the sides of the field drains during the day with nets. In this way boys could catch up to 3,000 adults per day instead of five or six hundred by the old method of hand collecting (Williams 1918 B. p. 170).

In Trinidad the same method was found to be useless owing to the habit of the froghopper here of spending the day hidden away in the axils of the upper cane leaves.

It was not until two years later that it was observed that in the early evening the adults leave this position, crawl out on the leaves of the cane and are readily captured.

On 9th July 1918 (1st brood) at about 6 p.m. I captured 700 adults in about two minutes with an ordinary butterfly net on a trace between infested cane fields. About 31 per cent. of these were females.

The same results can be obtained in the early morning and on the following day at about 6 a.m. I obtained 122 adults (including 29 per cent. females) in one minute by the same method.

At six p.m. on the following evening 1,210 adults were captured in five minutes with the same net, and two days later with a larger net, 6 feet wide by 2 feet high, drawn by two men 3,000 froghoppers were obtained in two minutes.

It will be seen that by this method adults, including about 30 per cent. females, can be destroyed in large numbers, the chief drawback being that the method is seldom successful before 5 p.m. and at the time of the second brood it is usually dark before 7 p.m., so that work can only be carried out for a limited time each day.

To increase the rapidity of the work and reduce the labour required, experiments have been continued with various forms of nets drawn by mules, one of the most successful being one in which a mule walks between two rows of canes and has attached on each side a net in the form of a pannier which sweeps the rows of canes on either side.

This will be tested more fully this season; it is not expected to be more than moderately successful but may be applicable to small and localised outbreaks.

An account of the net in its present form will be found in the Bulletin of Entomological Research Vol. XI p. 179.

It was thought at one time that it might be possible to use the froghoppers caught in the nets to infect with green muscardine and release, but in view of the high proportion of females caught and the impossibility of separating them from the males it is probably better to destroy them than to use them in this way.

A somewhat similar method has been suggested for use in Cuba by Cardin 1917 but in this case it is the pastures that are attacked, and the net or hopperdozer is mounted on skids which slide over the ground.

ENCOURAGEMENT OF NATURAL ENEMIES.

In the section dealing with the enemies of the froghopper the habits of each of them has been discussed so far as is known.

Some methods may be adopted by which they can be encouraged. Thus birds may be attracted to estates if trees are left here and there in the traces, or if necessary planted in areas where all have been destroyed.

Keskadees and other birds are encouraged if posts are put up for perches along the traces. On one occasion this was done and many of the posts took root and grew into convenient bushes.

The reduction of the amount of burning to the minimum will save many lizards, frogs, toads, spiders, and other enemies that would otherwise be destroyed.

To increase the number of egg parasites Urich brought grass from the moister parts of the island, where the vermilion parasite is abundant, in to the cane fields, but no conclusive results have yet been announced.

It is unfortunate that several good agricultural processes are destructive to natural enemies. Thus better drainage reduces the numbers of the frogs and toads, and the better cultivation of abandoned lands destroys the nesting places of many birds. At the same time it has been shown that these processes have also their beneficial aspects and they should be carried out in spite of any small possibly injurious effect.

THE INTRODUCTION OF NEW ENEMIES.

As the search for new enemies of the froghopper has been several times suggested and an attempt made in this direction, a few notes on this question will not be out of place.

When a new pest is introduced into a country and, adapting itself to its new surroundings, increases with great rapidity owing to the lack of controlling factors, the introduction of enemies of the pest from its original home to its new habitat is an obvious measure to be taken.

Success then depends on the ability of these parasites to adapt themselves also to the new surroundings and on their being in turn comparatively free from destruction by hyperparasites.

The latter condition is most likely to be fulfilled in a country with a small fauna, such as an island, particularly one well separated from the mainland.

Several cases are known in which great success has attended the method. Thus a leaf hopper (*Perkinsiella saccharicida*) was accidentally introduced into Hawaii and threatened to destroy the sugar industry of that island. The original home of the leaf hopper was found to be Australia. A search was made there for parasites, those found were introduced into Hawaii, and the leaf hopper ceased to be a positive danger although still ranking as a considerable pest.

In California the scale insect *Iceria purchasi* was accidentally introduced and spread with enormous rapidity, but was successfully reduced when a lady-bird beetle (*Vedalia*) was introduced from Australia, the original home of the scale insect.

More recently the hard-back beetle (*Phytalus smithi*) was accidentally introduced from Barbados into Mauritius, but its rapid spread has been quite checked by the deliberate introduction of the wasp *Tiphia parallela*, which was known to keep it in check in Barbados.

On the other hand parasites have been introduced from all parts of the world to combat the Gypsy and Brown-tail Moths in the New England States of U.S.A., yet they still remain a severe menace and spread over a larger area each year. Other examples could be given of the failure of the method to produce appreciable results.

In all the above cases we are dealing with a pest introduced into a new country without its enemies, which have been left behind in the country of its origin. In Trinidad we have quite a different condition. The froghopper is an indigenous insect; it has been here probably for thousands of years and almost certainly long before the introduction of the sugar cane. It has associated with it already a number of parasites and hyperparasites, and the complexity of relationship between them is indicated by the diagram in fig. 19. (p. 92).

