TRINIDAD AND TOBAGO.

133

Minutes and Proceedings

of the

Froghopper Investigation Committee.

PART XII.

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1928.

THE COMMITTEE.

Appointed by His Excellency the Governor to continue the Investigation of the Froghopper Pest.

HON. W. G. FREEMAN, B.SC., A.R.C.S., *Director of Agriculture (Chairman).*

MR. G. EVANS, C.I.E., M.A., *Principal of the Imperial College of Tropical Agriculture.*

HON. SIR FRANCIS WATTS, K.C.M.G., D.SC., *President of the Agricultural Society of Trinidad and Tobago.*

MR. S. W. FITT, *President of the Trinidad Chamber of Commerce.*

MR. E. A. ROBINSON, *Chairman, Trinidad Sugar Manufacturers' Association.*

CAPTAIN W. F. WATSON, O.B.E., *Attorney for Kleinwort, Sons & Co's. Waterloo Estates.*

MR. J. W. ARBUCKLE, *Attorney, Caroni Sugar Estates, Ltd.*

MR. J. H. TAYLOR, *Attorney, Orange Grove Estates.*

MAJOR A. M. MCCULLOCH, *Manager, Esperanza Estate.*

PROFESSOR F. HARDY, M.A., DIP. AGR., *Imperial College of Tropical Agriculture.*

FROGHOPPER INVESTIGATION COMMITTEE.

Minutes of the Twenty-eighth Meeting.

The twenty-eighth meeting was held at the Imperial College of Tropical Agriculture, on Wednesday, 16th May, 1928, at 9.30 a.m.

Present :—Hon. W. G. Freeman (*Chairman*), Mr. G. Evans (*Principal, Imperial College*), Sir Francis Watts, Major A. M. McCulloch, Messrs. G. C. Skinner, J. W. Arbuckle, J. H. Taylor, R. Follett-Smith, and F. W. Urich.

Before proceeding to the business of the meeting, the Chairman welcomed Mr. J. Burrell, a Director of the Ste. Madeleine Sugar Coy., who was present as a visitor.

1. The minutes of the twenty-seventh meeting, having been circulated, were taken as read, and were confirmed.

2. *Financial Statement.*

A statement of expenditure for the month of April, amounting to £301, was laid.

3. *Progress Report.*

A progress report to 15th May, 1928 was submitted (appended page 39). After adding "and have been handed over to the Professor of Botany at the Imperial College for growing" to the paragraph referring to cover crop seeds, it was approved.

4. *Treatment of farmers' lands if the froghopper becomes severe.*

The memorandum (appended page 45) prepared by Professor Hardy and Mr. Urich, which had been circulated, was discussed. It was decided to postpone consideration of all the suggestions with the exception of one—2 (*b*) dealing with the employment of school children.

The feeling of the meeting was that the use of Cyanogas and other direct control measures, in the absence of any large outbreaks in the past, had not been fully tested out on large estates to warrant compulsory measures for farmers being recommended ; it was thought advisable to await further results of dealing with an outbreak on a larger scale than the one of the past season.

In regard to school children, the meeting decided that an educational campaign in the schools would be of considerable value. It should consist of nature study lessons, not only on froghoppers, but also on the large and small moth borers of the sugar-cane. The secretary was directed to prepare suitable leaflets and wall diagrams in consultation with Sir Francis Watts and Mr. J. H. Taylor for the next meeting.

At this stage, Mr. Evans asked to be excused, and left the meeting.

5. *Liming trials at the Usine Ste. Madeleine.*

With reference to Progress Report of 18th April, 1928 "Liming trials" para. 1, Mr. Urich raised the question as to whether the cost of the 300 tons of lime required was to be borne by the Committee or by the Ste. Madeleine Sugar Coy.

In the discussion which followed, no definite decision was reached, but the consensus of opinion was that in an experiment such as this where liming was to be carried out beyond ordinary estate requirements, in order definitely to test whether it was possible to correct soil acidity, and as a result to reduce liability to froghopper blight, the cost of the lime should be met from the Committee funds. It was agreed to leave the matter in the hands of the chairman in consultation with Messrs. Turner and Follet-Smith.

W. G. FREEMAN,
Chairman.

18th July, 1928.

PROGRESS REPORT.

15th May, 1928.

Weather.—The weather for the past month has continued dry. A heavy precipitation of 1·5 inches on 13th April at Caroni was recorded. From that date the total rainfall has been 0·35 inches.

General.

Most of the canes have been reaped, leaving the fields bare and exposed to the action of the sun and wind. Froghoppers are almost absent, but a few nymphs have been observed on the Guaracara flat in damp spots on affected areas of last year.

Observation Plots.

Little change is noted in the moisture content of the soils of the observation plots.

Caroni.—Figures were presented in the last progress report demonstrating that the soil of the Caroni bad plot was dangerously dry. During the past month, two experiments have been made to compare the water supplying power of the soils of the good and bad plots at Caroni. The results were obtained by inserting artificial roots of porous porcelain in the soil at a depth of nine inches.

The weight of water absorbed by an artificial root.

Two hours exposure.

	27th April, 1928.	8th May, 1928.
Good Plot	0·399 gms.	0·470 gms.
Bad Plot	0·0252 gms.	0·043 gms.
Ratio Good to Bad	15·8	11·0

Conclusion.—The rate of water supply to cane roots at a depth of nine inches was 15·8 times greater in the Caroni good plot soil than in the bad plot soil on 27th April. On 8th May the rate was 11·0 times greater. The results of these experiments will be reported at greater length in the Proceedings.

Waterloo.— The observation plots at Waterloo Estate were reaped on Saturday, 21st April. The yields obtained were :

	1928.		1927.
Good Plot	15	tons per acre.	7·75
Bad Plot	11·75	do do.	3·80

The small difference between the yields of the two plots in the absence of froghopper attack should be noted.

The canes are second ratoons, B. 6308. The plots are to be left to ratoon another year (third ratoons).

Surface soil temperatures are being determined at Waterloo by means of a recording thermometer. The bulb of the thermometer lies upon the soil surface and is lightly covered with powdery soil. The highest temperatures recorded within the period 12th April-2nd May, are :

Date.	*Maximum temperature of surface soil.*
April 23	110°F.
25	109°F.
26	108°F.
27	108°F.
28	119°F.
29	112°F.
May 2	112°F.
3	108°F.

It is interesting to note that the killing temperature for froghopper eggs is, for five minutes exposure, 140°F. and for twenty minutes exposure, 122°F.

Treatment of Traces.

A mowing machine is being used at Caroni on dry traces. The dried grass is cut down and fired. This operation will clean the traces for possible dusting during the wet season.

Soil Survey.

1. The survey of Brechin Castle Estate by Mr. Ross has been completed; some 300 samples have been obtained. Their examination for reaction has been completed, and texture data are accumulating.

2. Mr. Ross has commenced the soil survey of Esperanza Estate. Sixty samples have already been collected.

3. On the completion of the survey of Esperanza, Mr. Ross will commence a survey of the lands east of Woodford Lodge Estate.

4. Mr. Steven is continuing the survey of Williamsville Estate.

5. The area between Caroni and Woodford Lodge Estates, and areas north of Caroni Estate are being surveyed.

Froghopper control.

The dusting of the cut stumps of recently reaped fields with Cyanogas-lime mixtures at Woodford Lodge Estate is proceeding very slowly owing to the shortage of labour. Nineteen acres have so far been treated. Adze samples of the dusted and undusted stools are showing more or less the same number of egg-hatchings; the dusted fields yielding a trifle less. It is, however, too early to draw any definite conclusions, since, at the present time, froghopper eggs are hatching irregularly.

The mixture used consisted of 1 part Cyanogas to 3 parts of ground limestone. It is possible that this dilution is too great, or that, in spite of all the precautions taken, the lime is not dry enough. A modification of the dusting mixture will be tried.

Mr. Ross, observer at Waterloo, is noting the reaping of fields suspected of containing eggs. He advises dusting where needed.

Study of froghopper eggs.

1. The batch of eggs of the 31st January has now completed development and the period of hatching has been between the 14th February, when the first nymph appeared, to the 30th April, when the last egg hatched.

Out of a total of 37 eggs, three turned black and did not hatch.

Mr. Rodriguez records the following observations :—

2. Of the batch laid early in February and put to hatch on 15th February, five hatched on 16th April. Hatching has continued since, and there still remain a few eggs unhatched.

3. Of the batch laid and put to hatch on 15th March, two hatched on 2nd May. Since then, no more hatching has been observed.

4. Of the batch laid and put to hatch on 20th March, none have hatched, though black lids started to appear on 12th April. Most of the eggs have now developed black lids.

A batch laid in February and kept moist for a month, followed by drying for two months, have now been put to hatch.

Liming Trials.

Caroni.—A further field of Caroni Estate is being treated with ground limestone.

Woodford Lodge.—A lime hole experiment is being set up by Mr. E. B. Smith at Woodford Lodge. Five holes are being treated with lime and five are left as controls. Ratoons stump are being planted in all these holes.

Lime requirements of Woodford Lodge soils are being determined for the information of the management.

Waterloo.—Liming experiments have been initiated on three estates of the Waterloo group. The experimental fields No. 3, Lime Fence, Perseverance, No. 51, Camden, No. 38, Exchange have been sampled before the application of the limestone.

U.S.M.—A lime hole experiment is being initiated at Harmony Hall Estate.

Irrigation.

Samples of skimmings water collected at Caroni were found to be acid. It has been found that on exposing skimmings water to the air in a dish, the reaction rises to neutrality. Soil treated with skimmings water and air-dried was found to have a more acid reaction. It is possible that exposure to air may cause the soil reaction to become more alkaline.

Artificial Pen Manure.

A series of laboratory trials to test the effect of molasses on cane megass for the making of artificial pen manure has been initiated. At the same time, small scale trials under estate conditions have been commenced at Waterloo.

Soil Maps.

Permanent reaction and texture maps of Caroni, Waterloo and Felicite Estates are being prepared by Mr. Williams.

Limestone.

Three samples of limestone have been mechanically analysed for Woodford Lodge Estate.

Cover crop seeds.

Five varieties of velvet bean have been received through the kindness of the Bureau of Plant Industry, U.S.A., and have been handed over to the Professor of Botany at the Imperial College.

Chemical analyses.

Samples of cane roots taken from plants growing in good and bad areas at Caroni and U.S.M. have been analysed.

A memorandum on the possible means of control in cane farmers lands has been drawn up by Professor Hardy and Mr. Urich, and circulated among the Members of the Committee.

New record sheets for broods.

Printed forms are being prepared for use in the coming wet season.

Weed collection.

Mr. Steven is making a collection of typical weeds of the chief soil types and of the observation plots at the Usine Ste. Madeleine.

Examination of Ratoon Canes.

An examination of ratoon canes growing on acid and alkaline soils for accumulations of iron and aluminium at the nodes has been initiated at the Usine Ste. Madeleine and at Caroni.

Special Soil Survey.

Mr. Turner is continuing the examination of the manner in which selected soils of the cane-growing regions dry out under controlled conditions.

Determinations are also in progress of the contents of exchangeable sodium, potassium and magnesium of certain representative soils.

F. W. Urich,
R. Follett-Smith.

MEMORANDUM ON THE POSSIBLE MEANS OF FROG-HOPPER CONTROL IN CANE FARMERS' LANDS.

By F. Hardy (*Chairman, Scientific Committee*) and F. W. Urich (*Secretary, Scientific Committee*).

Introduction.

The work of the Scientific Committee has so far demonstrated somewhat completely that there are three practical means whereby Froghopper Blight in Trinidad may be controlled and, at least, diminished in severity. They are :—

(1) *Dusting with Cyanogas*—Nymphs in the wet season ; eggs in the dry season.

(2) *Liming cane-lands*, so as to confer a marked alkaline reaction on the soil, and to improve its lime status.

(3) *Irrigation* in the dry season as so to improve the water relations of the cane crop.

To these may be added other procedures, such as *manuring* with pen manures, synthetic organic manures, and cover crops, so as to improve both water-relations and nutrient-relations of the cane-crop, and also changing the relative arrangement of fields under plant canes, ratoons and fallow. These subsidiary means have not yet been sufficiently explored experimentally to warrant definite conclusions.

Whilst these various means might nearly all be applied by the proprietors and managers of the larger sugar estates, it is evident that cane farmers cannot adopt them unaided. They should be encourgd at least to *lime* their acid soils, and to appreciate the value of *Cyanogas* dusting.

Suggestions for Dealing with Farmers' lands.

1. We believe that *immediate proclamation* of the Froghopper as a Pest under the Plant Protection Ordinance, would have a beneficial effect in (*a*) calling the attention of cane farmers to the seriousness of the situation, (*b*) permitting inspection officers to gain easy access to farmers' lands for purposes of observing and recording froghopper incidence.

We consider that these effects would be beneficial, even if the law were not generally enforced.

2. We recommend that additional observers be recruited during the seasons when the various broods of nymphs emerge (*i.e.* : June to September). These observers might be recruited (*a*) from employees of the larger sugar estates (*b*) from school children.

(*a*) *Estate employees*, such as drivers, have already rendered good service (*e.g.* : at Harmony Hall, Usine Ste. Madeleine) ; their spheres of activity may, in certain cases be extended to farmers' lands bordering the larger estates. They may be put under the control of section overseers, or of special senior observers, such as those already appointed.

(*b*) *School children* might be encouraged in the cause of public service, and by prizes and awards, to search for outbreaks of nymphs in farmers' canes during the proper seasons. The advice and assistance of the School Inspectors under the Education Department should immediately be sought on this matter. The opinion of the Director of Education would be especially valuable.

3. Having organized a more efficient system for observing and recording, it would next be necessary to take action to eradicate froghoppers on the farmers' lands. Farmers may be divided into two classes (*a*) those farming areas of *over* 10 acres, (*b*) those farming small holdings of *under* 10 acres.

(*a*) *The large farmers* should be encouraged to use Cyanogas on nymphs and on eggs. Meetings should be arranged at various centres, at which the aims and methods of Cyanogas dusting could be explained. A pamphlet, such as the one on the Cacao beetle, describing the life-history and the habits of the froghopper, might be prepared for distribution.

Cyanogas powder and dusting apparatus might be distributed at estate centres, and estate owners might (or might not) charge the farmers with the cost of the materials, as they think fit. For applying Cyanogas on a small scale, the bottle-and-quill equipment, described and used by Mr. E. E. Fabien at Cedar Hill Estate, (*Proceedings*, Pt. V, 1926, p. 134), might be employed.

