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THE EGGPLANT BLIGHT AND FRUIT ROT IN PORTO RICO

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The two major diseases of the eggplant in Porto Rico are the bacterial wilt and the Phomopsis blight. They are probably of about the same seriousness on this Island. Eggplant growing is probably on the increase. The Phomopsis disease is spreading over the various sections where the host plant is grown. Studies have been carried out with this malady during the last three years. It is the scope of this paper to present our knowledge of the disease up to the present time.

PLANTS AFFECTED

The eggplant (*Solanum melongena* L.) appears to be the only known host of *Phomopsis vexans* (Sacc. & Cyd.) Harter.

VARIETAL SUSCEPTIBILITY

The information in the literature is rather insufficient on the question of susceptibility of eggplant varieties to the Phomopsis blight. Halsted (9) in discussing experiments on the control of the disease lists four varieties, namely, Early Long Purple, New York Improved, Improved New York Spineless and Black Pekin. He does not cover the question of the relative susceptibility of those varieties. Figures are given in that paper on sprayed and non-sprayed plots, but they cannot be used in figuring the percentages of diseased fruit because of the small numbers. Bruner (1) reports the Florida High Bush and the Excelsior as showing considerable resistance to the Phomopsis blight in Cuba. He almost gives the former as the more resistant of the two. Stevenson and Rose (24) reported 43 per cent of dead or dying fruit in a count of 322 plants in Porto Rico. Although they mention in the report that the Improved Purple Thornless and the Florida High Bush were planted, they fail to state whether all the count was from only one or from both varieties. If both were included then the number of plants of each variety is wanting. Ed-

gerton and Moreland (**4**), however, found the Florida High Bush a very resistant variety as compared to the Black Beauty and the Mammoth Purple. Under conditions in which the latter two types fail the Florida High Bush "results in greater yields and a longer picking season". More recently Weber (**26**) has reported the native wild eggplant of Florida as immune and further states that selections from crosses between the commercial and the wild plants exhibited resistant qualities.

The disease having been found quite widespred in 1926, tests were conducted in 1927 and 1928 to determine the degree of susceptibility of some of the eggplant varieties in Porto Rico. The following commercial varieties were used in these tests: Black Beauty, New York Spineless, Excelsior, Florida High Bush, New Orleans Market, Large Round Purple. Some Porto Rican varieties not suitable for export were also planted in the experiment: "Fajardo", a plant bearing long, green gourdlike fruits. This is a very vigorous and prolific plant. The "Pompadour", a strong plant with long-ovate fruits of a white color with purple stripes. The "University", a plant bearing round pink fruits. The "Camuy", a prolific plant bearing small, cylindrical, light purple fruits. A plant with round green fruits was discovered in a population of New York Spineless plants and propagated. It has been tentatively referred to as "*Green*". All the varieties given above were planted in rows of 80 plants each, three rows of each variety. Observations of the preceedings season showed the land to be infested with the pathogen. The results appear in Table I.

TABLE I

SHOWS RELATIVE AMOUNT OF THE DISEASE ON DIFFERENT VARIETIES

Row	Variety	Plants		
		Sound	Diseased	Per cent Diseased
1, 12, 23	Black Beauty	90	150	62.50
2, 13, 24	New York Spineless	84	156	65.00
3, 14, 25	Excelsior	71	169	70.42
4, 15, 26	Florida High Bush	93	147	61.25
5, 16, 27	New Orleans Market	73	167	69.58
6, 17, 28	Large Round Purple	91	149	62.08
7, 18, 29	"Fajardo"	102	138	57.50
8, 19, 30	"Camuy"	94	146	60.83
9, 20, 31	"University"	70	170	70.83
10, 21, 32	"Pompadour"	128	112	46.66
11, 22, 33	"Green"	63	177	75.41
	Total all varieties	959	1,681	63.67

It was thought at first that counts of diseased and non-infected fruit would be of interest. It was soon found that such counts would not allow of a fair comparison for the reason that a large number of the infected plants died before any fruits were formed. Hence, in recording the number of fruits a large item would naturally be overlooked, which if it were not for the premature death of the plants would appear as diseased fruits. The only other means of estimating the percentage of infection in the various rows was by counts of the plants which bore fruit with disease spots or which had large cankers on the stems, those that had been girdled near the surface of the soil and were eventually killed and even those completely blighted before the production of blossoms. All these were included under "diseased." The plants considered as sound were those which bore only sound fruits and did not show any cankers on the stems or petioles, whether they had any small spots on the leaves or not. It must be observed that a large number of these "sound" plants had one or several leaves with small Phomopsis spots. This arbitrary classification was made because it is known that plants with these symptoms usually bear normal sound fruit.

An examination of the table shows that infection varies from 46.66 per cent for the variety named "Pompadour" to 75.41 per cent for that listed as "*Green*". Out of the eleven varieties nine showed more than 60 per cent diseased individuals. The differences among these nine varieties do not appear to be sufficient to class any of them as more resistant than the other. The difference between "Pompadour"—46.66 per cent infection and "Camuy"—60.83 per cent—, for instance, would appear to be significant and one might be tempted to regard the former as more resistant than the latter. In the writer's opinion, in this particular disease, the number of diseased plants fluctuates so much even within one variety that those differences should not be given much weight. To throw more light on this point figures are presented in Table II of diseased and healthy plants in a planting of the Black Beauty variety. Notes were taken in Cayey, Porto Rico, during the month of December, 1927. The plants were bearing and the same system was followed in the classification of the healthy and diseased plants as was observed in Table I.