Trinidad, though geographically an island, is biologically a part o the South American continent and has its rich and varied fauna only slightly reduced. Any new enemy introduced, before it can be the slightest economic value, has therefore to be able to hold its own against a number of hyperparasites, must be able to withstand the dry season uninjured, and in addition must be able to breed with such rapidity that it can overtake the froghopper. Against all these disadvantages, to be of any practical value, it must be sufficiently powerful to alter the present balance and prevent the froghopper from increasing beyond certain narrow limits.

A practical example of the results of the incessant struggle to which a new parasite may be subjected is seen in the history of the Mexican Bug introduced from Mexico in 1911 by Urich to destroy the froghopper. Many thousands of them were liberated in the cane fields and not one was ever recovered, in all probability owing to their extermination by other predaceous insects, spiders, etc.

However, the loss from the froghopper has probably averaged £50,000 per annum during the past fifteen years and with the increase in the value of sugar it may be worth while, if the agricultural methods now advocated fail to give relief, to take up once more the search for parasites.

If this is done it must be recognised that the method is under the circumstances long and uncertain, and success is not even assured by the arrival of the new parasite in Trinidad.

From the experience gained in eighteen months spent in searching for parasites in Central America two important notes can be added.

(1.) The wide distribution of the common froghopper parasites in Central America indicates that time will only be wasted searching for new ones in this area and it is probable that the most rapid results would be obtained by going far afield. I should be inclined to recommend the African continent, where numerous froghoppers of genera allied to *Tomaspis* are known to exist.

(2.) Such a search for parasites in new countries cannot be carried out by one entomologist working alone and unaided. At least two men and better still, three should be employed. The work will be more rapidly completed and more experience will prevent errors. To send one man is merely to gamble with the money expended, as the whole investigation may be wasted if he is taken ill.

In the section dealing with the natural enemies of the froghopper some indications are given of the types of parasites that might be expected.

Egg parasites are most likely to produce good results, especially if capable of continuing their activities in dry weather, as the froghopper is in the egg stage for the greater part of the year.

Parasites of the nymph might include species of *Drosophila* at present only known as parasitic on froghoppers of the genus *Clastoptera* (*see* p. 64).

In Europe the nymphs of froghoppers of the genus *Aphrophora* are taken from their froth and stored up by the wasp *Gorytes mistaceus* (Cambridge Natural History, Insects Vol. II. p. 93). No wasps have yet been found storing froghoppers in Central America, but it is possible that elsewhere others await discovery.

Finally there are several other known species of the genus *Salpingogaster* (which includes the Syrphid fly) and these are almost certainly parasitic on froghoppers.

Salpingogaster costalis Walk, *S. minor*, Aust. and *S. virgata*, Aust. are known from Brazil. *S. cothurnata*, Big. *S. limbipennis* Williston, and *S. nova*, Gig-Tos, from Mexico. *S. macula*, Schin. from Chile. *S. nigriventris*, Big. from Uruguay and *S. pygophora* Schin. from Brazil and Panama (Kértesz Cat. Dipt. VII 1910 p. 168). *S. pygophora* has also been reported from Cuba (Hine, Ohio Nat. XIV 1914 p. 336).

SUMMARY.

INTRODUCTION.

The Sugar-cane cultivation of Trinidad covers an area of about 78 square miles, out of a total area of 1,750 for the island. The crop has varied from 38,000 tons to 71,000 tons in the past twenty-one years. The rainfall is about 64 inches, with a dry season from January to May and a wet season from May to December (fig. 1). The crop is cut during the dry season. Three or four crops are usually cut before replanting. (p. 11.)

The growing canes have been subject for many years to outbreaks of a disease locally known as "Blight" or "Froghopper Blight," which consists essentially of a browning and drying up of the leaves and a check to the growth which may result in the total loss of the crop. The loss during the past fifteen years has probably averaged £50,000 per annum and in 1917–1918 reached about £300,000. The insect *Tomaspis saccharina*. the sugar-cane froghopper, is almost invariably found in abundance in the blighted fields, as well as various species of root fungi, and both have been held responsible in varying degrees for the damage. (p. 13).

Conditions similar to the froghopper blight were reported in 1863, but it was not until 1889 that the froghopper was discovered by Hart and its connection with the damage suspected. In 1906 a severe outbreak called attention to the subject once more and during the next three years, all of which were characterised by severe blight, various opinions were held as to the relative importance of the froghopper and root disease. In 1909 regular investigation was started by the Board of Agriculture and Rorer, Urich and Guppy studied the varied aspects of the problem. The life history of the froghopper was worked out, two egg-parasites were found, and the green muscardine fungus which destroys the adult, was cultivated on a large scale. In 1910 and 1912 Gough and Kershaw continued the investigations. The former discovered the Syrphid Fly, which destroys the nymphs, and the latter recommended the search for a more efficient parasite outside Trinidad, (p. 14).

During 1916 and 1917 I made a search for such parasites in British Guiana, Panama and Costa Rica. New froghoppers were found in all these countries, but the enemies were found to be the same as those already known in Trinidad. The range of the parasites is evidently much greater than that of their hosts. In Panama a few specimens of a new egg-parasite were obtained but they died before any attempt could be made to breed them. In July 1917, owing to the great difficulty of carrying on the work single-handed and with the prevailing conditions of transport, I returned to Trinidad to study the pest in the island. (p. 16).

In 1918 and 1919 Nowell, emphasized the relation between local infestations and the condition of the soil, and advocated the application of agricultural methods to the reduction of blight. (p. 18).

THE NATURE OF THE BLIGHT.

