DRY TOP ROT OF SUGAR CANE.

A VASCULAR DISEASE.

By JULIUS MATZ.

Since the latter part of the year 1919 the writer has had under observation a fibro-vascular disease, which is manifested outwardly by a dry top decay, of the sugar cane (*Saccharum officinarum* Linn.) in Porto Rico. A description of the organism *Plasmodiophora vascularum* n. sp. associated with the occurrence of this disease, was published by the writer some time ago (1).[1] Further observations were made on the distribution of the disease and data on its transmissibility were obtained since the publication of the first account. In view of the fact that no other record of the occurrence of the above-named organism has been found in the literature treating of sugar-cane fungi, and that the disease it causes is not distinctly differentiated by other authors from other similar troubles, it will be of interest to publish more fully the facts thus far known concerning this disease and to describe in greater detail its distinguishing features.

ECONOMIC CONSIDERATIONS.

From observations made on sugar-cane diseases in Porto Rico it is now certain that in so far as reduction of yield is concerned this dry top rot or vascular disease is the most serious of the three or four major diseases of sugar cane existing at present in Porto Rico. It arrests and dwarfs the growth and causes the death of the growing tips of the canes, and in advanced stages, on account of the drying of the cane tops, the tissues already made and matured are speedily broken down by the fermentative action of saprophytic organisms which invade the stalk through the dead or wilted top. The disease was found distributed in practically all the principal sugar-cane growing section of the Island, on the north coast as well as on the irrigated south coast, in isolated areas on the western end, and in the central district around Cayey and Morovis. It was particularly noticeable in fields which showed evident signs of retarded growth and dwarfing especially in ratoon fields.

[1] Numbers in parenthesis refer to references listed at the end of this paper.

In times of low sugar prices the growers depend largely for their returns on ratoon crops which naturally can be made at a lesser cost than plant cane, but it is a well-known fact that a large proportion of our sugar-cane fields can not be ratooned more than two or three seasons, and these produce very poor crops even in their first or second ratoons. In examining minutely representative samples of dwarfed, abnormally thin, dry top rotted canes from different sections of the Island during the last three years, it became evident that *Plasmodiophora vascularum,* an organism which was only recently recognized as a cane parasite, is an important factor and in many instances the chief cause of not only ratoon failures but also of poor stands of plant cane, especially when infected seed were used or when healthy seed were planted in soils infected with the above-named organism. A reduction of 25 per cent from normal tonnage was estimated for a considerable proportion of fields on the north coast during the 1921–22 harvest on account of this disease. At Río Piedras a field of Cristalina plant cane which was infected with this disease produced an average of only fifteen tons of cane per acre. An especially poor stand of plant cane was seen near Barceloneta, where about 25 per cent of the stalks in a field of Rayada (purple stripe) cane were infected and dead by the time of harvest, and a similar field of plant cane was found on the south coast. In all of these cases numerous microscopic examinations were made of the affected canes and *Plasmodiophora vascularum* was constantly found inhabiting their fibers. It was evident that this organism was the principal cause of loss of canes in these fields.

This disease was found in our best varieties, Cristalina, Rayada, D–109, Yellow Caledonia, Otaheite and others, and it works in an obscure and at first unnoticeable manner until the canes are almost mature when the leaves become yellowish and begin to dry out from the interior of the top. Such phenomena may be caused by other agencies such as excessive infestation of insects, especially borers, lack of drainage, drought, and lack of plant food in the soil. At the present time all of these play their parts in reducing cane production in the Island, but this dry top rot as a disease is independent of either soil defficiencies or insect pests. It occurs even when the soil is in good condition and apart from insect injury. It may not be equally severe in different years, but the

last three years evidently were favorable for the propagation of the disease.

SYMPTOMS.

The pronounced visible signs of this disease in the leaves are, first, loss of green color, rolling in and withering or wilting, and lastly, drying of the tips of the central leaf whorls. (Fig. 1.) This is followed by the death of the points or the uppermost joints of the canes. The result of the disease is seen in the wilted and stunted condition of the affected stalks. The last-named phase of the disease occurs naturally only when the infection is severe. The dead top does not, as a rule, possess characters of a soft decay, and no particular characteristic odor has been noted from the decayed tissue. It is in reality a premature drying out of the tender and growing uppermost leaves and joints due to the clogging of the vascular system with a foreign organism. Upon removing the leaf sheaths of an affected cane stalk it is noticed that the internodes are gradually shorter and thinner towards the top and the entire shortened stalk possesses a marked tapering appearance resembling a tallow candle. (Fig. 2.) Healthy canes normally possess shorter internodes near their bases

FIG. 1.—The three canes in the center of this photograph show rolled-in, withered and dry tips of the central leaf whorls.

while the internodes of the center and top are usually longer and of nearly equal thickness throughout. In canes more severely affected the entire stalk fails to develope to normal length. (Fig. 3.) Often the drying of the leaves begins with one or more dead, gray, longitudinal stripes, of about 1 centimeter in width, at about the middle of the blades of the innermost leaves. It is often noted that here the premature drying and death of the younger inner leaves often begins not from the outer edges but from points in the middle of the blades along and near certain fibro-vascular bundles.

