RE BLIGHT DISEASE IN NURSERY STOCK

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF CORNELL UNIVERSITY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

BY

VERN BONHAM STEWART

[Reprint of Cornell Agricultural Experiment Station Bulletin 329, April, 1913]

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THE FIRE BLIGHT DISEASE IN NURSERY STOCK*

V. B. Stewart

HOST PLANTS

SPECIES AND VARIETIES AFFECTED

Fire blight is undoubtedly a native disease of the American indigenous species of Pomeae. It is known to affect the pear, quince, apple, apricot, plum, species of Cratægus, *Amelanchier canadensis*, *Pyrus americana*, and a few of the native species of the apple family. Waite ('07) reports its occurrence on the evergreen *Eriobotrya japonica*, and states that this species is somewhat commonly attacked by the disease in Florida, Georgia, and California. He has also observed the blight affecting the red-berried California holly (*Heteromeles arbutifolia* Roem.) in various parts of California, where this native species of Pomeae occurs in the vicinity of cultivated orchards.

The disease is most destructive on the cultivated varieties of the pear (*Pyrus communis*), the apple (*Pyrus malus*), and the quince (*Cydonia vulgaris*). Intensive cultivation and artificial propagation have evidently tended to reduce the resistance to the blight in these plants. As a rule the pear and the quince suffer most, although the apple is often seriously injured and may be killed. This is particularly true of nursery stock and young orchard trees. Plums are seldom affected, but Jones ('02) found that the disease occurs on and kills the twigs of the Cheney plum (*Prunus americana nigra*). Paddock ('03) reports the same disease occurring on the fruit and twigs of the apricot. The cherry and the peach are not known to be attacked.

ECONOMIC IMPORTANCE OF THE NURSERY INDUSTRY

Although the nursery business is a somewhat specialized industry, it is, nevertheless, of considerable economic importance. The figures recently published in this connection by the Department of Statistics of the Bureau of the Census ('12) are of special interest. Within recent years the nursery business of the country has shown a rapid increase.

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Author's acknowledgments.—The writer is indebted to Professors H. H. Whetzel and Donald Reddick, under whose immediate direction the work was conducted, for helpful criticisms and suggestions.

('02) Jones, L. R. Studies on plum blight. Centbl. Bakt. u. Par. 2, **9** : 835–841. 1902.
('03) Paddock, Wendall. An apricot blight. Colorado Agr. Exp. Sta. Bul. 84 : 5–14. 1903.
('07) Waite, M. B. A new native host for pear blight. Science n. s. **25** : 286–287. 1907.
('12) Press Notice, Department of Statistics of the Bureau of the Census. June 25, 1912.

The total value of nursery products reported from 5,582 establishments in 1909 was $21,051,000; this was an increase of 591 establishments, or 11.8 per cent, and $10,927,000, or 107.9 per cent, in ten years. In 1909 the Middle Atlantic division ranked first, with products valued at $4,355,000 as compared with $2,523,000 in 1899 — an increase of $1,832,000, or 72.6 per cent, during the decade from 1899 to 1909. Although the number of establishments reporting nursery products was greatest in the East North Central division, being 1,159, this division ranked fourth in value of products, being exceeded by the Middle Atlantic, West North Central, and Pacific divisions. In percentage of increase the Pacific division ranked first, with 377 per cent; the West South Central division second, 179.4 per cent; and the South Atlantic division third, 117.4 per cent.

The three States ranking highest in value of nursery products in 1909 were: New York, $2,751,000; California, $2,213,000; and Texas, $1,253,000. The standing in 1899 was, New York, Iowa, Illinois. An increase in value of nursery products was reported from all States except Maine, Vermont, Virginia, and South Carolina; and also excluding the District of Columbia. In the State of Washington the value of products in 1909 was almost twenty times as great as that in 1899.

THE DISEASE

HISTORY

Names

The disease has been a theme for incessant discussion by horticulturists since the earliest days of fruit culture in this country. Various common names have been applied to the disease, depending to some extent on the host that is attacked and on the effect produced. Among the names most frequently used are fire blight, pear blight, blight, blossom blight, twig blight, fruit blight, sun scald, canker, and blight canker. The term " fire blight " is preferable, since it applies equally well to the characteristic symptoms of the malady on any of the different hosts.

Occurrence

Occurring as a disease of the indigenous wild crab-apple and hawthorn of eastern North America, the blight spread readily to orchards of pome fruits when the cultivated varieties were introduced into this country. It was first observed about 1780 in the Hudson River Highlands of New York State by William Denning (1794), an orchardist of that section.

(1794) Denning, William. On the decay of apple trees. Trans. New York Soc. Prom. Agr. Arts and Manfr. 1^2 : 219–222. 1794. [Second edition 1^2 : 185–187. 1801.]

Later, with the increase of the orchard industry, the disease became more prevalent and gradually worked its way westward, as the plantings followed the settlement of the country beyond the Allegheny Mountains.

Epidemics

It was early maintained that the malady was more or less periodic in its occurrence, the periods of time being placed at five, ten, or twenty years. A careful examination of the literature of the subject gives little support to these views, but indicates that the lapse of time between epidemics of the disease has been irregular and has often varied for different sections of the country.

The years 1826 and 1832 were notable for increased prevalence of the malady, and one of the most widespread and destructive epidemics is recorded by Beecher (1844) as having occurred in 1844. Few orchards escaped without partial or total loss of many trees and some orchards were completely ruined. Since that time epidemics have occurred in different sections of the country, among which might be mentioned the serious outbreak of the disease about 1860 in Massachusetts and bordering States, as recorded by Cooke (1867).

The most important epidemic of recent years was the appearance of the blight for the first time beyond the Rocky Mountains, reported by Pierce ('02) as having occurred in the pear orchards of California in 1902. In this and the succeeding two years it is reported by Smith ('06) to have wrought such havoc as has seldom been known.

Theories as to cause

The disease being so common, various theories were enunciated, naturally, as to the cause, it generally being regarded as resulting from several factors either acting together or brought about by dissimilar circumstances.

Action of sun.— Coxe (1817) in his horticultural book, which is said to be the oldest publication on fruit culture in this country, was one of the first to advance an hypothesis. He ascribed the cause of the disease to the hot rays of the sun, and admirably characterized the symptoms of this in the following words: " That species of blight which is sometimes called fire blight, frequently destroys trees in the fullest apparent vigor and health, in a few hours, turning the leaves suddenly brown as if they had passed through a hot flame, and causing a morbid matter to exude from the pores of the bark of a black ferruginous appearance.

(1817) Coxe, William. Cultivation of fruit trees. Pear blight, 175–176. 1817.
(1844) Beecher, H. W. The blight in the pear tree: its cause and a remedy for it. Mag. Hort. **10**: 441–456. 1844.
(1867) Cooke, S. S. Pear blight. Gardeners Monthly **9** : 73–78. 1867.
('02) Pierce, Newton B. Pear blight in California. Science n. s. **16** : 193–194. 1902.
('06) Waite, M. B., and Smith, R. E. Pear blight. Ann. Rept. California Fruit Growers Assoc. **31** : 137-161. 1906.

This happens through the whole course of the warm season, more frequently in weather both hot and moist."

Insects.— The ambrosia beetle, *Xyleborus dispar* Fabricius (*Scolytus pyri* Peck), was also believed to be the cause, and among the prominent supporters of this view was Patrick Barry (1847), a pioneer nurseryman of New York State.

Frozen sap.— The next hypothesis that attracted general attention was known as the "frozen sap theory," and was first promulgated by Reverend H. W. Beecher (1844). About this time we find the only mention of the disease with reference to nursery stock until the publications of more recent years. Gookins (1846), Ernst (1848), and James (1849) give brief mention of its occurrence in nursery trees.