Damage usually first appears six weeks to two months after the beginning of the wet season and the canes stop growing, and the leaves wilt and are streaked with brown marks. After some weeks recovery sets in, usually to be followed by a second and occasionally a third attack at intervals of about two months. (p. 20).

From each puncture of the adult froghopper on the leaf an elongated area of injury spreads, at first pale and later brown. Increase in size of this spot may continue for as long as four or five weeks and, from

an almost imperceptible point, the damaged area may reach five inches in length and a quarter of an inch in width forming a long discoloured streak on the leaf. The centre of this area finally dies completely (Pl. II). If these streaks are numerous they may join up to form large dead areas on the leaf. It follows that the injury to the leaf, and so to the plant, may continue to increase after the brood of froghoppers has passed. (p. 20).

The stem is only indirectly damaged by loss of food from the damaged roots and leaves. The growing point is frequently stained with red internally, especially at the young nodes; small pockets of gum are sometimes found, and an unnatural brittleness frequently causes the cane to break off just above one of the upper nodes. The internodes or joints which should be increasing in length and width, remain shorter and thinner than usual and harden while still in this condition, recording on the growing cane the check that the plant has received. Thus from the lengths and widths of successive internodes on a fully grown cane past attacks can be determined (fig 3). The shortening of the upper internodes causes the leaves to be crowded together in a fan-like arrangement. In addition the eyes near the top of the cane frequently send out shoots, and adventitious roots are developed from the joints near the ground. (p. 22).

The roots are damaged both by the sucking of the nymph, by the root fungi usually associated with blight, and by the unfavourable soil conditions nearly always found in fields liable to attack. The root system is poor and the plant can be pulled from the ground with comparative ease. (p. 24).

The blighted canes contain less sap than healthy ones, but often a higher sucrose percentage. The sucrose is said to be more easily inverted in sap from diseased canes, and the sap is frequently acid. (p. 24).

The different parts of the stool are usually damaged inversely as their size and vigour. The smallest shoots are killed, the medium sized ones severely checked, and the larger only slightly injured except in cases of severe continued damage. (p. 25).

As the brood passes the canes are able to send out undamaged leaves and gradual recovery sets in. This will vary according to the extent of the original injury. The length of time taken for a plant to produce a new set of leaves is however longer than the time between successive froghopper broods, and as a result the cane after one attack is in a weaker condition to withstand a second. This probably accounts for the greater damage caused by a second brood even when its numbers do not appear to be greater than the first. (p. 25).

The greatest intensity of the blight is about two to three weeks after the height of the froghopper brood, but the total damage varies greatly from year to year and from place to place. (p. 27).

Uncomplicated froghopper attack is distinguished from uncomplicated root disease by the presence of the brown streaks on the leaves. Froghopper injury is never confined to a few isolated stools as occasionally occurs in the case of root disease. Root disease further has not the periodic nature of froghopper blight. The blight resembles in symptoms the Sereh disease of the East, but does not become steadily worse each year as with the latter. The resemblance of the symptoms is largely accidental and Sereh does not occur in Trinidad. Certain fungi make discoloured spots on the leaves of the cane. The chief of these are the Eye-Spot (*Helminthosporium*) and the Ring-Spot (*Leptosphaeria*), but the marks are quite distinct from those of froghopper injury. The Eye-Spots are small, seldom more than half an inch in length, and have only been found up to the present on one variety of cane, D 109. The Ring-Spots are purplish-brown in colour with a paler centre and almost

round, seldom exceeding half an inch in diameter. In the Mosaic Disease, recently discovered in Trinidad, the leaf is irregularly mottled with indistinct streaks which are pale from the first and never become darker than the healthy leaf. (p. 27).

HISTORY OF THE BLIGHT.

Blight, apparently similar to the present one, was recorded in 1862, 1869, 1878, and various years up to 1889 when the froghopper was first recognised as the probable cause. From about 1890 onwards for several years, the gradual degeneration of the Bourbon cane was taking place, largely due to Red Rot (*Colletotrichum*). No outstanding attacks appear to have occurred again until 1906, although a few slight local outbreaks are recorded in 1900. (p. 30).

In 1906 commenced a series of severe attacks which has continued with occasional intervals up to the present time. The relative severity of blight in these years is shown in fig. 7, which indicates a recurrence of periods of severer blight at intervals of four or five years. The times of greatest damage were 1906–8, 1911–1912 and 1917–18. (p. 32).

The weather conditions for each year from 1906–1919 are summarised on Table I. (p. 33).

FROGHOPPERS IN OTHER COUNTRIES.

Tobago has its own species of froghopper, *Tomaspis carmodyi*, which however has done no damage. (p. 43).

In Grenada the Trinidad insect is known and in 1916 did severe damage in a few small areas. (p. 44).

From St. Vincent there is a single specimen of the Trinidad froghopper, in the collection of the British Museum, captured about 1890, but in December 1917 I made a close search in the southern half of the island and failed to find any. (p. 44).

No froghoppers have ever been found in Barbados, St. Lucia, Martinique, or the more northerly Lesser Antilles. Dominica has one species, *Tomaspis dominicana*, of which the habits are unknown. (p. 44).

In Cuba pastures and occasionally cane fields have been damaged by *Tomaspis bicincta*. In 1916 the loss due to damaged pastures in the province of Caminguey was about £4,000. (p. 45).

No damage has been reported from Jamaica, but several species of froghoppers are known to occur there. (p. 46).