The use of recording sheets should be encouraged.

(*b*) *The small holders* might be taught to employ simple mechanical means for eradicating froghoppers. For example, during the *dry* season soon after the canes are cut, the farmers might be advised to cut or shave off the exposed parts of the cane-stumps together with the surface soil immediately surrounding the stools, and to *bury* shavings and soil in deep pits. (Burning might be dangerous, and probably not every effective.)

During the wet season, many nymphs-in-spittle might be destroyed by poking with sticks. Damp trash, likely to contain froghopper eggs, might be stripped from the canes and used as bedding for the domestic cow or mule, or burned.

In some cases, Cyanogas powder and small hand-dusters might be lent to the more enterprising small farmers for use on their holdings.

4. It appears to us that the best way to deal with the farmers' problem is for the estate authorities to take over the responsibility of organizing future campaigns against the froghopper pest. It might be necessary for them to detail an overseer or senior driver to take charge of the work during the proper seasons, and even to establish one or more " flying squads " to aid farmers (particularly those whose lands lie at some distance from the estate centres) during times of need. Transport for the squads might be arranged by bicycle or estate railway trains, or even motor-cars.

Since it is likely that we shall have the froghopper pest with us for a considerable number of years in the future, it cannot be expected that the Froghopper Committee (which lapses in 1929) should take full responsibility for its eradication.

Were the necessary steps taken this year to organize the means for dealing with the problem, valuable experience could be gained, which would help matters considerably during coming years when weather conditions might favour the pest more than the proprietor.

Summary.

The methods recommended are :—

1. Proclaim the Froghopper a Pest under the Plant Protection Ordinance, and at once.

2. Recruit additional observers for locating and reporting out-breaks of nymphs, (*a*) from estate employees, (*b*) from school children.

3. Encourage and teach the larger farmers (farming over 10 acres) to use Cyanogas, and supply materials from estate centres.

4. Teach the smaller farmers (farming under 10 acres) to employ simple mechanical means for destroying nymphs and eggs.

5. Establish estate departments for dealing with the farmers' (and other) problems, and render aid by "flying squads" under proper control.

6. Initiate the means this year, so that the necessary experience may be gained whilst froghopper distribution is not wide-spread.

F. HARDY.

F. W. URICH.

24th April, 1928.

FROGHOPPER INVESTIGATION COMMITTEE.

Minutes of the Twenty-ninth Meeting.

The twenty-ninth meeting was held at the Imperial College of Tropical Agriculture on Wednesday, 18th July, 1928, at 1.30 p.m.

(There was no meeting in June.)

Present.—Hon. W. G. Freeman (*Chairman*), Professor R. C. Wood (*Acting Principal, Imperial College*), Hon. Sir Francis Watts, Major A. M. McCulloch, Messrs. J. H. Taylor, J. W. Arbuckle, R. Follett-Smith and F. W. Urich.

1. The minutes of the twenty-eighth meeting, having been circulated, were taken as read, and were confirmed.

2. *Financial Statements.*

Statements of the expenditure for the months of May and June, amounting to £335 and £324, respectively, were laid.

3. *Progress Reports.*

Progress reports to 15th June and 16th July, 1928 (appended pages 50 and 55), were submitted, and, after discussion, they were approved.

4. *Leaflets on froghoppers in connection with treatment of farmers' lands if the froghopper becomes severe.*

Mr. Urich submitted a pamphlet on the froghopper and its control, prepared in consultation with Sir Francis Watts and Mr. Taylor. Appended to the pamphlet were instructions to school teachers as to how it could be used as a basis for nature study lessons in schools.

After a full discussion, it was decided that the pamphlet, appended page 64, be published for general use, but that a four-page leaflet, appended page 71, in simple language, be prepared for the use of cane farmers principally.

Details of printing and cost were left to the Chairman.

W. G. Freeman,
Chairman.

19th September, 1928.

PROGRESS REPORT.

15th June, 1928.

Weather.—The rainy season is gradually approaching. More rain has fallen in the southern area than in the north, western and central areas during the last month. The rainfall recorded at these stations during the period under review (16th May to 13th June) is

Caroni	3·62 inches.
Waterloo	3·76 do.
Usine Ste. Madeleine	5·09 do.

The first heavy shower of the season fell in the southern districts on 17th May, when 1·45 inches were recorded at Usine Ste. Madeleine, 1·17 inches at Waterloo, but only 0·24 inches at Caroni on that day.

General.

It cannot be said that the first brood of nymphs has appeared. The few isolated nymphs reported at Caroni, Chaguanas and the Usine Ste. Madeleine are rather dry season hatchings. They occur in such places as the sides of drains, cracks in the soil, under clods of earth in ploughed fields and under trash in damp localities. No adults have been observed.

It is to be expected that the first brood of nymphs will appear towards the end of the present month. It is advisable that all arrangements for dusting should be made at once in order to be ready for any contingencies. The value of dealing energetically with the first brood cannot be too greatly stressed.

Experience during the past season of the practice of diluting Cyanogas with pulverised limestone does not warrant its continuation. The difficulty of obtaining dry limestone makes it advisable to use only undiluted Cyanogas.

Observation Plots.

Little variation, during the past month, has been recorded in the moisture content of the soils of the observation plots.

Caroni.—The plots are planted with young B.H. 10/12 canes. The plants average one foot in height. A marked difference is noted in the spring of canes in the two plots. In the last Progress Report figures were given for the water supplying power of the soils of the Caroni plots. It is proposed that further determinations be made during the advance of the wet season.

Waterloo.—Surface soil temperatures reported on 15th May showed that the maximum surface soil temperature was of the same order as the killing temperature for froghopper eggs (*i.e.*: 122°F for twenty minutes). Further figures obtained were :—

May 6	119°F.
7	119°F.
8	119°F.
9	119°F.

During the week 7th-13th June, the surface soil temperature was much lower, a maximum of 108°F. was recorded.

Usine Ste. Madeleine.—The observation plots of the Usine Ste. Madeleine support 1st ratoon BH 10/12 canes of an average height of five feet. Roughly one quarter of the bad plot has been accidentally burnt.

Treatment of Traces.

The use of a mowing machine for cutting grass on dry traces at Caroni is being extended.

Soil Survey.

The projected program of soil survey for the dry season will be completed within the next week.

The total number of all soil samples collected are :—

Up to 14th April, 1928, 3,136 samples.

Up to 14th June, 1928, 3,907.

During the past two months, 771 samples have been collected.

Examination of the Brechin Castle Estate samples for texture and reaction has been completed, and soil reaction and soil texture maps have been prepared.

The survey of Esperanza Estate by Mr. Ross has been completed, 264 samples have been taken on Esperanza, Phoenix Park and Lodge Estates. Examination of these samples for texture and reaction is in progress.

Mr. Ross has completed the survey of lands east of Woodford Lodge Estate.

Mr. Steven is continuing the survey of Williamsville Estate.

The survey of lands adjoining Caroni Estate, started by Mr. Shand, has been continued from the College, and will be completed within the next week. These samples have been examined for reaction, and texture data are accumulating.

Mr. Shand has surveyed the lands adjoining Orange Grove Estate.

Froghopper Control.

The dusting of cut stumps of recently reaped fields has been carried out at Waterloo. Mr. Ross has collected adze samples before and after dusting. These samples are being kept under moist conditions, and results will be reported in due course.

Adze samples from the dusted and undusted stools at Woodford Lodge Estate continue to yield nymphs; 12 samples from the control stools yielded 30 nymphs and 13 samples of dusted stools yielded 43 nymphs. No hatchings were obtained from 4 samples control and 3 samples dusted stools. At the time of writing, nymphs are still hatching, and final results cannot be given.

The results so far obtained are not encouraging. This, in all probability, is due to the fact that a very dilute mixture of Cyanog s with limestone (1 part Cyanogas to 3 parts of ground limestone) was used.

Nymphs are being dusted as they appear at Caroni and at Cedar Hill.

Study of Froghopper eggs.

These experiments are being continued by Mr. Rodriguez who reports as follows—:

1. The batch of eggs put to hatch on 15th February has completed development, the period of hatching extended from 3rd April to 30th May.

2. Of the batch put to hatch on 15th March, there still remain, a few unhatched.

3. Eggs mo'stened on 20th March, only started hatching on 30th May, but within just one week, all nymphs had emerged. This is a rather short period as compared with other hatchings.

4. In the case of the batch which was kept moist for a month followed by drying for two months, hatching commenced 13 days after remoistening, and has continued since.

Eggs laid on wet blotting paper and kept dry for three months were moistened on the 22nd May, and the first 2 nymphs hatched on the 8th June and subsequent days. The development of these eggs continue in the same irregular manner of the past dry season experiments.

Incidence forms.

The forms for recording the incidence of broods, as adopted by the Committee at the April meeting, have been issued to all estates with a recommendation to commence observations as from the week ending 9th June.

Liming data.

Owing to heavy rains, the large scale experiment planned at the Usine has been postponed until next dry season. The field, No. 7, Daisy, is being put under a cover crop during the interval.

Estate liming at Picton Papoure has been completed.

Irrigation Water.

Samples of water taken from the skimmings drain at Caroni after the completion of crop, and containing no factory waste, were found to possess the same reaction (pH 3·6) as a sample taken earlier and containing factory waste. The total acidity however is much lower (3·0 c.c. to 1·9 c.c. N alkali). Soil irrigated with this water undergoes no change in reaction. Examination of this problem will be deferred until it is possible to obtain samples representative of the water used for irrigation on the field scale.

Composite samples.

The examination of composite samples of soils for lime requirement and organic matter has been completed. The determination of the amount of available phosphate in the samples has been commenced.

Soil Maps.

Permanent reaction and texture maps of Caroni are being checked prior to distribution. Mr. Williams is preparing maps of Waterloo and Felicite Estates.

Examination of Cane nodes.

During the past month, experiments have been carried out with the view of investigating the effect of nodal accumulations of iron and aluminium. Solutions of iron and aluminium salts have been injected into growing canes, and the nodes and leaves of these canes are being examined in the laboratory.

Two large experiments have been carried out on the good and bad plots at Caroni and the Usine Ste. Madeleine. The accumulations of iron and aluminium at the nodes of cane have been estimated colorimetrically. The experiments have yielded very interesting results.

An experiment has been planned, and is about to be commenced, in which the accumulations of aluminium and iron will be estimated analytically.

Series of canes growing in cultures containing varied amounts of aluminium have been set up.

Cover Crops.

The Woolly Pyrol seeds, kindly ordered by the Principal of the Imperial College from India, have deen despatched, and are expected shortly. The consignment consists of 100 lb. each of the seed of the following varieties :—

Phaseolus Mungo (Mung).
do. *radiatus* (Urid).
do. *aconitifolius* (Moth).

F. W. URICH.
R. FOLLETT-SMITH.

PROGRESS REPORT.

16th July, 1928.

Weather.—The rainy season has commenced. The rainfall recorded at the Caroni and Waterloo Stations during the period (13th June-13th July) was :

Caroni	....	....	....	....6·94 inches.
Waterloo	....	....	....	....6·00 do.

More rain has fallen during this period in the north-western area than in the central area.

General.

With the advent of the rainy season, emergence of nymphs has continued, and at the end of the last month, it was evident that the first brood had made its appearance. Nymph emergence was first reported from the Usine Ste. Madeleine and from Waterloo Estate on 9th June. The first nymphs observed at Woodford Lodge were reported on 23rd June. Nymphs and adults were reported for the first time at Caroni on June 30th. Most fields on all estates, show 0-5 nymphs per stool, and in a few cases the incidence is higher, 11-15 nymphs per stool having been recorded in isolated spots. Adults are gradually issuing at the rate of 0-10 per stool, but in a sporadic manner.

Cyanogas dusting has taken place at the Usine Ste. Madeleine, Waterloo, Caroni, Rivulet, farmers lands at Esperanza and Woodford Lodge, but the work is not progressing at the desired rate on some estates owing to the lack of labour.

Natural Enemies.

Green Muscardine :—Observed at Chaguanas in Field No. 43. W/L on 13th July, 1928.

Egg parasite. — A specimen was blown into the laboratory at the College.

Birds : — Scissors Tail Fly Catchers are active in fields at Chaguanas.

Spiders :—Numbers of spiders are catching adult froghoppers at Chaguanas.

Ants. A Ponerine ant, *Ectatomma tuberculatum* was taken at Waterloo Estate by Mr. Ross. It was in the act of carrying off an adult froghopper. This is a new record, since this genus of ants generally preys upon weevils.

Observation Plots.

Caroni.—The soil moisture content of the Caroni observation plots has markedly increased during this period. The canes growing on these plots show definite improvement at the beginning of the month. Further determinations of the water supplying of the plots have been made.

Waterloo.—The soil moisture content of these plots has increased during the period under consideration.

On the 7th July, a soil compacter experiment was carried out on these plots.

Usine Ste. Madeleine.—The good observation plot of the Usine Ste. Madeleine supports BH 10/12 1st ratoons of an average height of six feet. The growth of canes on the bad observation plot is noticeably less dense, and the average height is five feet.

A determination of the water supplying power of these plots was carried out on 4th July. The results are appended.

The weight of water (in mgm.) absorbed by one soil point during a one-hour exposure period :—

Good plot.	*Bad plot.*	*Difference.*	*Difference required for significance.*
793 mgm.	694 mgm.	144 mgm.	198 mgm.

The difference in water supplying power of the soil of the two plots cannot be regarded as significant. The results however show a tendency towards a difference in favour of the good plot soil.

Soil Survey.

The projected program of soil sampling for the dry season has been completed.

All samples, with the exception of some twenty soils of Esperanza Estate, have been examined for reaction and texture.

Mr. Steven has completed the survey of Williamsville Estate.

Examination of these samples for texture and reaction is now proceeding.

The following maps have been prepared :

Brechin Castle	....Texture and reaction maps.
Esperanza, Lodge and Pheonix Park Estates	Reaction maps.
Survey of farmers lands, &c.	Texture map.

Study of Froghopper eggs.

These studies which had to be stopped on account of the absence of adults, have been resumed at the beginning of this month.

Eggs which had been kept dry for 3 months and had started hatching on 8th June completed their development on the 26th June. The first adults from this batch appeared on the 5th July, and emergencies are still occurring.

Composite Samples.

The examination of composite soil samples for available phosphate is being continued. Composite samples of Orange Grove, Woodford Lodge, Waterloo and Caroni Estates have been examined and the estimations completed.