Fungus theory.— The fungus theory of the cause of fire blight was advanced by Dr. J. H. Salisbury (1863), and twelve years later Dr. J. G. Hunt (1875) thought he confirmed the opinion that it was due to a fungus.

Electricity.— Electricity was believed by some investigators to be the cause of the blight, since diseased trees were often particularly noticeable after a thunderstorm.

Bacteria.— The last hypothesis of historical importance is the bacteria theory, advanced by Professor T. J. Burrill (1879), a pioneer pathologist of this country. In 1878, after the blight had been known for nearly a century, Professor Burrill distinctly stated that he believed the cause to be due to bacteria which he found occurring in great abundance in the tissues of diseased branches. Three years later he reported (1881) the results of his inoculation experiments, whereby he caused healthy pear twigs to blight by inoculating them with the juices of diseased ones.

Later, Arthur (1885) confirmed the results of Dr. Burrill and extended the cultural and inoculation experiments. His work proved absolutely that the malady is caused by bacteria. Since that time there have been a number of contributions to the knowledge of this disease, among which are to be mentioned the work of Waite (1898), Jones ('02), Whetzel ('06), and Jones ('09).

(1844) Beecher, H. W. The blight in the pear tree: its cause and a remedy for it. Mag. Hort. **10** : 441–456. 1844.

(1846) Gookins, S. B., and Downing, A. J. Remarks on pear blight of the West. Hort. **1** : 253–256. 1846.

(1847) Barry, Patrick. Insect blight. Genesee Farmer **8** : 218. 1847.

(1848) Ernst, A. H., and Downing, A. J. Fire blight in pear trees. Hort. **2** : 328–332. 1848.

(1849) James, J. H. Blight in pear trees. Mag. Hort. **15** : 13–23. 1849.

(1863) Salisbury, J. H. Pear, apple, and peach trees affected with blight. Ohio Agr. Rept. **1863** : 450–460, 469. 1864.

(1875) Meehan, Thomas, and Hunt, J. G. Pear blight. Gardeners Monthly **17** : 245. 1875.

(1879) Burrill, T. J. Fire blight. Trans. Illinois State Hort. Soc. **12** : 77–81. 1879.

(1881) Burrill, T. J. Anthrax of fruit trees: or the so-called fire blight of pear and twig blight of apple trees. Proc. Amer. Assoc. Adv. Sci. **29** : 583–597. 1881.

(1885) Arthur, J. C. Proof that bacteria are the direct cause of the disease in trees known as pear blight. Proc. Amer. Assoc. Adv. Sci. **34** : 295–298. 1885.

(1898) Waite, M. B. Life history and characteristics of the pear blight germ. Proc. Amer. Assoc. Adv. Sci. **47** : 427–428. 1898.

('02) Jones, L. R. Studies on plum blight. Centbl. Bakt. u. Par. 2, **9** : 835–841. 1902.

('06) Whetzel, H. H. The blight canker of apple trees. New York (Cornell) Agr. Exp. Sta. Bul. 236 : 104–138. 1906.

('09) Jones, D. H. Bacterial blight of apple, pear, and quince trees. Ontario Agr. Col. Bul. 176 : 1–63. 1909.

GEOGRAPHICAL DISTRIBUTION

The disease occurs throughout the United States and Canada in practically every section where pomaceous fruits are grown. No authentic records have ever been made of its occurrence in Europe or on any of the other continents. Its restriction to this country may be attributed, no doubt, to the fact that the quantity of stock of pomaceous fruits exported from America is comparatively small, thus eliminating to a considerable extent the possibility of the disease being transported across the ocean.

Fire blight is common in all the nursery districts of New York State and has frequently been destructive in the plantings of the Southern States, especially Alabama, Florida, and Georgia. It is a well-known malady in the nurseries of the Central and Middle West and has been reported by Orton ('02) as being especially abundant in Texas and Louisiana. The disease is somewhat generally distributed over the pear-growing section of the Pacific Coast, particularly in California and Oregon.

ECONOMIC IMPORTANCE

Without question, fire blight is the most important disease affecting the pomaceous fruits. Being of an epidemic nature, it may suddenly appear in a locality with increased prevalence and cause complete destruction or severe injury to the fruit-tree industry of that section. Pear orchards, especially, are severely attacked, and often an orchard is entirely destroyed in one season. Although the blight may have subsided as an epidemic, it is usually found to a limited extent in any locality and under conditions favorable for its development and propagation it again becomes a destructive disease. Usually, in the nursery it means total loss to the trees affected, and with its rapid spread through the blocks where the trees are thickly planted, often within a comparatively short time, thousands of young trees are ruined. In some cases entire blocks of apples, pears, and quinces have been destroyed. Such a condition prevailed in one of the nursery districts of New York State in 1908, and practically every nurseryman in that section suffered heavy losses from the disease.

SYMPTOMS

The limbs, blossoms, twigs, and fruit may be attacked. In the nursery the disease is most commonly found affecting the twigs, one exception being the two- and three-years-old quince stock. These trees often blossom profusely in the spring, and under this condition blossom blight frequently occurs.

('02) Orton, W. A. Plant diseases in the United States in 1901. Pear blight. U. S. Dept. Agr. Yearbook **1901** : 669. 1902.

Blossom blight

Sometime in the early part of the season, about two or three weeks after the blossoming period, the blight first attracts special attention and by a close examination the blighted blossoms may be detected even somewhat earlier. The first evidence of the trouble is the brown and subsequent blackened appearance of the young leaf tufts and the blossoms, from which the disease rapidly extends into the fruit spurs (Fig. 112). It prevents the development of the fruit and may even involve the larger twigs and branches.

FIG. 112.— *Blossom blight*

Twig blight

The wilted and brown or dead appearance of the stem and foliage is the characteristic symptom of twig blight (Fig. 113) The progress of the disease down the stem, in the early stages, may be in advance of any marked discoloration of the foliage, and to a considerable degree the blighted twigs resemble green brush that has been only partially burned. There is generally a viscid, milk-white substance exuding in small drops on the surface of the twig or the petioles, which later becomes oxidized into an amber-yellow or slightly brownish, then finally into a dark brown or almost black, gum.

FIG. 113.— *Twig blight*

The extent of the disease in advance of any discoloration of the foliage may be determined by the sappy and juicy appearance of the tissue. A faint amber-yellow or reddish discoloration of the tip is often a means of detecting recently affected apple shoots.

In pear twigs an intensive blackening of the tissue is usually characteristic, even in early stages of the infection. However, in all host plants the blight ultimately produces the same effect — the leaves shrivel, turn brown or black, and resemble foliage that has been killed by frost. One of the most striking symptoms of fire blight to be recognized is in the twig or limb with dead, brown or black leaves clinging to it, contrasting sharply with the dark green foliage in summer and the naked branches of the trees in winter. In no other disease of the pome fruits do the leaves cling so tenaciously to the dead twigs.

Body blight

The blight often works down the twigs or branches into the trunk of the tree and within a short time may extend into the roots, causing the destruction of the whole tree. While the disease is active in the trunk or the larger branches, the affected tissue is darker in color, often with a brownish or reddish tinge. The abundance of sap gives the bark a water-soaked, or occasionally a slightly raised and blistered, appearance. (The blisters have also been observed even in the smaller pear and quince twigs.) The characteristic exudation is common and, when the disease is especially active, it may be so abundant that it flows slowly down the side of the tree (Fig. 114).

With unfavorable conditions — as, for example, at the termination of the growing season, when the plant tissues harden and there is a diminution in the sap supply—the active progress of the blight becomes checked by natural causes. The diseased bark shrinks and subsides, resulting in a sharp line of demarcation between the healthy and the diseased tissues.