TABLE II

Row	Plants			
	Sound	Diseased	Total	Percentage diseased
1	23	48	71	67.61
2	29	42	71	59.15
3	27	50	77	64.94
4	36	42	78	53.85
5	41	42	83	50.60
6	37	42	79	53.16
7	37	45	82	54.88
8	38	37	75	49.33
9	43	52	95	54.74
10	43	48	91	52.75
11	41	38	79	48.10
12	53	35	88	39.77
13	51	45	96	46.88
14	48	40	88	45.45
15	53	57	110	51.82
16	41	45	86	52.33
17	38	42	80	52.50
18	59	34	93	36.56
19	47	47	94	50.00
20	59	41	100	41.00
21	53	43	96	44.79
22	60	36	96	37.50
23	49	48	97	49.48
24	42	57	99	57.58
25	50	46	96	47.92
Totals	1,098	1,102	2,200	50.01

A glance at the table will show that there are all kinds of variations in the percentage of diseased plants in the different rows. The lowest figure was 36.56 per cent in row No. 18; and rows No. 22 and No. 12 showed 37.50 per cent and 39.77 per cent of diseased plants respectively. On the other hand in rows No. 1 and No. 3 the diseased plants made 67.61 per cent and 64.94 per cent of the population respectively. The deviations from the average for the variety in this case are worthy of examination.

Should we attach much weight to those differences occurring within the same variety, in the same fields, all plants the same age, etc.? If we do not, and that would be the logical consequence, then should we establish any difference between this case and that of a field where many varieties are grown? In our opinion we should not. Therefore, we are regarding all the varieties of eggplant tested in Porto Rico as more or less equally susceptible to the Phomopsis blight.

It is of interest that color of fruit or of plant has no bearing on resistance. The white variety "Pompadour" is not so much less susceptible than the "Fajardo", a green-fruited variety. The

variety "Green", of green plant and fruit color, is almost as susceptible as the "University" variety—pink fruit—or the black purple fruited "Excelsior". (See Table I).

THE DISEASE

NAMES

Various names have been applied to the disease. "Leaf-blight", "fruit-rot", "leaf-spot", "stem-blight", "foot-rot", "eggplant-blight", and "seedling stem-blight", all appear in the literature. In Cuba (3) two names have been given to a disease on leaves—*"mancha de la hoja"* (leaf-spot) and on stems—*"enfermedad del tallo"* (stem disease). These are in all probability the same disease. In Porto Rico we know it as "lunares de la hoja y tallo" and "podredumbre de la fruta".

HISTORY AND RANGE

The disease has probably been known since 1881 when Spegazzini described a new disease of eggplant which is probably the same as that under discussion here. There exists a doubt as to whether that disease is different from the Phomopsis blight. In New Jersey, Continental United States, Halsted (6) was the first to study the malady in 1890. Rolfs (14) reported it from Florida in 1893. Subsequently it has been reported from other States. It occurs in Italy and in Cuba and probably in all countries where the eggplant is grown. The first report from Porto Rico seems to be that by Stevenson and Rose (24). The fact that the disease has been found on new lands where vegetables had never been grown before suggests that it is endemic here.

IMPORTANCE

Vegetable growing in Porto Rico has been shown to be profitable during the season when early shipments can be made to the New York Market. It is to be expected that experienced growers may start a systematic development of this industry here. Since the eggplant is easily grown and handled it will naturally be one of the few vegetable crops to supply the demand. This plant also forms a part of the small patches of vegetables which are grown for the local market. A disease which usually brings about a loss of more than 50 per cent of the crop is certainly a serious menace and should have a more careful attention on the part of the growers.

MORPHOLOGIC SYMPTOMS

For convenience, the symptoms of the blight are given on large plants (transplants in the field) first and for these on leaves, stems and flowers and fruits.

The symptoms on the stem appear as lens-shaped, eye-shaped spots, regular in outline or long irregular cankers. On these the fruiting bodies of the fungus soon appear giving the surfaces of the spots a black-dotted appearance. These spots are first greenish or brownish, soon grayish to white except for the black fruiting bodies scattered throughout. The spots may appear in any location on the stem or branches. In cases of heavy infestations these occur at the crotches of the branches and stems. The seriousness of the spots at this location will be realized when one considers the effect of winds. The slightest breeze will break the branches at this point. When the spots arise farther up on the branches then the weight of the fruit will eventually cause the breaking of the branches. In heavily infested fields or when seedlings from diseased beds are used the pathogene gives rise to serious cankers at or near the surface of the ground. A large number of the plants will die before the first flower bud is out, but in some of them the effects of infection are masked even until the first fruit is picked. In these cases the main stem of the plant breaks at the place of infection where callous formation has proceeded. The terms "tip over" and "foot-rot" have been applied to this condition. Another effect of stem cankers is the girdling of the growing terminal bud in young plants which are beginning to blossom.

On the leaves the disease is more severe on the young transplants when the photosynthetic apparatus is so much needed. During rainy weather the spots appear as small circular to irregular areas between the veins. The color of these necrotic areas is a paler green than that of the blade of the leaf. Soon large irregular spots result. They coalesce, in many cases covering more than three-fourths of the entire blade. In some cases the growth of the fungus seems to become arrested, when the dried tissues of the dead areas break away, leaving holes of all sizes and shapes on the blades of the leaves.

A second kind of symptom is exhibited as small, circular, brown spots which never attain a diameter beyond one-fourth inch, usually being about one-sixteenth inch across. These lesions are characteristic of late infections during the drier months of February, March and April and in the older mature leaves. It is serious in that defoliation is brought about prematurely on the lower part of the bushes,

but sound fruits may be found on these. The fungus spores seem to be able also to penetrate the cuticle and epidermis of the midrib and veins producing lesions of a reddish color on most varieties and which may extend for an inch or two. The lesions may extend into the tissues on both sides of the midrib and veins. Long lesions on the midrib may cause the blade to break at that point.

The fungus attacks are quite serious on the petioles of the younger plants. Lesions here are lens-shaped or oval to elongated and sunken. They are brownish at first, then whitish, beset with the black tips of the fruiting bodies the same as the spots on the stems. The fungus sometimes extends from the spots on the petioles down towards the stem where it infects the young shoots which arise at the axils of the leaves. In severe cases the ragged, branchless condition is due to the plant being unable to replace these shoots.