Soil maps.

Permanent texture and reaction maps of Waterloo and Caroni Estates have been prepared by Mr. Williams, and distributed.

Cane Node Examination.

The injection experiments with solutions of iron and aluminium salts, mentioned in the last report, have been concluded.

Two large scale experiments, one at Caroni, and one at the Usine Ste. Madeleine, have been designed with the following objects :—

(*a*) The confirmation of results, obtained by colorimetric methods, by analytical procedures.

(*b*) The detection of a correlation between amount of accumulation of these metals at the node and the length of the corresponding internode.

(*c*) Demonstration of the increased accumulations of these metals at the nodes of canes growing on acid soils.

The material of these two experiments has already been obtained. Examination in the laboratory is in progress.

Cover Crops.

The Woolly Pyrol seeds, mentioned in the last Progress report, have arrived, and have been distributed among the estates.

In this connection, it is worthy of note that all the seeds which were packed with napthalene were free from weevils, those that were not so treated were badly infested.

F. W. Urich.
R. Follett-Smith.

PROGRESS REPORT.

13th August, 1928.

Weather.

The rainy season is continuing. The heaviest precipitations during the period under review appear to have occurred during the week 14th-21st July and 28th July-3rd August. The rainfall recorded at the various stations during the month of July and the period 1st-10th August is appended.

		July.	*1st-10th August.*
Caroni	....	6·62 inches	3·88 inches.
Waterloo	....	6·34 do.	4·66 do.
U.S.M.	....	4·57 do.	4·08 do.

It will be seen that the rainfall in the north-western and central areas has been heavier than that in the southern area during the month of July. The first half of the month of August has been marked by heavy rain. The weather is favourable to the growth of Green Muscardine fungus.

General.

A survey of the incidence cards, returned to date reporting the occurrence and severity of nymphs and adult outbreak, is appended in abbreviated form. The figures refer to the total number of fields of each estate reported weekly.

ESTATE.		9/6	16/6	23/6	30/6	7/7	14/7	21/7	28/7	4/8	11/8
	A.				13	17	5	16	12	14	4
Caroni	B.				4	1	3	7	4	2	
	C.							1	2		
Woodford	A.			3	5	14	19	23	30	7	36
Lodge	B.			3	5	15	33	30	43	42	41
	C.							2	8	3	17
	A.	2		3	9	7	8	19	15	18	no returns.
Waterloo	B.					3	5	5	11	7	
	C.										
Brechin	A.			4	5	9	17	16	15	3	11
Castle	B.					1	13	14	20	16	7
	C.										
	A.	3	4	38	42	58	71	41	47	40	no returns.
U.S.M.	B.			4	21	35	50	34	38	25	
	C.					1	5	6	5		

A—Presence of nymphs. B—Presence of adults. C—Presence of blight.

From a general consideration of the data so far collected, it may be assumed that the froghopper outbreak of this season is slight, and so far is comparable to the records of 1921.

Inspection of the above, chart shows that the froghopper outbreak of 1928 became noticeable in the first place at the Usine Ste. Madeleine. This occurrence may be explained by the fact that the precipitation at the Usine during the period 16th May-13th June, was much greater than that reported at Caroni or Waterloo.

The first brood of nymphs appeared to have reached its height at the Usine by the 14th of July. The central and north-western areas attained a maximum one week later.

In most cases the degree of infestation has been slight, the majority of fields marking one (0 to 5 nymphs per stool). The nymphs, in most cases, are being dusted with Cyanogas as they appear.

On most estates the attack appears to be confined to a few isolated danger spots, and generally in the same fields as last year when they are still supporting ratoon canes.

The most general outbreak appears to have occurred at Woodford Lodge Estate. It is from this estate that the only reports of the occurrence of serious blight have emanated. Severe blight is reported as occurring in two fields during the week ending 11th August.

Large numbers of adults are being caught by traplights at Cedar Hill and Tarouba.

Observation Plots.

Caroni.

The soil moisture content of the plot soils has increased during the past month.

The canes of both plots appear to be growing steadily since the advent of the rains, although marked differences in growth of cane are still to be noted between the two areas.

A determination of the water supplying power of the soils of these two plots, made on 4th August, gave the following results.

Weight of water (mgm.) absorbed by one soil point during one hour's exposure.

Good plot.	Bad plot.	Difference.	Difference required for significance.
1,272 mgm.	982 mgm.	290 mgm.	195 mgm.

Although the water supplying power of the soil of both areas appears to be adequate, yet there is still a difference to be observed in favour of the good plot.

Waterloo.

The soil moisture content of the soils of the observation plots reached a maximum on 23rd July. During the subsequent week the soils dried out to some extent. It is possible that the moisture content has increased with the heavy rainfall of the first week of August.

U.S.M.

Figures for the soil moisture content of these plots are appended. They demonstrate a gradual increase in soil moisture during the month of July.

Moisture per cent, oven dry weight.

	Good Plot.		Bad Plot.	
	Topsoil.	Subsoil.	Topsoil.	Subsoil.
27th June	42·1	41·5	31·4	33·7
6th July	44·6	46·6	34·6	36·4
31st July	45·2	47·6	34·3	33·5

Soil Survey.

Examination for texture and reaction, of the soil samples, collected during the dry season, has been completed.

Mr. Steven is now surveying small areas of the Usine which were previously not in a condition for sampling.

A reaction map of the survey of lands outside estate boundaries has been prepared.

Study of Froghopper Eggs.

Blotting paper cultures were started on 10th July, and results have already been obtained from eggs laid by females since the opening of the rainy season. The following are the results for three average samples :—

Culture.		*Date laid.*		*Last nymph hatched.*
D.	....	10th July	....	4th August.
E.	....	10th do.	....	1st do.
F.	....	13th do.	....	5th do.

Average number of days of incubation 24. For comparison the following are the results of dry season hatchings :

Culture.		*Date laid.*		*Last nymph hatched.*
A.	....	31st January	....	30th April
B.	....	8th March	....	14th May
C.	....	12th March	....	27th June.

Average number of days of incubation 78.

A large majority of the wet season eggs hatch within the period of the 12th and 18th day of incubation. The dry season eggs hatched intermittently and few at a time. Both the dry and the wet season eggs were kept under optimum conditions of moisture.

Biochemical Work.

Laboratory examination of the material collected in the two large scale experiments mentioned in the last Progress Report, has been concluded. The results of these experiments have been worked up and yield interesting information. A further large scale experiment has been initiated at the Usine and will be sampled during the present month. It has as its object the confirmation of results hitherto obtained regarding the effect of nodal accumulations on the growth of cane.

Two large leaf sampling experiments are in hand which have as their objects the investigation of the transport of elaborated foodstuffs from the cane leaf, and also the water economy of the cane leaf.

F. W. URICH.
R. R. FOLLETT-SMITH.

THE SUGAR-CANE FROGHOPPER.

By F. W. Urich.

(*Specimen of Pamphlet to be issued to School Teachers.*)

The froghopper belongs to an order of insects called Hemiptera or Bugs. All through its life it takes only liquid food which it obtains by piercing plant tissues with thin tube-like mouth parts called a proboscis, and sucking the sap from leaves, stems or roots. It attacks many kinds of grass, but it is particularly injurious to sugar-cane growing on stiff clay soils.

There are four kinds of froghoppers in Trinidad. The Red and Yellow Froghopper, that does not live on any kind of grass, but is only found on Christmas Bush. The Black Froghopper, living on grasses growing near rivers and in damp places in the Northern Range. The Spotted Froghopper, feeding on a coarse grass growing in the southern part of Trinidad, and the Sugar-cane Froghopper, found all over the Island of Trinidad.

The froghopper and its life-history.

The young stage of the froghopper is called a nymph, and it hatches from an egg which the mother lays by means of a special organ, called an ovipositor, in damp soil, wet cane trash, and in the stems and near the roots of different kinds of grasses. The egg is very small, one-fortieth of an inch in length, yellow in colour when first laid, and of the shape of a torpedo. When near hatching, the egg develops a black streak which extends from the tip to near the middle. It is called the hatching lid, and, when the young nymph is about to issue from the egg, it pushes this lid out and emerges on the side. The newly-hatched nymph is small and delicate, about one-twenty-fifth of an inch in length, and of a general creamy white colour, slightly suffused with red blotches on the sides of the body. It avoids light as much as possible, and sucks young rootlets of grass or cane growing under boucans, in a crack of the soil, or under clods of earth. When the canes are tall, it feeds near the surface of the ground where it is well shaded. After feeding for a short time, it surrounds itself completely with spittle which comes from the anus, and affords it an efficient protection against most enemies and the influence of sun and air. Thus protected, the young nymph sucks roots of cane or grass all the time and grows, changing its skin three times before attaining the adult stage. When ready for the final moult, the nymph ascends a stem of grass or a cane stalk for a short distance from the ground and makes a moulting chamber of particularly thick spittle. In changing to the adult, the skin of the nymph splits on the back, and the adult froghopper works its way out of the old skin. It remains quiet in the chamber until the wings, which are at first quite small and shrivelled, expand. After two to three hours have elapsed, the froghopper comes out of the chamber fully coloured and hard. The adult froghopper is one-fourth to one-third of an inch in length and about one-sixth of an inch broad. It has two pairs of wings, of which the first pair is parchment-like. The second pair is delicate and transparent, and, when the insect is at rest is under the first pair and protected. The forewings are dark brown with two narrow slanting bands on the side which are dull yellow. The colour varies in some individuals, and there are some in which nearly all the yellow bands disappear. The males sometimes show more yellow colour than the females. The head and chest are dark bronzy-brown, and the body above and beneath, red-brown in the male, and brown in the female. The legs are blackish-brown. In the males, the end of the body appears as if cut off square, whereas that of the female ends in a point.

Life cycle.

The egg stage of the froghopper in the rainy season lasts for about 14 days; the nymphal stages occupy a period varying from 32 to 42 days. Adults issue from the nymphal stage during the morning. They crawl up a cane or grass stem, and secrete themselves in the axils of the leaves, or in the funnel of the canes. Here they remain with their legs drawn up close to their bodies in a state of rest when not feeding, until the late afternoon, when towards dusk they crawl out and walk about on the tops of the cane and grass leaves. They also take short flights. Pairing generally takes place on the first day after emerging, mostly at dusk, but sometimes in the day.

The male dies two to three days after, and the female survives for a month, more or less ; she takes about 10 days to lay all her eggs, from 40-100 can be laid by one female. In the dry season, the eggs ; remain dormant for months, and there there are few nymphs and adults to be seen on cane estates.

The entire life cycle of a froghopper during the rainy season occupies a period of 80 days. According to the time of the opening of the rainy season, it is possible for three broods to develop, and sometimes a fourth.

Damage to the Cane.

The damage inflicted on sugar-cane goes under the name of "blight" in Trinidad, and it is brought about principally by the sucking of the leaves by the adult froghopper. In the act of sucking, the froghopper injects saliva into the leaf which is poisonous to the green tissue. The damage starts from each puncture in a leaf. At first the leaf shows yellow patches, which gradually become reddish-brown, and then brown when the leaf tissue is dead. It takes roughly from three to four weeks for the leaf tissue to be killed, but the exact time for the blight to take effect is subject to a great deal of variation according to weather and soil conditions.

Natural Control.

The sugar-cane froghopper has many natural enemies which are quite efficient in the country districts away from cane estates, but are only partially so on estates owing to the changed conditions of surrounding abundance of food plants and agricultural and cropping operations.

Natural enemies of the froghopper.

Attacking eggs.

1. A tiny vermilion wasp-like parasite, which lays its eggs in the eggs of the froghopper, and the larvae of which destroy the egg by feeding on its contents.

2. Several species of ants carry off to their nests eggs found lying about on the ground.

Attacking nymphs.

1. Some birds pick nymphs out of the spittle, notably the Boat-Tail.

2. *The Syrphid Fly.*—The maggot of this fly devours the nymphs in their spittle.

3. *Ants.*—Several species will capture nymphs when they leave their spittle.

Attacking Adults.

1. Many insectivorous birds capture adult froghoppers, one of the most efficient being the Scissors Tailed Fly-Catcher.

2. Lizards, frogs and toads. There are not many lizards in cane fields, but they are useful ; toads are, however, the planters best friends.

3. Spiders are very useful, and several species can be seen in the cane fields capturing adult froghoppers.

4. *The Green Muscardine fungus.*—This disease always crops up during the wet months, and is a quite efficient check.

Artificial control measures.

All artificial control measures should be aimed at the eggs during the dry season, and at the nymphs at the opening of the wet season.

The simple mechanical means that should be tried are the following :—

1. During the dry season soon after the canes are reaped, slice off with a hoe the exposed parts of the cane stumps together with the surface soil immediately surrounding the stools, and bury the shavings and soil in deep pits.

2. During the wet season, nymphs in the spittle can be destroyed by pounding with sticks.

3. Damp trash likely to contain eggs might be stripped from the cane and used as bedding for the domestic cow or mule, or burned.

4. Cyanogas powder could be used for destroying nymphs and eggs by dusting them.

The powder may be supplied by the factory of the area.

5. Adults could be trapped at night by means of trap lights.

6. When resting in the cane funnels during the day, the adults could be killed by a sharp clapping action of the hands.

Preventative measures.

1. Liming cane lands will cause the canes growing there to become more resistant to blighting.

2. Irrigation in the dry season, when possible, would improve the moisture in the soil for the growing canes and lessen blighting.

3. When fields are not cultivated, do not let grass grow in them, but plant them up with cover crops such as Bengal Beans.

4. Dry bamboo brambles should be placed in the cane fields to serve as perches for insect-eating birds.

5. Protect all birds as much as possible, and do not allow any snaring on your lands.

6. Kill all mongoose and obtain the Government reward for their carcases.

INSTRUCTIONS TO TEACHERS.

THIS pamphlet can be used as the basis for nature study lessons, but the teacher should, however, bear in mind that nature study means the study of nature, and not the study of books, which only treat about nature. It is therefore quite obvious that on no account should any of these notes be committed to memory by the children ; they are intended as a guide for the teacher only.

The best way to study the froghopper is to go into an affected cane field, but as this is not always feasible, the froghoppers have to be brought into the school room or the school garden.