When only a definite area is affected, the diseased part surrounded by healthy bark is known as a canker (Fig. 115). The inner tissue of the diseased bark appears brown or dead, making a distinct contrast with the pale green or white, healthy tissue. In many cases the blight may still be present in a latent form or may remain throughout the winter in apparently nondiseased tissue. With favorable conditions the following spring it again becomes active and progresses farther into the adjoining healthy bark. Hold-over cankers, in which the blight remains in a latent form throughout the dormant season, are rather common.

WINTER INJURY VERSUS FIRE BLIGHT

Diverse weather conditions during the dormant season may cause severe injury to the fruit stock in the nursery and frequently such injury is confused with fire blight. The results of winterkilling are usually manifest early in the spring by the injury to the trunks of the trees.

There occur large cankered areas, which may completely girdle the tree and partially interfere with, or totally inhibit, the development of the new growth. If the injury has not been too severe some new growth

FIG. 114.— *Cankered limb, showing exuding milky drops*

may be made; but for lack of nourishment the young shoots soon wilt, turn brown, and die within a very short time, their condition thus resembling that brought about by fire blight. On the other hand, winter-killed trees show a uniform browning or dying of all the foliage; while with fire blight, in the early stages the dead discoloration is from the tip downward as the disease progresses toward the main part of the tree. The shoots of winterkilled trees appear wilted and dried out, due to inadequate food supply, and there is no gummy exudation nor water-soaked appearance which is so common with blighted twigs.*

FIG. 115.— *Canker on limb of tree*

ETIOLOGY

Name of parasite

The disease is caused by the bacterial parasite *Bacillus amylivorus* (Burrill) Trev. The organism was first described by Dr. T. J. Burrill (1883) and named *Micrococcus amylivorus*, the description of which is reproduced here:

New Species of Micrococcus (Bacteria) — *Micrococcus amylivorus.* Cells, oval, single or united in pairs, rarely in fours, never in elongated chains, imbedded in an abundant mucilage which is very soluble in water; movements oscillatory; length of a separate cell .00004 to .000056 inch; width .000028 inch; length of a pair .00008 inch; of four united, about .00012 inch.

In the tissues of plants causing the so-called "fire blight" of the tree and similar phenomena in many other plants. Through the action of the organism the stored starch is destroyed by fermentation and carbonic acid and hydrogen is given off (American Association for the Advancement of Science, 1880; Tenth Report Illinois Industrial University, 1880).

The species was at first referred to the genus Bacterium, but this came from too exclusive attention having been given to its shape. It is only found in tissues of affected plants or oozing from their cells and smearing the surface. It may, however, be cultivated in pure starch in water maintained at the temperature of ordinary summer weather. No doubt other nutritive ingredients would make the culture easier and more prompt.

The only recent system of classification of bacteria available at that time was that of Cohn (1872). Apparently Burrill placed considerable weight on the property of motility, and the fact that he did not observe this phenomenon in the fire blight organism (movements oscillatory) led him eventually to place it under the genus Micrococcus with the statement, "This species was at first referred to the genus Bacterium, but this came from too exclusive attention having been given to its shape." In the arrangement of Schizomycetaceae by De Toni and Trevisan in

*It has been the experience of the writer that in blocks of two- and three-years-old apple and quince trees, when an abundance of both fire blight and winter injury is apparent, winter-injured trees seldom, if ever, blight.

(1872) Cohn, Ferdinand. Untersuchungen über Bacterien. Biologie der Pflanzen 1[2]: 127–224. *pl. 3.* 1872.

(1883) Burrill, T. J. New species of Micrococcus (Bacteria). Amer. Nat. **17** : 319. 1883.

Saccardo's Sylloge (1889), the species is transferred (page 984) to the genus Bacillus with a reference to Trevisan (1889). An attempt has been made to see this pamphlet by Trevisan but all efforts to locate it in libraries of the United States have thus far been fruitless. It seems reasonably certain, however, that the rearrangement was made by Trevisan, not by De Toni as is sometimes stated.

The specific name *amylivorus* as originally proposed by Burrill has not been adopted by any other worker. The term *amylivorus* does not seem to be orthographically incorrect, and in conformity with the Vienna code of botanical nomenclature the writer has employed Burrill's name. It should be noted in this connection that Saccardo's reference to "Mitteilungen der Œsterreichischen Versuchs-Station für Brauerei und Mälzerei in Wien" as the place of original description is incorrect. Burrill's description is brief, but there can be no question whatever regarding the organism that he saw and described.

Description of Bacillus amylivorus

Several descriptions of *Bacillus amylivorus* based on cultural characters have appeared thus far in literature. Most of them, however, are incomplete and in several instances the various authors disagree concerning certain reactions of the organism.

The first cultural studies on the organism were made by Arthur (1887). He grew the bacteria in various kinds of broth or liquid media, and to a limited extent on solid media. Waite (1898) published a brief and condensed description of the characters in his article on the life history of the organism. The next description to appear is that of Chester ('01), based on the study of a single pure culture of the causal organism from a diseased pear twig. The organism was grown in but a relatively small number of kinds of media, and the reactions recorded differ strikingly from those obtained by L. R. Jones ('02). The work of Jones was based on a study of the bacillus from blighted twigs of both pear and plum, carried in parallel series through many kinds of media. Whetzel ('06) also reports some cultural work with the fire blight organism, and the results obtained apparently agree in general with the work of Jones. D. H. Jones ('09) of the Ontario Agricultural College has published the

(1887) Arthur, J. C. History and biology of pear blight. Proc. Philadelphia Acad. Nat. Sci. **38** : 322–341. 1887.

(1889) Saccardo, P. A. Sylloge Fungorum **8** : 923–1087. 1889.

(1889) Trevisan di Saint-Leon, Vittore. I generi e le specie delle batteriaceae; prodromo sinottico. Milano. **1889** : 1–36. 1889.

(1898) Waite, M. B. Life history and characteristics of the pear blight germ. Proc. Amer. Assoc. Adv Sci. **47** : 427–428. 1898.

('01) Chester, F. D. Notes on pear blight. Ann. Rept. Delaware Agr. Exp. Sta. **12** : 38–46. 1901.

('02) Jones, L. R. Studies on plum blight. Centbl. Bakt. u. Par. 2, **9** : 835–841. 1902.

('06) Whetzel, H. H. The blight canker of apple trees. New York (Cornell) Agr. Exp. Sta. Bul. 236 : 104–138. 1906.

('09) Jones, D. H. Bacterial blight of apple, pear, and quince trees. Ontario Agr. Col. Bul. 176 : 1–63. 1909.

first description of *Bacillus amylivorus* since the adoption of the chart by the Society of American Bacteriologists.

For the cultural studies made by the writer, nine different cultures were used. Most of these were obtained from different sources in order to determine, if possible, any variations in the reactions as influenced by environmental conditions or by the period of time that the causal organism had been cultured artificially. For convenience each culture was designated as a different strain and, unless otherwise stated, all nine strains were included in each test. The source and number of each strain is as follows:

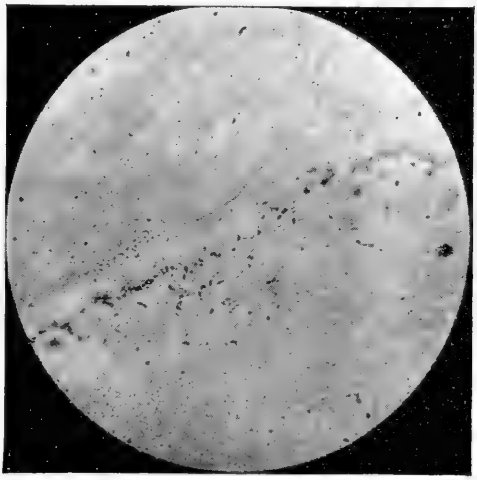

FIG. 116.— *Bacillus amylivorus, showing peritrichic flagella. Moore's modification of Loeffler's flagella stain*

No. 1. Isolated from pear tree, October 10, 1909, Cornell campus, near old forcing-house.