On flowers and fruits the pathogen is very injurious. Flowers and very young fruits seem to be affected late in the season when abundant spores have been produced on the decaying leaves and fruits and on the stem cankers. When the fungus attacks the stalk of the flower or young fruit, the infections cause a shrinking of the tissues. The lesion may extend into the calyx and finally reaches the young ovary or fruit. In any case the ultimate result is the abnormal laying of an abscission layer and the flowers or young fruits drop to the ground. Yet small mummies may be occasionally found attached to the stem. The spots on fruit of all ages and sizes are first evidenced by brownish discolorations of not more than ⅛″ or ¼″ in diameter, usually of regular outline. Necrotic areas will appear at any point on the surface of the fruit but more frequently near the stem end. The fungus spores seem to lodge under the calyx lobes where ideal conditions for their incubation appear to exist. From there the dead areas spread in all directions, finally resulting in the destruction of the fruit. The symptoms will more frequently appear on overhanging fruit which touches the ground.

External symptoms on seed are seldom found. It has been definitely established (Sherbakoff 18), that the fungus is carried with the seed. It is not very likely that seed may be separated into healthy and diseased. Usually seed from diseased fruit has all the appearance of normal healthy seed from sound fruit. It is only in very advanced cases of rotting that seed will be discolored.

Seedling stage.—On seedlings the morphologic symptoms given above for leaves and stems on full-grown plants usually exist. The rather crowded condition which prevails in the seedbeds is an in-

fluencing factor in determining the loss to seedlings. In very young seedlings an affection similar to that produced by the fungus *Pythium de Baryanum* Hesse, a bending-over resulting from the destruction of the young tissues at the surface of the ground, is produced.

Signs.—Pycnidia of the pathogene appear abundantly on the surface of lesions on stems, leaves and fruits. They are formed just beneath the epidermis, their beaks, when developed, extending beyond the surface. Ordinarily, beaks do not appear on the natural host except on very old lesions on plant parts which have dropped to the ground. However, they readily form on certain artificial media.

Histologic symptoms.—The most striking histologic symptoms is a hydrosis of the recently infected parts. The epidermal cells are the first to manifest this symptom and are followed in succession by the underlying cortex cells. The cells of the epidermis are more or less plasmolized. The cell walls of the epidermis as well as those of the cortex cells as far inward as the two or three outer layers of cortical parenchyma are stained brown. This discoloration of the cell walls has not been found to reach as far as the vascular bundles. In the case of lesions on the veins of the leaves and in the fruit, discoloration of the vascular bundles has been observed. In the small lesions on veins of leaves the fungus seems to stop its course after a short period of development. In the fruit the pigmentation is soon destroyed, the brown discoloration then appearing.

Etiology

Name, history and classification of the pathogene.—A number of diseases have been described on the eggplant which are probably identical. It is natural that various names should have been applied to the causal agent. In 1881, Spegazzini (**22**) described a new fungus on the eggplant leaves and fruit which he named *Phyllosticta hortorum.* Halsted (**6**) accepted this name for the fungus which he found in New Jersey in 1890 on leaves and fruit of the same plant. Halsted further attributes the damping-off or seedling stem-blight to *Phoma solani.* He evidently established differences between the various stages of the disease. It will be shown that the same fungus is able to produce lesions on all above-ground parts and in plants of all ages and therefore only one name should hold, either *Phyllosticta hortorum* Speg. or *Phoma solani* Hals. In 1904, Smith (**20**) reported the fungus *Ascochyta lycopersici* Brun, as different from what had been described as *P. hortorum* Speg. He found differences in size and septation of the spores and in the symptoms of

the leaves. In a later paper Smith (1905) was of the opinion that the seedling blight was also caused by this fungus. This year he regarded *Ascochyta lycopersici* and *Phyllosticta hortorum* as one and the same fungus. If they are really so and there is septation of the spores, then the former name would prevail and as Harter (13) rightly concluded, the name *Ascochyta hortorum* (Speg.) C. O. Smith should hold, for reasons of priority.

Voglino (25) extended into a consideration of the pathogene and designated his Italian fungus as *Ascochyta hortorum* (Speg.) Smith. Later, Harter (13) after examination and study of material from New York, Nebraska, New Jersey and Wisconsin found that the fungus was characteristically a member of the genus *Phomopsis*. His work is very illuminating. He concluded that this fungus and *Phoma solani* Hals. are identical. Saccardo and Sydow (15) had given the name *Phoma vexans* to Halsted's fungus because *Phoma solani* had already been applied to another species. Harter (13) then made his new combination *Phomopsis vexans* (Sacc. and Syd.) Harter. Harter had sent material to Spegazzini for comparison with type specimens of *Phyllosticta hortorum* and the latter apparently found them to be different. Therefore, Harter concluded that *Phyllosticta hortorum* had not been found in the United States. But Smith (20, 21) had found an *Ascochyta* and a *Phyllosticta* and had later accepted both to be the same fungus; and Voglino (25) had accepted Smith's views. Harter (13) was of the opinion that Smith had both an *Ascochyta* and a *Phyllosticta* on the same host. The latter would now be replaced by *Phomopsis vexans*. From host relationships and morphologic characters it appears that both Smith and Voglino had an *Ascochyta* which in Harter's opinion was *Ascochyta lycopersici* and hence distinct from the eggplant blight fungus.

The pathogene to which the disease is attributed in Porto Rico is characteristically *Phomopsis vexans* (Sacc. & Syd.) Harter. The fungus was not compared with any other from abroad because the writer thinks it has been thoroughly worked out by Harter and any further study on the taxonomic position would be a mere duplication of carefully done work. However, it has been given some attention.

