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ON THE OCCURRENCE OF PHYTOPHTHORA INFESTANS  
MONT. AND PLASMOPORA CUBENSIS (B. & C.) HUMPH.  
IN OHIO.\*

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The first named fungus, parasitic upon potato, *Phytophthora infestans* Mont., is a species of large economic importance, whose periodic epidemic outbreaks have become historic and have had far reaching economic and political effects. Most of you will recall the statements, that the potato rot resulting from this fungus, occurred in a virulent form in Eastern North America in 1842 and again in 1845—also in 1874. In 1845, and at later dates the disease spread to Great Britain, Ireland, Belgium and parts of Germany and France. In one earlier year, 1845, the greatest injury was done in Nova Scotia, New Brunswick and in Ireland.

This restatement of old facts is made to ask you to bear in mind the climate of the areas of greatest disease.

Doubtless most have heard of potato late blight and rot from this fungus and may be surprised to learn that it is of such rare occurrence in our state that not a single Ohio specimen of *Phytophthora infestans* is to be found in any of the herbaria of the country, save only a few collected at the Ohio Experiment Station within the last three years. However, I know that specimens were taken by the late Dr. E. W. Claypole, near Akron, O., in the early 80's, since I saw him once exhibit such material. This material was unfortunately destroyed in the fire

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\* Read at the meeting of the Ohio Academy of Sci.

which recently befell Buchtel College. In the preparation of this paper I have written to all the prominent herbaria and the laboratory of Vegetable Pathology, Washington. Michigan specimens are equally rare in Michigan, as are Illinois specimens in Illinois, so we are informed by those who know.

I may further state that from the writer's first connection with the Experiment Station in September, 1894, he was diligently striving to secure specimens of *Phytophthora* upon potato in Ohio, but did not succeed until August 1904, when it was collected in several counties. The fungus has reappeared and been collected in Northern Ohio each season since 1903, including that of 1906. The maximum injury to the potato crop was inflicted in 1905.

By the kindness of Mr. E. C. Green, of Medina, Ohio, I have been able to fix definitely the occurrence of *Phytophthora* in Granger township, Medina County, in 1883, thus confirming the Akron specimens destroyed by fire.

We are now prepared to ask, "What conditions determine the occurrence of outbreaks of *Phytophthora infestans* in Ohio?"—a question which all will admit is more easily asked than answered.

Before undertaking to reply to such a question we may consider what conditions favor the propagation and development of this fungus, which so far as is known, is propagated by short-lived *conidia* or by the *mycelium*, the vegetable portion of the fungus; no oospores are known. Herein, we find some diversity of opinion among mycologists. Dr. W. G. Farlow \* records that the potato rot due to *Phytophthora infestans* always occurs or begins about the first of August, that moisture is absolutely essential and that damp "muggy" weather is quite as favorable to its development as heavy rains. This applies more specifically to New England.

In this statement moisture is especially emphasized and properly so. Dr. B. D. Halsted † in his Mycological Notes of 1898 points out "A Close Relation between Rainfall and Potato Rot," in which he emphasizes the rainfall of 1889 (10.19 inches) and 1897 (11.42 inches); in both these years there were marked outbreaks of rot in New Jersey with none, or next to none, in intervening years, and states further: "It seems to me that *Phytophthora* or late blight is quite dependent upon an abundance of moisture in midsummer, and if this relation is noted sufficiently the time may come when it may be predicted with reasonable certainty, that a wet July will mean a decaying potato crop unless some successful method of checking this rapidly developing

\* Bulletin of the Bussey Institution; I:320 (1875).

† Bull. Torr. Bot. Club XXV:160 (1898).

fungus is employed, and, contrariwise, a dry summer will insure freedom from its ravages."

Professor L. T. Jones \* reports upon a favorable season for potato late blight in Vermont: "In 1902, the weather was remarkably cool and moist up to about August 1st, and it has continued cool and moist with more than the usual amount of rainfall since." That year we found the first *Phytophthora* July 13, "the earliest date in a dozen years' observations."