No. 2. Obtained from Professor T. D. Beckwith, Oregon Agricultural College, November, 1911.

No. 3. From same tree on Cornell campus as No. 1. Isolated in November, 1910.

No. 4. From the same pear tree as numbers 1 and 3. Isolated in October, 1911.

No. 5. From Professor D. H. Jones, Guelph, Ontario, Canada. Isolated from apple tree. Received culture from him in October, 1910.

No. 6. Isolated from pear by Professor W. G. Sackett, Colorado Agricultural Experiment Station. Received culture from him in March, 1911.

No. 7. Isolated from small pear twig by Professor W. G. Sackett, April 21, 1911. Colorado.

No. 8. From two-years-old quince tree in nursery. Orleans, New York, June, 1911.

No. 9. From apple tree, West Hill, Ithaca, New York, October, 1911.

In general, the reactions in different media for all the strains were fairly uniform and no marked differences were noticed; the behavior of the organism in milk cultures showed the greatest variation. It should be noted that a strain from Colorado, No. 7, always made a slower growth than any of the others; while No. 9, recently isolated from apple at Ithaca, New York, was usually the most rapid grower. Commonly the first indications of growth by No. 7 were not apparent until several hours after that of the other strains. When there were any differences in the reactions, strain No. 8, from quince, was always taken as a basis for comparison.

Morphological characters.— Vegetative cells. The fire blight organism is a bacillus of slightly variable length, usually within the limits of .6 to .9 by 1 to 1.8μ. Short rods with rounded ends, mostly single, sometimes in twos and occasionally in chains of three or four. Taken directly from fresh gummy exudate of diseased quince twig and stained with alcoholic carbol fuschin, the single rods measured .6 to .8 by 1.4 to 1.8μ. A two-days-old culture on agar when stained with carbol fuschin gave the measurements .7 to .8 by 1.5 to 1.7μ. Measurements of the same strain, No. 8, on agar cultures sixty days old were slightly less, .6 to .7 by 1.2 to 1.4μ. When taken from a three-days-old culture of bouillon and stained with carbol fuschin, the limits of size were .7 to .9 by 1.6 to 1.8μ. In general, the measurements in length of strain No. 7, from Colorado, were slightly less, the rods being somewhat shorter. Taken from six-days-old bouillon culture and stained with carbol fuschin, the size of rods was .7 to .8 by 1.2 to 1.3μ.

Endospores. No endospores have been observed.

Flagella. The organism is motile by means of peritrichic flagella, usually two or three in number, stained by Moore's modification of Loeffler's flagella stain (Fig. 116).

Capsules. None demonstrated.

Zooglœæ. None formed. In his work on the history and biology of pear blight, Arthur (1887) illustrates zooglœal formations. These were no doubt due to the presence of other organisms often found on the surface of diseased tissues, as was later pointed out by Miss Snyder (1898).

Involution forms. None observed.

Staining reactions. The organism stains readily with watery and alcoholic solutions of gentian violet, carbol fuschin, and methylene blue. Gram's stain, and also Ziehl-Neelson, proved negative.

Cultural characters.— In the preparation of the culture media the directions as given by Smith ('05) were followed as closely as possible. Distilled water was used in preparing all media unless otherwise stated. The beef broth was made from minced lean beef and Witte's peptone. All media containing nutrient bouillon titrated +15, Fuller's scale, unless otherwise stated; $N/_{20}$ sodium hydroxid was used for titrations, with phenolphthalein as an indicator.

(1887) Arthur, J. C. History and biology of pear blight. Proc. Philadelphia Acad. Nat. Sci. **38** : 322–341. 1887.

(1898) Snyder, Lillian. A bacteriological study of pear blight. Proc. Amer. Assoc. Adv. Sci. **47**: 426–427. 1898.

('05) Smith, E. F. Bacteria in relation to plant diseases **1** : 1–285. 1905.

Agar colonies. **Colonies appear on second day, characteristic on fifth day, at 23° C.** When isolations are made from diseased tissue, the colonies appear on the second day at a temperature of 23° C., becoming characteristic on the fourth or fifth day. The surface colonies are usually small, not more than two to three millimeters in diameter. They have a somewhat shiny luster, and are smooth, white, flat or slightly raised, having a finely granular or cloudy circular growth, with a dense opaque, sharply defined, white center. The margin is entire or slightly undulate. Older colonies are coarsely granular to grumose. Deep colonies are globose, or more often lens-shaped, with dense opaque center. Plates poured from young beef-broth cultures show colonies developing usually after forty-eight hours.

Agar stroke. **Moderate growth, filiform, slightly raised, glistening, slightly gray.** A moderate growth after twenty-four hours at 23° C., more characteristic, however, after forty-eight hours; filiform, has a glistening luster, opalescent. The white streak does not branch on the surface nor penetrate the agar. The growth often widens, becoming more diffuse, spreading mainly toward the bottom where moisture is present on surface of agar. Often in isolated colonies or beaded above before becoming diffuse and spreading at bottom. Water of condensation at base of streak turbid and with flocci. Does not stain the agar on which it grows. It is free from odor. Slightly to considerably raised, more or less pulvinate in cross-section, semi-opaque.

Agar stab. **Growth filiform, uniform, nontypical.** Feeble growth after twenty-four hours at 23° C., most characteristic after forty-eight hours, filiform, best toward the top. Surface growth smooth, with general tendency to spread somewhat. Agar not liquefied nor softened.

Nutrient gelatin colonies. **Colonies are round, slightly raised, entire, grayish.** In plates poured from a three-days-old beef bouillon culture the colonies were rather numerous but very small, appearing as tiny specks after three days. In the dilution plates the colonies were somewhat larger; after the fifth day they appeared finely granular under low power of microscope and later became grumose. Liquefaction of gelatin very slow, only slightly evident after fifteen days.

Gelatin stab. **Growth moderate, slight liquefaction after fifteen days.** Growth slow and feeble for the first two or three days on +15 nutrient gelatin at 20° C. Slight tendency to be beaded or granular along lower line of platinum needle stab. After eight days moderate increase in growth, with indication of slight liquefaction after fifteen days. Crateriform to stratiform.

Stab cultures were made in tubes of nutrient gelatin with the following acidities: neutral, +10, +15. In these cultures, strains numbers 1, 7, and

8 were used. At a temperature of 23° C. there was a slight growth in all tubes after twenty-four hours, more marked, however, after three days. The most vigorous strain was No. 8, and there was considerable surface growth in this strain; while No. 7 showed the weakest development, with surface growth but slight. The +10 and +15 tubes were somewhat more favorable for the organism than was the neutral medium. Although the liquefaction in the acid cultures was only slight after fifteen days, it was still less in the neutral cultures.

Potato plug. **Growth moderate, nonviscid, glistening white, no odor, spreading.** Growth generally appearing after forty-eight hours, not so rapid nor so abundant as on agar streak. Slightly elevated, glistening, moist, pearly white, slowly spreading over the surface of the potato, entire margin, not viscid. It is free from odor and turns the potato plug grayish, which later becomes darker in color.

Loeffler's blood serum. **Growth moderately slow, colorless, no liquefaction.** Feeble growth after forty-eight hours, more characteristic after four days at 23° C. No branching of the white streak on the surface nor penetration of the medium. Slight tendency to spread at the base, slightly raised, sometimes beaded or in isolated colonies, glistening. Does not stain nor liquefy the serum. (Strain No. 1 was used for these studies.)

Starch jelly.* **Growth moderate, diastatic action absent or feeble, medium unstained or slightly stained.** The experiment was repeated several times, but no marked changes as recorded by Jones ('09) were observed. One or two of the tubes showed a very slight liquefaction when left at 25° C. In the enzyme studies, subsequently discussed (under "Pathological histology"), tests were made for the production of diastase; but the results were negative except in one or two cases, when a slight test for reduction of starch was obtained.