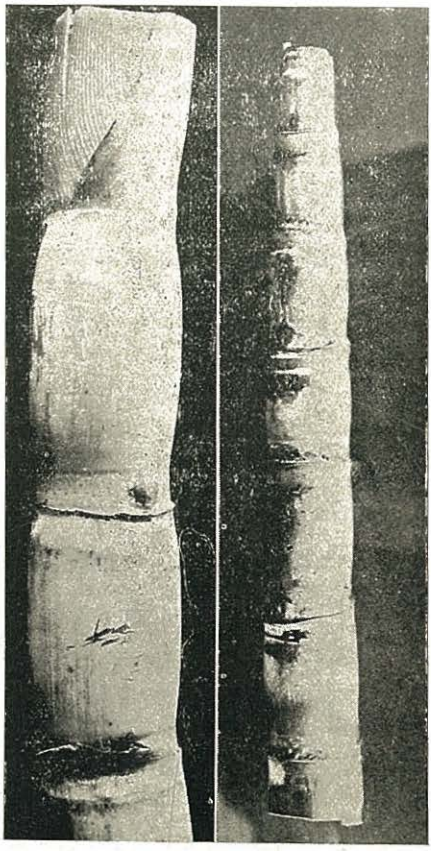

FIG. 2.—On the left is a top of a healthy Cristalina cane stalk; on the right is a top of a diseased cane of the same variety and of the same age.

There is another more distinct and important internal symptom which is characteristic of this disease, and that is, the color of the fibers which appear to the unaided eye orange, yellow, sometimes pink, and even red. This coloration is due to the presence of the organism *Plasmodiophora vascularum* in the pitted vessels and annular tracheids of these fibro-vascular bundles, and it is usually confined to the lower and subterranean portions of the diseased sugar-cane stalk and roots. A microscopic examination of a thin section cut across one or more of these fibers shows the spherical orange-colored spores and the slightly yellowish, almost hyaline yet granular masses of the younger stages of *Plasmodiophora vascularum* clogging the water-conducting elements, vessels and tracheids, in the above-named fibro-vascular bundles. (Fig. 4, 6.) This symptom has not been recorded to be associated with any of the

known sugar-cane diseases and it constitutes the most important feature in distinguishing and diagnosing this disease. Infected fibro-vascular bundles were found in several instances in the uppermost joints and leaf sheaths of cane.

The dry stripes in the inner leaves and the dry-top symptoms may not show until the disease is either well advanced or only when a larger number of fibro-vascular bundles are infected and clogged with the organism. The water content of the soils in which infected canes grow may have a direct influence upon the drying of the top leaves. During wet weather the external symptoms of the disease are not commonly noticeable, but as soon as the soil becomes dry the leaves turn pale green and even yellow and the characteristic drying from the tip or in stripes sets in. However, some cane stools which were grown from known infected seed were found to contain at the age of eight months, stalks, in addition to others showing top decay, which failed to show any abnormalities in their leaves, though these stalks were somewhat stunted and contained *Plasmodiophora vascularum* in some of their fibers. As a rule, the canes which show all the symptoms described above may be found to constitute only a small proportion of all the affected canes in a stool, but the few pronouncedly affected canes serve to indicate the presence of the disease, perhaps in a

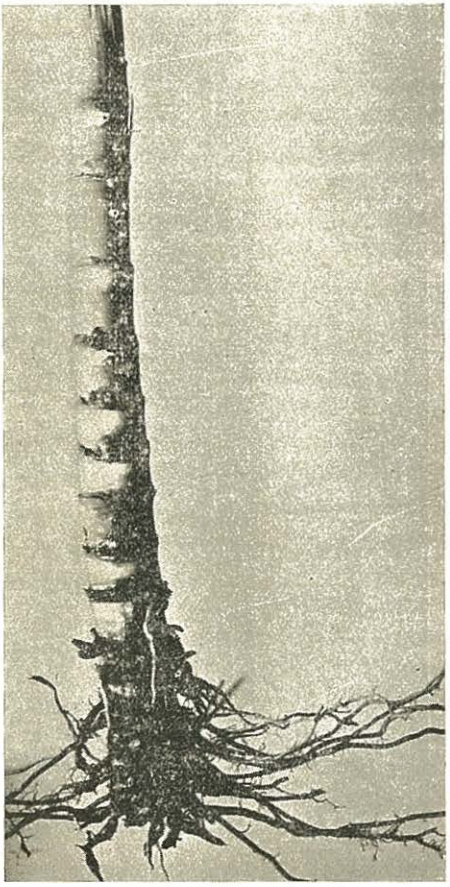

FIG. 3. — Mature sugar-cane stalk underdeveloped, as seen from its small number of joints, due to Plasmodiphora vascularum.

not advanced stage, among the other canes in the same stool.