Apparatus.—None but the simplest of cages are needed for rearing and observing froghoppers. Any kind of small box can be converted into a cage, as long as a small piece of wire netting is put into the top for ventilation, and a piece of glass of suitable size, fitted in grooves, is used as a door and for observation of the insects. Glass jars with wide mouths, which should be covered with a piece of muslin, also make excellent breeding cages for the adults and nymphs. For rearing nymphs, biscuit tins are best, and they should be used with the original covers into which but few holes are punched for ventilation. The froghopper nymph loves darkness, When glass jars are used, they should be kept in a cupboard, or covered with some opaque material.

Growing cane plants for the supply of food are essential, and they should be grown in the school garden, or in pots. A supply of growing savannah grass is also necessary.

Collecting materials.

Adults will be found on canes or grass in most parts of Trinidad, and may be caught by hand, in glass tubes, or by means of a butterfly net. Nymphs are to be looked for at cane roots, grass roots and under boucans in cane fields. The spittle masses should be handled gently, as the nymphs are very delicate. Another method is to collect grass, with the roots, from places where froghoppers are seen ; this grass is then put into a biscuit tin and kept damp. Any eggs in the grass will hatch, and young nymphs will appear. Provided with fresh cane tops placed in water in one of the cages, the adult froghoppers feed, and will lay eggs. For the purpose, a piece of damp blotting paper or a little wet clay in the cover of a tobacco tin should be placed in the cage. The eggs should be kept very damp in a suitable small tin box until they hatch, and there should always be a few fresh grass rootlets in the tin, so that the young nymphs can have food available as soon as they hatch. As the nymphs, grow they should be transferred to the larger tin boxes, provided with growing grass or pieces of cane with young roots

The pupils should be allowed to make their own observations, and exercises should be set by the teacher, material for which can be found in the text.

Last but not least, the children should be taught to observe and protect all the natural enemies. The importance of birds should be emphasised. All insectivorous birds are protected by law, and on no account should the pupils be allowed to snare birds or to shoot them with catapults commonly called "sling shots" in Trinidad. No bird nests or eggs should be disturbed or taken.

Toads should be protected ; not only are they valuable allies for the destruction of froghoppers, but they are the best friends of all Planters.

Imperial College of Tropical Agriculture,
1st September, 1928.

THE SUGAR-CANE FROGHOPPER.

BY F. W. URICH.

(Specimen of Leaflet to be issued to Cane Farmers.)

THE froghopper belongs to an order of insects called Plant Bugs. All through its life, it takes only liquid food which it obtains by piercing plants with thin tube-like mouth parts, sucking the sap from leaves, stems or roots. It attacks many kinds of grasses, but it is particularly injurious to sugar-cane growing on stiff clay soils.

There are four kinds of froghoppers in Trinidad : a Red and Yellow Froghopper (found only on Christmas Bush) and three others, viz. : The Black Froghopper living on grass growing near rivers in the Northern Range ; the Spotted Froghopper, feeding on a coarse grass growing in the southern part of Trinidad, and the Sugar-cane Froghopper found all over the Island of Trinidad.

The froghopper and its life-history.

The young froghopper or crawling stage hatches from an egg which the mother deposits in damp soil, wet cane-trash, and in the stems and near the roots of different kinds of grasses. The egg is very small, 1-40 of an inch in length, yellow in colour, and shaped like a torpedo. When near hatching, the egg develops a black streak which extends from the tip to near the middle. It is called the hatching lid, and when the young froghopper is about to issue from the egg, it pushes this lid out and comes out on the side. The newly hatched froghopper is delicate and about 1-25 of an inch in length, of a creamy white colour, slightly marked with red on the sides of the body. It avoids light as much as possible, and, as soon as it finds a young rootlet of grass, it sucks it. It will also crawl into the soil, or under clods of earth, but, when the canes are tall, it may remain on the surface of the ground. After feeding for a short time, it surrounds itself completely with spittle which affords it an efficient protection against most enemies and against the influence of sun and air. Thus protected, the young froghopper sucks roots continually and grows, changing its skin three times before attaining the full grown flying stage. When ready for the final change of skin, the young froghopper ascends a stem of grass or a cane stalk for a short distance from the ground and makes a moulting chamber of particularly thick spittle. In changing to the flying stage, the skin of a young froghopper splits at the back. and the full grown froghopper works its way out of the old skin. It remains quiet in the chamber until the wings, which are at first quite small and shrivelled, expand. After 2 to 3 hours have elapsed, the froghopper comes out of the chamber fully coloured and hard. The fully grown flying froghopper is 1-4 to 1-3 of an inch in length, and about 1-6 of an inch broad. It has two pairs of wings, of which the first pair is parchment like. The second pair is delicate and transparent, and, when the insect is at rest, it lies under the first pair and is protected by it. The forewings are dark brown with two narrow slanting bands of a dull yellow colour. The colour varies in some individuals, and there are some in which nearly all the yellow bands disappear. The males sometimes show more yellow colour than the females. The head and chest are dark bronzy-brown, and the body above and beneath red-brown in the male, and brown in the female. The legs are blackish-brown. In the males the end of the body appears as if cut off square, whereas that of the female ends in a point.

Life Cycle.

The egg stage of the froghopper in the rainy season lasts for about 14 days; the young stages occupy a period varying from 32 to 42 days. Adults issue from the young stage during the morning. They crawl up a cane or grass stem and hide themselves in the axils of the leaves or in the funnels of the canes. Here they remain with their legs drawn up close to their bodies in a state of rest, when not feeding, until the late afternoon. Towards dusk they crawl out and walk about the tops of the cane and grass leaves. They also take short flights. Pairing generally takes place on the first day after emerging, mostly at dusk but sometimes in the day; the male dies 2 to 3 days after and the female survives for a month, more or less; she takes about 10 days to lay all her eggs, from 40 to 100 can be laid by one female. In the dry season, the eggs remain dormant for months, and there are few young froghoppers or flying ones to be seen on cane estates throughout the dry season.

The entire life cycle of a froghopper during the rainy season occupies a period of 80 days. According to the time of the opening of the rainy season it is possible for 3 broods to develop in a year, and sometimes a fourth.

Damage to the Cane.

The damage inflicted on sugar-cane goes under the name of "blight" in Trinidad, and it is brought about principally by the sucking of the leaves by the full-grown froghopper.

Natural Enemies of the Froghopper.

Attacking eggs.

1. A tiny vermilion fly lays its eggs in the eggs of the froghopper, and the fly-worm destroys the egg by feeding on its contents.

2. Several kinds of ants carry off to their nests eggs found lying about on the ground.

Attacking young froghoppers.

1. Some birds pick young froghoppers out of the spittle, notably the Boat Tail.

2. *The Syrphid fly.*—The maggot of this fly devours the nymphs in their spittle.

3. *Ants.*—Several kinds capture young froghoppers when they leave their spittle.

Attacking Adults.

1. Many insect-eating birds capture froghoppers, one of the most efficient being the Scissors Tailed Fly Catcher.

2. Lizards, frogs and toads eat froghoppers.

3. Spiders of several kinds can be seen in the cane-fields capturing froghoppers.

4. *The Green Muscardine Fungus.*—This disease always crops up during the wet months, and is a quite efficient check. The froghoppers turn green when they are killed by the fungus.

Artificial control measures.

All artificial control measures should be aimed at the eggs during the dry season, and at the young froghoppers at the beginning of the wet season. The simple mechanical means that should be tried are the following :—

1. During the dry season soon after the canes are reaped, slice off with a sharp hoe the exposed parts of the cane stumps together with the surface soil immediately surrounding the stools and bury the shavings and soil in deep pits.
2. During the wet season young froghoppers in the spittle can be destroyed by pounding with sticks.
3. Damp trash likely to contain eggs might be stripped from the cane and used as bedding for the domestic cow or mule, or burned.

4. Cyanogas powder could be used for destroying young froghoppers in the spittle and eggs, by dusting them. The powder may be supplied by the factory of the area.
5. Adults could be trapped at night by means of lights.
6. When resting in the cane funnels during the day, the adults could be killed by a sharp clapping action of the hands.

Preventative measures.

1. Liming cane lands will cause the canes growing there to beeome more resistant to blighting.

2. Irrigation in the dry season, when possible, would improve the moisture in the soil for the growing canes.

3. When fields are not under cultivation do not let grass grow in them but plant them up with cover crops such as Bengal Beans.

4. Dry bamboo brambles should be placed in the cane-fields to serve as perches for insect eating birds.

5. Protect all birds as much as possible, and do not allow any snaring on your lands, or the use of sling shots by boys.

6. Kill all mongoose and obtain the Government reward for their carcases.

Imperial College of Tropical Agriculture,
1st September, 1928.

STUDIES ON THE AETIOLOGY OF SUGAR-CANE FROGHOPPER BLIGHT IN TRINIDAD.

I.—Introduction and General Survey.

By C. L. Withycombe, Ph.D., D.I.C.

(*Imperial College of Tropical Agriculture, Trinidad*).

Note.—*Since much of the later work on froghopper blight is a continuation of, and has been largely inspired by, the invaluable researches of earlier workers, it was thought advisable to publish in these " Proceedings " those parts of the late Dr. Withycombe's paper (the only one he wrote on this subject) that chiefly describe his detailed investigations and conclusions, both those drawn from his own survey of the problem, and those drawn from his study of the writings of F. W. Urich, J. C. Kershaw, W. Nowell and C. B. Williams, that are readily available in literature published by the Trinidad Department of Agriculture.*

In the first of this series of studies, it is proposed to give a general account of the interrelationships of sugar-cane plant and the froghopper, more particularly the adult insect, and from such central viewpoint the problem will be surveyed in a few of its aspects. It is hoped thereby to offer explanations of some of the previously observed although but vaguely understood phenomena, and to attempt co-ordination.

There are obviously two important sides to the question of froghopper blight which require elucidation; (1) the factors controlling the numbers of the froghoppers themselves, and (2) the conditions influencing resistance of the canes to and recovery from attack. Both may be interdependent and evidently often are, but it is to the second aspect almost entirely that attention will be devoted in the present paper.

Feeding of the Adult.

The mouthparts of the adult froghopper consist of styliform mandibles and maxillae which are ensheathed by a four-jointed labium, the latter being furnished at its distal extremity with small sensory hairs. The maxillae are simple and pointed, grooved

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on their inner sides and together forming two tubes, a dorsal suction canal and a ventral salivary ejector canal. The mandibles lie on either side of the combined maxillae ; they are also grooved internally and pointed apically but in addition they are serrate near their apices. Activating the stylet mouthparts are muscles contained within the head capsule.

The juices of the plant are sucked up by means of a large pharyngeal pump within the head. This takes off sap from the dorsal maxillary canal at the point where the stylets diverge on entering the head capsule. The pharynx, or as it might be better termed, the buccal cavity, is at first narrow antero-posteriorly. On the roof of its first portion are sense organs which are no doubt gustatory in function. Immediately behind this tasting region is a valve with muscles attached, which, from its structure would be most efficient in preventing regurgitation from the pharyngeal sucking bulb.

Ventrally to the pharyngeal pump is a powerful salivary pump which forces saliva along a spout opening just in front of (ventrally to) the gustatory region of the buccal cavity. Thus saliva is forced between the stylets at their point of concurrence and into the ventral salivary ejector canal. The salivary pump consists of a chitinous piston working within a bulb, into the floor of which the united ducts of the salivary glands open. To the piston are attached muscles. Retraction of the piston produces a negative pressure within the salivary bulb, causes closure of the spout valve and withdraws saliva from the salivary glands. Return of the piston into the salivary bulb forces saliva from the bulb into the spout and down the stylet salivary ejector canal.

The salivary glands consist of a small head gland and a larger thoracic gland which possesses twelve long diverticula. Feeding occurs as follows. The proboscis, which, owing to flexure of the head comes to project from rather well back, almost between the coxae of the first pair of legs, feels about for a suitable spot on the cane leaf. The position is no doubt tested by the sense organs at the tip of the labium, and a spot near a vein is generally selected. As the veins in the leaf are very close together, this selection cannot be difficult, and probably the froghopper really only has to select a place as free as possible from siliceous thickening. Having chosen a feeding spot, the serrate mandibles are driven into the leaf. This sometimes occasions a slight twisting or lateral movement of the body, especially in starved, weak insects. The smoothly pointed maxillae follow the mandibles, combined as a central column. These can be extended beyond the apices of the mandibles and they contain the sucking channels. The serrated mandibles seem to break through the hard cuticle of the leaf and then remain embedded firmly while the maxillae pierce other deeper tissues and conduct back their fluid contents.

Immediately, and while the stylets are still boring into the leaf, there is an exudation of saliva which can be seen around the stylets at the surface of the leaf. This saliva is not large in quantity, but it can be distinctly observed under a low power microscope. Within a minute usually, the small amount of saliva is seen to have been reabsorbed, indicating that sucking has commenced. In a further period of from one to three minutes, another exudation of saliva occurs, and this again is reabsorbed within a quarter of a minute or less after its appearance. The process of exudation and reabsorption of saliva then repeats regularly every minute or so. Such is a fairly typical case. Times vary.

It is seen that salivary expulsion usually precedes sucking. The saliva may serve as a stylet lubricant during the process of boring the leaf ; its main function, however, is that of an extra-oral digestive, as will be seen later. In some cases, salivary exudation is not conspicuous : subsequent examination of the leaf shows this to be correlated with deeper and more destructive puncture, generally inclusive of the xylem vessels. It is also frequently associated with more rapid excretion of faecal water, and generally with more robust and healthy insects. The operation first described can always be observed in an insect which has been starved all day and is consequently hungry and somewhat weakened. At first, starving the insects was done on purpose to observe feeding under the microscope. Vigorous and unstarved froghoppers may be rather restless and less tractable for observation.

Feeding times and methods vary. If a suitable position has not been found, the froghopper will leave the place within a minute or so and puncture elsewhere nearby. A suitable position is probably determined, not only by the amount of fluid withdrawable and the facility of sucking, but also maybe by the taste experienced at the gustatory patch on the roof of the mouth. On one occasion, a froghopper was noted to make about 100 punctures in a small area 2 cm. long by 3 mm. broad. In this rather exceptional case, the insect retained hold of the edge of the cane leaf with its legs of one side. It moved from side to side and also backwards during the several attempts at feeding. Other instances have been observed when satisfactory nutriment was obtained from one puncture during an hour or more.

Depth of puncture varies. Often the stylets penetrate to the epidermis of the opposite side of the leaf, at other times they go no deeper than the precincts of the vascular bundles. I have no evidence of preference for upper or lower sides of leaf. Under experimental conditions both sides have been attacked when the leaf has been vertically placed. Field observations are inconclusive.