In Surinam *Tomaspis tristis* occasionally damages the canes. The nymphs are not root feeders but are found two or three feet above the ground on the cane and bases of the leaves. (p. 46).

In British Guiana *Tomaspis flavilatera* was known as a minor pest from 1909 to 1917 but the harm done was negligible. In 1918 however an extensive outbreak occurred in three different localities and severe damage was recorded. It is believed to have been related to certain climatic and soil conditions. (p. 47).

In Colombia *Tomaspis bogotensis* has for some years been recorded as damaging pastures. (p. 48).

In Panama *Tomaspis lepidior* has been mentioned as damaging cane and grass, but apparently to no great extent. A froghopper of the genus *Clastoptera* was found destroying the flowers of Cacao. (p. 48).

In British Honduras damage was reported to sugar-cane by a froghopper in 1883, but no recent particulars are available. (p. 49).

In Mexico cane and pastures have been damaged for many years past by *Tomaspis postica*. (p. 49).

In Louisiana *Tomaspis bicincta* has been reported on cane without doing any serious damage (p. 49).

In the New York district grass is occasionally damaged by two species of *Philaenus*. (p. 49).

Roses and some pasture grasses in England and Jak and Cotton in India have also suffered from other species of froghoppers. (p. 49).

The text is given of the legislation in force in Barbados and St. Lucia to prevent the introduction of the froghopper. (p. 50).

THE FROGHOPPER.

The scientific name of the insect is *Tomaspis saccharina*. The name *Tomaspis varia* has been used in the past but there are reasons for not retaining it in use. (p. 53).

The species is only known from Trinidad, Grenada and possibly St. Vincent. It is almost certainly native to Trinidad and not an introduced insect. (p. 53).

The adult insect is about one-third of an inch in length, dark brown, with two transverse yellowish-brown bands on the wings. There is a light variety which has in addition the basal portions of the wings light in colour. (p. 54).

In the field the two sexes appear to be in almost equal proportions. (p. 55).

A short account of the anatomy of the insect is given, based chiefly on the work of Kershaw. (p. 56).

During the heat of the day the insects remain hidden at the base of the upper leaves of the canes. In the late afternoon and evening (earlier on cloudy days and later on bright days) they come up on to the leaves and start feeding. The males begin to fly at about dusk. Light traps examined every hour indicate that the greatest activity is from dusk to 10 p.m. In the early morning they gradually return to their hiding places in the axils of the leaves. (p. 56).

From 40–100 eggs are laid by each female, either in the dead partly decaying leaf sheaths near the ground or in the soil itself. (p. 58).

The egg is about one-thirtieth of an inch long, pale yellow in colour and pointed at each end. As it develops a black longitudinal streak appears at the head end. The egg stage lasts from two weeks to over six months according to the conditions of moisture. Many eggs from the second and third brood, however, do not appear to hatch until after the following dry season. (p. 58).

There are four nymph stages during which the insect increases in size and the wings are developed. (p. 59).

The nymphs suck the sap from the roots of the cane at and below the surface of the ground (Pl. III). They protect themselves with a white froth, which consists of the excretion of the alimentary canal in which air bubbles are formed by an arrangement of the breathing system. This froth is of considerable protection to the nymph from extremes of drought and moisture and also from various predaceous ants and other insects which are often abundant in the cane fields. (p. 60).

The froghopper feeds on sugar-cane, on almost all species of grass (*Gramineae*) and on some grass-like plants of the related order *Cyperaceae*. It has been reported damaging hill-rice, corn and pastures, but has never done any serious injury to them in Trinidad. (p. 61).

The nymph stages occupy five to seven weeks and the adult may live as long as a month. The complete cycle under normal wet season conditions takes slightly under two months. (p. 62).

The first flight of adults is at the end of June or during July, about seven weeks from the date of the first rains. The second brood is about two months later, usually in September, and the third may appear after a similar interval. Very occasionally a fourth brood appears about December. The later broods are usually less distinct in their limits than the earlier. During the dry season nearly all the froghoppers are in the egg stage, but occasional unexplained records are known of adults persisting through the dry season. (p. 62).

Four other froghoppers of the genus *Tomaspis* are known in Trinidad. *T. rubra* feeds on the Christmas Bush (*Eupatorium*). *T. pubescens* feeds on grass, chiefly in moist spots along river banks, and is an alternative host of some of the parasites of the sugar-cane froghopper. *T. guppyi* also feeds on grass but is very rare and local. An unidentified species is known only from two nymphs found on a creeper on a forest tree in the mountains. There are also species of the genus *Clastoptera* on Casuarina and Hibiscus, and *Cephisus sp.* feeding possibly on Immortelle. (p. 63).

THE ENEMIES OF THE FROGHOPPER.

The chief enemy of the eggs is the Vermilion Egg-parasite (*Oligosita giraulti*), a minute red Chalcid. Its life cycle is about thirty days and it can breed during most of the dry season when the froghopper itself is inactive. It is almost certainly native to Trinidad and is not likely to increase much above its present limits. It probably has some other host in Trinidad. Abroad it is known from British Guiana to Costa Rica on various species of froghoppers. (p. 65).

The Trash-Coloured Egg-Parasite (*Paraphelinus tomaspidis*) was recorded in 1913 as destroying froghopper eggs, but this habit has never been confirmed and it is doubtful if it is of any value as a control. (p. 65).