Stunting of sugar cane alone is not always a true indication of dry-top disease. There are other causes which may prevent growth in cane, but stunting, dry-top decay, and orange-pink coloration of otherwise uninjured fibro-vascular bundles of sugar cane constitute together the visible features of this disease which is distinct from any other sugar-cane trouble described from either Java, Hawaii, Louisiana, the Philippines, the West Indies and South America.

SIMILAR PHENOMENA IN OTHER CANE DISEASES.

There are other fungi which if gaining entrance into the sugar cane give a red, vinous, purple or even black coloration to the affected parts. *Thielaviopsis paradoxa*, *Melanconium sacchari* and *Colletotrichum falcatum* in their invasion of cane tissue penetrate all elements of the stalk and produce a brown, vinous, red and sometimes black coloration in the fibers and the pulpy tissue. The fact that these fungi penetrate parenchyma tissue as well as fibers and that their mycelial threads are easily distinguishable in the cells differentiates these from the dry-top organism. In the case of the latter no decay is directly produced; the organism does not possess any mycelium and has not been so far observed in parenchyma or pulpy tissue surrounding the infected fibers. It inhabits the fibro-vascular bundles exclusively; the parenchyma tissue surrounding these remain unaffected and unaltered in appearance. Unlike the other

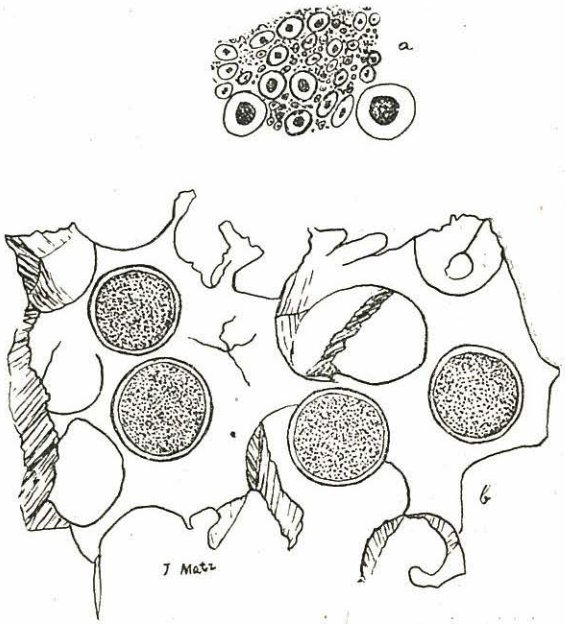

FIG. 4.—(*a*) Young stages of the spores of Plasmodiphora vascularum. (*b*) Mature spherical spores of the organism embedded in a broken gelatinous layer.

fungi it can not be considered a directly destructive agent. The damage which it causes to the cane plant in which it lives is only the result of interference through clogging of the vascular channels rather than actual breaking down of cells as is the case in most other obligate or facultative parasites. Thus it was found that canes in which the visible infection of fibers had not reached farther than the lowest three or four joints, yet the tops had already become dry and wilted due to the sole fact that the innermost fibers which feed the central leaves became clogged with the colonies of the organism at the base of the stalk. The partial death of leaves of sugar cane in the form of stripes parallel to the midrib does also occur in canes affected with gumming disease or moth stalk borer (*Diatræa saccharalis*). In these last two instances the dead stripes in the leaves may be traced to fibro-vascular bundles infected with *Bacterium vascularum* Smith in the case of gumming, and to severed vascular connections in cases of moth-borer injury. Therefore, in diagnosing the nature of dry-top decay of sugar cane in the field it is essential to examine for the borings of the moth borer and also for the more positive symptoms of gumming, which is the exudation of a yellow sticky mass of bacteria from the cut ends of the cane, in order not to confuse these with the symptoms of true dry-top rot. The last, however, occurs independently of any mechanical injury, or gumming disease. It may sometimes be mistaken for any one of the latter troubles when making casual examination of standing cane in the field, but a microscopic examination is necesary to determine whether the vascular *Plasmodiophora* is present in the infected fibers.

HISTORY.

This disease has no doubt existed in variable quantities in cane fields here and elsewhere for some time in the past. It can hardly be considered a newly introduced disease into Porto Rico, because it is present practically in every sugar-cane growing section of the Island and in such varieties as Rayada, Crystalina and Otaheite, some of the oldest kinds grown here. It is true that it was found in Yellow Caledonia and D–109, canes of more recent introduction, but it has also been found in the roots and stalk of a seedling cane which was originated at Río Piedras, within the last four or five years. It is evident from field observations, and especially from the fact that it was found in the roots and fibers of the seedling cane mentioned, that the disease causing organism *Plasmodiophora*