On disturbance, the adult froghopper frees its stylets quickly, and, although I have occasionally killed an insect with stylets *in situ*, these could not be retained in passage through reagents for embedding and sectioning.

After withdrawal of the stylets, a minute puncture can be seen, and around this generally a very small area with a whitish efflorescence which is the dried saliva.

During feeding, small drops of almost colourless fluid are voided from the anus at the rate of one every two to five minutes. Six froghoppers allowed to feed on a normal, full-sized cane leaf for 24 hours produced with considerable regularity 6 c.c. of fluid; in a shaded room and with a water-saturated atmosphere. This observation was repeated and verified a number of times, each time with adult froghoppers one day old in respect of emergence, and in good health. One may therefore say on an average that a single froghopper will extract and void 1 c.c. of fluid in 24 hours. Froghoppers evince greater hunger if kept dry, and die quickly if not given food, but it has not been possible as yet to observe a definite increase in amount of food taken in a dry atmosphere.

McLeod ([17]) states that a drop of liquid is produced every 12 to 13 seconds, and that an insect under observation excreted half a drachm (= 1·776 c.c.) of clear liquid in an hour. I have seen fluid excreted at greater rates than those which I have given above, but I can quote no instance of such quantity as that given by McLeod. Williams ([29]) refers to McLeod and adds that with 50 froghoppers per stool, each sucking for eight hours during the night, about $1\frac{1}{4}$ pints of sap would be removed. I must confess that I hardly think that such a great drain often occurs in nature, and I should expect that wilting and death of the cane would speedily follow under such conditions, without any intermediate symptoms such as are generally witnessed. No doubt, however, there is a considerable drain of fluid from the cane plant, and this is an important fact to be borne in mind.

The fluid voided by the adult froghopper while feeding is an almost colourless and clear liquid. In quantity, however, it is seen to be faintly tinged brownish, and to be slightly opalescent. It has a faint but disagreeable odour somewhat suggesting decaying vegetable matter or urine, but the odour seems most nearly to resemble that of certain amines or phosphorus compounds. The reaction of the fluid is slightly alkaline, *p*H 7·6 approx. It contains traces of various salts, including phosphates, but apparently no reducing or other sugars.

The amount of fluid excreted by a froghopper gives one a reliable indication of the amount of fluid extracted from the plant*, but it does not help one to determine whence this fluid has been derived, since all substances of nutritive value to the insect have presumably been absorbed from it before excretion. It might, however, be interesting to determine the amount of phosphorus in the excremental fluid quantitatively.

From the fact that saliva is frequently forced into the leaf during feeding, it is obvious that its action is more than a purely lubricatory one. This would be expected from the results of previous workers on the Homoptera. Recent among these, may be mentioned Davidson ([6]) and Horsfall ([11]), from whose papers

* The amount of water vapour given off by the insect and plant in transpiration was shown to be negligible in the saturated atmosphere which obtained in these experiments.

earlier references may be obtained. Davidson, for instance, has shown that the saliva of aphids is diastatic in action, converting starch into soluble sugars. Petri ([21]), Zweigelt ([30]) and Staniland ([24]) record similar results. The saliva has also been shown to penetrate cell walls and even lignified xylem vessels. Collapse of the cells, and plasmolysis of the cell contents often occurs. Frequently a stylet sheath is formed, which Petri, Davidson and Horsfall suggest as being due to a reaction with the saliva.

The saliva of the froghopper shows very similar properties. It has a distinctly diastatic action upon starch, and it contains, in addition, oxidases. Upon the cells and their protoplasmic contents it has marked effect, as will be seen. Apparently it has no power of inverting disaccharides. In reaction it is slightly acid, *p*H 6·0 to 6·2; Kershaw ([14]) states that it is neutral or faintly alkaline.

Effect upon the Leaf of Froghopper Sucking.

The adult froghopper in feeding, punctures the leaf near a vascular bundle. The stylets may break into the vascular strand, or they may only injure the surrounding tissues. The puncture made is not a neat one. It frequently passes almost through to the opposite side of the leaf, completely through in some soft grasses, and is often very destructive mechanically to neighbouring tissues. Saliva is pumped into the wound and sucking commences, roughly, it may be assumed, when well in action, at the rate of voidance of liquid excrement. The length of time of feeding at one puncture varies, and after effects on the leaf also vary, but only to a certain extent correspondingly.

Examining the leaf at once and while fresh under the microscope, the puncture is visible and around it, if feeding has been at all prolonged, there is a distinct bleaching of the chlorophyll, more longitudinally than laterally. A small amount of dried saliva may be visible around the aperture. The vein or veins themselves near the puncture, extending for a variable distance longitudinally, often appear paler or sometimes watery by transmitted light. At other times the vessels seem to contain air drawn in from the point of puncture; probably on release of the tension produced by the insect's sucking. Testing the spot with a cobalt chloride tripartite strip, the rate of transpiration is often found to be more than doubled. This may be, and very likely is, due purely to an oozing from the seat of puncture, and it is not necessarily connected with increased stomatal aperture, or with increased metabolic rate.

Fresh sections cut through the spot have, on very few occasions, shown a slight change in *p*H, in the direction of increased acidity, viz. : the contents of the border parenchyma cells appear slightly more orange-pink to methyl red—a never very reliable indicator. With iodine, there is no darkening in the region of the puncture when a distinctly positive reaction is obtained in other parts of the leaf. It is probable that the carbohydrates of the cane leaf are always easily extracted as they appear to be in the form of dextrins which are water soluble.

In a few cases where the sucking of the froghopper had continued for an hour or more, certain cells showed a slight pink or brown coloration, due probably to oxidation of catechol tannins, as will be mentioned again later.

Leaves were fixed in a variety of fluids at varying times after the cessation of feeding, and with known duration of feeding. The most striking effect noticeable even after only five or ten minutes' sucking is upon the contents of the border parenchyma cells. Other damage, apart from the purely mechanical rupture, and the formation of a stylet sheath, is of less apparent consequence at first. When the excretion of faecal water has been rapid, the vascular strands are invariably found to have been broken into and their contents presumably drawn upon.

The puncture made by the stylets is fairly straight, broad and somewhat conical. Its walls are lined with a peculiar material which arises probably as the result of interaction between the insect's saliva and certain plant substances. This lining has been referred to as the stylet sheath in connection with aphids, and various workers, Petri ([21]), Wells ([27]), Davidson ([6]), and Horsfall ([11]) have demonstrated the presence of pectic materials in this sheath. Calcium pectate especially has been mentioned, besides proteins and tannins.

If one were to judge by stained sections, one would consider the froghopper's saliva to be specific for the contents of the border parenchyma cells, and this is the more interesting in view of the probable great physiological importance of the border parenchyma sheath. The border parenchyma certainly accumulates carbohydrate materials temporarily, as it is evident from its deep staining with iodine in the daytime, and these carbohydrates probably pass from the border parenchyma into the vascular bundle at night. Again, since the border parenchyma sheath is interposed between the vascular bundle and the chlorenchyma cells, one may well postulate that water, salts, &c., from the vascular strands have to pass through the border parenchyma sheath to the chlorenchyma. The chlorenchyma around a froghopper puncture allows of slight spreading of the insect's saliva, probably due to the numerous air spaces in this tissue, but, in the border parenchyma, the saliva passes rapidly in a longitudinal direction. If the transverse walls of the border parenchyma were absent, one could hardly except a more rapid longitudinal spread. Lateral extension is, however, slow in the border parenchyma, and is usually associated with prolonged salivary action.

The remarkable effect of the saliva upon the contents of the border parenchyma may very likely be due to the fact that the enzymes of the froghopper's saliva exert their greatest activity at the H-ion concentration of these cells. If this be true, then it is to be remembered that the phloem has a *p*H value nearly in the same region, while the chlorenchyma is slightly more alkaline, and the xylem more acid. The air spaces in the chlorenchyma will tend to hinder extension of saliva in that tissue, as has been suggested already, but the phloem and border parenchyma certainly suffer severely. Xylem and sclerenchyma do not show damage so readily.

Sherman ([23]) has shown that malt diastase exhibits maximum activity at its isoelectric point, which is between *p*H 4·3 and 4·5. Now the enzymes of the froghopper are also likely to be proteins, and they may have isoelectric points in approximately the same region. It is quite likely that the xylem and sclerenchyma on the acid side, and the chlorenchyma and other tissues on the more neutral side, are not so markedly affected at first because of their *p*H being outside the optimum activity zone. This is put forward as a possibility, but further investigation along these lines has yet to be made.

In the case of short duration (5-15 mins.) sucking, then, one may say that the main apparent effect is upon the plastids of the border parenchyma cells. The effect upon the vascular tissues is less noticeable, and that upon the chlorenchyma very local. There may be slight plasmolysis.

With prolonged sucking, the effect is more widespread. Chlorenchyma and vascular tissues become more involved. The blanching of the former has been already mentioned, and this is usually followed by death of the cells, which no longer show photosynthetic activity. It is a mass effect which is to be expected, and it is of less interest in explaining the action of the froghopper's saliva *per se*, since post-mortem changes with consequent autolytic and other effects occur. These mass effects must and will of course be considered as the feeding punctures, from which spreads the typical and serious leaf damage, are invariably the result of prolonged sucking.

From the slight damage such as has been first described, a leaf may or may not recover, according to its condition. A normal healthy leaf, under good conditions, usually recovers completely. After a few days, the green colour of the leaf, if it had been slightly bleached locally, is restored, probably by regeneration of plastids, and sections of the leaf indicate that it is again in normal functioning state. Under less favourable conditions, such as will be indicated later, especially when coupled with prolonged sucking of the insect, the following external changes may be visible.

Paling of the green parts of the leaf extends, mainly in a longitudinal direction, on either side of the puncture, but often more towards the apex of the leaf than towards the base. Extension of the injury is often accompanied by the appearance of a red pigment which seems to be the result of oxidation of catechol tannins already mentioned as being present in the leaf. The appearance of red pigment varies with the variety of cane and with the conditions under which the cane is growing. Thus in B. 156, on certain heavy soils, the red pigment may hardly be visible at all. The injury spreads as a yellow, somewhat ill-defined streak for a time, and then becomes dead and brown in the centre. The yellow portions continue to advance, followed up by the brown dead central area. Usually, however, the red pigment is also seen in B. 156, although maybe to a less extent than in other varieties. Uba, and other varieties, under good conditions, and often under bad, may show little yellowing. Within a day or two after puncture, a red, finely stippled streak appears. This elongates and the centre later becomes brown and dead. Peripheral yellowing of the streak may later be visible.

The case of a fairly healthy leaf Ba. 6032 may be taken as an example. Two days after puncture, with two hours of sucking by a froghopper, there was a pale streak, very narrow and indistinct, 0·5 cm. long, showing some minute red stippling. In three days, the length was 0·8 cm., almost entirely red. Next day the red streak reached 3 cm., and it continued as below :

5th day	5·0 cm. × 0·15 cm.
7th day	6·8 cm. × 0·25 cm.
8th day	9·5 cm. × 0·25 cm.
9th day	11·0 cm. × 0·30 cm.

On or about the 9th day, the centre of the red streak appeared brown and dead. Yellowing was visible in some places at the periphery of the red area. Elongation continued. On the 11th day the streak measured 13·5 cm. × 0·45 cm., and on the 14th day it was 18 cm. × 0·70 cm., dead and brown with little or no red pigment. Following upon a yellow margin, 1 to 1·5 mm. wide, the dead leaf area continued to extend.

The case cited is only one of many. There is much variation with variety of cane and with environmental conditions. A detailed study of these varying symptoms seems likely, from observations already made, to afford valuable clues to the nature and mechanism of recovery from or resistance to attack, but such study is beset with many difficulties, especially in the standardisation of conditions, and results so far obtained, while interesting, cannot be regarded as necessarily significant. Much and prolonged yellowing of the leaf is frequently followed by more extensive subsequent death of the tissues. Production of red pigment and reduction of yellowing is commonly a more favourable reaction, indicating resisting vigour.

While the external symptoms just mentioned are developing, certain important internal changes responsible for them have occurred. The immediate effect of the froghopper's saliva upon the border parenchyma has already been described, but there is less immediate effect apparent upon other tissues, unless feeding has been much prolonged, in which event blanching of the chlorenchyma and sometimes faint local reddening, due to oxidase action, may be seen.

After a day or two, the cells of the phloem are seen to have deposits within them, probably of pentosans, which give a tannin reaction : tannins are, however, present in nearly all tissues. These deposits are often associated with red pigment. The chlorenchyma cells around such affected vascular bundles are apparently dead or dying. Water supply to them is obviously checked, since leaves, after injury by froghopper, when placed in eosin solution show conduction of the dye to be prevented or greatly reduced wherever injury has spread, whereas normal and uninjured veins conduct the solution freely and rapidly. This effect extends in a longitudinal band apically. A transverse section through an early red streak (three days or more old), shows the phloem almost completely blocked with reddish material, and the walls of xylem and sclerenchyma in the same bundles stained red, but with lumina not usually at all blocked. Death and disorganisation of the surrounding tissues is obviously in progress.

The red pigment found in damaged leaves is also formed, with varying rapidity, when any aerial part of the cane plant is cut and exposed to the air, and, as has been said, it is probably the result of oxidase activity upon catechol tannins. The red pigment is slowly dissolved out in cold water, more rapidly on heating. Upon addition of ammonia there is a colour change to yellow. Reactions of a catechol tannin are given by the red pigment, and it seems probable that the pigment is an oxidation product of such tannins. Further, and much more detailed examination is necessary before a conclusion can be reached. Wolzogen Kühr ([16]) states that the red decomposition product of cane juice is purpurin, 1 : 2 : 4-trihydroxyanthraquinone, or a very nearly allied substance. Petrie ([22]) has investigated the red pigment produced in *Eucalyptus* consequent upon injury due to *Eriophyes eucalypti*, and considers it to be derived by decomposition from a catechol tannin. Several reactions are given by him, but the cane pigment appears to differ from that which Petrie had under examination.

The spread of injury from a froghopper puncture would then seem to be explained somewhat as follows. Firstly, besides the direct injury and drain upon the contents of the vascular tissues, there is a marked injurious effect upon the border parenchyma, with removal of carbohydrates, &c., stored temporarily therein. The injury to border parenchyma is extensive longitudinally. The immediate effect upon chlorenchyma is more localised. The injury produced by the saliva is effected by several ferments of which diastatic and oxidising enzymes have been demonstrated. Probably others exist. The metabolic equilibrium of the plant is upset. The rate of respiration probably increases locally with oxidation. Supernormal oxidation with the formation of red pigment occurs from the action of plant oxidases, possibly aided by the oxidase in the insect's saliva. Transpiration has, on a few occasions, been shown to increase in the injured region, but not always.