In Panama a new egg-parasite of the genus *Anagrus* was found. (p. 66).

Thrips of the genus *Haplothrips* and ants are known to destroy the eggs, and eggs are sometimes found filled with a fungus which may have killed them. (p. 66).

The nymph is eaten by some birds but the frothy covering seems to render them unpalatable to most. They have been found in the stomachs of the Boat-tail (*Quisqualus lugubris*), the Golden-head (*Agelaius icterocephalus*) and the Manicou-Bird (*Geothylpis aequinoctialis*). (p. 66).

The Syrphid fly is the most important enemy of the nymph. It lays its eggs in the froth of the froghopper, and the maggot, which hatches in about two days, destroys the nymphs by piercing their skin and sucking out the juices. One maggot may destroy 30–40 nymphs. The larval stage lasts nine or ten days and the pupa about the same time. The complete cycle takes about three weeks. In the moister parts of the island the fly breeds throughout the year, but in the cane fields it is not found in the dry season and is seldom common before the second or third brood of froghoppers. It ranges outside Trinidad from Mexico to Brazil on various species of froghoppers. (p. 67).

An attempt was made by Kershaw and Guppy in 1914 to breed large numbers of this fly through the dry season so that they could be liberated to destroy the first brood in the following year. Owing to the difficulty of obtaining, during the dry season, enough nymphs for the syrphid maggots to feed on, the work had to be abandoned. (p. 69).

Another parasite of the nymph is the Mermis worm, a Nematode which is occasionally found coiled up in the abdomen of the nymph or adult froghopper. It is not common and nothing is known of its life history or habits. (p. 70).

The Green Muscardine fungus is only rarely found on the nymphs in the field (p. 70).

The adult froghopper has a long list of parasites and enemies. Seventeen different birds have been proved to eat adult froghoppers (*see* Table IV p. 71). One of the most important of these is the Scissors-tail Fly-Catcher which migrates to Trinidad from the mainland of South America at the beginning of each wet season, arriving in May or June and leaving in October and November. (p. 70).

Lizards are an important enemy of the froghopper in uncultivated land but in the cane fields they are generally scarce, perhaps more so in Trinidad than elsewhere. This has been said to be due to the mongoose, but agricultural processes, particularly burning the trash, destroy many lizards. (p. 78).

Cultivation, and possibly also the mongoose, have had a similar effect in reducing the number of frogs and toads in the cane districts (p. 79).

Two predaceous grasshoppers, *Xiphidium* and *Pflugis*, destroy small numbers of froghoppers, but both are commoner in the traces and abandoned land than among the canes. (p. 79).

Four species of ants have been found killing froghoppers in Trinidad and others are known in other countries. Ants sometimes do more harm than good by carrying off froghoppers that are infected with green muscardine. (p. 80).

On one occasion an adult of the small luminous beetle, known locally as the candle-fly or fire-fly (*Lampyridæ*) was reported eating an adult froghopper. (p. 80).

Several Soldier-Bugs (*Reduviidæ*) are known to destroy froghoppers in Trinidad and other countries. The Mexican Bug was one of these; it was introduced by Urich but failed to establish itself. Owing to their varied food it is difficult to estimate the relative harm and good done by these insects (p. 81).

Spiders, particularly the jumping spiders or *Attidæ*, destroy many adult froghoppers (p. 82).

The green muscardine fungus is probably the most important natural agent in the control of the adult froghopper. Under favourable conditions the greater part of a brood may be killed by it. It is, however, rarely common on the first brood and with the later broods its prevalence depends on weather conditions (p. 82).

Attempts to infect fields artificially have been made but so far the results have not been conclusive. The fungus can, with precautions, be readily produced in quantity by growing on sterilised rice or similar media. The spores so obtained are mixed with rice flour and spread on the fields by blowers, or the adults are attracted into the mixture by light traps. The success or failure of the individual experiment depends entirely on atmospheric conditions. In unfavourable weather even the natural infection dies out, while when conditions are suitable for its spread there is usually sufficient natural fungus present to start an epidemic. The cost of such treatment is however comparatively small and on most estates would be repaid by the saving of a few acres of cane. The method is worthy of further investigation (p. 84).

The Empusa fungus kills the adult froghoppers and fastens them to the leaf of the cane in exposed situations usually some distance from the base of the leaf. It is much rarer than the green muscardine and has

never been recorded before October. It can only be cultivated with difficulty and does not lend itself to artificial distribution. On occasion it has destroyed large numbers of froghoppers and infected specimens are killed more rapidly than by the green muscardine (p. 86).

Hyper-parasites. Under this heading are included the animals which destroy the enemies of the froghopper and so allow it to increase.

The mongoose has been held responsible for the increase of the froghoppers by destroying their enemies. Comparisons of the food of the mongoose in districts where it has been long abundant with districts where it has only recently appeared, do not show any change of diet, which would be expected if it had been responsible for the extermination of birds, lizards, frogs and toads. Blight was known before the introduction of the mongoose and the outbreaks of recent years have not been correlated with the spread of this animal. The conclusion reached is that the mongoose, although doubtless undesirable, and possibly to a very limited extent contributing to recent outbreaks of pests, is not the cause, nor is it even one of the most important causes, of the outbreaks of froghopper blight in Trinidad (p. 87).

The mongoose eats a number of rats and these can climb and have been found destroying the nests of insect-eating birds.