Edgerton and Moreland (4) consider that the fungus exhibits variations in Louisiana in the manner of infection, rate and manner of growth and ratio of the two kinds of spores. We have not found much variation in our fungus. That apparently two kinds of spots were produced on the same plant made the writer believe that there

might possibly be two strains of the fungus. Not less than fifteen isolations from each type of lesion were made. All these pedigree cultures were compared in three media, oatmeal agar, corn flour agar and one per cent dextrose nutrient agar. The rate of growth of the different cultures is not given here because of the uniformity throughout. All the cultures produced a rapid growth in the dextrose agar, forming a thick creamy mycelial stratum over the medium which filled the entire dish (90 mm.) in seven days. Fruiting bodies were scanty in this medium and were formed on the edge of the colonies. In oatmeal agar and corn flour agar growth of mycelium was very slow. The size of the colonies was about 60 mm. in diameter on the seventh day in the oatmeal agar and about 50 mm. in the corn flour agar. Stromata began to develop in these media on the fifth day and large numbers had appeared on the twentieth day. The stromata are black. One to several pycnidia arise in each stroma in these media. The pycnidia are typically beaked. The beaks are from 1 mm. to 1½ mm. in length extending beyond the surface of the stromata.

The same cultures were used in cross-inoculation tests on egg-plant leaves and fruit. It was found that all the cultures from the supposedly different strains invariably produced the same symptoms when inoculated into these plant parts. The inoculations on leaves were made during rainy weather and the spots which resulted were of the large, irregular type. In no case was the small, circular spot reproduced. The writer, therefore, believes that the Porto Rican fungus is more or less uniform.

Harter's (13) description of the pathogene, p. 338 of his paper, is here given:

"*Phomopsis vexans* (Sacc. and Syd.), n. comb.
Phoma solani Hals., not *Phoma solani* Cooke and Hark.
Phoma vexans Sacc. and Syd.
Ascochyta hortorum (Speg.) C. O. Sm. not *Phyllosticta hortorum* Speg.

"On the foliage and stems pycnidia loosely gregarious in more or less definite spots, on fruit compact, at first buried, later erumpent, black without, beaked, flattened or irregular in shape, on leaves and stems 60 to 200 microns broad, on fruit 120 to 350 microns broad; pycnospores subcylindrical, somewhat acute, 5 to 8 by 2 to 2.8 microns, continuous, hyaline, 2-guttulate, rarely 3; basidia simple, short, straight or slightly curved, hyaline, continuous; stylospores filiform, curved, rarely straight, 13 to 28 microns long."

Stylospores were infrequently found in our material, both from

culture or from the lesions on the various affected parts. Pycnidiospores are generally found. The size of the latter as figured on the basis of 400 spore measurements is 5 to 8 × 1.3–3 microns. The size of the pycnidia agrees more or less with that given by Harter.

Life History

So far as known the fungus *Phomopsis vexans* is propagated asexually throughout its entire cycle.

Primary cycles may originate in the seedbed or in the field on leaves, stems, flowers or fruits.

Pathogenesis

Inoculation.—The fungus growing in a saprophytic condition in decaying vegetable matter gives origin to pycnidia where the asexual spores are produced in great numbers. These and the mycelium itself are the sources of the inoculum of the primary cycles.

Incubation.—None of the investigators that have dealt with this pathogene have ever succeeded in germinating the stylospores. The pycnidiospore (Phyllosticta type) germinates readily in distilled water or nutrient solutions at room temperaure in three and one-half hours. At the end of five hours germination is at its maximum.

The germ tube of a spore germinating on any above-ground plant part, either enters through a stoma or through a wound or penetrates through the cuticle into the epidermal cells.

Infection.—Infection begins in the epidermis. The germ tube becomes thicker and much branched in the epidermal cell. The branches invade the surrounding epidermal and cortex cells. The hyphae pierce through the walls of the cells, becoming slightly constricted at the point of passage into the next cell. In the larger parenchyma below the cortex the hyphae become profusely branched. (See plate VII, fig. 1). The whole cortex is soon involved and destroyed resulting in a sinking of the collapsed epidermis.

Saprogenesis

Phomopsis vexans is capable of a saprophytic existence in the soil. The fact that the disease has made its appearance in fields on new land which had never grown any Solanaceous species except tobacco, indicates that the fungus is susceptible of a prolonged saprophytic condition, although there exists the possibility of a wild non-solanaceous plant harboring it. In this phase pycnidia are prob-

ably produced abundantly and there is the least doubt that primary cycles originating on fruits and leaves are set up by the pycnidiospores from the saprophytic mycelium.

Secondary cycles are repeatedly occurring in a field where the pathogene is present. Pycnidiospores from lesions on decaying plant parts such as leaves from infected seedlings, affected flowers or fruit and stems start the secondary cycles. The most severe injury to plants is caused by these cycles.

EPIPHYTOLOGY

Outbreaks of the eggplant blight occur in Porto Rico at almost any time throughout the year if eggplants are grown. The writer has observed the disease during all the months between September and March. During one year (1927) when a crop was grown during the summer the plants were severely attacked towards the end of the season, in July and August. The temperature which prevails for the whole year seems to be adequate for the production of spores and their germination. Moisture probably regulates the appearance of the malady. Severe outbreaks always follow periods of light or heavy rainfall.

CONTROL

It is very likely that control of this serious affection of the eggplant can be effected through crop rotation. Edgerton and Moreland (4) believe that a three-year rotation will be necessary.

Eradication through destruction of the after-crop is probably of little value in heavily infested fields. Much will be gained, however, if seedlings which show symptoms of the disease are destroyed as soon as detected. The removal of any plant in the field which bears the characteristic lesions should also be practiced. The fungus may be partially eradicated by seed treatment. It is a known fact that the mycelium of the fungus is actually present in the interior of the seed. This makes the effectiveness of treatment less likely.