Bouillon +15 with 1 per cent Witte's peptone. **Cloudiness uniform, moderate, no pellicle, no ring, no odor.** Tubes of +15 peptonized beef bouillon were inoculated from sixteen-days-old slant agar culture. After twenty-four hours at 23° C. there was a uniform clouding with flocci and slight sediment. After forty-eight hours, cloudiness increased, flocci abundant and more or less persistent. No pellicle formed and odor not marked. Culture fluid showed tendency to clear after seventeen days.

Sugared peptone water. **Growth very moderate with apparently no staining of the fluid,** in flasks of sterilized lake water containing Witte's peptone, c. p. glucose, and Baker's c. p. calcium carbonate.

Milk. **Coagulation slow, extrusion of whey beginning only after several days. Partial to complete digestion of curd.** Tubes of sterile

* For composition see Smith, "Bacteria in relation to plant diseases" 1 : 196. 1905.

('09) Jones, D. H. Bacterial blight of apple, pear, and quince trees. Ontario Agr. Col. Bul. 176 : 1–63. 1909.

milk titrating +8 with phenolphthalein were inoculated with a one-millimeter loop of a beef bouillon culture, two days old, and kept at 23° C. No apparent change was observed until after nine days, when there was a slight formation of whey as a shallow layer on the surface of the milk. After twenty days coagulation was more advanced. At the end of five weeks there was a tendency for partial to complete digestion of curd. No discoloration of coagulum.

Litmus milk. **Reduction of litmus slow.** Tubes of sterile litmus milk were inoculated with a one-millimeter loop of a two-days-old beef broth culture and kept at 23° C. After ten days there was a very slight increase in the blue color. In twenty days the reduction of the litmus was apparent, with the formation of whey at the surface. Tubes after forty to fifty days showed a return of the neutral lavender color, with a slight change to red after sixty days. Coagulation slow, with partial to complete peptonization of the curd which was wholly bleached.

Although several tests were made with the growth of the organism in milk cultures, there was never any rapid separation and digestion of the coagulum such as Jones ('09) describes. The changes in the medium were always slow.

The most constant and marked differences in growth of the various strains were also apparent in the milk cultures. The general tendency for all strains was a slow separation and digestion of the curd. However, as is to be noted in the table below, the completion of this process was more marked in some cases than in others.

TABLE 1. REACTION OF STRAINS OF BACILLUS AMYLIVORUS IN STERILE, LAVENDER, BLUE LITMUS MILK AT 23° C.

Strain	Ten days	Sixty days
1	Slightly bluer than check	Complete digestion of curd, white bacterial precipitate in bottom, whey lavender to red
2	Slightly bluer than check	Complete digestion of curd, white bacterial precipitate in bottom, whey rose purple
3	Slightly bluer than check	Moderate digestion of curd, wholly bleached, whey reddish
4	Slightly bluer than check	Partial to complete digestion of curd, whey reddish
5	Unchanged	Moderate digestion of curd, whey rose purple
6	Bluer than check	Slight digestion of curd, wholly bleached, whey red
7	Much bluer than check	Very slight digestion of curd, wholly bleached
8	Slightly bluer than check	Partial to complete digestion of curd, whey lavender to red
9	Slightly bluer than check	Partial to complete digestion of curd, whey red

('09) Jones, D. H. Bacterial blight of apple, pear, and quince trees. Ontario Agr. Col. Bul. 176: 1–63. 1909.

Cohn's solution. **No growth.**

Uschinsky's solution. **Growth moderate, not viscid.** Tubes of Uschinsky's solution were inoculated from a beef broth culture two days old. After twenty-four hours at 23° C. a scanty growth was apparent, slightly clouding the solution by the granular particles suspended in the liquid. At the end of four days the maximum growth was reached. The liquid was moderately cloudy; did not become fluorescent or viscid. There was no pellicle formed, but a slight sediment was apparent in the bottom of the tube.

Sodium chlorid bouillon. **Six per cent of sodium chlorid inhibits growth. Five per cent inhibits or retards growth.** Transfers were made with a one-millimeter loop from a two-days-old, +15, peptonized bouillon culture to +15 bouillon tubes containing 2, 3, 4, 5, and 6 per cent of c. p. sodium chlorid. At the end of two days there was a good growth in the tubes containing 2 and 3 per cent of sodium chlorid, but the growth in the 3- and 4-per-cent solutions was best after four days. There was a gradual retardation of growth up to 6 per cent of sodium chlorid, which inhibited the growth of the organism in practically all cases. Apparently 5 per cent of sodium chlorid is about the limit for the development of the organism. Most recently isolated strains appeared least adapted to the high concentrations of the solution.

Best media for long-continued growth. Cultures in litmus milk, milk, and bouillon and on agar stab, which had been growing for five months, showed growth when transferred to +15 bouillon. Cultures on potato and gelatin of the same age showed no growth.

Growth in bouillon over chloroform. **Growth inhibited.** Transfers of a two-millimeter loop from a two-days-old, +15, peptonized bouillon culture were made to Erlenmeyer flasks containing 30 cubic centimeters of +15 peptonized bouillon. To each flask was added 15 cubic centimeters of chloroform (Squibb's). The tops of the flasks were covered with oil-paper in order to prevent evaporation. No growth occurred after ten days in any of the flasks.

Quick tests for differentiation purposes. The following are perhaps the most satisfactory tests: agar colonies, agar stroke cultures, gelatin stab, behavior in Cohn's solution, growth on starch jelly and also in beef bouillon, inoculation into young succulent twigs of apple, pear, or quince trees.

Fermentation tubes. **No gas is produced and the organism is aerobic in its tendencies.** A solution was made by adding 2 per cent of Witte's peptone to filtered lake water. From this, six solutions were then made, each containing 1 per cent, respectively, of one of the following carbon compounds: cane sugar, dextrose, glycerin, mannite, maltose, and lactose. Four fermentation tubes were filled with each of the solutions and sterilized in an Arnold steamer for twenty minutes, on three days in succession. Three tubes of each set were inoculated and one was left for control. The inoculations were made by transferring a one-millimeter loop from a three-days-old, +15, peptonized beef bouillon culture. Three days after inoculation all tubes showed a slight cloudiness in the open ends of the tubes. After five days the cloudiness was more marked in the tubes containing dextrose, cane sugar, mannite, and maltose than in the glycerin and lactose. After eighteen days the cloudiness had extended slightly beyond the middle of the U in the dextrose, cane sugar, and mannite tubes, and in all solutions there was a distinct, moderately flocculate precipitate formed, with solid particles floating in the liquid. The precipitate in the glycerin and maltose was slightly less; however, the cloudiness extended to the bend in the tube. The least growth was obtained in the lactose solution; there was a moderate amount of precipitate, which had a tendency to be stringy, and the cloudiness extended nearly to the middle of the U.

There was but little variation in the appearance of the different strains of the organism grown in the above solutions, and tests made after nineteen days with respect to the acidity of the different cultures gave uniform results for all the strains. Tests made with litmus gave the following reactions for the cultures in the different solutions, the increase in acidity being proportionate to the amount of growth in the various solutions:

Lactose — strongly alkaline
Glycerin — alkaline
Maltose — alkaline
Mannite — neutral to weakly acid
Cane sugar — weakly acid
Dextrose — strongly acid

Another series of tubes gave the same tests after the cultures had been running fifteen days.