Birds, lizards, ants, spiders and other general insectivorous enemies of the froghopper sometimes do harm by destroying its insect enemies (p. 91).

The spider and grasshopper enemies of the froghopper are destroyed by fossorial wasps, while the former are also killed by an entomogenous fungus (*Gibellula*) (p. 91).

A worm believed to be parasitic, has been found in the pupa of a Syrphid fly (p. 91).

In Fig. 19 (p. 92) an attempt has been made to show the relation of the froghopper to its parasites and hyper-parasites. In the centre the froghopper is shown and in the first ring round it all its natural enemies grouped according as they feed on the egg, nymph or adult. In the outermost ring are the hyper-parasites or enemies of the enemies, and in the intermediate ring are shown other hosts or foods of the parasites and hyper-parasites. The arrows indicate that the animal at the tail of the arrow destroys the animal at the head. A careful study of this diagram will show the extraordinary complexity of the relationships and the great difficulty of deciding whether any particular animal is desirable or undesirable. (p. 92).

THE CANE ROOT FUNGI.

Two distinct kinds of root fungi are found attacking the canes in Trinidad.

The *Marasmius* type mats together the lower sheaths of the cane with a white dried-paste-like mycelium (Pl. VII) and produces spores on small mushrooms (Pl. VIII). The *Odontia-Himantia* fungus mats the lower sheaths of the cane with a feathery mycelium (Pl. IX) and produces spores on a rough granular surface growth on the outside of the sheath (Pl. X) (p. 93).

Both these fungi can exist in a healthy field of canes living only on decaying vegetable matter and doing no harm. There is hardly a field in Trinidad where traces of one or the other cannot be found after a close search.

Under certain little understood conditions, particularly when the canes are suffering from other causes, these fungi become parasitic and

invade the root and rootstock, causing greater or less destruction according to the length of time the attack persists. Damage is usually most conspicuous in dry weather. If conditions become normal recovery takes place rapidly and diseased canes may throw out quite healthy shoots. Root disease is almost always more serious in ratoon canes than in those recently planted. (p. 94).

FACTORS INFLUENCING THE PREVALENCE OF BLIGHT.

Rainfall. It has been shown in a previous report that the distribution of the rainfall during the year has an important effect on blight.

(1) Alternation of wet and dry periods during the growth of the cane is an important factor in determining the prevalence of blight.

(2) A long dry season followed by unusually heavy rains in June and July is frequently connected with wide spread blight.

(3) The most important climatic condition however appears to be the severity of the "Indian Summer", a dry period in September or October. A severe Indian Summer is a general condition both of localities damaged by blight in one year and of years of widespread blight in one locality. (p. 96).

This effect is brought about in several different ways:

(1) The effect on the froghopper itself.
(2) The effect on its enemies.
(3) The effect on the cane.
(4) The effect on root disease of the cane.

(1) Except in damp localities, the conditions during the dry season are below the minimum moisture required for the froghopper to breed. With the first rains of the wet season all the eggs hatch and breeding starts. The dates of the broods are determined by the date of the first rains. The first brood is about 57 days after the beginning of the rains, and the second and third at successive intervals of about 50 days. The continuation of the rainfall late in the year does not cause the production of a fourth brood so frequently as might be expected, even when, as indicated by the large first brood of the following year, many eggs are present. (p. 102).

(2) The vermilion egg-parasite can carry on at a lower degree of moisture than that required by the froghopper, and has been captured during the dry season in places where the froghopper has ceased to breed. The Syrphid fly disappears in the dry season, and appears to require a higher minimum of moisture than the froghopper. The severe fires that occur in prolonged dry seasons destroy large numbers of the lizards, frogs, toads, spiders, etc. that feed on the froghoppers. (p. 103).

(3) The cane is checked by a severe drought during its growing period (p. 104).

(4) The root fungus is always more severe in canes suffering from the effects of dry weather (p. 104).

Contour. Low-lying districts are in general more liable to attack than hilly ones. In some cases the blight is worse at the top of a slope than at the bottom, in other cases the reverse is found. This is nearly always a question either of the distribution of different soils at different levels or of drainage and surface washing (p. 105).

Soil. An outline is given of the chief types of soil which are found in the sugar districts of Trinidad. These soils are more uniform in the north and more confused and irregular in the south. Correspondingly we find the blight more uniformly widespread over large areas in the Northern districts and more irregular and patchy in the Southern districts (p. 106).

A number of examples are given of the great influence of the soil. The red soils in the Naparimas are always more liable to damage than the black soils. Badly damaged parts of the field are always found to correspond to patches of heavier poorer soil. Fig. 29 shows a very striking instance of the way in which the damaged fields on one estate have been confined to the red soil areas (p. 109).

Chemical analysis of a number of soils of damaged and undamaged fields show that the undamaged fields are, on an average, alkaline or neutral in reaction, with a higher content of lime, carbon dioxide and humus. The damaged fields were neutral or acid with a lower percentage of lime, carbon, dioxide and humus, and possibly a higher relative amount of SO_3 (p. 110).

Drainage has considerable influence on the prevalence of blight, and in fields liable to damage the drainage should be improved wherever possible. A field in which the drainage had been improved in one-half showed a distinct line across the field between the unimproved part that was distinctly blighted and the improved part that was much less damaged (p. 113).

Manuring. Pen manure is the most valuable natural manure in use in Trinidad and its effect on the condition of the soil is so beneficial that every effort should be made to increase the quantity available. Sheep manure from Venezuela and lagoon mud from the Oropuche Lagoon are also good, and fields treated with them are considerably improved and suffer less from blight (p. 114).