The first treatments of seed for the control of *P. Vexans* were made by Sherbakoff (17) in 1916 using 1:10 formaldehyde solution for 10 minutes at 60° to 70° F. and 1:1000 corrosive sublimate for the same length of time at 80° to 85° F. He did not arrive at any conclusions that year. The same writer reported in 1927 (18) a 7 per cent contamination from non-disinfected seed and only more than 1 per cent for that disinfected in 1:1000 corrosive sublimate solution for 10 minutes. Sherbakoff (19) again in 1918 made further studies

with the disease and found that 1 per cent copper sulphate solution for five minutes destroys various bacteria and partly destroys saprophytic fungi on the surface of the seed. *Phomopsis vexans* was not affected by the treatment. Burger (**2**) in 1926 recommended the use of a 1:1000 corrosive sublimate solution for eight minutes for the disinfection of eggplant seed. He did not state which fungus he had in mind but it is assumed it was *P. vexans,* since work had been done previous'y with this pathogene in that Station. Edgerton (**4**) had reported in 1921 unsuccessful results in the elimination of *P. vexans* from seed by the use of a solution of one part commercial formaldehyde to 300 parts of water. The seed was kept in the disinfectant for fifteen minutes. He concluded that the formaldehyde treatment reduces the infection slightly but does not eliminate it.

From our own experience with the disease for three years we find it inadvisable to carry on treatments of seed. The results of tests made by other writers as given above shows that the mycelium within the seed is hard to be reached by any of the known practical disinfection methods. It seems more reasonable to insist on getting clean seed which comes from sound fruit. The production of clean seed is within the bounds of possibility. If seedsmen do not furnish seed guaranteed as coming from a clean source then the grower should grow his own seed. It is possible for him to select a number of good sound fruits and remove the seed which he can store away until the following season.

When growers do not grow their own seed and have to depend on unreliable sources, the next best thing to do is to exercise strict care in the seedbeds.

When clean, disease-free seed is sown on non-sterilized soil and the pathogene lives in that soil we are sure to get the seedling stage of the blight. In order to test the effectiveness of soil disinfectants in the control of the disease the following experiment was conducted.

Nine beds, $20' \times 3'$, the soil of which was known to be infested with *Phomopsis vexans* because a previous crop on the same beds had been seriously affected, were treated in the following manner: The first, second, third, seventh, eighth and ninth beds were drenched with a 1–50 formaldehyde solution, at the rate of one-half gallon per square foot of soil surface. The fourth and sixth beds received a drench of 4–4–50 Bordeaux mixture and the fifth bed remained as check. The seed was sown a week after treatment of the beds. Counts were made at time of appearance of symptoms in the untreated bed, at time of removal of seedlings to a second bed and

at time of transplanting. In the case of the check bed, bending-over of the seedlings occurred at an early age. The affected seedlings were removed and counted at that time. Tissue plantings from the tender stems of the affected lesions were made on artificial media to verify the presence of *P. vexans*. The organism was recovered in each case. The results of counts made at various intervals are collected and given in Table III. The large numbers of seedlings obtained in the beds may be accounted for by the fact that a considerable number was transferred to a second bed as soon as they developed two pairs of leaves. The second set of beds where these seedlings were planted and kept for five or six weeks before setting out in the fields, were sterilized in a manner similar to that given before. Of eighteen beds, twelve were treated with formaldehyde, four with Bordeaux mixture and two left untreated. The seedlings coming from the formaldehyde-treated beds were naturally transferred to those beds of the second set which had also been treated with formaldehyde. The same was true for the Bordeaux and check plots. In the second set of check plots, were planted only those seedlings from the check of the experiment which did not show any symptoms of the disease at the time of the transplanting from the treated beds. It should be noted that the seed used in this experiment was obtained from sound fruit grown by us.

TABLE III

EFFECT OF SOIL STERILIZATION ON THE SEEDLING BLIGHT OF THE EGGPLANT

Bed No.	Treatment October 15, 1928	Results—Seedlings			
		Healthy	Diseased	Total	Per cent diseased
1.....	1–50 Formaldehyde.....	6585	23	6608	0.35
2.....	1–50 Formaldehyde.....	5689	0	5689	No
3.....	1–50 Formaldehyde.....	6781	42	6823	0.62
4.....	4–4–50 Bordeaux.....	5007	892	5897	15.13
5.....	Check.....	51	6268	6319	99.19
6.....	4–4–50 Bordeaux.....	4989	1236	6225	.....
7.....	1–50 Formaldehyde.....	5437	0	5437	No
8.....	1–50 Formaldehyde.....	6897	37	6934	0.53
9.....	1–50 Formaldehyde.....	4979	0	4979	No

From an interpretation of the results of Table III it is evident that infested soils should not be used for eggplant seedbeds. Infested soils can be rendered safe for seedbeds if treated with formaldehyde, 1–50 solution at the rate of one-half gallon per square foot of soil surface. Very few plants were found with the disease

in beds treated in this way. An application of 4–4–50 Bordeaux mixture at the same rate as the formaldehyde solution gives fairly good results. The formaldehyde treatment is to be preferred because it practically eliminates the infestation and prevents secondary cycles. In the Bordeaux mixture treated beds some of the fungus escaped the action of the disinfectant or survived it, and spread rapidly over a large number of seedlings. The cost of the formaldehyde treatment in Porto Rico is as follows:

Formaldehyde (cost of material delivered at the Station), 11 gallons enough for 18 beds (20′ × 3′)-----	$24.75
Labor (application of formaldehyde)----------	3.00
Total----------	$27.75

This is the additional expense incurred when growing seedlings and does not include the cost of land, cultivation, etc.

Twelve beds were used as transplant beds as has been previously stated. These beds held about 900 seedlings each, the latter had been set at 3 inches apart each way. The twelve beds made a total of 10,708 seedlings. An examination of Table III will show that the six formaldehyde-treated beds yielded a total of 36,368 healthy seedlings. Those 10,708 seedlings in the twelve transplant beds given above proceeded from these 36,368 seedlings. The difference of 25,660 were left in the original beds and from there removed to the fields at intervals. From this number should be deducted nearly 2362 seedlings which were discarded from the original beds and which made up the number of diseased seedlings and those not planted because of poor development. The total of healthy seedlings, that could be used safely for planting was 34,006 and would have been sufficient to plant about five and one-half acres. The planting distances on which this calculation is based is three and one-half by two feet. The additional cost would have been about $4.50 per acre. A grower can easily afford this expense.

