PHYTOPHTHORA ROT OF TOMATO, EGGPLANT, AND PEPPER.[1]

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A Phytophthora rot, apparently identical with buckeye rot of tomato appeared in epidemic form in an experimental plot of tomatoes at Lafayette, Indiana, August 1-3, 1921. The disease continued throughout the summer and destroyed about 40 per cent of the tomato fruits. A few weeks later, a very similar disease developed on eggplant and sweet pepper fruits growing adjacent to the tomatoes, and from all of these, the same Phytophthora was repeatedly isolated. With the Phytophthora isolated from tomato, successful inoculations were secured on eggplant and pepper fruits. The organism was repeatedly isolated from inoculated eggplant and pepper fruits. So far as has been determined, this disease has not been previously reported in Indiana under field conditions.

History.—The genus Phytophthora contains a number of species which are separated by apparently minor and none too stable differences. Rosenbaum[2] made an extensive comparative study of nine described species of Phytophthora and presented a tentative table for the separation of species based on his studies.

Sherbakoff[3] working in Florida, described a buckeye rot of tomatoes in 1917 which he attributed to an undescribed species of Phytophthora to which he gave the name, *P. terrestris*. Using the fungus isolated from tomato, he inoculated tomatoes, sweet peppers, watermelon fruit, lemons, and tubers of Irish potatoes and secured infection in every case.

Late blight of potatoes, caused by *Phytophthora infestans*, has been reported on tomatoes in West Virginia by Giddings.[4] It occurred on leaf, stem and fruit, causing a rot of the fruit. He reports serious losses due to blighting of the plants before many fruits were set. The organism, according to Giddings, is morphologically identical to *P. infestans* which causes a serious blighting of potatoes.

In 1915, Haskell[5] while stationed in Dutchess county, New York, observed a disease on eggplant fruit pedicles and calyces and a decay of a few of the younger fruits. The eggplants were growing adjacent to a field of potatoes which were badly infected with *P. infestans*. A comparison of the organism causing the disease on the eggplants with *P. infestans* from the potatoes showed that the two were identical.

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[1] Contribution from the Botanical Department of Purdue University Agricultural Experiment Station, Lafayette, Indiana.

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[2] Rosenbaum, J. Studies of the Genus Phytophthora. Jour. Agr. Res. 8:233-276, 13 fig., 7 pl., 1917.

[3] Sherbakoff, C. D. Buckeye rot of tomato fruit. Phytopath. 7:119-129. 5 fig., 1917.

[4] Giddings, N. J. Potato and tomato diseases. West Virginia Agr. Exp. Sta. Bul. 165, 18-19. 1917.

[5] Haskell, R. J. Phytophthora infestans on eggplant in the United States. Phytopath. 11:504-505. 1917.

Leonian[6] recently described a stem and fruit blight of peppers caused by a species of Phytophthora which he named *P. capsici.* Peculiar tuberous growths on the mycelium resembling sporangia were considered a distinctive morphological character of this species. No reference is made to Sherbakoff's work[7] on *P. terrestris.*

The morphological characters of the fungus causing the disease in Indiana do not agree with either *P. infestans* (Mont.) DeBary, or *P. capsici* Leonian, but do agree very closely with *P. terrestris* Sherb. The symptoms of the disease on tomato are very similar to the symptoms of buckeye rot of tomato as described by Sherbakoff[7], and therefore it seems likely that the causal organism of the disease of tomatoes, eggplants and peppers in Indiana is *P. terrestris.*

Distribution and Economic Importance.—Buckeye rot of tomatoes, caused by *P. terrestris* has been reported from Florida[7] where it has caused serious losses due to the rotting of the fruits, especially those touching or very near the ground. In 1919, Weimer observed buckeye rot on tomatoes in the U. S. Department of Agriculture experimental field plots at Arlington Farms, Virginia. In 1920, Jehle[9] reported the loss from buckeye rot of tomatoes to be one to two per cent in the coastal plain counties of North Carolina. Pritchard[9] the same year reported a 0.5 per cent loss on the experimental farms at Arlington, Va. It was also reported as causing loss of lower fruits in greenhouses in Indiana[8].

In 1921, Sherbakoff[10] reported the loss in Tennessee from buckeye rot to be approximately ten per cent, and Pritchard[10] again reported the disease prevalent on the experimental farm at Arlington, Va. The rot was reported on tomatoes shipped from Texas and Mexico in 1919 in the plant disease survey bulletin.

Buckeye rot is primarily a tropical or subtropical disease. It often causes serious losses in greenhouses in the north where tomatoes are grown under warm humid conditions.