Loss of sap with its contained food materials from the vascular tissues can be made good by translocation from elsewhere, but local translocation has been interfered with and probably arrested by the injury to the border parenchyma sheath. This results in reduction of water supply, with solutes, to the chlorenchyma and other neighbouring tissues and, unless loss of water, etc., is reduced by decreased transpiration, a local shortage in the tissues is likely to result. There is, however, certainly no decrease in transpiration rate. Interference with translocation is further intensified when the phloem becomes blocked. Water deficiency prevents recovery of the protoplasts in all affected cells and culminates in a drying up of the tissues. This slow desiccation extends unless the local rate of water supply can be increased, or unless water loss by transpiration can be reduced. Assuming continued effect of the enzymes introduced by the froghopper, the metabolic equilbrium of the plant will continue to be upset unless a sufficiently powerful counter-reaction is forthcoming. This counter-reaction is likely to be impeded by difficulties of conduction.

As regards the possibility that the froghopper may be the vector of disease organisms ; this was considered early. Juice from parts of leaves showing froghopper injury was inoculated into healthy leaves ; small pieces of dying tissue were inserted into healthy leaf tissue, but all without success. Froghoppers bred from the egg upon healthy canes were still, as adults, capable of producing typical leaf injury. These experiments suggest that disease transmission is unlikely, although they do not disprove the possibility of such.

Conditions Influencing Extension of Leaf Injury.

As one of my earliest experiments, a healthy cane, growing in a large concrete pot, was placed in a wire gauze cage, shaded above, and between two and three hundred adult froghoppers were released in the cage. They gradually died off in a few days and I was surprised to find that only one small typical froghopper streak was finally produced upon the cane. Lesser injury was discernible with difficulty.

Urich ([26]) p. 10, says : " By way of testing the action of feeding of adults on cane leaves, a young and vigorous cane plant, whose roots were free of nymphs, was isolated, and, during a week, 100 adults were introduced every day into the cage. A month after the leaves did not show any signs of blight, but they bore a few yellow spots, not enough to disfigure the plant."

On the other hand, Williams ([29]) was successful in producing typical signs of blight upon a healthy cane by caging froghoppers over it.

In an endeavour to determine the reasons for the above contradictions, a number of experiments were made with the result that further inexplicable discrepancies were encountered. Results were sometimes positive, sometimes negative. Most even results were obtained with small plants from single eye sections bearing five or six leaves and few roots, but the damage was often not quite of the same type as field damage. Usually the injurious effects were more rapid in their spread. The leaf yellowed and showed dead tissues often in a week after puncture. Frequently the whole leaf rolled and died rapidly back from the apex. It was decided that these symptoms were really due to similar causes to those producing the more typical damage in older canes with larger food reserves and better root systems and therefore, as older canes were uncertain and difficult to manipulate, experiments were carried on with young cane plants such as have been described.

Six small B.S.F. 12·27 plants, growing in pots in local soil, which has the consistency of a clay-loam, were selected. Of these, three were kept with reduced water supply for two weeks to such extent that the leaves tended to roll, especially at midday. This shortage of water was kept as near constant as possible without any auto-irrigation device. The other three control canes were watered lightly and regularly, so that the soil was moist but not waterlogged. Six froghoppers were placed in gauze-topped cylinders over each of all six canes for 12 hours overnight. The cylinders with froghoppers were then removed and conditions of growth maintained as before. The canes short of water showed signs of injury after two or three days; they paled, and later the tips and margins of especially the older leaves withered and died. On the other hand, much less signs of injury appeared on the well-watered plants. They seem little worse after their exposure.

The experiment was repeated with B. 156, and with similar results, but it was thought that possibly the froghoppers under dryer conditions sucked more than those in the fairly saturated atmosphere over damp soil. (It is easily shown that the adult froghoppers become hungry more rapidly in a dry than in a water-saturated atmosphere.) A single froghopper was therefore enclosed upon one leaf and was allowed to feed for 10, 20, or 30 or 60 minutes, when it was removed. Absolutely consistent results were not obtained, but on an average the leaves of well-watered plants showed little appreciable injury after up to 20 or 30 minutes' sucking, although a slight local yellowing occurred in one or two cases after 30 minutes' sucking. On the other hand 20 or 30 minutes' sucking often caused later spread of injury, not serious, upon leaves of canes lacking sufficient water. It was found, however, that the tips of leaves were apparently more susceptible to injury than the bases, also the older the leaf, after prime, the more susceptible to injury it became. With additional experiments it was concluded that results obtained by allowing the insect to suck for a given time were not reliable. Too many exceptions and irregularities occurred. The first method of experimentation, using six or twelve insects overnight, was therefore again resorted to.

Plants growing in washed quartz sand only, showed less susceptibility than those grown in a heavy clay soil from a blighted field. It should be mentioned that both series in this experiment had pieces of parent cane, with its food reserves, still attached. Both had ample water.

Reduction of roots, by cutting several of them through near the base of the plant, had the effect of increasing susceptibility.

Exposure of previously attacked plants to full sunlight increased extension of injury, while shade from direct sunlight had a beneficial effect and aided recovery from the effects of sucking.

Plants in waterlogged heavy soils did not appear to be more susceptible than control plants in the same soil but with less water.

In all these experiments, attention of course was paid, as far as possible, to the standardisation of conditions other than the variables under consideration.

All the above results are not considered by the writer as proving that water shortage is a predisposing cause of increased susceptibility to froghopper injury, but they at least point in that direction. Many more experiments, under better controlled conditions, are necessary before any proof can be considered to have been established. Such experiments are in the course of arrangement, and, among other plans, it is hoped to set up a series of canes under controlled atmospheric conditions with auto-irrigators to control soil moisture, &c. These experiments necessitate much careful preparation and manipulation, and opportunity has not yet been forthcoming to carry them through satisfac orily. Preliminary experiments reveal several objections to the type of auto-irrigator commonly employed for the present work, and these objections have yet to be obviated. For instance, many roots of the plant grow round the porous pot water source, thus obtaining water direct from it instead of through the medium of the soil. This reduces any toxicity effect of the soil.

Increased susceptibility of cane to other diseases besides insects' sucking, has been observed by the writer in Trinidad. Thus *Coniothyrium* sp. n., which causes a leaf injury, often very similar to that of froghopper, only makes its presence conspicuous towards the end of the dry season.

Again, a disease of unknown origin, which may be described as a localised leaf rash, does not appear until the end of the dry season, and even then only upon certain varieties of cane. The writer first noticed it upon B. 156, upon which it appears as a rash of small red spots running on either side of the midrib of the leaf. The individual spots are at first only about a millimetre in length, but later may be 1 mm. × 2 mm., although varying considerably. The spots are closely placed together, and the rash extends as a rule for a length of from 2 cm. to 10 or 15 cm. by from 5 mm. to 25 mm. in breadth. The spots may become slightly confluent, but the disease does not appear to exert any seriously deleterious influence. The present interest of the disease lies in the fact that it can be inoculated into other B.156 plants, but not if they are well-watered and healthy. Sometimes the plant will show a slight stippling. The disease is never visible in the wet season. It can also be inoculated into other varieties of cane with slightly varying results, but varietal resistance is shown, and in all cases the canes must be deficient in water to show effect. In one of the College seedlings, the midrib shows a red coloration as well as the rash on either side. In another, the principal effect is a red coloration of the midrib with little or no rash. These varietal responses are most important, and should be studied further. Various other reasons for disease resistance in plants have been assigned by other investigators. Some of these will be considered later.

It is very fortunate that the froghopper requires damp conditions for breeding, and that it does not appear as a rule in any numbers during the dry season. Were this otherwise, it is certain that the damage done would be very great in time of severe drought.

It has been said that old leaves appear to be slightly more susceptible to injury than those not past their prime. As a leaf increases in age, lignification of the vascular tissues increases in proportion. One might expect that this would prove a greater obstacle to the froghopper in piercing the tissue. As to preference shown by the insect for old or young leaves, I can offer no evidence, but it seems clear that changes associated with increased lignification of the leaf render the latter less able to recover from the effects of the insect's sucking. This may be purely an effect of senescence and generally lowered vitality. It may also be that the passage of water in the vascular tissues is impeded by lignification.

Also, it was noted that the apical portions of the leaf died more rapidly than the basal portions after froghopper injury. It seems obvious that the basal portions of the leaf are better supplied with water than the apical ones, and I would also restate the fact that cross-veins are less frequent apically than basally.

THE ROOT SYSTEM OF THE SUGAR-CANE.

The root system of the cane varies, as might be expected, with the variety of cane and with soil conditions. Generally speaking, there is a dense mat of roots which are fairly near the surface, and which usually vary in length between 5 and 12 inches. These constitute the principal roots of the stool. A few roots, however, penetrate much more deeply, and travel directly downwards. Such roots may reach a length of several feet. Sometimes there may be only two or three such roots, at other times a dozen or two.

A number of cane varieties were grown for a year under fairly good soil conditions in the College grounds. At the end of this period, the soil was carefully washed away with water, and the roots examined. Individual stools varied to a certain degree, and it would be difficult to pass an opinion on the six or seven stools of each variety examined. Many had really good root systems, and this remark would apply to most of the generally favoured varieties. Uba was particularly good, with stool roots averaging 10 to 12 inches long, and about a dozen roots of 2 to 3 feet or more in length. The observations were unfortunately complicated by the presence of *Leucotermes tenuis* which had badly attacked the bases of the stems of several varieties, especially Badilla.

A few stools were examined, as far as was possible, in the very heavy low-lying clay soils which suffer so heavily under froghopper, and in these the roots appeared to be very superficial. In nearly every case, D. 116, B. 156 and B. 347 had very slight hold of the ground, and the root system was extremely poor. Many roots were dead. On such very heavy clay, Uba certainly grows better than any other variety.

In all these heavy soils a large percentage of dead roots was noticed, but, as the majority of stools examined were first and second ratoons, it would not be advisable to stress this point until further and wider observations have been made. Root fungi were also often noticed.

Nowell ([20]), paragraph 11, observed that dead roots were found in blighted stools, but he adds that the same applied to many uninfested ratoon fields in poor and compacted soils. It has often been noted that roots are killed by prolonged lack of aeration, and also by various toxic products in the soil. I am inclined to believe that such uninfected fields as Nowell mentions, with poor root systems, would have suffered badly had they been attacked.

In view of what has been stated as regards the increase in susceptibility the nearer the cane approaches its wilting point, it is unnecessary to stress the vital importance of the roots. In a dry soil, the roots obviously have greater difficulty in obtaining water than in a moister one, but it is also well known that in heavy, waterlogged soils, with reduced aeration, a condition of physiological drought obtains, and plants behave as though actually deprived of water. It has been observed by Nowell, Williams and others that froghopper is likely to be serious on water-logged, heavy clays, and this is bound to strike any investigator of the froghopper problem. The soil question will receive further consideration later.

It is noteworthy that with canes in fields subject to froghopper, or especially in fields after froghopper attack, as observed by Williams ([29]), adventitious roots are frequently sent out from the nodes. This is a natural response of a cane with soil root system inadequate to meet the demands made by the aerial portions of the stem, or else it may indicate faulty conduction in the basal portions of the stem. It is probably associated with changes in the osmotic pressure of the cell sap, and is consequent upon the increased acidity and enzyme action which results from serious froghopper injury. Whatever may be the cause, the upper portions of the plant are clearly in a state of deficiency.

Added to a poor root system is often the effect of root disease. Root fungi more frequently attack weak canes than healthy ones, especially old and used up ratoons. Roots with root disease are reduced in efficiency, and water shortage to the plant is a natural sequel. Root fungi and froghopper may therefore often be interdependent. Canes weakened by the fungi are more susceptible to froghopper, and also canes weakened by froghopper, especially possibly by the nymphs, are more susceptible to root diseases.

Recovery after froghopper requires a good root system and plenty of available water. Laboratory experiments have shown that serious reduction in the number of roots is inimical to recovery, and the same undoubtedly holds in the field where roots have been reduced and killed by root fungi. A shallow root system, such as is formed in fields of badly aerated heavy soil, especially when low-lying and waterlogged, is very inefficient, and, in slight drought, when it can obtain no surface water, it is considerably handicapped by the absence of deeper roots. Also it should be remembered that the percentage of water non-available on a heavy clay soil is considerably higher than that of a better aerated soil.

The Stem of the Sugar-Cane.

The stem of the sugar-cane is cylindrical and is divided into nodes and internodes. Leaves arise alternately at the nodes, and in each leaf axil is an eye or dormant bud. Also from the nodes adventitious roots develop. The internodes of the stem are smooth, with hard, variously coloured rind, often covered with wax. A cross-section of an internode shows that the vascular bundles, which run parallel to each other embedded in parenchymatous tissue, are more numerous, though smaller, at the periphery than in the centre of the stalk. The stem serves for conduction of fluids, with solutes, and for storage of sugars and other reserves.

Effect of Froghopper Blight upon the Stem.

When froghoppers have attacked a cane, the leaves die prematurely, as has been described, and as a result photosynthesis receives a check. The stem, deprived of photosynthetic products, grows more slowly, and the internodes laid down while the cane is in an injured condition are shorter and narrower than those produced by normal growth. The internodes are also usually brittle, and snap readily immediately above the nodes. Williams ([29]) showed that an exactly similar effect upon the stem was produced by cutting off the leaves of the cane and this experiment has been repeated and confirmed by myself. It is clear that injury to the stem is due to the check which reduced leaf metabolism gives to the plant by failure to continue the supply of elaborated food materials.

There are other changes which occur in the stem consequent upon death of the leaves. These are largely due to enzyme activity, the enzymes being resident mainly in the tops of the canes. By oxidation, a red-brown discoloration is often produced, similar to that noticed in the leaves, but more striking is the change in reaction of the cane sap, with hydrolysis of sugars, &c. Normal cane sap varies slightly in reaction with age and variety of cane, with the soil upon which it has been grown, and also with the region of the cane from which the juice has been extracted. Care has to be exercised in taking *p*H readings not to expose the sap unduly to air, and to avoid delay. Using Clark and Lubs' indicator dyes, the reaction of a healthy cane sap is found to lie between *p*H 6·0 and 6·3, when grown in soil in the College vicinity. The young parts of the top of the cane often have a slightly greater acidity, *p*H 5·9 or so. Canes grown on heavy clay soils, often when less acid than the College soils, showed greater acidity.

