INSECTS AND MOTTLING DISEASE.

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The fact has been brought out by Professor Earle, in a preceding page, that most previous investigators of the sugar-cane mottling (or "yellow stripe") disease, notably in Java and Hawaii, have dealt with it as an inheritable bud variation and have failed to recognize its infectious nature, or at least to consider it as an important factor from an economic standpoint. Even in Porto Rico the infectious character of the disease was not recognized until the latter part of 1917. It is not surprising, therefore, that few attempts have been made, previous to the present work, to demonstrate a possible connection between insect attack and secondary infection with mottling disease.

The laboratory experiments detailed in this report were started in the spring of 1918, but had been preceded by a considerable amount of field work, made in the districts where the injury from mottling disease was most acute, in attempt to ascertain what insects might be concerned in the spread of the epidemic. In the experiments, four successful inoculations by insects have resulted, to date, while no control plants have become diseased, which would seem to fasten the responsibility, in these cases at least, upon the insects as carriers of the virus. It is felt, however, desirable to obtain duplications of the few positive results before conclusion may be safely drawn that insects are a principle means of communicating the disease.[1]

The idea that insects might carry the disease in Porto Rico found its origin in the knowledge of a number of unique, well-established facts:

1. Mottling disease is spread not alone by planting infected "seed," but may easily communicate itself to plants germinated from healthy cuttings. Experimental evidence tends to show that this spread of infection takes place neither through the soil nor by physical contact.

2. Such natural agencies of spread of disease as wind and surface water cannot account for the equal and general spread of mottling disease in all directions from infected to healthy plants.

[1] Since the above was written, two additional plants have become mottled (diseased) as result of the attack of virus-bearing *Stenocranus saccharivorus*, and three others have shown positive secondary infection (inoculation) in cages containing both cane-fly and yellow aphis. No control plants have yet become diseased.

3. Secondary infection is by no means confined to the plants immediately adjacent to diseased plants, but may occur on isolated plants at considerable distance from the seat of infection.

4. The rate of spread varies greatly with the season, not apparently in conformity with any seasonal abundance of wind or rainfall, nor with the amount of irrigation or cultivation, but in possible (if not probable) conformity with the seasonal abundance of certain insect pests.

5. Some very similar diseases of other cultivated plants, notably those known as virus diseases (such as mosaic diseases, spinach blight and sugar-beet curly-leaf) have been proven to be carried by insects; and in the case of some of them there has been found no other means of communicating the disease than by insects.

6. The two classes of insects proven to act most commonly as vectors of virus diseases—the leafhoppers and the plant-lice—are well represented among sugar-cane pests, and are often abundant in cane fields of the Island.

The accompanying tables (Tables I and II) give the names and hosts of a number of plant diseases occurring in the States that have proved to be transmitted, at least in part, by insects. An attempt has been made to show in these tables what characteristics the cane mottling disease has in common with other insect-borne diseases, and in what important details it differs from one or another of them.

Field Evidence in Support of Insect Transmission.

From such data as has been accumulated from field trips over the Island, it appears that there is no single species of cane-infesting insect or mite sufficiently common and prevalent in all districts, and at all seasons, where the disease is present and spreading, to account for the very general "run" of epidemic that has occurred.

If it shall later develope that several insects are concerned in the spread of the disease—and the results of our experiments to date lead to that belief—then we may possibly attribute the spread of the epidemic to one or another prevalent pest in each district where spread has been in progress. For instance, during periods of most rapid spread in the Guánica and Ponce districts, the yellow thrips has been the prevailing cane pest, and in fact the only one present in large numbers on both young and mature cane, and therefore the only one which might account for wholesale secondary infection in both young and mature cane. Rapid spread of mottling disease observed on numerous occasions in the Arecibo section might have been

blamed upon the green leafhopper, which occurred in all fields, particularly of young cane. On some occasions, local rapid spread of the disease has been observed to occur simultaneously with abundance of the yellow cane aphis, and this has seemed at the time significant. The spread of mottling disease in fields of the experiment station at Río Piedras has occurred usually at times when there was considerable cane-fly present in the fields, but no other cane pest that seemed to be able to account for the spread.

In the following paragraphs will be discussed briefly the cane insects which may be suspected of having possible connection with spread of the mottling disease, from a judgment based purely upon field observations.

Cane Insects as Possible Carriers of Mottling Disease.

the yellow cane thrips (*Frankliniella* sp.).

This small thrips has been observed for the past two years to be very abundant on young to half-grown sugar cane in fields on the south coast, in the Guánica and Ponce districts. It is most prevalent in the winter season, which is the time during which spread of the disease is most rapid. It is the only cane pest of those districts that has been found universally present, in large numbers, in both young and mature cane, being considerably more abundant, however, in the young cane. The ratio of its numbers in young and mature cane bears, in fact, a striking similarity to the proportion of secondary infection in young and mature cane. These thrips lay their eggs in the cane leaves, and breed in large numbers between the terminal, young, unfurled leaves, where their attack scarifies the leaf surface along the midrib, near the base of leaf, causing white scars that later turn brown. Young plants two to three feet in height often bear dozens of the thrips among their terminal leaves, which are not very visible except by tearing open the terminal bud; and it has been noted that the first evidence of mottling on a young plant usually occurs near bases of the terminal leaves in the region showing attack by this thrips.

This insect has not been noticed in abundance in other parts of the Island, though on one occasion it was found in young canes in a field at Río Piedras, during a dry spell, which indicates that it may also occur at other points along the north coast at some seasons. The adults are strong fliers, and could spread rapidly to other parts of a field from a few infected canes. Such search as has been made

TABLE

A SUMMARY OF OUR KNOWLEDGE OF INSECT-BORNE

Name of Disease	Principal Economic Hosts	Other or Wild Host Plants	Nature of Disease
1. Hawaiian Cane "Root Disease" (*Ithyphallus coralloides*).	Sugar cane.....	Lantana and other roots.	Fungus.....
2. White Pine Blister Rust (*Cronartium ribicola*)	5-leaved pines (18 spicies).	*Ribes* spp.....	Fungus.....
3. Chestnut Blight (*Endothia parasitica*).	Chestnuts and chinquepin.	.....	Fungus.....
4. Currant Stem Blight (*Botryosphaeria ribis*).	Currant and gooseberry.	Wild spicies of Ribes	Fungus.....
5. Tree-cricket Canker (*Leptosphaeria coniotherium*).	Raspberry ("Cane blight").	Apple, rose and elm.	Fungus.....
6. Apple Bitter-rot (*Glomerella cingulata*).	Apple, pear, peach, grape, quince.	Citrus, cocoa, coffee, mango, etc.	Fungus.....
7. Tomato Leaf-spot (*Septoria lycopersici*). (2)	Tomato	.....	Fungus.....
8. Carnation Bud-rot (*Sporotrichum poae*).	Carnation.....	June grass (*Poa pratensis*).	Fungus.....
9. Internal Disease of Cotton Bolls (4 undetermined fungi).	Cotton.....	Over 15 plants in 7 families.	Fungus.....
10. Fire Blight (*Bacillus amylovorus*).	Pear, quince, apple, apricot.	....	Bacterial...
11. Bacterial Wilt of Cucurbits (*Bacillus tracheiphilus*).	Cucumber, squash, melon, gourd.	Wild cucurbits.....	Bacterial...
12. Sugar Beet Curly-top.....	Sugar beet.....	14 known plants in 8 families.	Virus.....
13. Spinach Blight.....	Spinach.....	Not yet determined..	Virus.....
14. Tobacco Mosaic Disease.....	Tobacco, tomato, pepper, petunia.	*N. rustica*, Jimson weed, and *Hyoscyamus niger*.	Virus.....
15. Potato Mosaic Disease.....	Irish potato.....	.....	Virus.....
16. Cucumber Mosaic Disease.....	Cucumber, pumpkin, squash cantaloupe	Gourd.....	Virus.....
17. Potato Hopperburn (4).....	Irish potato, apple, raspberry.	Dahlia and box-elder	(?).....
18. Sugar Cane Mottling Disease.....	Sugar cane, corn?, rice?, millet?	Sorghum, foxtail, crabgrass and Panicum. (5)	Virus (?)...