It is possible that the organism causing buckeye rot may be carried from one locality to another in the soil on the roots of young plants. In 1920, about a hundred tomato plants grown in Georgia were put out in the experimental field at Lafayette, Ind. In 1921, tomatoes were grown on this same soil and it was in these tomatoes that the epidemic of buckeye rot occurred. Tomatoes were again grown there in 1922, but no buckeye rot developed, possibly due to drier weather conditions.

Symptoms.—The disease as observed in Indiana affects only the fruits of the host plants. The lesion first appears on the green tomato fruits as a very small web or lace-like blotch five to ten mm. in diameter. (Fig. 1, A). These spots look like a few dark-brown tan-

[6] Leonian, Leon H. Stem and fruit blight of peppers caused by Phytophthora capsici sp. nov. Phytopath. 12:401-408, 2 fig., 1922.

[7] Sherbakoff, *loc. cit.*

[8] Haskell, R. J. and Wood, Jessie. Diseases of field and vegetable crops in the United States in 1919. U.S.D.A. Plant Disease Bul., Supplement 10, p. 217, June 1, 1920.

[9] Haskell, R. J. and Wood, J. I. Diseases of field and vegetable crops in the United States in 1920. U.S.D.A. Plant Disease Bul., Supplement 16, page 224, June 1, 1921.

[10] Coons, G. H. Diseases of field and vegetable crops in the United States in 1921. U.S.D.A. Plant Disease Bul., Supplement 22, p. 328-329, July 20, 1922.

gled threads embedded in the epidermis of the fruit. This develops rapidly into a dark water-soaked spot, and in a few days may increase to 20 to 30 mm. in diameter. Several spots often occur on the same fruit and later coalesce into one large spot. (Fig. 1, B). As the rot progresses dark-brown concentric rings or zones are formed in the diseased area, giving it the buckeye appearance. (Fig. 1, C). The fungus

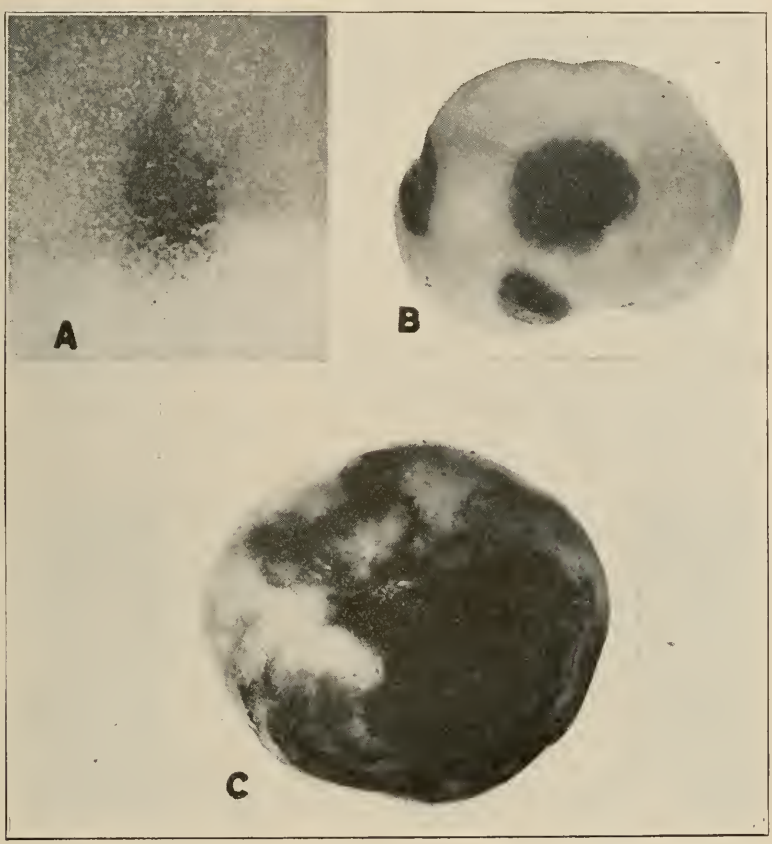

Fig. 1. *Phytophthora terrestris* on tomato fruit. *A*. Incipient infection showing the dark brown web- or lace-like early stage of the lesion (X3). *B*. Lesions three to four days older than the lesion in *A*. *C*. A later stage showing the concentric brown markings in the diseased area.

does not cause a marked disintegration of the tissues. The host cells are killed, but the tissue involved is firm until a later stage of the disease, by which time saphrophytic bacterial invaders have entered and caused a soft rot of the fruit.