In 1903, Dr. Halsted † again reports serious outbreaks of rot in New Jersey, and mentions moisture as essential to this development of *Phytophthora* and states "A second favoring condition is warm weather—not hot or cold, but a condition of the atmosphere which obtains when there is a week or month of showery summer weather, often spoken of as close or "muggy"—just such as we have experienced throughout the state during August."

In this same connection Dr. Halsted gives the mean monthly temperatures and rainfall for New Jersey during the 15 years previous to 1903. These show for 1903 a June mean of 64.0° (-5.5°), July 73.3° (-0.6°) and August 68.4° (-3.9°) with rainfall about double the mean for June, normal for July and 2.32 inches in excess of normal for August. These conditions of 1903 followed a cool summer in 1902. Without closer analysis of these data we may now turn to other sources.

Scribner ‡ summarized the conditions favoring the disease as follows:

"1. Humidity—The years of great outbreaks have always been years of excessive humidity."

"2. A temperature ranging from 65° to 75° F.—a few degrees above 74° will check the development entirely, and down to 45° F. the fungus will continue to grow."

"3. Moisture in the soil—hence a clayey soil or one that will retain moisture is more favorable to rot."

While we may always need to keep in mind the distinction between *Phytophthora* rot, and certain other forms of rot, we may pass to a statement of Dr. Galloway's|| "The rapid spread of the disease is dependent in a large measure upon certain conditions of moisture and heat. A daily mean, or normal temperature of from 72° to 74° F. for any considerable time, accompanied by moist weather, furnish the best conditions for the spread of the disease"; on the other hand, if the daily mean or normal temperature exceeds 77° F. for a few days the develop-

\* Report Vermont Exp. Station: 15:210: (1902).

† Report New Jersey Exp. Station: 1903: 541-555.

‡ Report Section of Veg. Path., U. S. Dept. Agric. 1888: 338.

|| Galloway, B. T.—Some destructive potato diseases—Farmer's Bull. 15: 1894: U. S. Dept. Agric.

ment of the disease is checked. This explains why the potato blight fungus seldom occurs to any extent in sections where the mean or normal daily temperature exceeds for any length of time 77° F."

I am unable to state at this time the basis upon which the above statements rested at the time, but with certain modifications they will fully cover Ohio conditions. Recalling that the years 1883 to 1886 inclusive, and 1903 to 1906 in Ohio, were periods of prevalence for *Phytophthora infestans* in Ohio, we may glance at the weather conditions for these periods and compare with the means of the past 24 years. It seems only necessary to consider the months of June, July and August. Unfortunately our data do not extend back further than 1883.

I have prepared a table showing the mean summer temperatures and mean rainfall in Ohio for 1883 to 1906:

MEAN SUMMER TEMPERATURES AND RAINFALL IN OHIO 1883-1906

MEAN TEMPERATURES.					MEAN RAINFALL.			
YEAR.	June.	July.	August.	Season's Mean.	June.	July.	August.	Season's Total.
					Inches	Inches	Inches	Inches
1883	69.0°	72.1°	68.2°	69.8°	4.25	4.16	1.88	10.29
1884	71.1	71.5	70.1	70.9	2.96	3.83	1.45	8.24
1885	67.1	75.2	68.9	70.4	4.34	3.20	6.33	13.87
1886	67.5	72.0	70.9	70.1	3.53	2.88	3.62	10.03
1887	71.0	77.9	77.9	75.6	3.85	2.16	2.39	8.40
1888	70.4	72.1	70.4	71.0	3.41	2.40	5.10	10.91
1889	66.7	72.5	69.1	69.4	4.13	4.25	1.50	9.88
1890	73.3	73.0	68.8	71.7	4.50	1.99	4.70	11.19
1891	71.0	69.0	70.0	70.0	4.82	3.82	3.07	11.71
1892	73.0	73.0	71.0	72.3	5.61	3.80	2.99	12.40
1893	70.6	74.5	70.7	71.9	3.34	2.49	2.17	8.00
1894	71.3	74.3	71.2	72.3	2.65	1.56	1.67	5.88
1895	72.0	71.6	73.5	72.4	2.47	2.00	2.96	7.43
1896	69.5	73.2	71.8	71.5	4.81	8.11	3.38	16.30
1897	68.1	75.5	69.4	71.0	2.85	4.65	2.72	10.22
1898	71.9	70.0	73.5	71.8	2.86	3.98	4.50	11.34
1899	71.5	74.1	73.7	73.1	2.96	4.18	1.82	8.96
1900	69.8	74.1	76.3	73.4	2.99	4.62	3.68	11.29
1901	70.9	78.1	73.1	74.0	4.38	2.73	3.32	10.43
1902	66.9	74.0	67.4	69.4	7.48	4.69	1.67	13.84
1903	64.4	72.9	70.7	69.3	3.97	3.67	3.20	10.84
1904	68.4	71.4	68.8	69.5	2.88	4.13	2.74	9.75
1905	69.2	73.0	71.7	71.3	4.72	3.93	4.46	13.11
1906	69.8	72.1	74.6	72.2	3.41	5.14	4.72	13.27
Ohio...	69.7°	73.9°	71.5°	71.7°	3.94	3.97	3.04	10.95