(*) A continuation will be found in Table II, following. These data have been taken from such sources as were available to the writer, and an attempt was made to make them as complete as possible, for purposes of comparison. The arrangement of the diseases is one of convenience only. A bibliography of the more important writings on insect transmission of plant diseases will be found at the end of this article, on page 112. The vacant spaces and question marks, in this table, serve to show how imperfect is our knowledge of the entire subject of insect transmission of plant diseases, and how great the need of research work along this line to aid in solving important problems of disease control. The deficiency of results from past endeavors to demonstrate insect transmission of disease shows, furthermore, how faulty is our system of technical training as regards a proper appreciation of the close co-ordination of pathology and entomology.

(1) Manner of transmission of the spores or virus by insects concerned. By the term cyclical is meant, substantial proof that the inoculum of disease, taken internally, must un-

I. (*)

DISEASES OF PLANTS OCCURRING IN AMERICA.

Proven Insect Transmitters	Insect Carriers of Viable Spores	Probable or Suspected Insect Carriers	Mechanical or Cyclical (1)	Externally or by Ingestion (1)	Disease
.....	Sarcophagid and Muscid flies.	Ants; a beetle; sow-bugs; earwigs.	Mechanical	Both....	1
(Urediniospores) Lepidop. larvae; rose beetle; ants; stink-bugs; a weevil.	Any insect coming in contact with spores.	(Aeciospores) *Porthetria dispar* and *Pissodes.*	Mechanical	Probably both	2
.....	Any insect coming in contact with spores.	*Leptostylus maculata,* a beetle.	Mechanical	Both....	3
....	.....	*Psenocerus supernotatus,* a beetle.	Mechanical	(?).....	4
Œcanthus niveus; Œ. angustipennis.	Same	*Œ nigricornis: Œ. exclamationis;* bees to the fruit.	Mechanical	Both....	5
Pomace flies (*Drosophilidae*).	Same	Tree-crickets; fruit frequenting insects.	Mechanical	Both....	6
....	Potato beetle; tomato horn-worm; a lady-beetle. (2)	Flea-beetles and leaf frequenting insects.	Mechanical	Both....	7
.....	.....	A Tarsonemid mite. *Pediculopsis graminum.*	(?)	(?).....	8
Dysdercus spp., *Nezara, Leptoglossus, Phthia.*	Same	....	Mechanical (?)	(?).....	9
Scolytus rugulosus; bees; aphids; *Lygus pratensis; Empoasco mali.*	Same	*Ceresa bubalis;* wasps, flies, ants, thrips, borers, tree-crickets, Elateridae	Probably mechanical	Both....	10
Diabrotica vittata and *D. duodecimo punctata.*	Same	.....	Mechanical; doubtfully cyclical	Both....	11
Eutettix tenella.	.....	No other	Apparently cyclical	Ingestion	12
Macrosiphum solanifoliae; Rhopalosiphum persicae; Aphis rumicis; Lygus pratensis.	.....	....	Possibly both (3)	Apparently both	13
Rhopalosiphum persicae; Macrosiphum tabaci.	.....	Flea-beetles; some sucking insects.	(?)	(?).....	14
Rhopalosiphum persicae and another aphid.	.....	.....	(?)	(?).....	15
Aphis gossypii	.....	.....	(?)	(?).....	16
Empousco mali	.....	No other.....	(?)	(?).....	17
W. I. cane-fly; leaf scale: yellow aphis; mealybug. (6).	.....	Yellow cane thrips; shot-hole borer.	(?)	(?).....	18

dergo a period of incubation before it becomes infectious to a healthy plant, which is taken as evidence that it undergoes some change, perhaps cyclical, within the body of insect.

(2) The same insects are reported also as carrying the spores of early blight, *Alternaria solani,* that attacks also potato.

(3) The fact that the virus of this disease may be inherited through several generations of the aphid gives grounds for belief that the transmission is of a cyclical nature.

(4) It has not yet been determined, according to the author of the investigations, whether this malady is a specific disease, though it gives evidence of being one.

(5) The list of host plants of the cane mottling disease is taken from the bulletin by E. W. Brandes, not from the present publication.

(6) As noted in the text, the apparent transmissions resulting from attack of the four insects here listed are considered to require to be experimentally repeated before the evidence against these insects is conclusive.

TABLE

A SUMMARY OF OUR KNOWLEDGE OF

(*Continuation*

Disease	Length of time insect can carry inoculum	Infectivity inheritable in insect	Other means of natural dissemination
1 Hawaiian Cane "Root Disease"	6 to 18 hours internally.	No	Mechanical spread of mycelium.
2 White Pine Blister Rust	(?)	No	Wind; rain; animals; birds; nursery stock.
3 Chestnut Blight	(?)	No	Wind; rain; animals; birds; nursery stock.
4 Currant Stem Blight	(?)	No	Wind.
5 Tree-cricket Canker	Over 20 days externally; 6½ hours to 5 days internally.	No	(?)
6 Apple Bitter-rot	(?)	No	Wind and rain from cankers and mummies.
7 Tomato Leaf-spot	(?)	No	Hands of pickers; wind and rain.
8 Carnation Bud-rot	(?)	(?)	(?)
9 Internal Disease of Cotton Bolls	(?)	(?)	None known.
10 Fire Blight	(?)	(?)	Rain; unsterilized tools; nursery stock; infected prunings.
11 Bacterial wilt of Cucurbits	Over winter	No	Rarely by root contact.
12 Sugar Beet Curly-top	Over 111 days	No	None
13 Spinach Blight	For 4 successive generations.	Yes	None known.
14 Tobacco Mosaic Disease	(?)	(?)	Hands of pickers; contact of leaves.
15 Potato Mosaic Disease	(?)	(?)	Mosaic tubers; through the soil.
16 Cucumber Mosaic Disease	(?)	(?)	None known.
17 Potato Hopperburn	(?)	(?)	Apparently none
18 Sugar-cane Mottling Disease	(?)	(?)	Cuttings

II.

INSECT-BORNE DISEASES OF PLANTS.

from Table I.)

Successful methods of artificial inoculation	Disease transmitted through soil	Carried through the seed	Transmitted by vegetative reproduction	Infectious by contact or handling	Disease
By mycelium only	Yes	No	Principally	No	1
By spore germination	No	No	No	Urediniospores on currant.	2
By spore germination	No	No	No	No	3
By spore germination	No	No	By cuttings		4
With the excrement of tree-crickets.	No	No	No	No	5
By spore germination	No	No	No	By spore contamination.	6
By spore germination	No	No	No	Very	7
None performed	No	(?)	(?)	(?)	8
None	No	No	No	No	9
Spraying or rubbing with spore-laden material.	No	No	No	Rarely	10
Needle pricks; water suspension of spores poured over soil.	Rarely, when roots are injured.	No	No	No	11
By grafting; no other	No	No	Yes	No	12
Needle pricks; juice of crushed virus-bearing aphids.	No	No	Would be	Yes, if tissue is crushed.	13
Needle pricks; rubbing or spraying with virus.	Rarely, when roots are injured.	No	Would be	Very	14
Injection of or rubbing with virus.	Yes	(?)	Principally	Yes, if tissue is crushed.	15
Needle injections; contact of virus with wounds.	No	(?)	Would be	Yes, if tissue is crushed.	16
None	No	No.	No	No	17
(See preceding articles by the pathologists).	No	(?)	Principally	No	18

has failed to reveal the presence of this species on "malojillo" (*Eriochloa subglabra*), the common grass of the cane fields, but it is altogether probable that the species may breed in some wild grasses as well as in cane, and this fact will be determined.

THE WEST INDIAN CANE-FLY (*Stenocranus saccharivorus* Westw.).