Two-per-cent ammonium lactate and two-per-cent carbon compounds. **Moderate growth with cane sugar and slight growth in the mannite solution.** A solution was made by adding 2 per cent of c. p. ammonium lactate to filtered lake water. Six solutions were made, from cane sugar, dextrose, mannite maltose, glycerin, and lactose. The solutions were placed in test tubes and sterilized in an Arnold steamer for twenty minutes, on three days in succession. Inoculated tubes received a one-millimeter loop of peptonized beef bouillon culture, six days old. All nine strains were used and cultures were grown at a temperature of 23° C. After five days there was a faint cloudiness in the mannite solution and a moderate growth occurred in all the tubes containing cane sugar. There was a moderate reduction of the cane sugar to glucose, and the cultures were slightly acid to litmus. No growth in any of the other solutions after fifteen days. Fermentation tube cultures made at the same time showed no gas production.

Potassium nitrate and carbon compounds. **Slight growth in tubes containing dextrose.** Six solutions were made, containing 1 per cent c. p. potassium nitrate and distilled water plus one of the following carbon compounds: cane sugar, dextrose, mannite, maltose, glycerin, and lactose. Tubes of these solutions were inoculated with a one-millimeter loop from a five-days-old, +15, bouillon culture.

A faint cloudiness was apparent in the dextrose solution tubes, but no growth occurred in any of the others after fifteen days. All dextrose tubes gave alkaline reaction with litmus. No gas production in fermentation tubes containing the above solutions.

Two per cent asparagin. **Slight to moderate growth.** Sterile tubes of a 2-per-cent solution of asparagin and filtered lake water were inoculated with a one-millimeter loop from a three-days-old, +15, bouillon culture. A slight to moderate growth occurred after five days at 23° C. This would indicate that the organism is able to obtain both its nitrogen and its carbon from asparagin.

Ammonia production. **None produced.**

Nitrates. **Nitrates are not reduced.** Transfers of each of the nine strains were made to 10 cubic centimeters of +15 peptonized beef bouillon, to which had been added enough potassium nitrate to make a 1-per-cent nitrate bouillon solution. After three days there was a distinct cloudy growth in the tubes, and tests were made for nitrites as follows: To the inoculated tubes that had grown for four days, 1 cubic centimeter of boiled starch water and 1 cubic centimeter of potassium iodide solution (1–200) were added, then there were added a few drops of strong sulfuric-acid water (2:1); but no blue color resulted, indicating that there was no formation of nitrites. Other tests made with various strains at different intervals always gave negative results for the presence of nitrites.

Indol. **None formed.** The indol tests were made by using concentrated sulfuric acid and dilute sodium nitrate (1–200 in water). Tests were made with all nine strains of the organism. Two-days-old peptonized beef bouillon cultures were tested, and also similar cultures eleven and twenty days old respectively. No trace of indol was detected in any of the cultures, even on heating to 80° C. after the sulfuric acid and nitrate were added.

Toleration of acids. **Toleration of acids is slight.** Transfers from a two-days-old, +15, bouillon culture were made to tubes of +8, +10,

+12, +15, +16, +19, +20, +23, +25, and +27 peptonized beef bouillon.* After four days, growth was apparent in all tubes up to +23. No growth occurred in +23, +25, and +27. The addition of malic acid in small amounts to +10 beef bouillon favored a slight increase in growth. Increasing the acidity from +10 to +12 by malic acid appeared to favor the growth of the bacilli. No growth occurred in +15 peptonized beef broth acidified to +25 by addition of normal malic acid.

Toleration of potassium hydroxid. **Toleration of alkalies rather low.** Tubes of bouillon titrated with phenolphthalein to —4.5, —5.5, —6.5, —7, and —8 were inoculated with a one-millimeter loop from a three-days-old, +15, bouillon culture. At 23° C. after six days, growth occurred in all the tubes except the —7 and the —8.

The experiment was repeated, and after four days there was a faint cloudiness in the —4.5 tubes. Two days later slight growth was apparent in all tubes up to the —7. In the —7, strain No. 1 showed a slight cloudiness in three of the five tubes. An alkalinity of —6 is about the limit for growth of the organism.

Optimum reaction for growth in bouillon. **The optimum reaction lies between +8 and +16 on Fuller's scale.** From studies made on toleration of acids and alkalies, the optimum reaction appears to be between +8 and +16. The limits for growth in peptonized beef broth are between —7 and +25, Fuller's scale.

Temperature relations.— Thermal death-point. **The death-point is about 47° C.** Tests were made by exposing for ten minutes in +15 peptonized beef bouillon. Preliminary tests indicated that the thermal death-point must lie between 43° and 49° C. Three different strains of the organism were used in these tests, numbers 1, 7, and 8. The tubes of peptonized beef broth were inoculated with a one-millimeter loop of a two-days-old beef bouillon culture, and then placed in water at practically constant temperatures of 46°, 47°, and 48° C., respectively. At the end of ten minutes the tubes were removed from the water bath and incubated at a temperature of 22° to 24° C. After four days, growth was apparent in the tubes subjected to the temperature of 46° C. No growth occurred in any of the others. The experiment was repeated three times with the same result, which indicates that the thermal death-point of this organism is about 47° C. No differences were noticed for any of the strains used.

Optimum temperatures. **Best growth between 22° and 25° C.** Growth on +15 nutrient agar was much better at 23° C. than at 32°. A temperature of 10° to 12° C. also retarded the growth of the organism.

* The bouillon for these tests was made from Liebig's beef extract instead of from fresh minced beef.

Cultures in incubator. Transfers of strains numbers 1, 7, and 8 were made to peptonized +15 bouillon from a two-days-old bouillon culture and immediately placed in the incubator at a temperature of 37° C. No growth appeared after twelve days. Check cultures made good growth at 23° C.

Resistance to drying. **Moderate resistance to drying.** Tiny drops of a ten-days-old peptonized beef bouillon culture were transferred to sterile cover-glasses in a covered sterile petri-dish and allowed to dry in the dark at a temperature of 20° to 22° C. The covers were then taken up by means of sterile forceps and dropped into tubes of sterile bouillon, one to each tube, with the following results: number of days dried, 1, 2, 3, 4, 5, all cultures were alive and gave good growth in the bouillon tubes. The experiment was repeated, using a two-days-old peptone bouillon culture. The drops were about the same size as in the previous tests. Covers were kept in the dark. Results as follows; first tests made after six days drying:

6 days — 4 tubes — all good growth
7 days — 2 tubes — all good growth
9 days — 2 tubes — no growth
12 days — 2 tubes — no growth
14 days — 2 tubes — no growth

Minimum temperature. **Organism resistant to prolonged freezing.** Freshly poured agar plates were made from a six-days-old peptonized beef bouillon culture of strain No. 8. The plates were wrapped in paper and immediately placed in a tin can, which was imbedded in an ice-salt mixture contained in a granite pail. The temperature obtained by means of the mixture varied from —14° to —16° C. Two plates were removed at each of the following intervals: three hours, four and one half hours, seven hours, twenty-three hours; and in each case the plates were immediately placed in the incubator at a temperature of 23° C. Colonies developed in abundance in all the plates. Plates subjected to the freezing temperature for twenty-three hours showed some retardation; however, there was practically no decrease in number of colonies that developed.

On February 3, 1912, three bouillon tubes and three agar slant tubes freshly inoculated from an agar slant culture of strain No. 8 were placed in a quinine can containing a mixture of pulverized ice and salt. The can, being provided with holes in the bottom in order to allow the escape of water from the melting ice, was placed in a granite pail. The freezing apparatus was kept out of doors and the temperature of the mixture was recorded three times a day. The cultures were re-iced twice each day, a new supply of salt (about three tablespoonfuls) also being added each time. The average temperature was about —14° C.; owing to extreme cold weather, however, it was as low as —28° C. on one or two occasions.