vascularum, can be transfered from cane to cane through the soil, which may become infected with the above organism if diseased ratoons are allowed to decay in the ground. There is, therefore, the possibility that the organism might have been brought here in some new cane variety and that our older varieties became infected, by contact later, because of their strong susceptibility to this particular disease. Previous workers interested in sugar-cane diseases in Porto Rico have not recorded the occurrence of this vascular disease in sugar cane, though Johnston and Stevenson (2) mention a withertip of sugar cane which has appeared in Porto Rico during the years of 1911 to 1914 and name several fungi, *Hormiactella sacchari, Periconia sacchari* and *Colletotrichum falcatum,* found on the leaves of diseased plants. It is not stated whether search for organisms or other phenomena was made in the vascular bundles of the affected canes. The occurrence of the orange-pink and bright yellow-colored fibro-vascular bundles indicating the presence of *Plasmodiophora vascularum,* might have been overlooked due to the fact that no alteration in appearance in the surrounding parenchyma is caused, nor is the organism commonly found all through the stalk, the lowest joints only being infected in most cases, especially when the canes proceed from partially infected seed, which is perhaps the most common origin of the existing infections. The custom here is to use top seed, this has the advantage of eliminating the heavier infected portions of the cane stalk from being used as seed, and in this manner the distribution of the disease is kept down to its present proportions. Some heavily infected fields at least are known to owe their infections to the use of seed from old "run-down" ratoons; in other words, from canes in which the organism has most likely penetrated to the uppermost joints. It is of little importance to attempt to prove whether this disease was known to exist here in the past; such knowledge would be of little profit since the nature of the disease surely was not known. But what is of real value is to know its present distribution in the world, for should it exist at present in other sugar-cane growing countries there may also exist such controlling factors which might be applied here. Dr. E. J. Butler, of the Imperial Bureau of Mycology, in a letter to the writer stated that he did not see *Plasmodiophora vascularum* in India. Dr. L. O. Kunkel, of the Experiment Station of the Hawaii Sugar Planters Association, after having examined a mounted slide of *Plasmodiophora vascularum* in sugar cane tissue which was sent him, stated in a letter that

this disease does not occur in Hawaii nor has he seen the organism previously in his studies of *Plasmodiophoras.*

Not until the discovery of *Plasmodiophora vascularum* in the fibro-vascular bundles of the lowest joints in canes which were affected with Mosaic, and soon afterwards in non-Mosaic canes, was dry-top decay considered distinct from root disease. The rolling-up, withering and death of the top leaves of sugar cane was considered a symptom of root disease. This is true where root rot occurres, but dry-top rot appears on soils where root rot may not at all be present. Color in the fibers, such as the orange reddish of the dry-top rot, is not associated with what is usually considered as root disease. From the mode *Plasmodiophora vascularum* lives and grows in the interior of sugar cane, it is of a distinct nature from organisms which might cause root decay. There seems to be no true parasitic relationship in the form of host-cell destruction between this organism and the sugar-cane plant, since the vessels of the fibers though becoming filled with the organism do not suffer direct change, and in no case was it noted in the surrounding parenchyna cells. Apparently the organism is not able to break through cell walls. It may enter, however, through a broken or decayed root, and this is very likely the usual way the organism finds entrance into hitherto healthy canes. Canes which showed more than half of their number of fibers infected with the organism did not reveal any signs of decay in the parenchyma tissue. However, the phloem in some of the infected fibers was reddish and apparently dead.

TRANSMISSIBILITY OF THE DISEASE.

Infected seed when planted may produce one or more infected stalks. These become infected directly through the fibers connecting the original buds with the mother seed piece, the organism passing directly to the new shoots through the continuous fibro-vascular system. As the fibers in the basal parts of the canes become filled with the organism the tops of the shoots begin to die as a result of blocking the food and water channels. Ordinarily the effects of the disease are not noticeable in young cane, since the growth of the organism is exceedingly slow, but in heavily infected seed a considerable number of young shoots die early.

Several trials to transmit the disease were made. The organism *Plasmodiophora vascularum* was teased out from the fibers and introduced into the root eyes of healthy seed. The resulting stools from these inoculated seed were stunted and presented symptoms

of dry-top rot but the organism was not recovered in the fibers of the stalks in these new canes.

Another experiment to prove whether infected seed are vehicles of transmission for this disease came out successful. Fifty Rayada seed were obtained from an infected plantation. These seed were examined with the aid of a microscope and razor-cut sections of these were found to contain numerous fibers infected with *Plasmodiophora vascularum.*

TABLE SHOWING THE NUMBER OF STALKS AND THE PROPORTION OF INFECTED STALKS PRODUCED FROM SINGLE SEED INFECTED WITH PLASMODIOPHORA VASCULARUM.

Stools numbered in consecutive order.	Canes in stool.	Canes infected.	Stools numbered in consecutive order.	Canes in stool.	Canes infected.
1	2	2	22	1	1
2	5	5	23	1	0
3	2	0	24	1	0
4	4	4	25	3	0
5	4	1	26	2	0
6	2	0	27	1	0
7	1	0	28	3	0
8	5	1	29	2	0
9	6	0	30	3	3
10	4	2	31	1	0
11	6	0	32	2	0
12	3	3	33	1	0
13	3	1	34	2	0
14	2	1	35	3	0
15	5	0	36	7	0
16	4	3	37	2	0
17	3	1	38	1	1
18	2	1	39	2	1
19	1	* 1	40	4	2
20	2	2	41	4	3
21	3	1			
				115	40

* Infection in this stalk reached to a height of three feet from its base.