With injury by froghopper and death of the leaves, the *p*H of the cell sap falls gradually, starting at the top of the cane. In fairly good soil, it rarely drops below *p*H 5.7, but on some heavy soils it may be as low as 5·4. This increase in acidity is most noticeable at the top of the cane where enzyme activity is greatest. Following upon increased acidity, the top of the cane gradually dies, and the terminal bud rots. Shoots may be sent out from eyes near the base of the stem. This final condition is characteristic. With continued post-mortem changes in the top of the cane stem, the *p*H rises again, and it may become less acid than a normal healthy cane some time after death. Death of the terminal bud, when not itself directly injured by the froghopper, is undoubtedly due to interference with the supplies from the stem and the formation of toxic products during the course of pathological changes in the stem. Shooting from the lower eyes is to be expected as a sequel to death of the growing point and alteration in the osmotic pressure of the cell sap.

Recovery of the cane, so far as the stem alone is concerned, is dependent upon an arresting of the pathological changes above described. A cane which is likely to recover does not show much increased acidity after the leaves have died, but it is questionable whether a cane with more highly buffered juice would be more resistant than one with a less highly buffered juice. Uba is noteworthy as being a very vigorous cane and one which is resistant to many diseases under difficult soil conditions. It stands up better than any other variety under froghopper attack. One may associate with this vigour the fact that the juice has an unusually high colloid content, only too well known to sugar manufacturers as increasing their difficulties in clarification. We are therefore forced to recognise the possibility that the more resistant a cane is to froghopper, the less acceptable it may be to the manufacturer.

The importance of good conduction in the stem to resistance against froghopper attack was most strikingly illustrated by the single case described below. In a patch of farmer's canes at St. Augustine on 1st February, 1925, one stool was noticed bearing four canes. Of these canes, one was slightly taller than the others, but it bore somewhat smaller leaves, and was obviously in poorer condition. The remaining three canes of the stool were fairly vigorous. There was evidence of slight froghopper attack throughout the whole cane plot. The striking feature of the stool noted was that the slightly taller cane showed much froghopper damage on the leaves, while the three smaller but more vigorous canes were quite insignificantly damaged. This was totally unexpected, a varying resistance within one plant, and the cane was therefore carefully examined. The roots of the stool were apparently quite healthy. Examination of the stem showed that the taller cane was badly bored by *Diatraea* larvae, while the smaller canes were untouched. The explanation of this phenomenon would seem to be that conduction had been interfered with by borer to such an extent in the taller cane that the leaves were in a state of water shortage. The three healthier canes with good stems did not show such suceptibility to froghopper injury. It may also be added that the bored cane showed more acid sap than the unbored canes, as was to be expected.

Carmody ([5]) noted the coincidence of local attack by the large moth borer, *Castnia licus* and froghopper at Caroni in 1908. Nowell and Williams have mentioned other cases with *Diatraea saccharalis*, but they refer to the borer attack as a complication of the froghopper attack.

Effect of Soil Conditions.

The optimum soil conditions for sugar-cane are apparently unknown. We do not even know definitely the range of H-ion concentration which is most conducive to good development. With such ignorance it is obviously impossible to proceed very deeply into the effect of soil conditions upon froghopper attack.

It has been mentioned by Williams and others that attacks from froghopper are worse upon acid soils, and evidence has been adduced in support of this opinion. The present writer was struck by the possibility, after a perusal of existing literature, and therefore made a preliminary survey of the reactions of Trinidad soils subject to froghopper attack. A Wherry double-wedge comparator was used in most of these investigations, and was found to give sufficiently accurate results for the purpose. Its ease and relative rapidity of manipulation was a distinct advantage. From these preliminary studies, it became evident that acidity alone had little to do with susceptibility to froghopper attack, and that the *p*H recorded from most bad fields could not be considered as injuriously acid. Moreover, when attention was turned to the good fields, many of these were found to be equally acid, or even more so, than the bad ones.

In Williams' time and before, the method of testing soil reaction was by means of litmus paper, and the selection of soil samples was not in accordance with the more careful modern methods. The sources of error with litmus are well known.

In the present cursory survey, it was found that several heavy clay soils on lands attacked badly by froghopper were even alkaline in reaction, and a *p*H of 8·0 was by no means rare for some reddish and some grey black clays. Many of the very bad red clays were neutral. The acid soils were often not more acid than *p*H 6·5. Further north in the island, on lighter soils which are hardly subject to froghopper, the pH was found sometimes to be as low as 5·5. A *p*H of 6·5 was perhaps the average for the samples taken. Without going further, it was obvious that acidity of the soil could not be correlated with froghopper blight, and this line of research was therefore no longer pursued. There is much work, however, to be done, and a soil survey of Trinidad upon modern lines is badly needed. It is useless to attempt to draw conclusions from the casual examination of a few blighted fields when the conditions obtaining in good fields are unknown.

The opinion has been expressed by both Williams and Nowell that much of the remedy for froghopper blight lies in the improvement of soil tilth. It is considered, and rightly, that canes grown upon soil in a good state of tilth will be healthier and more readily able to withstand the effects of froghopper attack than those grown upon soil in bad condition. The need for sound agricultural methods cannot be over-emphasised in Trinidad, but improvement of the physical condition of many soils in the island will be a long and tedious process. Some of the most noteworthy froghopper soils are incredibly heavy clays, and it is indeed remarkable that canes will grow at all upon them. Speaking of certain lands well known for their predisposition to blight, G. W. Robinson of University College, Bangor, says (in litt.) "The Cedar Hill black subsoil is the heaviest clay I have ever seen. I don't think we could show such heavy soils in cultivation in this country. If there are soils as heavy they are down to grass."

In the great majority of cases, the most serious froghopper attacks occur upon heavy compacted soils in thoroughly bad physical condition. It is in no way surprising that canes growing upon such soils are frequently in a state of physiological drought. It is a well-recognised fact that plants growing upon waterlogged and oxygen deficient soils behave as though in a state of water deficiency. Interference with water absorption by the roots is one of the first effects of the removal of oxygen. Xerophytic adaptations are characteristic features of plants native to badly aerated soils. In the case of some of the soils noted in Trinidad, it would seem as though failure of the plant to obtain an adequate water supply could be attributed to soil toxicity, but more often it is probably due to the fact that the clay soils with their high content of hydrophilic colloids are actually more retentive of water, and the plant is unable to exert sufficient pull against these retaining forces. Ecologists are well aware that the percentage of non-available water in clay soils often reaches a high figure, and that it is distinctly greater than that of soils more open in texture Thus Gain ([8]) as far back as 1895, showed that, with a mesophyte such as *Lupinus albus*, the non-available water in clay was more than 11 per cent., whereas that in garden soil was nearly 3 per cent. and that in sand less than 1 per cent. The work of other plant physiologists from an even earlier date until the present confirms this fact.

It is not, therefore, a matter for surprise that on the very heavy clays of some parts of Trinidad, the canes are extremely susceptible to a slight diminution in water supply, and that, in time of even mild drought, they readily succumb to froghopper attack. Quite a small amount of extra water might serve to turn the balance, and enable the canes to make better way to recovery from the attack.

This point is well illustrated by an instance to which Williams ([29]) refers on p. 109. The Government Pond at Hermitage is situated by the roadside, and to the south and southwest of it is an incline of 40 feet in 180 feet down to a footpath. The soil in the vicinity of the pond is a heavy brown clay, and part of this field, coincident with the worst clay outcrop, was three years in succession damaged by froghopper. Extending down from the pond, where seepage supplied a slight extra amount of moisture, a strip of canes, approximately equal to the width of the pond, showed distinctly less damage.

While emphasising the importance of the water supplying power of the soil to the plant, which the writer believes is by far the most important bearing of the soil upon froghopper, it should not be overlooked that weakness of the cane may be due to other than water starvation. Soil toxicity has already been mentioned as a possible factor in the latter connection, but its toxic action may also affect the health of the plant directly. This requires much further investigation.

Again, the soil may be deficient in materials essential to cane growth. The neglect of crop rotation, which is almost without exception in the island, is bound to have the effect of depleting the soil of constituents necessary to cane. It is also noteworthy that old ratoons, which have for years drawn upon the soil in their immediate neighbourhood, are much more subject to blight than young plants. Of course this is also largely attributable to an old and worn out root system. The great need for rotation of crops has been stressed by Williams and others, and it deserves full attention.

In certain undulating lands such as occur in the south of the island, there is an interplay of two or three soil types. Nearly all these soils are exceedingly heavy. There is some evidence, from the general contour of the land, that occasionally localised blight on land generally believed to be good is due to the presence of retentive subsoil pans which interfere with drainage. To test out this hypothesis a subsoil survey is necessary.

Effect of Fertilisers in Aiding Recovery.

With the knowledge that failure of cane under froghopper attack was due to loss of green leaf surface, and that the best method of aiding new leaf development was by providing a ready supply of soil water with required food materials, it was thought that fertilisers applied immediately after attack might have the desired effect. It was recognised that addition of artificial manures, such as nitrates and potash alone, could have little or no effect in increasing availability of soil water, and that they might, by increasing the osmotic pressure of the soil solution, and by deflocculation, even decrease the availability. From the foregoing study, available water was believed to be of first-class importance, and unless these added materials had also the effect of flocculating soil colloids, or in other ways of reducing the retentiveness of the soil to water, they might do more harm than good. For the purpose, soluble phosphates seemed to be specially indicated on the heavy clay soils, and in addition it was thought that they might stimulate root growth. It has already been noted that canes upon compacted clays showed poor and shallow root systems.

Two series of experiments were made, with various manures, on blighted fields upon heavy clay. The second and larger series was very kindly undertaken by Mr. G. A. Jones of the Usine Ste. Madeleine Sugar Estates. In both cases, the control plots which had no dressings, gave higher yields of cane and better juice than the manured plots. These results will be given and discussed in a subsequent paper of the present series.

Effect of Rainfall.

Williams ([29]) has given lengthy consideration to the subject of rainfall, and reference must be made to his papers. He shows that moderate rainfall for both wet and dry seasons is associated with decrease in the amount of blight, while excessive dryness, or excessive rain for either season, tends to favour increased blight. These views have been corroborated in the present study.

A wet dry-season favours some breeding of the froghopper. A wet spell in the dry season induces emergence of aestivating stages as adults, and, if this is followed by further dry weather damage, becomes manifest on the canes, as has been described earlier in this paper.

In the wet season, the froghopper breeds continuously, and its numbers vary with natural controls. Given the presence of a large number of froghoppers, a slight dry spell will intensify the appearance of damage upon the canes very considerably by reducing the water available to the cane at this critical period.

Excessive rain in the wet season favours increase in the severity of blight. In addition to the effect of excessive rains upon the froghopper, and the influences controlling it which Williams ([29]) has considered, I would draw attention to the effect of such upon the cane itself. Excessive rain on retentive soils is bound to cause temporary waterlogging with defective aeration which produces a result physiologically equivalent to water shortage. This effect has been frequently observed and needs no further elaboration.

Briggs and Shantz ([4]), p. 88, state : "The experiments made in connection with the effect of soil moisture content on the water requirement show, as a rule, an increase in the water requirement when the soil moisture content approaches either extreme." This further helps to explain the apparent contradiction that both drought and excessive rainfall have similar effects upon blight intensity.

Discussion and Conclusions.

Monecphora saccharina is a natural denizen of cane and grass fields when conditions are sufficiently moist and suitable for its breeding. Nevertheless canes do not necessarily show serious blight when froghoppers have been abundandant, nor is abundance of the insect a necessary condition for serious blight. Of course a mass attack of enormous numbers of froghoppers cannot but have a seriously adverse effect upon canes, whether they be growing under good or bad conditions, and attacks of this nature do occur.

The foregoing study has indicated a few of the predisposing causes for increased intensity of the blight. It has not been an object here to attempt explanation of increase in actual numbers of the froghopper, although it is recognised that this has an essential bearing upon the problem. Williams has examined many sides of this question in detail, and my own observations can add but little as yet to his careful enquiry.

It seems quite clear that at times the conditions favouring increase in numbers of froghoppers are correlated with those tending to increase susceptibility of the cane. Also susceptible canes sometimes appear to be actually more attractive to the insects. Whether this is really so or not, it is impossible to say at present, but it is quite likely that cane leaves with subnormal water content contain carbohydrates in a less advanced stage of condensation, and consequently more water-soluble and more easily available to the insect, than those of normal cane leaves. Horn ([10]) has shown that the sucrose content of leaves increases with decreasing water content, and, at the same time, starch decreases. Ahrns ([1]) further observes that sucrose and hexoses are products in a wilting leaf. That, except for a small loss due to respiration, the total sugar formed is represented by a corresponding reduction in starch content. That, in presence of starch, the sucrose content rises with falling and falls with rising water content, and this is true whether in darkness or in light. Sucrose content is to be regarded as a function of water content. Hexose content always rises in starch-containing leaves kept in the dark, but reaches a higher va'ue in wilting leaves than in moist ones. Other investigators have recorded somewhat similar observations. As far as the cane itself is concerned, I can offer no proof. Certain micro-chemical tests made by me were not at all conclusive, although it is highly probable that in cane leaves the same rule holds good.

Other conditions favouring the froghopper may possibly be found in cane leaves with reduced amount of lignified tissue, thus allowing easier penetration of the insect's stylets. Such a suggestion does not appear to be borne out in fact. Also no variety appears to possess any appreciable degree of immunity from attack. Uba certainly stands up well under froghoppers, but it is equally subject to attack with other varieties.

Tannin content may have some effect upon the preference of the froghopper. Maranon ([18]) has shown that mildew resistance in *Oenothera* is associated with higher tannin and water-soluble acid content.

The acidity of the cane was thought possibly to have some influence upon preference of the froghopper, in view of the probability of an optimum pH zone for the activity of the insect's saliva. Again proof has not been forthcoming.

General observations indicate that the froghopper exhibits some, but no very marked preference among canes, and that when increased numbers are found localised in fields of specially susceptible canes, this is usually due to other causes as yet not fully understood.

The effect of the sucking of the froghopper upon the cane can be briefly outlined as a removal of water, carbohydrates, proteins, &c., from the plant, and an injection of enzymes, &c.