On mature tomato fruits, the disease causes a premature ripening and decay. No young lesions were observed on ripe fruits, but young lesions were observed on green fruits of all sizes. From these observa-

Fig. 2. *A.* Rot on eggplant fruit induced by inoculation with the Phytophthora isolated from tomato. The diseased fruit has separated from the stem, a condition which is characteristic of the disease on eggplant. *B.* Longitudinal section of an infected eggplant showing the darker infected tissue and discoloration of the vascular bundles over the entire surface, especially at the stem-end. *C.* Growth of the fungus after nine days incubation at different temperatures. The numbers denote the temperature on the centigrade scale.

tions, it seemed likely that the bulk of the infection took place when the fruits were green.

On the eggplant, the fungus produces a dark-brown spot on the fruit with a conspicuous light-colored border. (Fig. 2, A). When the fruit is cut open, the fungus is found to extend well into the flesh as evidenced by the dark-brown discoloration of the tissues. (Fig. 2, B). The fungus appears to advance most rapidly in the vascular bundles since these show as dark strands running out from the badly discolored area. (Fig. 2, B). Affected fruits drop from the stem prematurely and in no case was a fruit observed to remain on the stem after more than one-half the fruit had become involved. This premature dropping of the fruit from the stems is attributed to the invasion of the fibro-vascular tissues at the stem-end and a stimulation of the abscission process.

The symptoms on pepper are not as pronounced as on either tomato or eggplant. The first symptom is a small dark-green water-soaked spot. The lesion enlarges rapidly and before the rot involves one-half of the fruit, it drops from the plant. The somewhat wilted pedicels remain attached to the fruits and when cut longitudinally, show discolored vascular bundles. When these pedicels were incubated in a damp chamber, a fungus similar to the one isolated from the fruits grew out of them. The fungus penetrates the pedicels of the pepper fruits but apparently not the branches of the plant. In the eggplant, the fungus apparently does not invade the pedicel at all. In the case of peppers only the green fruits are susceptible.

The Fungus.—The fungus was readily isolated from infected tomato, eggplant and pepper fruits by planting small blocks of infected tissue, cut out aseptically, in poured plates of potato agar. In practically every case, a white, rather dense, spreading and somewhat tufted fungus developed from the tissue plantings. The organism grows well on potato agar, which has been used almost entirely in the laboratory cultural work.

The mycelium is at first continuous, but later becomes sparingly septate and branched. Peculiar distortions or tuberous outgrowths are very common on the mycelium in old cultures. Conidia are produced in cultures on potato agar in four to six days, but not abundantly. In Petri dish cultures on sterilized sugar beet and radish leaves in water, an abundance of conidia are produced in three days. Conidia are usually borne terminally, but often are intercalary, and are oval to oblong and papillate at the apex. The great majority of the conidia are uniformly oval in shape, especially in liquid cultures. The measurements of the conidia from the liquid cultures were 47.6x54.9 $(45.9\text{-}50\text{x}53.2\text{-}55.8)\mu$, while from agar cultures they were 31x41 $(29.5\text{-}33.5\text{x}33\text{-}92.5)\mu$. The conidia germinate either by swarm-spores or by one to three or more germ tubes.

Chlamydospores were produced rather abundantly, especially in old cultures. They were globose and measured 24.7 $(27.5\text{-}27.9)\mu$. Oospores were found in old cultures. These were thick-walled and globose and measured 21 $(17.5\text{-}26)\mu$.

The above description agrees closely with that given by Sherbakoff for *P. terrestris*, and since the symptoms on the tomato were identical with those described by the same author for buckeye rot of tomato, the organism causing the disease in Indiana is in all probability that species.

Inoculations.—Inoculation work was done in the field late in the summer of 1921 with cultures of the Phytophthora isolated from tomatoes. Eighteen eggplant fruits were inoculated by making a very slight wound on the surface of the fruit with a flamed scalpel and placing very small pieces of mycelial growth from agar cultures on the wounds. Nine of the 18 inoculated fruits developed the rot, from which the same Phytophthora was later reisolated.

Thirteen pepper fruits were similarly inoculated and ten of the 13 inoculated fruits developed the rot. Six pepper fruits were inoculated by placing fragments of an agar culture on the unwounded surface and four of the six developed the disease. The fungus was reisolated from these infected fruits.

Inoculation of green tomato fruits in moist chambers in the laboratory, both with and without wounding the surface, by placing fragments of agar cultures on the surface of the fruits and over the wounds, produced a typical Phytophthora rot.