All the infected seed were planted singly in holes in land which was known not to have been planted to cane for many years. As a check 100 healthy seed of the same vaviety were planted in an adjacent plot alongside the infected seed. At the end of nine months all the canes were harvested and none of the healthy seed produced a single stalk which contained *Plasmodiophora* in its fibers while the diseased seed produced in 41 surviving stools only 115 stalks and 35 per cent of these were infected with *Plasmodiophora.* The stools from the healthy seed were normally developed in every

respect the number of canes in each stool ranged from four to ten and the canes attained a normal height. In the diseased stools the number and size of the canes were so reduced that it represented a very inferior crop for plant cane. At first when these seeds germinated there was nothing abnormal to be noticed. Numerous shoots were produced in the two lots of seed, but in the third and fourth month many of the younger shoots in the diseased seed stools began to dry up and die. The dead shoots did not yet reveal the presence of *Plasmodiophora* in their fibers at that time. Apparently the organism had not yet reached, in its development the interior of the stalks of these young shoots. In the seventh month, however, typical dry-top rot began to appear and *Plasmodiophora vascularum,* the same organism previously seen in the parent seed, was now noted in the fibers of their offspring stalks. From this experiment it became evident that diseased seed carrying the vascular *Plasmodiophora* transmit the disease to the next generation of canes. This mode of transmission is very likely the most usual one. The prevalence of the disease is proportional to the amount of its intensity in the fields from which the seed came.

Experiments bearing on the possibility of soil infection and the transmisibility from infected soils to healthy seed planted there are not terminated at the present time, but field observations were made with that point in view. At the Insular Experiment Station Cristalina cane, which were imported from Santo Domingo and which were noted for their vigor, were planted and produced three crops. During their second ratoon dry-top rot was noted in five stools at one corner of the field. That was the end of ratooning in that field, and it is being rested during this year. On the south coast a field of cane was examined and found to be heavily infested with dry-top rot. Numerous canes contained *Plasmodiophora vascularum* in their fibers. It was learned that cane planting failed there persistently in spite of renewal with vigorous seed from other parts. At present there is an experiment in progress on that field under the immediate care of Mr. F. S. Earle of Central Aguirre. The most conclusive case of soil transmission was noticed in 1919 at the Insular Experiment Station when *Plasmodiophora vascularum* was found in the roots and stem of a cane seedling which was originated only two or three years previously. It should be borne in mind that certain root-infesting insects might act as conveyors of the disease, but the disease has been found in uninjured cane.

There are therefore two possible means by which the disease can be transmitted and propagated. The surest way of its propagation is by the use of infected seed as was proved experimentally, and the probable way is through infected soils. The organism may become liberated from the decayed roots of infected stools and remain in the soil to be taken up again by the roots of the cane of the following planting. However, practically in all the severely infected fields, with the exception of the one field on the south coast mentioned above, which were examined, the infection was directly traceable to infected seed. As this is a vascular disease and the fibers being always enclosed by unbroken layers of tissue it is only reasonable to assume that the most likely entrance for the organism from the outside is through the soil and through roots which are likely to become decayed and broken.

COMPARISON WITH OTHER DISEASES.

The "Sereh" disease of sugar cane, though quite distinct from anything we have in Porto Rico, has points of similarity to our dry-top rot, *i. e.*, in the occurrence of the red fibro-vascular bundles, in the stunting of canes, also that it is transmissible by diseased seed. From a recent colored illustration of Sereh disease in an article by Dr. Lyon (3) it is clearly seen that the red color in the fibers is localized mostly around the nodes and are not, as a rule, continuous through the internodes, while in the dry-top rot in Porto Rico the colored fibers, besides being only occasionally red or pink but more often orange-brown and yellow, are found mostly in the basal part of the cane and are continuous there through the internodes and nodes. In other words the colored vascular bundles, which are in reality not colored in themselves but contain an organism which possesses inherent color, are noticed in a region where the organism is most abundant, and that is nearer the root region or the mother seed which carried the original sources of colonies of the organism. The substance in the red fibers in Sereh is described as gum, while in dry-top disease it is distinctly granular and more often composed of larger spherical spores, with distinct walls and contents, embedded in hyaline or yellowish gelatinous matrix. This last substance is noticed with a microscope when an infected fiber is crushed and the compact mass of spores in the vessels is pressed out and broken up (Fig. 4.) Since Dr. Lyon has set forth so clearly the characteristics of Sereh it is evident that there is no disease in Porto Rico which can be diagnosed

as Sereh. However, in dry-top rot we find an analogous infectious dwarfing accompanied by a dry-top rot and associated with yellow to reddish colored fibro-vascular bundles.

Fiji disease with its characteristic galls is not present in Porto Rico. No swelling of tissue accompanies dry top rot.