Withdrawal of water alone from the cells of the leaf results in a local water deficit, which tends to be corrected if the osmotic pressure of the cell sap is increased such that water passes into the deficient cells from the surrounding tissues. Increase in osmotic pressure of the cell sap is, however, commonly effected by hydrolysis of carbohydrates and the decomposition of other complex molecules to simpler structures, and, as rapidly as these hydrolytic products are formed, they are removed by the insect, whose saliva is also assisting in the decomposition processes. It is clear that a state can be reached in which the physiological equilibrium of the plant cell has been so far thrown over that recovery, even with ample and immediate water supply, is impossible.

Ullrich ([25]), working with *Zea*, has shown that only such chloroplasts as have lost relatively little protein by nitrogen starvation are capable of renewed protein formation. The froghopper undoubtedly removes proteins among other products from the chloroplasts, and this may be responsible for death of the chloroplasts from which removal of carbohydrates is possibly not so serious a matter. Chloroplasts, as also other protoplasmic structures, may of course be killed directly by the toxins presumed to be present in the saliva of the insect if they are sufficiently exposed to their action.

The almost specific and primary effects which have been noticed upon the border parenchyma cannot be without effect upon the translocation of plant food materials, and it would seem more than likely that the very necessary local water supply should be interfered with.

The effect on the phloem and on other vascular tissues which cannot be detected immediately is probably very important and far reaching. In a day or two the phloem begins to show blocking, and is obviously disorganised in function. Such a state cannot fail to impede the passage of water, &c., to and from the neighbouring tissues. Meanwhile, the enzymes of the froghopper's saliva and the released plant enzymes continue their action, and spread from one water-deprived cell to another. Extending death of the tissues is the consequence, until cells capable of reacting successfully are able to arrest further progress of the pathological changes.

Increase in transpiration may occur locally after puncture. It has been demonstrated on a few occasions, but continuance of the increase is doubtful. There is certainly no immediate reduction in transpiration in the vicinity of injury. Reduction in transpiration rate would, by retaining the cell water, probably assist materially in local recovery.

Oxidases of the plant and of the froghopper's saliva seem to be responsible for colour changes and the production of red pigment, but more important is their effect upon the H-ion concentration of the cell sap. It is almost certain that increased acidity results directly from oxidation. Increased acidity may quite probably bring the tissues of the phloem, border parenhcyma, and chlorenchyma nearer the optimum for the insect's salivary enzymes, and also for those of the plant which have been released. Sherman ([23]) has shown that the zone of optimum activity for malt diastase lies between *p*H 4·3 and 4·5, that is in the isoelectric zone of the enzyme itself. This enzyme, which is a protein, therefore exerts its greatest effect upon starch when it is least hydrated and least ionised. It may well be that the diastase of the froghopper's saliva has an optimum zone very near that of malt diastase, in which case one would expect increased acidity of the above-mentioned tissues to favour the enzyme action. Be this as it may, a lowering of the *p*H of the cell sap of the cane is a marked pathological symptom, and canes which show but slight lowering usually recover. A rapid and considerable drop is associated with canes likely to succumb. It therefore seems reasonable to expect that, for a cane to recover, it must resist the change in *p*H, or in other ways arrest continued autolytic enzyme action. H-ion concentration could be stabilised by buffering agents on the cell sap. Uba cane, which stands up against the effects of froghopper better than any other variety, is noted for the higher colloid content of its juice. May not certain of these colloids, especially the albumins, exert a beneficial buffering effect? It is more than probable that they do so. Again, tannins are known to have an inhibitory effect upon enzymes, and they may be important anti-enzymes in the cane. Decreased susceptibility to froghopper may be inseparable from increased colloid content of the cane sap, and should this prove to be true, a good cane for froghopper conditions will probably be a poor cane from the viewpoint of the sugar manufacturer. Various authors have shown that drought and frost resistance in plants may be associated with increased hydrophilic colloid content of the sap, particularly the pentosans. *Vide* Newton ([19]) and bibliography to this paper.

The loss of active leaf surface resulting from frohgopper injury may be very considerable, and, as has often been remarked, the canes present appearance such as if a fire has passed through them. The reduction of photosynthesising surface must result directly in a corresponding reduction in the supply of elaborated products. This accounts for the small starved internodes of the stem which are laid down during the course of blight. Further, the pathological changes already noted in the leaf may continue in the stem from the top downwards; the top being itself richer in oxidases is the first to show a rise in H-ion concentration. With rise in H-ion concentration and continued enzyme activity, carbohydrates are hydrolysed in the stem, and it is likely that the increased osmotic concentration of the cell sap thereby produced is responsible for the shooting of the eyes lower down the stem—another feature of blighted canes. This of course occurs especially if the terminal bud has died.

Recovery of the stem is only possible with renewed leaf surface and renewed power of photosynthesis. This necessitates ample water with required solutes from the soil. The soil may be, and often is, on badly blighted fields, physically or physiologically retentive of its water so far as the plant is concerned; heavy clays and badly aerated or toxic soils being in mind. Fertilisers have not been found beneficial at this critical time. They may possibly increase the osmotic pressure of the soil solution by a small fraction, but none the less sufficient to affect a struggling cane. This point, however, requires investigation. The explanation offered here is not too probable.

Suggestions for Consideration and Trial, Based upon the Foregoing Study.

I. Cane varieties most suitable to the soil conditions should be grown. There is however little choice Canes likely to withstand froghopper attack best are such as can obtain and maintain a water content well above the wilting point under adverse conditions. In this connection it should be remembered that the water requirement of plants upon unfertile soils is greater than that of those upon fertile ones, as Kiesselbach has shown ([15]), although the *total* water necessary is more on the fertile soil, due to increased growth. The more xerophytic types of cane such as Uba suggest themselves as more suitable for employment upon bad soils. Uba plants used as supplies among seedling varieties stand up markedly in blighted fields when the seedlings have been annihilated. No freedom from froghopper attack can be claimed for Uba, merely greater vigour under adverse conditions and this is rather offset by its less desirable factory qualities, which may be directly associated with its drought and other resistance. Agaul might be tried, as it is stated to be resistant to drought and higher in sucrose content than Uba ([31]).

II. As far as possible, a high water content should be maintained in the cane plants. Experimentally, some promising results have been obtained by decreasing transpiration, but field tests have thus far been inconclusive. A slower transpiration stream may be undesirable if reduced transpiration results in reduced solute intake by the roots. As field confirmation is not yet forthcoming, the two following suggestions are not put forward with confidence, although it is intended to continue further along these lines: (1) maintenance of a humid atmosphere around the leaves, to reduce evaporation, and (2) shading from light, to reduce transpiration as such. Wind breaks might be indicated, but they are unlikely to be of practical value. Blight on the tops of ridges in dry weather may sometimes be intensified by wind passage. As regards shading, this again is a matter for practice to decide. The planting of shade trees with cane is never done; it would increase difficulty of reaping, and, if too much light were cut off, the sucrose content of the canes would undoubtedly suffer. An optimum shade could only be determined experimentally. The temporary erection of light shade over blighted canes in the field has given no definite results, but the period was exceptionally wet during these experiments. It is hoped to repeat them in dryer weather.

III. An endeavour should be made to increase the available water in the soil. Water may be unavailable to the cane (1) from actual deficiency, or (2) from physiological unavailability. Actual deficiency of water may occur during the wet season, especially in time of the Indian summer or *petit carême*. A dry spell during the wet season while froghoppers are abundant is disastrous, especially upon infertile soils, where plants exhibit a greater water requirement. Physiological unavailability of water may result from many conditions. (1) High content of hydrophilic colloids, such as is found in very heavy clay soils. This is noteworthy in several districts of Trinidad. (2) Oxygen deficiency in the soil. This again obtains especially on heavy compacted clay soils in bad state of tilth. They have a lower oxygen content than more open soils, even under the same rainfall conditions. Livingstone and Free state that interference with water absorption by the roots is the first result of reduction of oxygen content of the soil. Roots die with prolonged lack of oxygen and drought following upon this is dangerous. Waterlogged soils again are lacking in aeration. Severe blight has been noted on several occasions as a result of waterlogging and defective drainage. There are indications occasionally suggesting that an impermeable subsoil pan may be interfering with drainage, and that such may be responsible for very local intensification of damage. This might be very difficult to rectify. (3) Soil toxicity of various kinds, inorganic and organic. Root development and intake of water is interfered with on toxic soils. (4) A poor root system. Canes on compacted or toxic soils often have ill-developed roots. The same applies to canes affected with root disease, and it is probable that nymphs of froghoppers feeding upon the roots have a deleterious effect upon root development. All these factors may be interdependent. Fertilisers applied at the surface may sometimes have a bad effect by inducing a superficial root formation which is dangerous in time of drought. (5) High soil temperature. In certain rare cases of blight following upon weeding and trashing of the canes (which may be done by planters in the hope of reducng the number of frohgoppers at the last moment) it is possible that greater exposure of the soil to the rays of the sun, particularly at midday, may produce a soil temperature sufficiently high to retard root absorption at a time when water is most needed by the leaves. (6) High osmotic concentration of the soil solution. Such is unlikely on ordinary soils, but it is a possibliy to be borne in mind.

From the most cursory observation, it is clear that usually many factors operate at once, and it is for this reason that evidence often appears conflicting.

An obvious recommendation falling under the present heading of increasing water availability, is one which both Nowell and Williams particularly have emphasised, namely, the improvement of the physical condition of the soil by thorough tillage and attention to general agricultural practice. Liming is probably more valuable under this heading than in its capacity for correcting soil acidity. Phosphate applications would seem to be indicated on many heavy clays both for their flocculating powers, for correction of possible aluminium toxicity and for stimulating root development, but experimental results have not been promising. The matter will be dealt with in a later paper. On the other hand, one would do well to avoid fertilisers known to have a peptising effect upon the soil.

One great desideratum in Trinidad is a crop, preferably leguminous which can be grown in rotation with cane, to be used as a green dressing. It should be a good cover crop, to keep down weeds, and when turned into the soil, should be sufficiently woody to decay slowly and leave air channels, thus assisting in aeration of the soil.

Irrigation is not practicable in most parts of Trinidad, and, in any case, it would be troublesome and difficult to regulate upon heavy clays. It might do more harm than good by reducing soil aeration. It would be costly to establish. Trinidad has a heavy rainfall, and an excess rather than a scarcity of water during the greater part of the wet season. Irrigation during the dry season would no doubt induce the frohgopper to continue breeding throughout the year. Flooding to kill the nymphs is useless as they ascend the stems with a rise in water level.

Several other sucking insect pests have been noted as being influenced by environmental conditions, and highly commendable research is that of Andrews (2) upon the Tea Mosquito Bug, *Helopetis*. He shows that " an approach to waterlogged conditions, and an increasing soil acidity, conduces to a greater liability to suffer from serious attack',' but he lays most stress upon the ratio of available (not total) potash to phosphorus in the soil. Similarly, he finds that the amount of potash compared with that of phosphoric acid in the leaf is correlated with degree of immunity. Finally, he clinches his arguments by stating that when a constant supply of soluble potash is applied to attacked plants, they can throw off the attack completely, and remain immune for the rest of the reason.

Response to manuring with potash has not been obtained with froghopper blight, and no analyses have been made of the leaves. Similar influences may be at work in both tea mosquito and froghopper blights. Potash may be necessary in Trinidad but unavailable due to some interfering factor. Further work needs to be done along these lines.

There is a possibility that the relative abundance of various species of thrips is dependent upon the water relations of their host plants. When in England, some years ago, the writer had occasion to observe a case of thrips attack upon *Fuchsia*, under greenhouse conditions, following upon reduction of water, while similar plants regularly watered were not attacked. Recommencement of regular watering resulted in a gradual disappearance of of the insects, and a final freedom of the plant. Dr. S. C. Harland tells me that he has observed another such case at the Shirley Institute, Didsbury. Cotton plants were being grown with varying water supplies. Thrips attacked only those plants which were short of water.

In the West Indies and elsewhere, *Selenothrips rubrocinctus* seems to behave similarly upon cacao. The pest often occurs on the edges of the plantations where the atmosphere around the leaves is presumably less humid, or else it commonly becomes a nuisance in the dry season. Such is the rule. Ballou (3), quoting an exception to the dry season incidence of thrips in Grenada, says, "I may say that whenever I was shown thrips attacks, I found root disease, or insufficient drainage, or very shallow soil with terrace or heavy clay beneath or lack of humus. I was shown several instances where trees had been freed from the insects by drainage." Thus again we probably have a state of physiological water shortage, probably associated with reduced foliar transpiration; conditions favourable to the insect.

Wilkinson ([28]) remarks that *Diarthrothrips coffeae* is unable to live on shaded coffee trees in Uganda. The shade no doubt is responsible for increased atmospheric humidity, and reduction in transpiration probably preserves a higher and more equable water content of the foliar tissues of the coffee trees.

Other examples, giving similar indications, could be quoted, and I think that one may say that there is fair evidence of the water relations of plants being responsible for the prevalence or otherwise of several sucking insect pests.

The importance of the availability of plant food materials other than water has not been overlooked, but the availability of these is inextricably interrelated with the availability of water. All food materials, minerals, &c., must be taken up in solution by the roots. Water is the vehicle. With further research we may reach deeper. This is passing beyond the work of an entomologist, indeed it is with much trepidation that the writer has ventured so far, but it is hoped that further work by those competent will complete our evidence on this most important phase of insect control.

Summary.

(1) Of the two important aspects of the problem, namely, (1) the factors controlling the numbers of the froghoppers themselves, and (2) the conditions influencing resistance of the canes to, and recovery from attack, the second is considered in the present paper.

(2) The saliva of the froghopper is slightly acid (pH 6·0-6·2), and it contains amylytic and oxidising enzymes.

(3) The effect of the froghopper sucking the cane leaf is described, noting especially the peculiar and primary effects upon the border parenchyma.

(4) Later spread of injury is described in detail, and various fluences at work are considered.

(5) The water relations of the plant appear to be highly portant in connection with recovery from injury and retardation the spread of injurious effects.

(6) Fertilisers have not been shown to aid recovery.

(7) The problem is discussed in several of its aspects and the ntents of the paper, with suggestions for further investigation e thus summarised. " Canes do not necessarily show serious ght when froghoppers have been abundant, nor is abundance the insect a necessary condition for serious blight." A *great* undance of froghoppers, of course, is bound to have a seriously leterious effect, quite apart from the conditions of the cane. ne importance of water relations is emphasised.

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