CONTROL BY PREVENTION

Attempts at the prevention of the malady were made as early as 1893 by Rolfs (14) who employed Bordeaux mixture and ammoniacal copper carbonate. No results are recorded. In 1895 Halsted (7) used Bordeaux mixture (5–5–50), Eau celeste (1–1½–50), copper sulphate (1. oz. to 8 gallons) and sulphide of potassium

(1 oz.–2 gallons) in an attempt to control the disease. Bordeaux was the only disinfectant which was satisfactorily applied. In 1896 the same writer (8) reported the testing of soda-Bordeaux, potash-Bordeaux and the 5–5–50 Bordeaux of his preceding year with the latter alone giving satisfactory control. The following year he (9) repeated the experiments adding this time a fourth fungicide, cupric hydrate, to those used in 1896. This year he found "little difference in the effectiveness of the four fungicides". In 1899 (10) Bordeaux and soda-Bordeaux were used but the number of fruits was not sufficient to be used in arriving at any conclusions. Halsted's (11) experiments of 1900 showed Bordeaux sprayings resulted in "less infested" plants and "somewhat larger" yields.

In 1921, Edgerton and Moreland (4) reported the results of four experiments with 4–4–50 Bordeaux mixture. Up to 13 applications of the mixture were made during a single season. There was a consistent increase in yield with applications of the fungicide but they concluded that it may not be practical to spray in Louisiana. Furthermore they found that "a few applications of the spray solution seem to have had no good effects". Yet they believe that in climates with less rainfall it may be profitable to spray.

Bordeaux mixture (4–4–50) has also been recommended by Bruner (1) in Cuba. Geise et al (5) reported in 1922 successful results in the control of *P. vexans* with copper lime dust and 4–6–50 Bordeaux mixture with 2 pounds powdered calcium arsenate. They obtained equally good control with both the dust and the spray. Spencer et al (23) found that Bordeaux with arsenicals gave satisfactory results. Bordeaux with zinc arsenite gave as good and in some instances better results than Bordeaux with calcium arsenate. Bordeaux dust with 20 per cent calcium arsenate was superior to Bordeaux dust alone or to the Bordeaux calcium arsenate spray (4–8–2–50).

It was deemed necessary to have a knowledge of the treatment for the control of the disease under the conditions which prevail in Porto Rico and especially in relation to its cost and practical application. One experiment was carried out in order to ascertain whether the blight of seedlings could be prevented by sprays. Three beds, $20' \times 3'$ each, were planted with eggplant seed as follows: the first bed, sterilized with formaldehyde and sown with seed coming from diseased fruits; the second bed, divided into two sections across the middle, in one section (*a*), the soil being sterilized with formal-

dehyde, and seed from diseased fruits employed. The second section (*b*) had soil which was known to be infested with the blight organism. Here seed from sound fruit was used. The third bed had soil known to be also infested with the pathogene and in it seed from sound fruit was used. Seed was planted on October 3, 1928. The first and third beds were sprayed every week with Bordeaux mixture (4–4–50), the first application being made on November 1st., when the first symptoms of the disease appeared. The second bed remained untreated. As soon as symptoms appeared on seedlings these were removed from the bed in order to reduce the source of inoculum as much as possible. A total of five treatments were made. At the time the fourth treatment was applied, Nov. 21, a large number of the healthy seedlings were of transplanting size and age and were removed from the beds. An additional treatment was then necessary for those which would reach the desired size in a week or two more. The results accumulated by the time when the majority of the plantlets were of the proper size for transplanting are given in table IV. The number of seedlings in the beds were small due to the fact that the sowing was made quite sparse.

TABLE IV

RESULTS OF 4–4–50 BORDEAUX TREATMENT FOR THE PREVENTION OF THE SEEDLING BLIGHT

Bed	Treatment	Seedlings			
		Healthy	Diseased	Total	Per cent Diseased
1 Formaldehydetreated. Seed from diseased fruit.....	4–4–50 Bordeaux	3231	893	4124	21.41
2a. Formaldehydetreated. Seed from diseased fruit.....	Check.....	1468	1509	2977	50.69
2b. Infested soil Seed from sound fruit.....	Check.....	1891	1686	3577	47.13
3. Infested soil. Seed from sound fruit...	4–4–50 Bordeaux	3818	632	4450	14.20

The highest percentage of diseased seedlings (50.69 per cent) was on the bed with sterilized soil but where infested seed was employed. The infection in the untreated bed, with clean, sound seed, was lower only by a narrow margin.

It is plain that Bordeaux mixture has highly beneficial results in seedling blight prevention. When infested seed was used the effectiveness of the treatment was much reduced.

Notwithstanding the fact that rather fair control can be obtained by prevention we are of the opinion that one should rather endeavor to eliminate the infestation in the soil as has been recommended in the preceding paragraphs. One can easily see how apparently healthy plants may be carriers of the spores of the fungus which will infect the suscept when transplanted. A small amount of the diseases in a bed is a menace to the healthy seedlings in the same bed unless these are thoroughly wet with Bordeaux mixture previous to pulling for transplanting. Experience tells us that it is only with considerable difficulty that the fungicide is made to reach every above-ground part of the seedling. This is because of the rather crowded condition which holds during the fifteen or ten days which precede the operation of transplanting.

Experiments have been made to ascertain whether control of the disease in the field is possible and practical in Porto Rico. Bordeaux mixture of the formulas 4–4–50 and 3–3–50, and copper lime dust have been tried out. The results with the dust are to a certain degree misleading and will be omitted. Further and more extensive trials should be made before conclusions are drawn.