This green plant-hopper is very generally distributed over the Island in the cane fields, but seems never to become abundant, due, it is believed, to the activity of its natural enemies. These consist principally of three parasites (a Stylopid, a Mymarid and a Dryinid) and a common grass lizard (*Anolis pulchellus*). Because of the close relationship of this insect to the sugar-cane leafhopper of Hawaii (*Perkinsiella saccharicida* Kirk.), which has been accused of causing the destructive rind disease to a great extent in those islands, it is plausible to believe that it might become a factor in the distribution of cane mottling disease in fields where it becomes fairly prevalent. That the cane-fly is capable of very great increase in numbers, and of correspondingly serious damage to cane, in situations where it is not kept in check by rain, high wind, and other natural elements of the weather in addition to its natural enemies, has been shown by its phenomenal increase in the experimental greenhouse of the experiment station, and in certain screen-covered breeding cages, where it has often literally covered the undersides of cane leaves, and caused by its copious secretion of honey-dew a growth of black mold that smothered the lower leaves of the plants. As a cane pest, it must be considered an element of great potential danger in connection with possible spread of mottling disease, if not from its own injuries to cane.

THE YELLOW SUGAR-CANE APHIS (*Sipha flava* Forbes).

This small insect is a source of danger, in connection with the spread of disease, not alone from the fact that it is quite prevalent and generally distributed in cane fields, and often becomes so abundant as to assume the proportions of an epidemic, but also from the fact that it is closely related to certain insects (also aphides) that are known to carry virus diseases in other plants. Such diseases, transmitted by aphides, are the tobacco mosaic, the spinach blight, and the potato mosaic. The yellow aphis has been found prevalent in a number of fields where mottling disease was present and spreading; but there have, at the same time, been fields subject to spread of the epidemic where the yellow aphis was not found; so

that indictment of this insect from field observations alone is not permissible.

THE GREEN SUGAR-CANE LEAFHOPPER (*Kolla similis* Walk.).

This bright green leafhopper, because of its prevalence in fields of young cane in nearly all parts of the Island, was one of the first to fall under suspicion. Its close relationship to the leafhoppers that transmit curly-leaf of sugar beets, and hopper-burn of potato, in the United States is added reason for placing it among the species worthy of investigation. In the laboratory this insect has been reared from egg to adult, generation after generation, on sugar cane, and the frequent finding of nymphs on sugar cane in the fields adds to the belief that it breeds on cane commonly, though perhaps to a greater extent on Para grass (*Panicum bardinode*) and "malojillo" (*Eriochloa subglabra*), its wild food plants.

The two facts which throw question on the possibility of this insect carrying the disease are: first, the fact that it occurs commonly only on cane under three feet high, and rarely on half-grown cane, but almost never on mature cane, whereas secondary infection may take place in cane of any age; and second, the fact that all experimental tests (and there have been more with this than with any other species) have failed to demonstrate its ability to carry the disease.

THE SUGAR-CANE SHOT-HOLE BORER (*Xyleborus* sp.).

This very small boring beetle was observed by the writer, two years ago, to be present and infesting the seed sections from which were sprouting some young canes in the Guánica district that were highly infected with mottling disease. It was stated by the field manager that the seed had come from healthy cane; and observation showed that there was no older mottled cane in immediate vicinity, though fields of mature cane at distances of a quarter to half mile from the young cane were considerably infected. As this insect is known to attack and bore into live standing cane, particularly when soured or unhealthy, it seems not improbable that adults migrating from mature mottled canes in cankered condition, and attacking the seed in the ground before or at time of germination, might easily carry the disease with them and transmit it to the sprouting young canes. Experience in other parts of the Island has shown seed-cane sections in sprouting condition to be very often infested with this pest, so the chance of the disease being thus caried may not be re-

mote. Laboratory tests with the insect have not yet been made. A closely related species of *Xyleborus* (*X. perforans* Woll.) has been accused of complicity in the spread of a sugar-cane disease in Trinidad (see Insect Life, Vol. V, page 51).

THE MEALYBUG.

Of this there are two species, *Pseudococcus calceolariae* Mask. and *Ps. sacchari* Ckll., which are almost indistinguishable except under a microscope, and are apparently about equally common. They attack mature cane on the stalk about the node, protected beneath the leaf sheaths, but on young cane are confined largely to the base of plant and the roots. As mature female mealybugs do not fly, and crawl but very little, they are wholly dependent upon foreign agency for their distribution. This takes place largely through the scattering of infested stalks or cane tops during the hauling, or from scattering by hand. Mealybugs may be carried also on floating fragments of infested cane on irrigation water. Birds may carry the young on their feet, but such dispersion is very limited. It is claimed that ants carry live mealybugs from plant to plant, and thus start new colonies, but this contention needs further corroboration. A field may become infested from insects that migrate upward onto young plants from the infested seed pieces, and is still more often infested from the stubble of the previous crop, or from grass or volunteer cane in the field that has harbored thousands of the mealybugs from the preceding crop. By any of the means here mentioned, mealybugs might be able to carry the mottling disease from a previous to a new crop, and even to spread it to some extent, if it may be shown that they are able to transmit the infective principle of this particular disease; but it is quite inconceivable that an insect so utterly dependent upon human agency for its spread, could be responsible for rapid spread of the disease in a field planted entirely to healthy seed, and in which a previous crop had not been seriously infected—conditions very frequently met with in connection with a study of the mottling disease.

THE CANE RUST-MITE (*Tarsonemus spinipes* Hirst).

This very minute white mite attacks principally the stalk and leaf sheaths, where it forms large clusters of very small, flat brown blisters, that give the plant tissue a scabby or scarred appearance. The mite infests new plants by migrating upward from the infested seed pieces. Its bionomics are little known, but it is possible that

the rust-mite may also be spread by attaching itself to winged insects that frequent the cane, which may carry it to new plants. This is a habit shared by many of the mite pests of plants. Altogether, however, what has been said of the mealybugs, in connection with their possible agency in the rapid spread of the mottling disease, may also be said of this pest. Its means of transportation are too limited to give it serious import in this connection.

THE SUGAR-CANE RED-SPIDER (*Oligonychus viridis?*)

This very small acarid pest of cane, while often abundant and doing damage to cane foliage in our greenhouse and in rearing cages, has not been noted as abundant at any point in the field, and is in fact rarely seen. Being a sucking insect, it may be regarded as a possible disease carrier when abundant. As its principal means of distribution are the wind and other insects, to which it attaches, and to some extent mechanical carriage on clothing or animals, there is probably small chance of its taking any part in a general and rapid spread of the disease.

THE CANE ROOT MITE (*Uropodus* sp.).

This pest was first noted in the Arecibo district more than three years ago when making studies of the sugar cane in connection with mottling disease, and has since been found abundantly at Río Piedras and in other districts. Its damage arises from its attack on the roots, which in some cases it tunnels and severs to a coniderable degree. Although diseased plants seem to be most badly attacked by it and the roots showing its injury are in many cases diseased and partly decayed, it has been found attacking also healthy roots, so in some cases is believed to be the primary cause of the root decay. What connection the root decay accompanying attack of this mite may have with the external symptoms which we know as mottling disease has not been fully worked out, but is the subject of investigation. This animal belongs to a group of mites which possess the habit of attaching themselves to beetles as a means of transportation and distribution.

THE FIRE-ANT (*Solenopsis geminata* Fabr.).

This is the commonest species of ant in the cane fields of Porto Rico, and attends all species of aphis, scale and mealybug. Some of these insects it even protects by building earthen shelters over the

colonies, when these latter occur on the stalk near the ground, and it will attack vigorously any intruder on the insect colonies. The possibility of this ant carrying a disease mechanically on its feet or body, as the gypsy moth larva carries the white pine blister rust or the Colorado potato beetle carries the early blight, is not to be ignored; yet until the mottling disease of sugar cane is proven to be caused by a definite spore-bearing organism capable of isolation and of causing reinfection of the disease in a healthy cane plant, the idea of ants carrying this particular disease need not be looked upon seriously.

CHEWING INSECTS.