Earle (4) in a discussion on sugar-cane root disease concludes that "Root disease as here understood is a complex including phases often known as 'Root Rot,' 'Wither Tip,' 'Top Rot' and 'Rind Disease.'" According to Mr. Earle, root disease is a collective name embracing phenomena which might be due primarily to an affection of roots by one or more obligate parasites or to defective cultural methods which enable the facultative parasites to attack the already weakened plants. The same author distinguishes the top rot in young overshadowed suckers, and the top rot caused by the moth borer (*Diatreæa*) known as "dead heart," from that top rot which is due to root infection by parasites. Of these parasites there are those which attack the roots proper, such as *Rhizoctonia* and *Pythium,* and *Plasmodiophora vascularum,* which does not cause actual decay but clogs the water passages in the fibro-vascular system.

Gumming disease of sugar cane caused by *Bacterium vascularum* causes decay of the terminal part of the stalk. This is rather common now in Porto Rico, in fields where the Otaheite, Rayada and Cristalina canes are planted together. However, this disease is easily distinguished by the peculiar reddish spotting on the almost white and light-green areas in the top leaves in the early stages of infection and by the yellow gummy exudation of the cut surfaces of infected canes, symptoms which are not associated with dry-top rot.

Kruger (5) in his book mentions on page 336 an uninfections top rot which occurs here and there amongst healthy stalks in young cane. At first the young and yet unrolled heart leaves are attacked. These turn brown and die, then the older leaves begin to die as well. The vegetative point is attacked. It also turns brown and produces when cut an unpleasant odor. The disease works from the top down into the stalks, which finally dies. No specific cause is assigned. Kruger distinguishes this disease from the Australian and South American gumming disease and from the borer "dead heart," and suggests that it may agree with a disease of the same name described from Mauritius.

V. Gorkum (6) describes a top rot from Brazil which is accompanied by a crinkling and folding of the growing point as if

the innermost leaves were confined by an outer tightly enclosing envelope. This was noted here in a few rare instances but the plants soon recovered their normal appearance.

The drying of the top and resulting loss of tonnage of sugar cane in Porto Rico, which is the subject of this paper, refers only to cases where the initial withering or drying takes place without the direct action of microorganisms, insects or other direct agencies, on the tissues of the younger, inner leaves of the cane tops. In such instances where specific parasites cause directly the destruction of tissue they are recognized, whether they be insects, fungi, or bacteria, by closer observation. *Plasmodiophora vascularum* does not directly attack nor destroy the tissues of the cane stalk. It merely clogs the lower portions of the fibers, thus starving the top of the plant. Perhaps the nearest approach in point of similarity in behavior is the disease of sugar cane described by Butler (7) and by Dash (8) under the name of "wilt." The presence of the fungus *Cephalosporium sacchari* But., however, distinguishes that disease from the dry-top rot of Porto Rico. It is possible that the former is present here as well, but in diagnosing dry-top rotted cane no mycelium was found in the tissues of the stalk, neither was noted in them the hollowness of the stalk which accompanies wilt.

Cook and Horne (9) in their discussion of insects and diseases of sugar cane in Cuba mention a drying out of cane with the following symptoms: "Many of the stalks of these diseased plants have made an apparently good growth of several feet, but the leaves are thickly clustered at the top, the internodes having failed to elongate, and a rot is found passing down along the inner or younger leaf sheaths to the top of the stem." They further state "The more easily recognized common enemies of the cane are present, but their individual or combined effect is not sufficient to account for the drying out." Their illustration suggests a strong similarity to dry-top rot of cane as it occurs here.

In summarizing the above review of the recorded occurrence of top decay in sugar cane it is apparent that there exists a brown top rot or dead heart, causing discoloration and decay of the tender tissues of the tops of younger cane, as described by Kruger from Java, mentioned by Earle from Porto Rico and discussed by von Gorkum from Brazil. This decay is attributed to borers or overshadowing of young shoots and to other not fully determined physiological interferences. There are also bacterial top rots; one at least is caused by the gumming disease organism, *Bacterium vas-*

cularum, and it is probable that there exist other bacterial organisms capable of causing top decay in sugar cane; then there is wilt as described by Butler and Dash and which disease they attribute to the fungus *Cephalosporium sacchari* which attacks the interior of cane stems; and lastly we have wither tip as recorded by Johnston and Stevenson, and the drying out of cane described by Cook and Horne from Cuba. The last two diseases are perhaps the same as the dry-top rot, which is at the present time distributed widely in Porto Rico and which is the subject of this paper.

THE DISTRIBUTION OF THE DISEASE IN PORTO RICO.

Our knowledge of the present distribution of the disease in Porto Rico is based on the finding of *Plasmodiophora vascularum* in the interior of the fibers of affected cane. The organism was first noted near the town of Bayamón, in the variety Cavangerie or Caña Colorada, a claret-colored cane with a dark-green stripe in the stem and sometimes with a yellow or white longitudinal stripe in the leaves. The cane did not show typical top rot, at least it was not noticeable. Later it was found in a Porto Rico seedling at Río Piedras; in Rayada at Río Piedras, Guánica, Cayey, and Salinas; in D–109 at Loíza, Toa Baja, and Morovis; in Cristalina at Mayagüez, Manatí, Barceloneta, and Arecibo; in Yellow Caledonia at San Germán and Cambalache; in Otaheite at Guayanilla and Mayagüez. In a number of occurrences it was most commonly found in Rayada. This, however, does not imply that this variety is the most susceptible. This cane variety is the most commonly grown in a large proportion of the cane fields of the Island, and because of the superiority of this variety in sweetness little discrimination is exercized in using it for seed purposes. Old diseased ratoons which are perhaps of no value for grinding are cut and used for seed, and thus the disease is propagated in this variety.