Sulphate of Ammonia is the commonest artificial manure in use but the acid conditions found in the soils most liable to blight emphasizes the fact that this manure should not be used continuously on soils deficient in lime (as are most Trinidad soils) without counteracting the effect at intervals by heavy applications of lime. (p. 114).

The age of the Cane at the Time of the Attack has a very important effect. Plant canes in their first year are much less frequently attacked than ratoon canes. Second ratoons are usually worse damaged than first ratoons. (p. 115).

There is some evidence that the ensuing crop of ratoons in a field cut earlier in the year is worse damaged than in a field cut later. The canes are larger but a relatively greater increase in the number of froghoppers may take place (p. 116).

Rotation. The system of replanting a field immediately after the old crop is very undesirable from the point of view of disease and insect control. Conditions are most suitable for the insects and diseases to pass on from one crop to the next. Abandoning the land to whatever grasses and bush may grow up is little better, as many insects, including the froghopper, persist in the grass and the abandoned plot is a source of danger to the surrounding fields. (p. 117).

Tillage. There is evidence that good cultivation, by loosening and aerating the soil, not only improves the cane but actually reduces the number of froghoppers present. Occasionally damage is reported following immediately on the use of implements, particularly sub-soil ploughs, but when one considers the time taken for the development of the greatest injury, it is usually seen that the damage in these canes would have appeared whether or not the implements had been used. (p. 118).

Variety. No variety of cane is immune, but a few are more resistant than others. "Uba" and "Badilla" are the most resistant, but are unfortunately not generally considered suitable for cultivation (p. 119).

Presence of Pests and Diseases. As a general rule 20 froghoppers per stool will produce visible signs of damage, and 50 to 100 per stool will produce severe damage. Fields in poor condition suffer more from a small number of insects than better fields do from a larger infestation (p. 120).

Root fungi are constantly found in blighted fields as well as various insect pests of cane which weaken the cane and make it less resistant to froghopper attacks (p. 120).

Allowing for changes in season and age of plants a field attacked one year is more liable to be attacked in the following year than one previously free (p. 121).

GENERAL PROBLEMS.

The question of the relative importance of the adult and nymph froghopper and of the root disease is discussed.

The froghopper is considered as the most important cause of the blight because of (1) its constant presence in blighted areas, (2) the constant presence of streaks on the leaves in severe blight, (3) the occurrence of blight in plant canes when no other complicating disease is present, (4) the variation in time of the first appearance of blight according to the date of the first brood, (5) the periodicity of the blight (p. 122).

The adult is considered as more important than the nymph because the blight is never severe until the streaking of the leaves has developed and is at its worst shortly after the greatest flight of adults. Symptoms of blight have been produced in canes, which have never had nymphs, by caging on them a number of adults (p. 123).

In addition several of the symptoms of blight, including in particular the narrowing of the cane, have been produced in normal canes by imitating the leaf destruction of adult froghoppers by removing the greater number of leaves from the cane (p. 124).

The spread of injury in the leaf from the original point of infection indicates the possibility of some toxin or enzyme being introduced into the plant (p. 124).

Root disease is considered as playing its most important part after the froghopper has damaged the cane and particularly after the second brood, when the damage may cease to be periodic and continue to increase entirely owing to the effect of root fungi (p. 125).

The attacks of root disease follow on the froghopper attacks which are the prime cause of injury (p. 125).

There is no definite evidence as yet that canes damaged by root fungi are more attractive to froghoppers. On the other hand the conditions which lead to root fungus attacks are nearly always those which allow the froghopper to breed more freely (p. 126).

Influence of Environment. A study of Section IX indicates that the most important factor in determining the prevalence of blight is the humidity just above and just below the surface of the ground.

(1.) Extreme dryness in dry season tends to increase blight.
(2.) Moderate dryness in dry season tends to reduce blight.
(3.) Dry weather in wet season tends to increase blight.
(4.) Normal weather in wet season tends to reduce blight.
(5.) Very wet weather in wet season tends to increase blight.

In Table VII. an attempt is made to explain these facts by the known effect of moisture on the cane, the root fungi, the froghopper and its enemies (p. 126).

It is shown that with excessive dryness both the froghopper and all its enemies are dormant, so that no reduction in numbers will take place. At a slightly higher grade of moisture the vermilion egg-parasite is able to breed and reduce the number of eggs. At the third grade the froghopper can breed and so outdistance the vermilion egg-parasite. At a still higher humidity both the syrphid fly and the green muscardine fungus come into play and reduce the froghopper, while the heaviest rains do not affect the froghopper, but reduce its enemies and have an injurious effect on the canes (p. 128).

Size of Broods and Periodicity of attacks. There is no definite relation between the size of the broods in one year. Sometimes the first is the largest and sometimes the smallest. The second, is as a rule, that by which most damage is caused. Frequently the third brood is very small after a large and injurious second brood. More accurate study of conditions may lead to an explanation of these facts (p. 129).

No adequate explanation is available to explain the periodic recurrence of severe blight at intervals of three or four years (*see* fig. 7). It is possibly connected with the cycle of agricultural operations. (p. 130).