After five days of constant freezing, one agar and one bouillon tube were removed. A very slight growth was apparent on the agar slant, and on melting the bouillon it showed a faint cloudiness. The tubes were placed in the incubator at a temperature of 23° C., and after eighteen hours agar plates were poured in which developed the characteristic fire blight colonies. On the eleventh day of freezing two more tubes were removed and placed in the incubator. After thirty-six hours, growth was apparent in both the agar and the bouillon tubes. The last two tubes were removed from the freezing mixture on the fourteenth day and they gave good growth after thirty-six hours at 23° C.

Effect of sunlight.— Freshly poured agar plates were exposed on ice to direct sunlight after covering a part of each plate with heavy pasteboard. Plates exposed for one hour showed several colonies developing after four days incubation at 23° C. Plates exposed for four hours and then incubated at about 23° C. gave no growth in the unprotected parts. The temperature of the agar throughout the exposure was between 23° and 26° C.

Ferments.— Invertase. The different strains of the organism were grown for nineteen days in sterilized filtered pond water containing 2 per cent of Witte's peptone and 1 per cent of c. p. cane sugar.

Tests were made for glucose with Fehling's solution. All tubes showed considerable reduction, being the strongest in cultures of strains numbers 2, 5, 7, and 8. The checks gave a negative test for glucose. It is to be inferred from these tests that a moderate amount of the invertase ferment is produced.

Crystals.— Silky, needle-like crystals were formed in old litmus-milk cultures. The washed crystals were sparingly soluble in water; and when this aqueous solution was mixed with a solution of mercuric nitrate a yellow precipitate was produced, which, when boiled with dilute nitric acid, acquired an intense red color. This reaction is used as a test for tyrosine. The crystals were also tested with Mormer's reagent (1 volume formaldehyde, 45 volumes distilled water, and 55 volumes concentrated sulfuric acid), which gives a green color with aqueous solution of tyrosine.

Germicides.— Poured agar plates were made with strain No. 8 of the organism after exposure to various concentrations of copper sulfate, mercuric chlorid, and formaldehyde solution.

Poured plate cultures showed growth after three days when exposed for ten minutes to copper sulfate 1:10,000; no growth occurred when exposed for fifteen and twenty minutes to the same strength. No growth in poured plate culture after ten and twenty minutes exposure to mercuric chlorid 1 : 20,000. Plate cultures showed growth after three days when exposed for ten and twenty minutes to formalin 1 : 750, also 1 : 1,000. Growth occurred after ten minutes exposure to formalin 1 : 500, but none after twenty minutes. Checks gave good growth in all cases.

Pathogenicity.— The organism is pathogenic to many species of genera in the tribes Pomeae and Pruneae of the Rosaceae family.

Loss of virulence.— In cultures carried for several months there was a slight loss of virulence as compared with cultures recently isolated. But little difference could be noticed in cultures that had been carried for one year and three years, respectively.

Group number.— The group number, according to the descriptive chart of the Society of American Bacteriologists, is 211.2322033.

LIFE HISTORY

The cycle

Following the work of Burrill and Arthur, subsequent investigations were concerned more with the question of the life cycle of the organism and the conditions under which blight occurs. Waite (1898) has contributed the most to our knowledge of the life history of the germ and advanced the first authentic evidence as to how blossom and twig blight are brought about. He proved that insects, such as flies and bees, carry the bacteria from oozing cankers to opening blossoms and from there to other trees, spreading the bacteria to the blossoms. More recently the observations of other investigators tend to show that a number of other insects are responsible agents in spreading the disease. The bacteria are probably not blown by the wind, as they are contained in a sticky gum. It would be practically impossible for them to be carried in this manner. Furthermore, Waite has shown that the probability of infection being produced in this way is very small, since a considerable mass of the organism is required in order to produce infection.

As previously stated, the bacteria that remain alive throughout the winter in " hold-over " cankers become virulent with the ascent of sap and the increased temperature of spring. They multiply and spread into the adjoining healthy bark. Often, when their increase is augmented by warm, rainy weather, the gummy exudation, laden with bacteria, oozes out of the lenticles and cracks of the infected tissue. This exudation, containing millons of the minute bacteria, usually takes place first about the time when the blossoms are opening. Various insects, such as wasps, honeybees, and flies, are attracted to these hold-over cankers by the

(1898) Waite, M. B. Life history and characteristics of the pear blight germ. Proc. Amer. Assoc. Adv. Sci. 47 : 427–428. 1898.

sweet, gummy exudate, become smeared with it, and carry the infection material to the blossoms. Here some of the bacteria brought by the infected insect are left in the nectar of the flower. The sweet solution greatly favors their increase in numbers, and the next bee or other insect carries the organism to all the succeeding blossoms that are visited.

FIG. 117.—*Blighted shoots. Infection occurred at base of petiole*

After the parasite has established itself in the nectary of the blossom, the tissues of the flower soon become diseased and within a short time the characteristic symptoms of blossom blight are apparent. After the blossoming period, or sometimes even before it is entirely over, the blight may appear in the young succulent shoots, or twigs. Ordinarily in the nursery, where blossoms are not common except in the two- and three-years-old quince stock, the first occurrence of the blight in spring is in the twigs. However, instances have been observed when the disease first appeared in the quince blossoms and was later spread to the succulent shoots. Not only do the new infections occur throughout the summer, but the disease continues to spread in an affected tree and, unless checked in some manner, may involve the entire tree. Infections usually occur through the tips of the shoots, but the bacteria are frequently introduced into the tissues at the base of a petiole (Fig. 117).

Disseminating agents

Such agents as bees and wasps have been conceded, largely on evidence presented by Waite (1898), to be important in the spread of blossom blight. In recent years certain other insects have been associated with abundant twig infections. It has been definitely proved that the aphids (*Aphis pomi* De Geer) spread the disease (page 341), and observations during the past two seasons indicate that several other sucking insects may disseminate the blight bacteria in the nursery. On July 1, 1912, the following

(1898) Waite, M. B. Life history and characteristics of the pear blight germ. Proc. Amer. Assoc. Adv. Sci. 47 : 427–428. 1898.

species of sucking bugs were collected from apple nursery stock by Professor C. R. Crosby of the Department of Entomology, Cornell University: *Reduviolus ferus* Linn., *Plagiognathus politus* Uhler, *Platymetopius acutus* Say., *Empoasca mali* Le Baron, *Typhlocyba rosae* Linn., *Compylomma verbasci* Meyers, and *Lygus pratensis* Linn.

It has not as yet been definitely determined that these species do spread the disease, but a large percentage of them are undoubtedly active agents in disseminating the blight bacteria. Visiting blighted tissues, the insect becomes smeared with the gummy exudate and carries the bacteria to the tender twigs; here, in sucking the sap, the insect punctures the tissues, thus forming a means of entrance for the blight germs, with the result that the twigs may soon become infected.

Tarnished plant bug.— It is believed that one of the most important agents in transmitting the blight parasite to healthy trees, for the last two seasons at least, has been the tarnished plant bug (*Lygus pratensis* Linn.). This insect has been recognized for many years as causing severe injury to peach stock, but until recently it has never been considered a serious pest to other nursery trees. Due to the stinging of the terminal shoot of first-year peach buds, there is a tendency for the trees to make a stunted, bushy growth, thus failing to reach the proper height. Not only has peach stock been injured in this way, but also considerable damage was apparent during the season of 1911 in several blocks of first-year apple buds.

The same trouble was again noticed in 1912, and a large number of apple shoots that had been stung by the insect a few days previous developed infections of fire blight. Apparently this tarnished bug was responsible for the infections that occurred. Being abundant also in blocks of two-years-old apples where there was considerable blight, the insects frequently visited the sweet, gummy exudation on infected trees. It is possible that in this manner they not only spread the disease in the larger trees, but also carried the bacteria to adjoining blocks of one-year-old apple stock, where infections occurred through the punctures made by them.