The plan of the experiments has been as follows. An examination of the field was made when the plants had developed about six leaves, this number including only one of the leaves of the partially expanded growing bud. All leaves that showed symptoms of the disease were gathered. At the time of the removal of the diseased leaves, records were taken of the number of diseased plants, number of diseased leaves, number of unaffected plants, number of plants with all leaves diseased, and the number of lesions on the leaves. These counts were made in order to have an idea of the general infestation of the field at the time of the first application. The number of lesions will give an idea of the number of inoculations, each spot representing, in our judgment, a distinct inoculation. The diseased leaves were removed from the field in order to make sure that any new lesions came as a result of inocula from other than the primary cycles.

In each experiment two rows on the edge of the particular field were kept as checks.

The results appear in Table V.

TABLE V

SHOWS RESULTS OF TREATMENTS FOR THE CONTROL OF EGGPLANT BLIGHT AND FRUIT ROT

	4-4-50 Bordeaux	3-3-50 Bordeaux
Total number of plants	1497	894
Total number of untreated plants (check)	63	121
Total number of treated plants	1434	773
Total number of plants with diseased leaves prior to treatment	517	396
Percentage of diseased plants	36.05	44.29
Total number of leaves	6674	5244
Total number of diseased leaves	979	935
Percentage of diseased leaves	14.67	17.83
Total number of lesions on leaves	6601	5002
Ratio of lesions to leaves	6.74:1	5.35:1
Total number of fruits at end of season on treated plants	6115	3772
Total number of sound fruit on treated plants	5976	3581
Total number of diseased fruits on treated plants	139	191
Percentage of sound fruit in treated plants	97.73	94.94
Percentage of diseased fruit on treated plants	2.27	5.06
Total number of fruits in "check rows"	137	206
Number of sound fruits in "check rows"	21	42
Number of diseased fruits in "check rows"	116	164
Percentage of sound fruits in "check rows"	15.33	20.39
Percentage of diseased fruits "in check rows"	84.67	79.61

An examination of Table V makes clear that the infestation of the three fields was very heavy. On the basis of number of plants the infection varied from 36.05 per cent to 44.29 per cent while on the basis of diseased leaves it would be much lower, 14.67 per cent to 17.83 per cent. The latter will probably better indicate the amount of infection at the time the treatments were made. The total number of lesions offers a still clearer idea of the general conditions of infestation. The counts of the lesions in all the diseased leaves throws a ratio of from 6.74 lesions per affected leaf to 5.35. This ratio is a clear expression of what was occurring in the fields at the time the treatments were made. Had no applications of fungicides been made the disease would surely have spread from the diseased to the unaffected plants.

The effect of the fungicides is calculated on the basis of sound to diseased fruit rather than on healthy or diseased foliage because of the difficulty in counting the leaves of the full grown plants throughout the season. A comparison of the results obtained with 3–3–50 or 4–4–50 Bordeaux mixture shows that the latter is more effective under more or less the same conditions of infestation. With the 4–4–50 Bordeaux mixture there were 97.73 per cent sound fruit as against 94.94 per cent for the 3–3–50 Bordeaux-treated field. The results in the check rows although with smaller numbers, show clearly

the danger to which the plants are exposed when no protection is employed.

The cost of Bordeaux mixture (4–4–50) and of its application at the Experiment Station are given here. These figures will apply to many sections of the island. The cost will, of course, vary according to the cost of labor and cost of transportation.

The cost of eight applications of the mixture was as follows:

43 pounds of copper sulphate at 7.7¢	$3.31
43 pounds of live lime CaO) at 1.8¢	.77
Cost of application, 118 hours of labor at 12.5¢ per hour	14.75
Depreciation of sprayers, estimated	2.00
Total cost of spraying 1,497 plants	$20.83
Cost per 1,000 plants	$13.91
Cost per 6,000 plants in about one acre	83.46

We have found that the cost of spraying eggplants in Porto Rico is highly prohibitive under ordinary conditions. Unless the cost of application is reduced it seems that our growers will not be justified in spraying. The solution of the problem of the cost of treatment lies in cheaper application or fewer applications. During certain years it may not be necessary to make as many as eight applications.

Probably the cheapest and safest plan of control of the blight and fruit rot is to grow healthy seedlings in the manner suggested in the preceding paragraphs and plant them in uninfested soils.

SUMMARY

1. A serious disease of eggplants known in Porto Rico as "lunares de la hoja y tallo" and "podredumbre de la fruta", in the United States of North America as leaf blight, foot-rot, leaf-spot, stem-blight, fruit-rot, eggplant-blight and seedling-stem-blight and in Cuba as "mancha de la hoja" and "enfermedad del tallo" exists in Porto Rico.

2. All varieties of eggplant are more or less equally susceptible under Porto Rican conditions. Color of plant or of fruit has no bearing on susceptibility or resistance.

3. The disease usually brings a loss of 50 per cent or over of the crop.

4. The symptoms of the disease appear on all above-ground parts of the plant. A seedling blight, stem and petiole cankers, spots on

leaf blades, fruit stalks and calices and a rotting of the young and mature fruit are produced.

5. The fungus may occur inside the seed.

6. The pathogene responsible for the malady is *Phomopsis vexans* (Sacc. & Sydow) Harter.

7. Variations of the fungus as have been observed elsewhere do not appear to occur in the fungus in Porto Rico.

8. The size of the pycnidiospores ranges from 5 to 8 microns in length to 1.3 to 3 microns in width.

9. The germ tube of a germinating spore may either enter through a stoma, enter through a wound or force its penetration through the cuticle.