What has just been said of the fire-ant, and of its possible ability to transmit the cane mottling disease, may as well be said of the majority of the so-called chewing insects, excepting only those which by habit may bodily leave the tissue of one plant and enter that of another, as does the shot-hole borer or the root mite. Of cane pests like the Lepidoptera that attack the plant only in the larval stage there seems, for the present at least, very remote possibility of the infective principle being transmitted from larva to adult and in turn to the egg and next generation larva, and by that means reaching healthy plants from diseased ones. The idea of Lepidoptera carrying a virus disease by any other means seems still more remote, as larvae seldom feed upon more than one plant, or migrate from plant to plant, between hatching and maturity.

Among leaf-feeders like the Orthoptera (grasshoppers and crickets) and certain Coleoptera (beetles), we have to consider not only the possible transfer of the virus, or inoculum, on the mouth parts, by which means it might be carried from plant to plant, but also the possibility of the ingestion of the infective principle and its later transfer to healthy plants with the excrement of the insect. There are plentiful records of the transfer by this means of spore-bearing diseases, but none to our knowledge of such diseases as do not bear definite sporing bodies.

One other element should be considered, namely, the fact that the chewing insects, though they include over fifty per cent of the cane pests, are very much fewer in numbers in cane fields than the smaller, sucking insects; and during the winter season one may often examine hundreds of cane plants, even in fields where mottling disease is present and spreading, without noting any evidence of the attack of leaf-chewers or stalk-borers. Thus it would seem

difficult to attribute a spread of disease, taking place in all parts of a field, to insects that are nowhere in evidence.

While such a generally prevalent pest of sugar cane as the *changa* (*Scapteriscus vicinus* Scud.) may easily fall under suspicion as a carrier of mottling disease, we cannot ignore the fact that the rapid spread of the disease has in no instance been found to coincide with the areas most heavily infested with *changa,* and in many fields of heavy soil where no *changa* was present the disease has spread alarmingly.

Experimental Methods Employed.

Some difficulties have been experienced in developing methods for confining insects upon living cane plants—upon large numbers of plants—in such manner as not to interfere with the natural growth of the plants nor to disturb their root systems. Our first experiments having demonstrated that the transference of the disease through insect attack takes place rarely, and only under very favorable conditions, it became plain that we must subject large numbers of plants to insect attack in order to entertain any hope of obtaining results. This rendered it impossible to use the sort of cloth-covered cages, placed over field-grown plants, that are usually employed in plant-disease transmission experiments. Other methods were therefore devised. The following four methods have proven satisfactory, for experiments with different kinds of insects or different ages of cane plants.

(*A*) Screen-covered cages 3 feet square and 6 feet high, placed over field-grown cane, one containing mottled plants and the others healthy cane. These are adaptable for the larger insects. A number of insects are introduced into a cage with mottled cane. At end of a determined period, which may vary from a few hours to a number of days, as many as possible of the insects are recaptured in the cage containing diseased cane, and transferred to one containing healthy cane, where they remain for another determined period of time. They are then removed from cage and the cane is watched, week after week, for appearance of mottling.

(*B*) Cages of same size as preceding, either screen or cloth covered, but containing both healthy and diseased cane, planted simultaneously. When cane has reached a desired height, insects of a given species are introduced, and the healthy cane is watched thereafter for appearance of disease.

(*C*) Insects collected on mottled cane in the field are transferred,

either individually or in numbers, onto single potted young cane plants, germinated under cover, in confinnement of glass lamp-chimneys or cylinders of fine wire screening, as the size of the insect may require. The healthy cane is subjected to attack for a determined interval of time, when the insects are removed and the cane transferred to the open field.

(*D*) Insects reared in confinement on mottled cane plants, or confined on mottled plants for a known length of time, are transferred to healthy young plants in confinement, as in preceding method.

Checks and Controls.

Throughout the course of the experiments there has been an effort to keep growing, side by side with test plants and under exactly similar conditions of growth, cane plants of the same age which were not subjected to attack of insects previously fed on mottled cane. These were the check plants, or controls, and were of three classes:

(*a*) Simple checks. Plants identical with test plants, but subjected to no artificial treatment whatever.

(*b*) Control plants which had introduced into cages with them, at same time that insects were introduced with test plants, portions of leaves of mottled cane bearing no insects. These were used usually as check on test plants with which it was necessary, or convenient, to introduce portions of the plant bearing the insects from mottled cane, and such controls were designed to show that infection had not resulted from the portions of mottled plant, but from the insects.

(*c*) Control plants having introduced into cages with them a number of insects equal to that introduced with the test plant and of same species of insect, but the insects collected from healthy and not from diseased cane.

In the earlier experiments, it was customary to grow only one or two checks, or controls, with each series of test plants; and a few series of test plants were, principally through oversight, unaccompanied by checks or controls. In the later experiments, however, greater accuracy was maintained in this regard, and a check plant, or control, was grown side by side with every test plant.

It is noteworthy that, while four distinct cane plants became infected with mottling disease in our experiments, apparently as result of insect transmission, no checks or controls became similarly infected. (See foot note on page 83.)

Two control plants did contract the disease, but only by secondary infection, after they had grown beside mottled plants in the field for periods of 3 and 3½ months.

Secondary Infection Among Experimental Plants.

As has been mentioned in preceding discussion, the mistifying feature connected with secondary infection is that it is not confined to the plants growing immediately adjacent to diseased plants, but may occur on isolated plants at some distance from the seat of infection. That the adjacent plants are, however, most apt to contract disease, or at least, to contract it first, seems fairly well established. In proof of this statement may be given our experience in the plots of experimental cane plants on the grounds of the experiment station.

As it has been our desire to prevent the disease from gaining a foothold in station fields, efforts have been made to avoid growing mottled canes outdoors, in exposed situations, for any length of time, where they might become a source of secondary infection. The first two canes that became infected with mottling in our insect transmission experiments were never transplanted to the field, as they gave evidence of infection prior to date of transplanting. The last two, however, were transplanted to field before attack of the disease became evident; and so it happened that they were allowed to remain, in diseased condition, among healthy plants for a period of three to four months. They were intentionally left, as it had seemed that secondary infection had ceased to occur at Río Piedras. As result of these two plants (Nos. 531 and 577), however, secondary infection did occur, the disease showing up simultaneously in two control plants (Nos. 531 *a* and 577 *a*) that were planted immediately adjacent to the test plants. The length of time required for secondary infection to become evident, after the date on which infection had appeared in the test plants, was three months in the one case and three and a half months in the other.

It may be remarked here that, five days after the secondary infection had appeared in these two check plants (on January 31st), both they and the two mottled test plants were transplanted to large cans in the green house, and 16 days later (on February 16th) the symptoms of disease appeared in another plant in the field, as result of secondary infection. This time it was a test plant that became mottled (No. 530), which had stood next to the mottled plant 531, but on opposite side of it, in the row, from the check plant (No. 531 *a*).

As for the insects present in the experimental plat that might have been responsible for the secondary infection, there have been rather few species, and none of them abundant. Some yellow aphis has been present and some cane-fly, and while the plants were still small the green leafhopper was very common. Presence of ants (*Solenopsis geminata*) and their earthen shelters about the roots also indicated that some mealybug was present. No other cane-feeding insect than these was seen on the plants. Of course, the mealybugs and yellow aphis originally infesting the plants had been transferred along with them to the field; but of these two, the yellow aphis had not multiplied on them, but had gradually disappeared.

Another matter worthy of note, in connection with a discussion of secondary infection, is the fact that no transmission of the disease to canes in the experimental plat has taken place in over a year, other than the three plants mentioned above, in spite of the fact that not ten paces from the plat is the greenhouse in which dozens of exposed mottled canes have been constantly growing. Both doors of greenhouse have been wide open on many occasions, a ventilator in the roof has been open nearly a foot, quite continuously, and the two ends of building are covered only with a screening of wide mesh (seven strands to the inch), leaving apertures large enough for the cane-fly, yellow aphis and red-spider, the three worst pests in the greenhouse, to pass with ease. It is difficult to see why these three pests, if capable of carrying the disease, should not have carried it from the greenhouse to the outdoor plat in a year's time.