THE SYSTEMATIC POSITION OF *Plasmodiophora vascularum.*

In my description of the organism in an article published in 1920 (1) the characters of the organism were described from material as it was found to exist in the cane plant. The outstanding features of the organism and its behavior may be summarized as follows:

1. The organism possesses a young stage in the form of a plasma or plasmodium composed of a hyaline or slightly yellowish granu-

lar mass of cytoplasm. This is noted to occur at the advancing point of the organism; that is, at the forward extreme of its penetrations in the fibers of the sugar cane. Development in this stage takes place through the enlargement of the individual granules. A gradual increase in size of these granules is noted towards its maturer or lower portions in the fibers of the cane. These maturer granules are composed of a densely granular center surrounded by a definite clear layer of cytoplasm of variable size depending on the age of the individual granule. This phase in the life of the organism resembles the plasmodia stage of *Plasmodiophora brassicæ* in the cells of its host, the cabbage. However, the granules of the sugar-cane organism cannot be considered as merely nuclei of the plasmodium because actual growth takes place in them. They develop from the size of a minute granule to a mature spore which may measure sixteen microns in diameter, therefore these bodies must be considered as individuals living together the same as the amoeboid bodies do in *P. brassicae.*

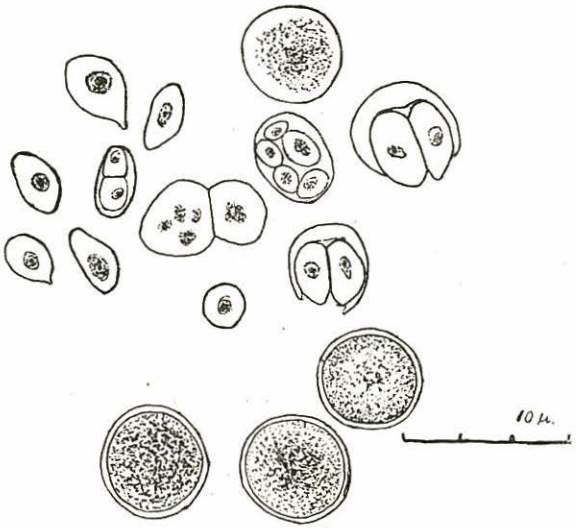

FIG. 5.—Stages in the development of Plasmodiophora vascularum.

In studing the behavior of *P. vascularum* it was observed that the individual bodies, which are composed of a granular center surrounded by a larger hyaline layer, undergo a process of division which is rather unique in itself. At first the central granule divides into two or four and sometimes six parts. Each subdivided granular portion becomes surrounded by a hyaline layer which grow until they force the outer layer of the mother granule to break and they are liberated. (Fig. 5.) This phase of growth finds no parallel in the described life phases of *P. Brassicæ.* It is hardly conceivable that these bodies should be nuclei and that this is their mode of division, because it was definitely observed that

these bodies gradually mature directly into large resting spores. They must therefore be considered as immature spores.