The froghopper appears to have been more serious within the last fifteen years than formerly. This is the case not only in Trinidad but in other countries and with other insects besides froghoppers. It is not considered that either the introduction of the mongoose or the development of seedling canes are responsible for this increase. It is more likely part of a wider influence of the spread of civilisation, population, and cultivation in a country which has not yet worked out for itself reliable rotational methods of agriculture to combat the disadvantages inherent in Man's artificial method of planting large areas with the same crop (p. 130).

CONTROL.

With tropical crops, and particularly with sugar-cane, methods of prevention are more practicable with most pests than methods of cure. With the froghopper the most important preventative consists of getting the soil and the crop into such a condition that a less suitable environment for the breeding of the froghoppers is produced.

Soil Improvement. The drainage should be improved wherever practicable; on the flat lands the drains should be run as close together as is economically possible and they should be kept in working order even on lands temporarily abandoned (p. 132).

Manuring. Nearly all lands in Trinidad require more pen manure and more lime. The shortage of labour should produce an increased demand for animal cultivation and these animals will produce pen manure. Artificial manures are best used in cases of blight only where the land is good, but suffering from an outbreak owing to temporary unfavourableness of other conditions (p. 133).

Tillage. Every opportunity should be taken to improve the tilth and depth of the surface soil by careful tillage. Fields should when possible be laid out to correspond with soil changes so that the tillage necessary for one part will not be injurious to the other (p. 133).

Selection of Varieties. There is so little difference in resistance between different varieties, with the exception of "Uba" and "Badilla", that the planter, unless he is willing to grow one of these two, is best guided in his choice by other circumstances than the prevention of disease (p. 134).

Reduction of Ratooning. Only plant and 1st ratoon canes should be grown on lands which have shown themselves constantly liable to blight, until the soil can be worked up into a better condition by more frequent cultivation and manuring (p. 134).

Rotation. This is is one of the most important methods of soil and cultivation improvement, which sooner or later Trinidad will be forced to adopt. Sugar countries in other parts of the world have already worked out systems and examples will be found on p. 135.

As rotation crops pasture, corn, guinea grass, and upland rice have been suggested but, all being *Gramineæ*, they suffer from similar pests and the froghopper and root disease are not eliminated (p. 136).

The best rotation crops are *Leguminosæ* of which many have been tried. Bengal beans, cow peas, and sword beans in particular have shown signs of being adapted to use as cover crops (p. 137).

Among the non-leguminous crops, yams and sweet potatoes are the best, as they ensure good cultivation of the ground and produce a financial return (p. 137).

On good lands a crop of peas, beans, or sweet potatoes could be grown between the cutting of the canes and replanting later in the same year.

On poorer lands a crop of yams, or beans followed by sweet potatoes could be grown after the cutting of the crop, and the field replanted as crop plants early the next year.

On the poorest land a crop of yams or cassava could be grown for the remainder of the year after cutting and a leguminous crop the following year, followed by the cane plants in the fall (p. 138).

Direct Control. *Destruction of Eggs.* Removal of the dead leaves from the cane will remove many of the eggs, but the trash so removed must not be left in the fields but should be carried to the pens. The trashing to be of any value as a control must be done when the greatest numbers of eggs are in the trash, which is about ten days after the height of a brood. Neglect of this will render the operation valueless. Trials have shown that there is little if any chance of the survival of eggs in trash carried to the pens and distributed as pen manure some months later (p. 138).

Weeding has a similar but less important effect and to be of any use must be done at the same period (p. 139).

Burning destroys a certain proportion of the eggs of the froghopper, but also many of its enemies and much good vegetable matter which would have formed humus. As little burning as possible should be carried out (p. 139).

Spraying has been recommended but is not practicable (p. 140).

The nymphs may be reduced by weeding and in some countries, but not in Trinidad, by flooding the land (p. 140).

Spraying for nymphs has been recommended, but no reliable cheap liquid has yet been discovered. The cost of the method, even with a cheap spray, and the labour required to distribute it are much against its general adoption (p. 140).

The nymphs can be crushed in their froth or hand collected by gangs of children, but both methods are expensive and only possible on a small scale.

The adult froghoppers are sometimes collected by hand, but this is laborious (p. 143).

Spraying with kerosene emulsion has been recommended by Gough, but no field trials have ever been made (p. 143).

Light traps catch large numbers of adults, but only about 1 per cent. of these are females. Bright lamps are but little more attractive than oil lamps, and green and red lights are found to attract fewer adults than white, and no greater percentage of females. Lights near the ground are more successful than if placed two to four feet up. Other insects are destroyed by the lamps, but on the whole more are injurious than useful. The light traps may be used for the spread of the green muscardine fungus, but the method suffers from the limitations due to the effect of weather on the spread of infection (p. 143).

The adult froghoppers can be caught in very large numbers by the use of nets in the late evening and early morning when the adults are sitting on the grass and cane leaves. Nets have been designed drawn by mules in order to cover the ground rapidly in the limited time available. Experiments are being continued on this line (p. 146).

Natural Enemies can be encouraged to a limited extent by providing trees for birds to nest in, and by stopping all unnecessary burning. At the same time the froghopper is a native insect and its enemies are probably on the average as efficient as they are ever likely to be (p. 147).

If the search for new enemies in other countries is again carried out it must be recollected that it is a long and uncertain process. New enemies are more likely to be found outside Central America, and Africa is suggested as a likely place. At least two men should be engaged in such a search, as results will be obtained sooner and there is less likelihood of failure (p. 147).

Several possible types of new enemies are indicated (p. 149).

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