The idea that ants may carry the mottling disease seems also to find poor substantiation from the fact that screened cages containing mottled canes have stood immediately adjacent to the experimental plat for more than a year and the ants have moved rather freely through the meshes of the screening; yet no secondary infection has taken place from this source. Within the greenhouse, mottled and healthy plants have on some occasions grown side by side in a pot or can for months, both infested with mealybug and equally attended by the ants, without any transference of the disease.

As has been stated by the pathologists, some secondary infection has taken place in the greenhouse, where over a hundred cane plants, mottled and healthy mixed, have been growing constantly; but this infection has seemed small, quite out of proportion with the great abundance of insects in the greenhouse, particularly of the three pests mentioned in a previous paragraph (the cane-fly, yellow aphis and red-spider).

Results of the Transmission Experiments.[1]

The green sugar-cane leafhopper (*Kolla similis* Walk.).

The first experimental tests made with this leafhopper were by method A, the length of time during which the leafhoppers were confined on the mottled cane varying from a few hours to a week, and the number of individual hoppers employed varying from 4 to 39 (see Table III).

Two tests were made by method B, 48 adults being used in each instance (see Exps. 283 and 284 in Table IV).

By methods C and D, 91 plants were tested with this insect, using both nymphs and adults, the number of individuals employed per plant varying from 1 to 7. In some cases individuals confined on healthy plants were of the third and fourth generation that had fed almost continuously upon mottled cane.

The results of all experimental tests made with this leafhopper were negative.

Table III.

FIRST CAGE EXPERIMENTS WITH *KOLA SIMILIS* WALK.[2]

Date	No. of Adults	Period of Previous Feeding on Mottled Cane	Results
July 25	39	7½ hours	Negative.
" 24	14	1 day	"
" 18	21	2 days	"
" 22	4	3 "	"
" 26	10	3 "	"
" 22	9	4 "	"
" 15	8	6-7 "	"
" 16	30	7-8 "	"

Successful inoculations, none.

[1] In each case of infection with the mottling disease as result of attack by insects in confinement, the true presence of the mottling symptoms was verified by at least two other experts of the station staff in addiion to the writer, usually the director and one of the pathologists, Professor Earle or Mr. Matz.

[2] In these transmission experiments method A was used (see page 95,) and the leafhoppers remained on the healthy cane plants until they died or disappeared.

TABLE IV.

EXPERIMENTS WITH *KOLLA SIMILIS* WALK.

Plant numbers	No. of test plants	No. of check plants	Date of confinement	Insects confined per plant	Days insects confined	Cane transplanted	Plants became diseased	Date disease appeared	Check plants diseased
157 to 161	5	2	January 10	1 Adult	4-10	February 3	None		None
176 & 177	2	1	" 10	1 "	17-31	" 15	"		"
216	1	1	" 20	1 "	12	" 17	"		"
217	1	0	" 31	1 Nymph	7	" 17	"		
218 to 222	5	2	" 31	1 Adult	7	" 20	"		None
224	1	0	February 1	1 "	6	" 24	"		"
226	1	1	" 7	1 Nymph	17	" 24	"		
227 to 230	4	2	" 7	1 Adult	17	" 24	"		None
239	1	0	" 7	1 Nymph	12	" 19	"		"
240 to 214	5	2	" 7	1 Adult	12-14	" 19 to March 14	"		
255 to 258	4	0	" 19	1 Adult	21-22	March 14	None		None
259	1	0	" 20	2 Nymphs	21	" 14	"		
267	1	0	" 22	5 "	20	" 14	"		
268	1	0	" 23	1 Adult	19	" 15	"		
269	1	0	" 23	7 Nymphs	19	" 15	"		
270 & 271	2	1	" 24	1 Adult	19	(Both died)			
272	1	1	" 24	3 Nymphs	19	March 15	None		None
274	1	0	" 24	5 "	19	(Died)			"
283 & 284	2	1	" 25	48 Adults	1 month	***	None		None
287 to 290	4	2	" 26	1 Adult	17	March 15	"		"
294	1	0	March 10	4 Adults	3	" 14	"		"
302 & 303	2	0	" ?	3 Nymphs	?	" 17	"		
304	1	0	" ?	1 Nymph	?	" 17	"		
312	1	1	" 14	4 Adults	16	June 2	"		
315	1	1	" 14	2 "	43	April 29	"		None
338 to 343	6	0	" 17	1 Adult	43	" 29	"		"
341	1	0	" 14	2 Nymphs	43	" 29	"		
361	1	0	" 31	2 Adults	24	" 29	"		
362 to 369	8	0	" 31	1 Adult	24	" 29	"		
370 to 373	4	0	" 31	1 Nymph	26	" 29	"		
422	1	0	April 28	2 Nymphs	**		"		
435 to 442	8	0	" 30	2 "	**	August 4	"		
443	1	1	" 30	3 "	**	" 4	"		None
454 to 461	8	2	" 30	1 Adult	**	" 5	"		"
463	1	0	May 27	2 Nymphs	**	" 6	"		
478	1	0	" 31	2 Adults	**	" ?	"		
489 & 490	2	0	June 2	2 "	**	" 13	"		
491	1	1	" 2	3 Nymphs	**	" 13	"		
Total	93	22					None		None

* Plant died.

** The insects were not removed from these plants up to the time the latter were transplanted to field.

*** Tests made by method B.

THE WEST INDIAN CANE-FLY (*Stenocranus saccharivorus* Westw.).

Trials with this insect were made mostly by the last two methods, C and D, though two tests were made by using method A (Exp. Nos. 316 and 325) and four by method B (Exp. Nos. 506, 508, 510 and 512). A total of 87 tests was made, of which number only one test gave successful transmission. The plant that became infected, No. 377, was one of a series of three plants, each subjected, on March 31st, to attack of two adults taken from leaves of mottled cane in the greenhouse. The plant showed, by April 29, no apparent signs of mottling. On May 27, however, when next examined, it presented a very aggravated case of the disease, which must have become apparent very early in May.

TABLE V.

EXPERIMENTS WITH *STENOCRANUS SACCHARIVORUS* WESTW.

Plant numbers	No. of test plants	No. of controls	Date of Confining Insects	Insects Confined per Plant	Days Insects Confined	Date Plant put into Field	Test Plants Became Mottled	Date Mottling Appeared	Controls Became Mottled	Date Mottling Appeared on Controls
183 - 186..	4	2	1/20	1 adult.....	11+	2/17	None	.....	None	.....
187 - 188..	2	1	"	2 nymphs.....	28	2/17	"	.....	"	.....
189 - 190..	2	1	"	6 "	28	2/17	"	.....	"	.....
246 - 252..	7	2	2/17	1 adult	7	2/25	"	.....	"	.....
254	1	0	2/19	30+ nymphs	(n)	3/14	"	.....	.....	.....
275	1	0	2/8	30+ "	35	3/15	"	.....	.....	.....
276 - 279..	4	2	2/24	1 adult.....	19	3/17	"	.....	None	.....
280	1	1	"	2 adults.....	19	3/17	"	.....	"	.....
316	1	0	3/14	100+ nymphs	(n)	***	"	.....	.....	.....
325	1	0	3/17	100+ "	(n)	***	"	.....	.....	.....
326 - 329..	3	1**	"	10 nymphs.....	(n)	4/29	"	.....	None	.....
330	1	0	"	1 adult.....	16	4/10	"	.....	.....	.....
331 - 336..	6	1	"	1 nymph.....	16	4/10	"	.....	None	.....
376 - 378..	3	0	3/31	2 adults	29	5/2	One	5/27	.....	.....
383	1	0	4/10	6 nymphs	17	4/29	None	.....	.....	.....
384	1	0	"	6 adults.....	17	4/29	"	.....	.....	.....
385 - 387..	3	0	"	5 "	17	4/29	"	.....	.....	.....
406	1	0	4/25	8 "	.....	(Died)	.....	.....	.....	.....
533 - 536..	4	4	9/30	12+ nymphs.....	15	10/15	None	.....	None	.....
554 - 555..	2	2	10/10	24+ "	20	10/30	"	.....	"	.....
556 - 562..	7	7*	10/11	12+ "	6+	10/17	"	.....	"	.....
586 - 591..	6	6**	10/22	40+ "	5+	10/27	"	.....	"	.....
600	1	1**	10/23	Many nymphs and adults	20+	11/12	"	.....	"	.....
608 - 618..	11	11*	10/30	24+ nymphs.....	13+	11/12	"	.....	"	.....
625 - 633..	9	9*	11/12	30+ "	12+	11/24	"	.....	"	.....
506 - 508..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
510 - 512..	4	0	8/12	Many nymphs and adults	(n)	***	None	.....	.....	.....
Total..	87	51	.....	.....	.....	.....	One	.....	None	.....