10. Secondary cycles repeatedly occur in fields.

11. The fungus is capable of a saprophytic existence.

12. The prevailing temperature in Porto Rico seems adequate for spore germination.

13. Moisture is a very important factor in outbreaks of the disease.

14. The disease is probably controlled by a three- or four-years rotation.

15. Plants with the symptoms of the disease should be promptly removed from fields.

16. Although seed treatment is beneficial it never completely eliminates the pathogene.

17. Clean seed from unaffected fruit should be demanded.

18. Infested soils should be avoided in preparing seedbeds.

19. Inoculated soils can be rendered safe for seedlings if drenched with a 1–50 formaldehyde solution at the rate of one-half gallon per square foot of soil surface. An application of 4–4–50 Bordeaux mixture is highly beneficial but the formaldehyde treatment is to be preferred. The latter treatment will cost about two-thirds of one cent per seedling.

20. Bordeaux mixture (4–4–50) is quite effective in preventing seedling blight. The treatment is too expensive and therefore inapplicable under ordinary conditions. Bordeaux mixture may be of practical application where labor cost is reduced. The safest and cheapest control measure is to grow healthy seedlings and set them out in uninfested soils.

The writer wishes to express his appreciation to Dr. Melville T. Cook, Chief of the Division of Plant Pathology and Botany, for help in the final preparation of the manuscript.

Explanation of Plates

PLATE VII

Fig. 1. The fungus hyphae penetrating a cortical parenchyma cell from two adjacent cells. Note luxuriant growth inside the cell and the constriction of the hyphae at place of entrance.

Fig. 2. A fungus hypha in the cells below the epidermis.

Fig. 3. Conidiophores and conidia of *Phomopsis vexans* (drawn from the high power magnification).

Fig. 4. Germinating conidia (drawn from the oil immersion).

Fig. 5. Two plants affected with *P. vexans*. Note that there is only one healthy branch on the plant to the right. Stems, fruit and leaves, all severely infected.

PLATE VIII

Fig. 6. Lesions on stems. Note the black fruiting bodies on the whitish background of the lesion.

Fig. 7. Mummified fruits. Note that mummies are produced from fruits of all ages.

PLATE IX

Lesions on fruits of all sizes and age. Note the fruiting bodies on the fruit at the upper right hand corner.

PLATE X

The lesions on the leaves. Note two types of spots and also the fact that lesions are produced on the veins and parts of the blade between the veins.

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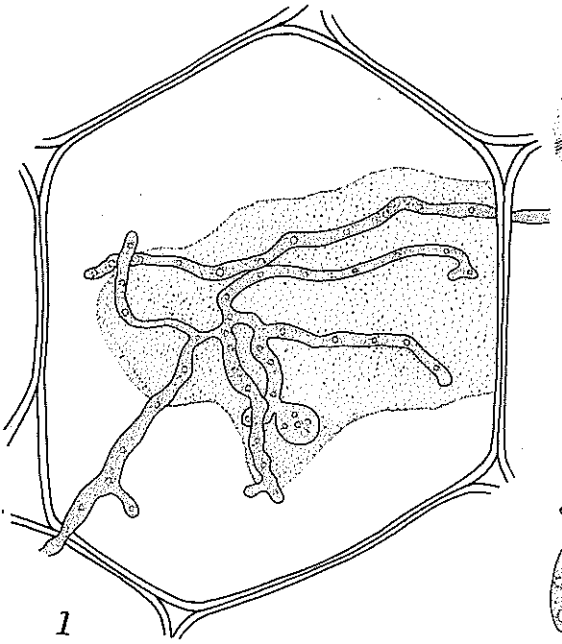
PLATE VII.



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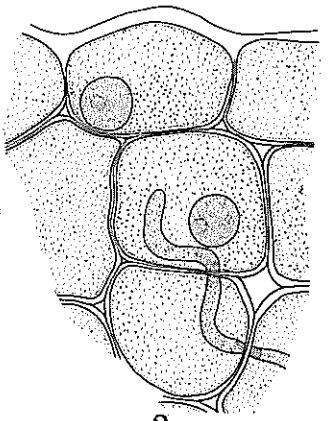

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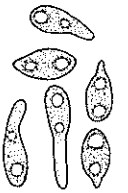

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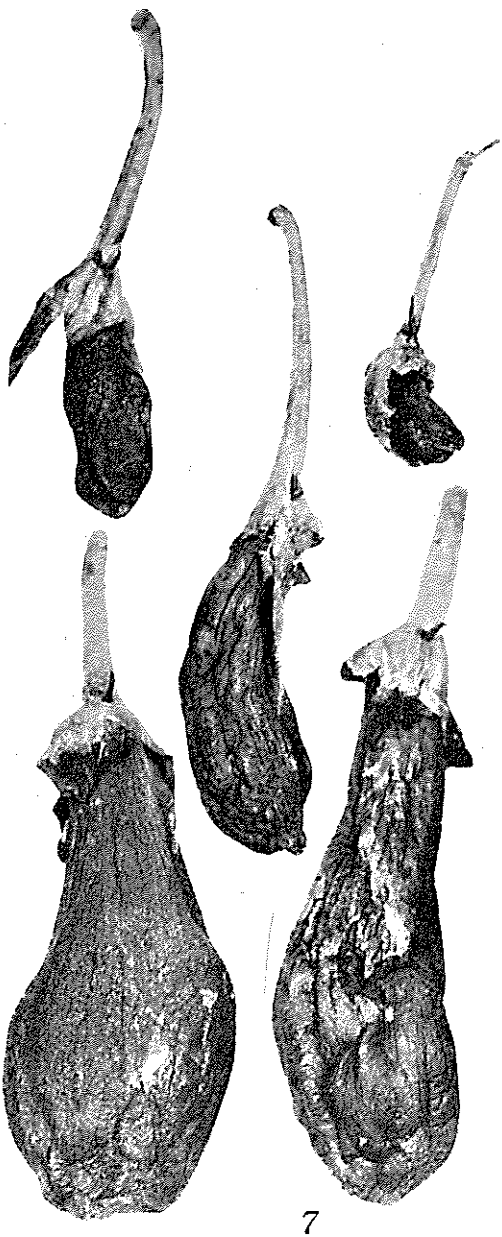

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PLATE IX.