The summer temperatures for the years 1883 to 1886, taken as a whole, were decidedly below the normal. The same is true for the summer months for the years 1902 to 1906, excepting the month of August 1906.

The data at hand indicate that when we have cyclar periods of low summer temperatures we may anticipate one or more seasons of *Phytophthora* outbreaks. A single season, or a single month scarcely controls; abundant moisture alone may not determine, as is shown in contrasting the years 1905 and 1906 in Ohio. In 1905 the July rainfall was 3.93 inches; that for August 4.46 inches, while in 1906 the July rainfall was greater, 5.14 inches, and that for August 4.72 inches; however, in 1906 the August temperatures rose above the optimum, the mean being 74.6° F.

It will be well at all times to bear in mind that hot and cold are relative terms; our mean summer climate is above the optimum for *Phytophthora infestans*—so that in Ohio the seasons that are below normal are the ones which favor the fungus. In Maine, Nova Scotia, New Brunswick and Ireland, this may not be relatively the case. The mean summer isotherm of 70° F. crosses Northeastern Ohio, in an irregular line, entering the state in southern Columbiana county and emerging at Vermillion Erie County; a second area in northwestern Ohio is crossed by the same isotherm. The southern area of the state is excluded from the *Phytophthora* areas by the higher temperatures, as well as by the early potato crop grown there. It may be mentioned in passing, that very early potatoes in Georgia and Florida are also attacked by *Phytophthora*.

From other known considerations, the foregoing suggestions do not appear unreasonable. The potato plant is native in cool regions and is most successfully cultivated in the cooler portions of Ohio and in states of more northerly latitude. That the development of the parasitic *Phytophthora* should be favored by analagous conditions even though limited by a much narrower range of temperature and rainfall than the host itself, can scarcely be regarded as strange. The irregularity of the outbreaks of *Phytophthora* in Ohio, is an economic difficulty in its control, since the public mind acts only after the fact. For Ohio it seems not improbable to the writer, that a succession of favorable or cool seasons leads to the gradual southward advance of *Phytophthora*, until established within our area; we then have one or more violent outbreaks of disease, followed in turn by the gradual disappearance of the fungus during a cycle of hot or dry seasons, or both hot and dry seasons. It seems very evident that we do not always have it with us.