2. The mature stage or the resting stage of the organism is the

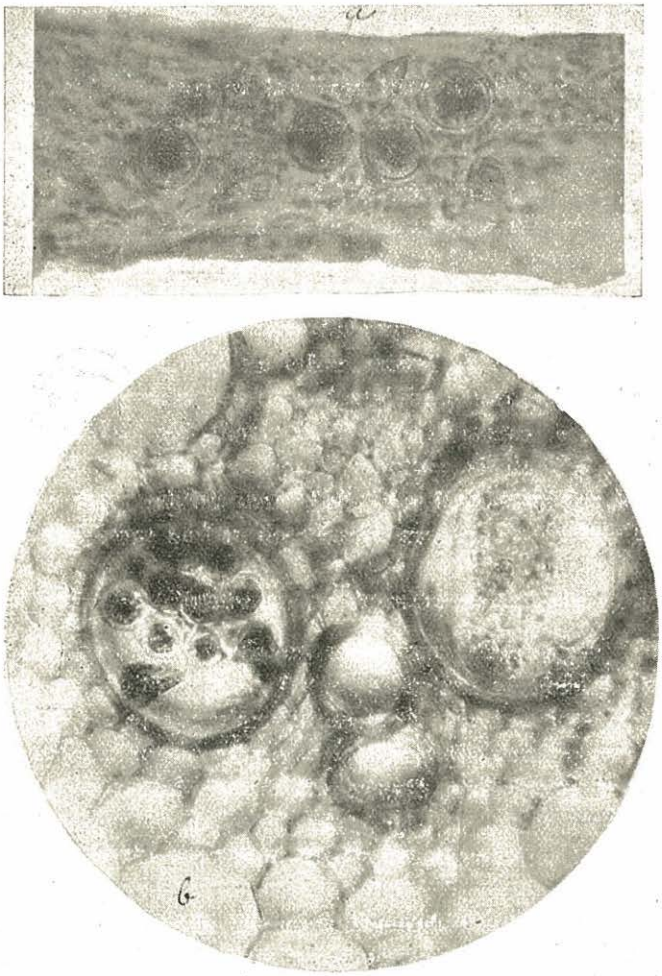

FIG. 6.—*a*, Continuous mass of the plasmodium pressed out from a vessel of a sugar-cane fiber. *b*, A fibro-vascular bundle with the two stages of the organism in its large vessels.

more commonly noticed in infected cane. It consists of comparatively large, spherical smooth spores which are granular or sometimes coarsely granular in the interior with somewhat thick but

hyaline walls, and are yellow, orange, sometimes slightly brown in color, measuring around .014–.016 millimeters in diameter. These spores are imbedded in a clear or somewhat yellowish, at length hardened homogenous matrix. At this stage the organism resembles the well-known Physoderma zeae-maydis in the cells of the corn plant. However, the sporangia of the latter are considerably larger and are not spherical but flattened on one side. The mode of germination of *Physoderma* as illustrated by Tisdale (10) has not been observed in the sugar-cane organism. No mycelial connection of any sort was observed in connection with the latter. Another point of distinction between the two is that *Physoderma* lives in the parenchyma cells of its host, while the sugar-cane organism has so far been found exclusively in the vessels of the fibers. In this respect it also differs from *Plasmodiophora brassicæ* since the latter occurs in the parenchymatous tissues of its host. However, the sugar-cane organism has after many attempts refused to grow outside of its host, the sugar-cane stalk, and no success was obtained in the many efforts to germinate its resting spores for that reason the exact relationship of this organism cannot be definitely placed. The fact is that one of its stages is a free *Plasmodium* limited by the walls of the vessels of the host and it thus possesses a principal character of the *Plasmodiophoraceæ*.

Dr. Elliott described a new organism, *Cystospora batata*, as the cause of sweet-potatoe soil rot or pox (11). In comparing some of his illustrations of that organism with the different phases of the life history of the sugar-cane organism some very strikingly analogous figures are noted. The cysts of *Cystospora batata* are admirably resembling the resting spores of *Plasmodiophora vascularum*, but there is a radical difference in the mode of formation of the two. According to Dr. Elliott the cyst does not gradually grow into its final shape. He states the "plasmodium which fills the cell becomes dark and heavily granular. It gradually contracts into a dark dense central mass surrounded by a clearer zone which becomes a thick clear wall surrounding the central neclear material." Evidently the cyst does not undergo growth as does the resting spore of *P. vascularum*. In his illustration of stages in the growth of a plasmodium Dr. Elliott figures an individual plasmodium with sixteen nuclei which resembles the spore-forming stage of the sugar-cane organism, but instead of designating the smaller bodies within the plasma nuclei these are in the sugar-cane organism really spores in the process of formation, because all the stages

from the minutest granule to the completely developed spore are to be seen in the same continues vessel in the fibers of the cane. Dr. Elliott concludes that his organism undoubtedly belongs to the *Plasmodiophorales,* but because of the formation of the heavy-walled cyst with its large number of spores separates this plasmodium from *Plasmodiophora.* The behavior of *P. vascularum* is indeed not like *P. brassicæ,* nor is it like any of the *Plasmodiophorales,* especially when its partiality to the interior of cane fibers is considered. But it possesses no marked feature which would throw it definitely into another group.

SUMMARY.

Dry-top rot of sugar cane is a distinct disease in Porto Rico, and is constantly associated with *Plasmodiophora vascularum.*

The disease occurs generally all over Porto Rico, but its existence outside of the Island has not been recognized.

The damage which this disease causes is heavy when diseased seed are used. Infected soil may also contribute to the failure of the crop, since it is possible that the disease may be transmitted to healthy seed planted in lands where the disease existed previously.

The disease has been transmitted experimentally by using seed which were naturally infected with *Plasmodiophora vascularum.*

To control this disease it is of primary importance that seed selection should be practiced. No seed should be taken from fields which have diseased cane; at least only topmost seed should be selected.

The entire length of the stalk is not always infected. Usually only the lowest or basal portions of the canes are infected, but if the disease has the opportunity to extend itself as in old ratoons of infected plantings where the canes are comparatively short, even top portions of these canes contain the disease-causing organism in an active stage and no seed should be taken for planting from such fields.

As a measure of precaution it is advisable to use seed from six or seven months' old stools, in which the disease did not have the opportunity to work up, provided the stools themselves come from healthy seed.

Soils, which are known to have produced heavily infected crops should be rotated to legumes or other crops, in order to starve out the disease-causing organism, since it appears that the sugar plant is, so far, its only host.

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