* Control plants of style *b* used.

** Control plants of style *c* used.

*** These plants were in an outdoor cage.

(n) Insects were not later removed from test plants, so exact length of exposure is not known.

THE MEALYBUGS (*Pseudococcus calceolariae* Mask. and *Ps. sacchari* Ckll.).

Because of the very close relationship and resemblance of these two species—it being impossible to separate them without microscopic examination—and because their habits are so nearly identical, no attempt was made to distinguish or separate them for experimental purposes.

Tests made with mealybugs were all by use of the last two methods, C and D. A total of 40 tests was made, of which number one test plant (No. 577) became infected with mottling disease, apparently as result of transmission by the mealybug.

This was one of a series of seven plants, each subjected, on October 21st, to the attack of 6 adult female mealybugs from mottled cane. For each plant of the series there was grown a control, kept under exactly similar conditions to the test, and having introduced upon it approximately the same number of insects as the test, but insects taken from healthy instead of mottled cane. The plant that became infected first showed indications of disease on November 23rd, a month and two days after introduction of the insects onto plant. The note of this date reads: "Plant shows evidence of mottling near the bases of two uppermost leaves." Note of December 2nd reads: "Plant is becoming quite decidedly mottled, though check plant, No. 577 *a*, shows no sign of disease."

The notes on this plant further show, however, that the check plant also became mottled, the first symptoms becoming manifest on January 26th, over three months after the mealybugs were introduced with plant. There is little doubt that the inoculation of the check plant can be justly considered to have resulted from secondary infection from the test plant, No. 577, in the interim since they were transplanted, side by side and without cover, into field on October 30th.

TABLE VI.

EXPERIMENTS WITH *PSEUDOCOCCUS CALCEOLARIAE* AND *PS. SACCHARI.*(1)

Plant numbers	Number of test plants	Number of controls	Date of confining insects	Insects confined per plant	Days insects confined	Date plant put into field	Test plants became mottled	Date mottling appeared	Controls became mottled	Date mottling appeared on controls
231 to 328..	8	2	2/7	1 Adult.....	11+	2/18	None...	.....	None...	
321 to 324..	4	2	3/15	1 "	*	4/28	" ...	.....	" ...	
473 to 476..	4	1	5/30	15 Adults.....	74+	8/12	" ...	.....	" ...	
502.....	1	0	8/5	15 Nymphs...	65+	10/9	" ...	.....	.....	
516 to 520..	5	1	9/29	10 " ...	18+	10/17	" ...	.....	None...	
521 to 522..	2	1	9/29	2 Egg batches.....	18+	10/17	None...	.....	None...	
573 to 579..	7	7**	10/21	6 Adults....	94	10/30	One.....	11/23	One.....	1/26***
580 to 585..	6	6**	10/22	24 Adults and Nymphs ...	81	10/30	None...	.....	None...	
595.....	1	1	10/23	7 Nymphs...	*	.....	" ...	.....	" ...	
596 to 597..	2	2	10/23	15+ " ...	*	.....	" ...	.....	" ...	
Total....	40	23	....	.....	.....	.....	One.	.....	One***	

(1) It has been impracticable to attempt separation of these two species.

* Insects were not later removed from plant, so exact length of exposure is not known.

** Control plants of style *c* used.

*** As over three months elapsed from the time that insects from healthy plants were introduced onto this control (No. 577 a) before it showed mottling, and as it was contiguous and within ten inches of test plant No. 577 that became mottled, the control is considered to have become diseased as result of secondary infection.

THE YELLOW SUGAR-CANE APHIS (*Sipha flava* Forbes).

It is a matter of regret that a larger number of tests was not conducted with this species, which shows some promise of being one of the principal vectors of the disease. One reason for this statement is the fact that cane plants that are subjected when quite young to the attack of large numbers of the yellow aphis transferred from mottled cane, very early show a kind of very characteristic, long, yellow striping on the leaves, which does not appear on the check plants. This is not considered to be a direct result of the punctures of the aphis, as that manifests itself in another manner, namely, in a dull scarlet stain appearing first near the tips of leaves, where the aphids are most numerous, and extending gradually toward base of leaf. The yellow striping appears along the full length of leaf, not only on the leaves attacked by aphis but on others as well. Unfortunately, many of the plants which displayed the yellow striping most strongly died when they were transferred to field, appearing as if weakened by the condition. A few others recovered entirely from the striped condition. So there is not yet sufficient proof to establish a definite connection between this yellow striping and the

mottling disease, but it is the intention to make further experiments to ascertain if there be a connection.

Only 21 experimental tests were made with the yellow aphis, all of them being by the last two methods, C and D. Of this number, one plant gave evidence of successful transmission of the disease by means of the insect. This plant (No. 531) was one of a series of twelve plants, all similarly subjected to the attack of yellow aphids from mottled cane on September 29th. The first evidence of infection was on October 9th, the note for which date reads: "This plant shows every evidence of being in the first stages of the mottling disease." A later note, of October 30, reads: "Shows advanced stage of attack by mottling disease so far as foliage striping is concerned."

It will be noted that the incubation period of the disease was in this case very short—only 10 days—where in other cases of experimental inoculation by means of insects it has been usually about one month. No explanation has been found for this difference. (See Table VII, page 108.)

THE SUGAR-CANE LEAF SCALE (*Pulvinaria iceryi* Guer.).

This long, pink and green scale, which infests only the leaves, is a species so rare in the cane fields of the Island that there seems small likelihood of its ever becoming an important agent in the transmission of the cane mottling disease. So far as we know it has been observed and collected only by the writer, who found it first on sugar cane in an outdoor breeding cage at Santa Rita, on the south coast, on October 3, 1914, and again on December 26, 1914, in the same rearing cage, on which occasion it was recorded as highly parisitized by two small wasps, a black one and a still smaller yellow one.

The scale was not again observed until the spring of 1918, when the writer found it heavily infesting a cane plant in the experimental greenhouse of the station at Río Piedras; and on this occasion also it was heavily parasitized by the two species of Chalcidids. These facts would lead to a belief that both the scale and its two parasites are endemic to the Island, though not yet observed in cane fields.

In the late summer of 1918 specimens of this scale were sent at my request by Mr. M. A. Crespo, then assistant entomologist of the station, to Dr. L. O. Howard, entomologist of the U. S. Department of Agriculture, and the species was determined by Mr. H. Morrison, of the federal department, as *Pulvinaria iceryi* (Guer.), a species previously recorded only from Mauritius and Reunión. If it proves

true that this scale is identical with the "poche blanche" of Mauritius, but is indigenous to Porto Rico, it may turn out to have been introduced into Mauritius from this Island, and will constitute a very parallel case to that of the introduction of *Phytalus smithi* Arrow from Barbados into Mauritius—a case in which a species held in natural check in its native environment, greatly multiplies and becomes a serious pest in the new environment, where it is freed from its parasites.

For the past year this scale has been reared generation after generation on cane in confinement, but when infested canes are transplanted to the outdoors the scales soon disappear from the plants.