#### CONCERNING *Plasmopora Cubensis*.

This second fungus, *Plasmopora Cubensis* (B. & C.) Humph., parasitic upon the cucumber, *Cucumis sativa*, and upon other cultivated and wild species of *Cucurbitaceae*, offers a contrasting history of development. There is a brief history given in Bulle-

tin 89 O. Agric. Exp. Station, published by the writer in 1897, and is as follows:

"The history of this trouble is not an extended one, yet its restatement may help in later considerations. The fungus was first described in 1868, by Berkely and Curtis,<sup>6</sup> from specimens on a wild plant from Cuba. It was at the time called *Peronospora Cubensis*. In 1888 the same fungus was found upon cucumbers in Japan<sup>7</sup>. Meanwhile, before this fact had been published, that is in 1889, Dr. Halsted, of New Jersey, had found the fungus upon hot-bed cucumbers at New Brunswick.<sup>8</sup> He then expressed the fear that "Market gardeners may have in the cucumber mildew a serious enemy, especially should it spread to squashes, melons, and other members of the *Cucurbitaceae*, and attack the seedling plants." It was afterwards found by him upon cucumbers, squashes and pumpkins in various parts of the State.<sup>9</sup> The same year it was reported by Professor Galloway<sup>10</sup> from Anona, Fla., and College Station, Texas. Humphrey<sup>11</sup> reported it from Massachusetts, for 1890, upon garden cucumbers and squashes. He changed the name to *Plasmopara Cubensis* (B. & C.) Humph., since it was found to belong to that genus. In 1891 it was again reported by Dr. Halsted<sup>12</sup> who found it almost everywhere about New Brunswick, though it had not been observed in 1890. Watermelons were attacked by it both there and at New Haven, Conn. The same disease was again prevalent in New Jersey in 1892 and in 1893. About this time it began to be destructive to field cucumbers in south-eastern New York<sup>13</sup>, where it continues to be prevalent and destructive to the present time. In 1895, the same trouble appeared in forcing houses in Ohio and in the writer's garden at Wooster<sup>14</sup>, but did not prove serious.

In 1896, it was very destructive in forcing houses at Hyde Park, and while not reported or studied, so far as known, in the pickle fields of Ohio and Kentucky, where the disease proved so injurious in 1897, there are some evidences, chiefly later inferences from observations made at the time by growers, that the downy mildew prevailed to a more limited extent in 1896."

This subtropical species reproduces itself by short-lived *conidia* which germinate by swarm spores; no oospores are

6. Journal Linnæan Society, Botany, x, 363.

7. Farlow, W. G. Botanical Gazette xiv, 189.

8. Botanical Gazette, xiv, 152-153.

9. Journal Mycology, v, 201.

10. Journal Mycology, v, 216.

11. Eighth Annual Report Mass. State Ag'l Exp't Station, 210-12.

12. Report Botanist N. J. Exp't Station, 1891, p. 248. See also Report Conn. Exp't Station 1891, p. 97.

13. Stewart loc. cit., p. 155.

14. Bulletin 73, pp. 231-4.

known. Observations made by the writer during the years 1895 to 1906 inclusive, show that this *Plasmopora* makes its appearance upon field *cucurbits* in northern Ohio very much earlier in a warm season than in a cold one; it has never been collected earlier than August 10th in the vicinity of Wooster (August 3rd, Marietta, O.) and it is sometimes as late as Sept. 10th, and, possibly, altogether absent. The cool seasons of 1902-1905 have brought very late or no development of *Plasmopora* in Ohio, while the warm August of 1906 witnessed an early development near Wooster, August 11-14. These dates but repeat those of 1898 and 1897. While the optimum temperatures of *Plasmopora Cubensis* are not specifically known to me, these are probably near the summer maximum in Ohio. Seeking to get fuller data upon the occurrence of this fungus in the United States, the writer through the co-operation of Dr. T. B. Galloway, U. S. Department of Agriculture, mailed letters of inquiry to most mycologists and pathologists of the United States in 1898. The replies elicited the fact from Prof. H. H. Hume that the *Plasmopora* evidently survives the winter upon wild *cucurbits* in Florida and from other data, the same appears at successively later dates northward as the season advances. At that time the writer suggested the possibility that the *Plasmopora* upon *cucurbits* is propagated northward each season by means of its *conidia*; a possibility that may now be regarded as a probability. In addition to this the disease is occasionally domiciled in forcing houses and there survives. May this northward advance each year, like that of migrating birds, be the true explanation of its recurrence with us? The matter is difficult of proof but yet scarcely improbable.