The inoculation of six small watermelon fruits by making a slight wound near the blossom-end and placing small blocks of agar cultures over the wounds gave negative results.

On Nov. 30, 1921, potatoes were surface sterilized, sliced with a flamed scalpel and placed in sterile moist chambers and inoculated by placing mycelium from an agar culture on the cut surface and incubated at 23°C. and 27°C. No infection occurred.

Temperature Relations.—A series of cultures was grown at different temperatures to determine the optimum temperature for the mycelial development of the organism. A very small block of an agar culture was planted in the center of each of a number of poured plates of potato agar. These plates were then placed in moist chambers and incubated at the following temperatures: 8°-9°, 12°, 15°, 20°, 23°, 27°, 30°, and 35°C. Measurements of the diameter of the colonies were made at different intervals. The measurements made at the end of nine days are given in table 1.

TABLE 1. Growth of *P. terrestris* at Different Temperatures.

8-9°C.	12°C.	15°C.	20°C.	23°C.	27°C.	30°C.	35°C.
No growth.	20 mm.	30 mm.	32 mm.	35 mm.	35 mm.	50 mm.	32 mm.

From the above table it is evident that the optimum temperature for mycelial development is about 30°C. and that low temperatures are not favorable to its development. (These temperature relations are illustrated in figure 2, C.)

The fact that the organism attains its maximum development at a relatively high temperature in a humid atmosphere might explain the outbreak of Phytophthora in Indiana in 1921. The disease appeared at Lafayette during the first three days of August, 1921. The weather conditions at Lafayette, as given by the U. S. Weather Bureau at Indianapolis, show that for the last three days of July and the first three days of August the mean temperature was 77.5°F. The average maximum temperature for the six days was 86.5°F. which is equivalent to 30.2°C. The average minimum temperature for the six days was 68.5°F. or 20.2°C. The average maximum temperature was very favorable for the maximum development of the fungus, and the average minimum temperature was high enough to permit good growth of the organism. The record of precipitation for the last three days of July and the first three days of August show that on July 30, there was 1.06 inches of rainfall, on August 2, 2.20 inches, and on August 3, 0.85 of an inch, or a total of 4.11 inches for the six days. This is more than the average total rainfall for the entire month of July or August.

From the above data, it is quite evident that temperature and moisture conditions were ideal for the development of the fungus, especially the amount of soil moisture which is undoubtedly the most important of the two factors.

The records further show that the weather conditions for the months of August and September were conducive to the continued development of the disease. The average mean temperature for both months was above normal, and the total precipitation was about double that of the normal for these two months. In August it rained 0.01 of an inch or more on ten different days and 0.01 of an inch or more on twelve different days in September, supplying an abundance of soil moisture at all times.

As previously stated, tomatoes were grown on the same ground in 1922 and no buckeye rot developed. The importance of the soil moisture is again brought out when the records of the U. S. Weather Bureau are consulted. During the months of July, August, and September, 1922, the temperature at Lafayette averaged slightly above normal, but the rainfall for the same months was far below normal, being 0.61 of an inch below normal for July, 1.35 inches below normal for August, and 1.53 inches below normal for September. Thus it can be seen that the most important factor in the development of the disease was lacking in the summer of 1922.

SUMMARY.

A Phytophthora rot of tomato, eggplant and pepper fruits occurred in the field at Lafayette, Indiana, in the late summer of 1921.

The same fungus was repeatedly isolated from diseased fruits, and successful inoculations were secured on eggplant and pepper with the fungus isolated from tomato. Subsequent reisolations from inoculated fruits were made.

The symptoms of the disease on tomato resemble very closely buckeye rot of tomato as described by Sherbakoff, and the fungus agrees mor-

phologically with *Phytophthora terrestris* Sherb., the causal organism of buckeye rot.

Under field conditions, natural infection of immature, uninjured, green tomato fruits occurred.

The lesion on the eggplant fruit was characterized by a conspicuous light border. The fungus grows rapidly in the tissues and causes a browning of the vascular elements and a premature dropping of the infected fruit from the pedicel. Infected peppers also dropped prematurely.

It is possible that the fungus causing the disease may be carried from one locality to another in the soil on the roots of young transplants.

The fungus attains its maximum development at about 30°C. in a humid atmosphere.

The weather records show that the temperature and moisture conditions at Lafayette during the week that the disease first appeared were very favorable for the development of the fungus and that conditions continued to be favorable for the development and spread of the disease.

Tomatoes grown on the same soil in 1922 showed no buckeye rot, probably due to the lack of soil moisture.