Only 14 experimental tests were made of the possible transmission of cane mottling disease by this scale, and of this number, one successful inoculation resulted. This plant (No. 426) was one of a series of four test plants, each subjected on April 28th to the attack of from 5 to 10 adult scales transferred from mottled cane. First evidence of the disease appeared on May 31st, on which date the following note was made: "Plant shows none of the mottling due directly to scale attack, as in 423 and 425, but the terminal 2 leaves show strongly a mottling very similar to mosaic disease." A later note, of July 22nd, reads: "Plant is most decidedly mottled now, and quite heavily infested with the scale."

As to the direct injury to young cane plants from attack of the scale, mentioned above, a note concerning another test plant of the same series (No. 423), under date of May 31st, may be quoted: "Some lower leaves show a peculiar yellow mottling, more profuse and quite unlike the mosaic disease (which appears in terminal leaves first). This is especially true of leaves most heavily infested with scale." This mottling effect on the foliage was of a rather different nature than the yellow striping caused on young plants by aphis attack, but like it, seemed to disappear as a plant increased in growth, so its connection with the mottling disease is doubtful. (See Table VII, page 108.)

THE YELLOW SUGAR-CANE THRIPS (*Frankliniella* sp.).

This thrips appears to be an undescribed species of the genus, and will be described by the writer in an early number of this journal. The pest and its damage have been fully discussed in a previous paragraph.

Seventeen test plants were subjected to the attack of this thrips, but no succesful inoculations resulted. This may have been due,

however, to the fact that the living specimens which were introduced into cages with young plants had been brought across the Island from the south coast, and were one to two days on the journey and weakened to a certain extent, many of them having died *en route*. The species has not been found in sufficient numbers on cane at Río Piedras to make experimental tests. It is the intention to make further tests with this insect in the coming year. (See Table VII.)

THE BLACK SUGAR-CANE THRIPS (*Haplothrips tibialis* Hood?).

This insect has been doubtfully refered to the above species of Hood on the strength of that species having been described from a thrips collected on sugar-cane at Río Piedras; but the description is not at present available. In Moulton's key the insect runs to the genus Anaphothrips.

In habits this species differs from the yellow cane thrips in that both nymphs and adults live near the extremeties of the leaves, never at the bases. The species may be found on young cane only, and seldom becomes abundant. Usually only isolated individuals are found. Specimens were first noticed on grass blades on March 13th, both adults and nymphs, but when transferred to a young cane they continued to thrive, and by April 25th had become so numerous on the cane plant as to cause its death. The leaves were entirely speckled with brown from the attack. From April through June succeeding generations were reared on cane. Under outdoor conditions, the insect is probably more common on grasses.

Only four tests were made with this insect, in attempt to transfer the mottling disease, all of which were negative. (See Table VII.)

THE FALSE-MOTTLING LEAFHOPPER (not determined).

Like some other cane pests, this leafhopper lives more commonly on grasses, and seems to attack only very young canes. In the field it has been rarely observed, probably because of its small size, inconspicuous coloring, and its agility. The nymphs are very pale, almost white in color, and live near the tips of the leaves on sugar-cane, though on grasses they may occur anywhere on the undersides of leaves.

In common with the black thrips, this insect made its appearance on young cane plants during February, and in March became very common, but by April adults were again scarce. A second generation appeared in May and June, and what is believed to be a third generation in August. Cane leaves showing attack become streaked

with long white marks, from the extraction of the chlorophyll, in a manner very suggestive of the mottling disease. From this the insect receives its common name, false-mottling leafhopper.

Only five tests, of their ability to transmit mottling diseases, were made with this leafhopper, all of which gave negative results. (See Table VII.)

THE CANE SEED-HEAD LEAFHOPPER (*Balclutha* sp.).

This is a small leafhopper of the general shape of *Kolla similis* Walk., but only two-thirds its size and varying from pale green to yellowish-brown in color. In December and January it occurred in the greatest abundance in the seed tassels of such cane plants as bore seed, and is believed to have been a principal cause of the low fertility of the seed. For this reason it may be a serious retarding factor in production of new cane varieties. The nymphs, which are dark in color with lighter dorsal stripe, could be shaken by thousands from a single cane seed tassel. They were heavily preyed upon by larvae of a Syrphid fly.

Through the summer, when no cane is seeding, this leafhopper thrives in great abundance on the seed-heads of common pasture grass, or "malojillo" (*Eriochloa subglabra*), where it is heavily parasitized by a black, ant-like Dryinid wasp (*Chalcogonatopus* sp.), and by a fungus that seems to follow attack of the parasite larva.

These leafhoppers come in abundance to electric light, and might be controlled by means of trap lights. As they do not appear to attack sugar cane except rarely when it is not in seed, it is unlikely that they can be a factor in transmission of the mottling disease. Five tests were made with the species (two of them by method B), all giving negative results. (See Table VII.)

THE SUGAR-CANE RED-SPIDER (*Oligonychus viridis?*)

This very small mite is barely visible to the naked eye because of its size and protective coloration. It lives and reproduces on the cane foliage, usually on underside along the midrib, sometimes spinning a fine web over the infested portions of leaf, and by sucking the chlorophyll from the leaf it causes a white blotching or streaking that might be mistaken for mottling by one unfamiliar with the disease. The adult insect has eight legs and is a very small spider, pale greenish or yellowish in color with dark markings at the sides. It differs only in feeding habits and microscopic details from some

other common species of red-spider, and is a species capable of rapid multiplication.

Because of its minute size, this mite has been difficult to keep out of experimental cages containing other insects; and if it be proved to transmit the disease, it can have been responsible for apparent transmissions by other insects, since any portion of leaf bearing insects that is dropped into a cage to infest a plant, or plants, will unavoidably harbor young or eggs of red-spider. The six tests made using red-spider alone gave negative results. (See Table VII.)

TABLE VII.

EXPERIMENTS WITH *SIPHA FLAVA* FORBES.

Plant Numbers	Plants Subjected to Insects	Control Plants	Date of Confining Insects	Insects Confined per Plant	Days Insects were confined	Date Plant put into Field	Test Plants Became Mottled	Number of Mottled Test Plant	Date Mottling Appeared	Controls Became Mottled	Number of Control	Date Control Became Mottled
353	1	0	3-19	1 adult.....	.....	(Died)	.....	.....	.....	.....	.....	.....
412-417.	6	1	4-26	20+ adults and young	34(c)	8-11	None	.....	.....	None	.....	.....
418-419.	2	1	4-26	12+ " " "	34(c)	8-11	"	.....	.....	"	.....	.....
523-532.	12	3(a)	9-29	100+ " " "	16(c)	10-15	One	531	10-9	One	531	1-26
Total	21	5	Plants became diseased				One test plant			One control (d)		

EXPERIMENTS WITH *PULVINARIA ICERYI* (GUER.).

423-426.	4	0	4-28	5-10 scales.....	(c)	8-11	One	426	5-31	.....	.....	.....
550-552.	3	3(a)	10-10	10+ "	(c)	10-17	None	.....	.....	None	.....	.....
593-594.	2	2(b)	10-23	12+ "	(c)	11-12	"	.....	.....	"	.....	.....
605 607.	3	3(b)	10-30	10+ "	(c)	11-12	"	.....	.....	"	.....	.....
660-661.	2	2( )	11-30	15+ "	(c)	2-16	"	.....	.....	"	.....	.....
Total	14	10	Plants became diseased				One test plant			No control		

EXPERIMENTS WITH THE YELLOW CANE THRIPS.

163-174.	12	2	1-10	8+ adults	24+	2-3	None	.....	.....	None	.....	.....
178-182.	5	1	1-10	8+ "	36+	2-15	"	.....	.....	"	.....	.....
Total	17	3	Plants became diseased				No test plant			No control		

EXPERIMENTS WITH THE BLACK CANE THRIPS.

467	1	0	5-28	18 adults.....	(c)	8-12	None	.....	.....	.....	.....	.....
484-486.	3	1	5-30	15+ adults.....	(c)	8-13	"	.....	.....	None	.....	.....
Total	4	1	Plants became diseased				No test plant			No control		

TABLE VII—Continued.

EXPERIMENTS WITH THE FALSE-MOTTLING LEAFHOPPER.

Plant Numbers	Plants Subjected to Insects	Control Plants	Date of Confining Insects	Insects Confined per Plant	Days Insects were Confined	Date Plant put into Field	Plants Became Mottled	Number of Mottled Plant	Date Mottling Appeared	Controls Became Mottled	Number of Controls	Date Control Became Mottled
348.....	1	1	3-17	8 adults	(c)	6-2	None	.....	.....	None	.....	.....
360.....	1	1	3-31	4 nymphs	24	6-2	"	.....	.....	"	.....	.....
374.....	1	1	3-31	2 adults	30	6-2	"	.....	.....	"	.....	.....
464.....	1	1	5-27	1 nymph.....	(c)	8-12	"	.....	.....	"	.....	.....
487.....	1	1	6-2	2 adults and 1 nymph..	(c)	8-13	"	....		"	.....	.....
Total	5	5	Plants became diseased				No test plants			No controls		

EXPERIMENTS WITH THE CANE SEED-HEAD LEAFHOPPER.

273.....	1(e)	1	2-19	100 adults	(c)	....	None	.....	.....	None	.....	.....
282.....	1(e)	0	2-19	100 adults	(c)	.....	"	.....	.....	.....	.....	.....
313.....	1	1	3-14	1 adult.....	(c)	6-2	"	.....	.....	None	.....	.....
405.....	1	1	4-25	1 adult.....	(c)	8-12	"	.....	.....	"	.....	.....
Total	4	3	Plants became diseased				No test plants			No checks		

EXPERIMENTS WITH THE SUGAR-CANE RED-SPIDER.

447-452.	6	2	4-30	All stages (f).....	(c)	8-5	None	.....	.....	None	.....	.....

(a) Control plants of style *b* used.
(b) Control plants of style *c* used.
(c) Insects not removed from cane plant before it was transplanted to field.
(d) This control plant undoubtedly became diseased by inadvertent secondary infection.
(e) Mottled and healthy plant in same cage, method A.
(f) A portion of mottled cane leaf containing all stages of the red-spider dropped into cage with plant.

EXPERIMENTS WITH CHEWING INSECTS.

As explained in a previous paragraph, the possibility of mottling disease being transmitted by any species of chewing insect seems so remote that very little experimntal effort has been expended along this line of investigation.

The insect that has received most attention is the cone-headed katydid (*Neoconocephalus mexicanus* Sauss.). Seven test plants were employed, one with adults and six by using nymphs. The latter were transferred successively from mottled to healthy plants several times, in close succession, but the healthy plants eaten as result of these transfers gave no later indications of mottling. (See Table VII.)

With the common field grasshopper (*Schistocerca columbina*

Thunb.) and the dusky ground grasshopper (*Sphingonotus haitensis* Sauss.) two tests each were made, all proving negative.

A test each was made with the changa (*Scapteriscus vicinus* Scud.), the spider-legged cricket (*Amphiacustes annulipes* Sauss.) and a common roach (undetermined), in each case the insects being introduced into a small cage with young healthy cane after confinement for a week or more with mottled cane. All gave negative results. (See Table VII.)

A test each was made with the two common May-beetles of the north coast (*Phyllophaga portoricensis* Smyth and *P. citri* Smyth), adults in each case being introduced in numbers into a cage containing young mottled and healthy cane plants mixed. No healthy plants became mottled as result, within a space of six months, when plants were uprooted.

A test each was made with the three following arthropods, using the same method as that used with the crickets and roaches: sowbugs (*Porcellio* sp.), the flat greenhouse milliped (*Parajulus* sp.), and young of the common bush milliped (*Rhinocricus arboreus* Sauss.). All gave negative results.

TABLE VIII.

EXPERIMENTS WITH CHEWING INSECTS.

Species of insects	Plants subjected to attack	Control plants	Date of confinement	Insects per plant	Days confined	Results
Neoconocephalus mexicanus.....	1	1	Jan. 10.....	1 adult.....	16	Negative
" "	1	0	" 10.....	1 nymph	10	"
" "	1	1	Feb. 17.....	10 nymphs....	4	"
" "	1	1	" 21..	1 nymph	17	"
" "	1	0	" 21.....	1 "	17	"
" "	1	1	Mar. 14.	1 "	17	"
" "	1	0	" 14.....	1 "	17	"
Schistocerca columbina.....	1	1	Jan 10.....	1 adult.....	20	"
" "	1	1	Oct. 23.....	2 nymphs....	7	"
Sphingonotus haitensis.....	1	1	Jan. 10.....	1 adult.....	4	"
" "	1	0	" 10.....	1 "	10	"
Amphiacustes annulipes.....	1	1	Oct. 10.	3 nymphs....	7	"
Scapteriscus vicinus.....	1	1	" 23.....	1 adult	**	"
Roach (*Blatta* sp.).....	1	1	" 24	3 nymphs....	19	"
Sow-bug (*Porcellio* sp.)....	1	1	" 24.....	11 adults.....	19	"
Milliped (*Parajulus* sp.).....	1	1	" 10.....	6 "	7	"
Milliped (*Rhinocricus arboreus*).	1	1	" 23.....	15 young.....	**	"
Phyllophaga portoricensis.....	2*	0	May 29.....	10 adults.....	**	"
Phyllophaga citri.....	2*	0	" 29.....	10 "	**	"
Total number of plants.....	21	13	All results negative			

* The May-beetles were introduced into outdoor cages containing both mottled and healthy cane, according to method A.

** Insects were not removed from these plants up to the time plants were transplanted to the field.

Summary.

1. Failure of other and ordinary means of dispersion of plant diseases to account for the rapid spread of the cane mottling disease, under normal conditions, has led to a belief that the disease may be carried by insects.

2. Until substantial proof has been given that the cane mottling disease results from an organism capable of bearing fructifications or forming spores, there seems better reason to suspect sucking than chewing insects of transmitting the disease.

3. Field observations have thrown little light on the problem of insect transmission of mottling disease, the only insect yet observed which might satisfy all conditions, on the South Coast at least, being the yellow cane thrips (*Frankliniella* sp.).

4. It is believed that secondary infection with mottling disease, in a field planted to healthy seed, might occur from slow-moving insects like the mealybug or rust-mite, that could harbor over in numbers on stubble, volunteer cane or grass from a previous infected crop. This renders important the clean cultivation of cane fields between crops. These pests cannot, however, account for wide and rapid spread of mottling disease among plants grown from healthy seed and planted in new ground.

5. From the large number of experimental tests made in insect transmission, only four successful inoculations resulted. These four were all from different species of insects; but it is unique that all resulted from sucking insects. One of these was the West Indian cane-fly, a second the cane leaf scale, a third the yellow cane aphis, and a fourth the mealybug. (See foot note on page 83.)

6. No successful inoculations of mottling disease resulted from experimental tests with chewing insects. The number of such tests made was, however, not large.

7. In view of the small number of successful inoculations secured, as compared with the rather large number of tests made, under conditions which were considered favorable, the question of insect transmission of cane mottling disease cannot be looked upon as settled. Factors not visible to the investigator may have entered into the success of the inoculations, other than the factor of insect attack.

8. Future attempts will be made to duplicate inoculations which have thus far been secured from apparent insect transmission. It is significant, however, that in our experiments as thus far made

no control plants have become diseased (except by what was very evidently later secondary infection).

9. It is not improbable that, in common with certain other similar diseases of plants, inoculation of a healthy cane plant with mottling disease requires that the plant be in a condition of rapid growth. As our potted cane test-plants were not always in a condition of rapid growth at time that insects were introduced with plants, this may have acted as an inhibitive factor in the success of the inoculations.

10. The question of the infective principle of the disease being carried by the insect for some length of time, and undergoing a cyclic change within the insect body, or of its being transmitted to the young through the egg, before it becomes pathogenic to the plant host through the medium of the insect's bite, is yet to be investigated.

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* See foot note on poge 134.