During the month of July the tarnished bugs are most abundant on the apples, and as a rule the blight has become more prevalent with their appearance. In two large nurseries this was especially noticeable in the season of 1912. The presence of the insects greatly augmented the spread of the blight. New infections continued to occur. After some time (about the middle of August), when the tarnished bugs left the apple stock, the disease subsided. Comparatively few new infections occurred throughout the remainder of the season, even though the trees continued for some time to make a succulent growth.

Aphids.— The common green aphids (*Aphis pomi*) have also been associated with the blight disseminators, and their importance was especially noticeable during the season of 1909 when there was an unusually severe aphid infestation on fruit stock throughout New York State. In one of the large nurseries considerable blossom blight had occurred in a block of two-years-old quince trees; and with the appearance of the aphids, not only did the disease become more abundant in the quinces, but the bacteria were carried to the blocks of apples. From all indications the blight followed the path of the aphid infestation, since no infections had been observed in any of the apples until after the appearance of the aphids. By dipping the infested shoots in whale-oil soap solution, seven pounds to fifty gallons, thus eradicating the aphids, the prevalence of the blight was soon greatly reduced.

Jones ('09), in his studies and investigations on fire blight, is also led to conclude that aphids are important in the dissemination of the blight bacteria, both in the nursery and in the orchard. He suggests that possibly blight epidemics can be associated with years when aphids are unusually common. The writer, however, is inclined to the opinion that the occurrence of aphids does not play such an important part in the spread of the disease. Without question, when aphids appear in trees that are blighted, there is a tendency for the bacteria to be more widely disseminated; but a number of instances may be cited in which entire nurseries have been severely infested with aphids and yet practically no blight has appeared in the same season. It is also an important point that periods of prolonged dry and hot weather are favorable to aphids, whereas such conditions can hardly be considered conducive to blight epidemics. Blight infections occur regularly only in succulent tissues, and in the nursery, especially, where the rapidity of growth is greatly decreased by such diverse weather conditions, it is not to be expected that infections will occur so abundantly. However, the infection experiments conducted by the writer during the winter of 1911–1912 in the greenhouse proved conclusively that blight infections do occur through aphid punctures in young succulent tissues.

Shoots of three pear seedlings were smeared by means of a camel's-hair brush with an agar culture of *Bacillus amylivorus*, and a number of aphids (*Aphis pomi*) were transferred to these shoots. In the same manner shoots of two other seedlings were smeared with the agar culture of the organism, but no aphids were transferred to these trees. All the trees were covered with large bell glasses, and on the tenth day four of the aphid-infested shoots showed the characteristic symptoms of fire

('09) Jones, D. H. Bacterial blight of apple, pear, and quince trees. Ontario Agr. Col. Bul. 176:1-63. 1909.

blight. Of the shoots from which the aphids had been excluded, none blighted. In another experiment a number of aphids were smeared with an agar culture of *Bacillus amylivorus* and placed on the shoots of two seedlings. The shoots of two other seedlings were smeared with the agar culture as in the experiment above. All trees were covered with bell glasses, and on the eleventh day three of the aphid-infested shoots were blighted. None of the other shoots became diseased. Isolations were made from the blighted twigs and a pure culture of *Bacillus amylivorus* was obtained.

When the aphids were present to puncture the tissue and thus furnish a means of entrance for the bacteria, about fifty per cent of the shoots in the above experiments became diseased. No infections occurred when the shoots were smeared with the culture of the organism and the insects excluded. The best results were obtained with the use of tender and succulent shoots, and no doubt the percentage of infections would have been greater had it been possible to select the tenderest growth in every case.

Dissemination by pruning tools

Besides the general distribution of the blight germs by insects, man himself is often an active agent in spreading the parasite. Pruning tools are certainly a frequent means of transmitting the organisms. Whetzel ('06) has demonstrated this point, and the experience of others proves fairly conclusively that the disease may be transmitted by the tools in use. Waite ('06) states: "In Maryland the writer once saw a nursery block of 10,000 trees of Bartlett and other pears completely destroyed by blight. This block, as determined by the specimen, carried actual samples of hold-over blight in the stocks. When the stocks were cut off above the dormant buds in the spring, the pruning tools became infected and the disease was transmitted to nearly every tree reached by the pruners. Instead of the buds pushing up, the cut surface began to gum and blight."

A somewhat similar incident occurred during the season of 1910 in one of the nurseries of New York. A large number of scions of Kieffer pears were obtained from a nursery in Alabama and used for budding several thousand seedlings (Fig. 118). Some time later, when the block was being rebudded, a number of the stocks showed the characteristic symptoms of blight in the region where the buds had been inserted. Other varieties were rebudded at this time, and after a period of about ten to fourteen days blighted stocks were common over the entire block. With-

('06) Whetzel, H. H. The blight canker of apple trees. New York (Cornell) Agr. Exp. Sta. Bul. 236 : 104–138. 1906.
('06) Waite, M. B., and Smith, R. E. Pear blight. Ann. Rept. California Fruit Growers Assoc. **31** : 137–161. 1906.

out question the disease was transmitted to other stocks from the seedlings budded with Kieffer scions, by means of the infected budding-knives. All indications were that the blight was first introduced with the Kieffer buds, which had no doubt been cut from diseased trees; and at rebudding time, the knives becoming infected, the spread of the disease was general.

During the summer of 1912 the source of infection of a number of blighted apple seedlings, as determined by scions examined, was attributed to the use of diseased buds that had been cut from a block of two-years-old trees on which there had been considerable blight. Not only did the

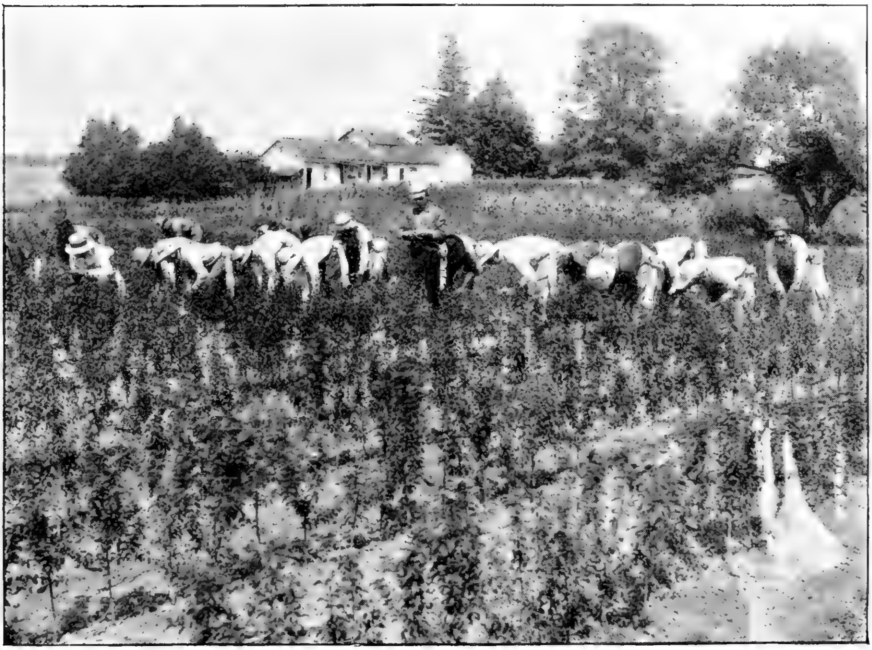

FIG. 118.— *Budding pear seedlings*

seedlings blight which were budded with the diseased buds, but the bacteria were carried on the budder's knives to other seedlings. Later, at rebudding time, the budders, being unfamiliar with the disease, frequently attempted to rebud the blighted stocks, their knives became infected, and the bacteria were transmitted to other seedlings. The number of diseased seedlings was also increased when the strings used for tying the buds were cut. Frequently, in cutting a string a slight incision was made in the bark, and many trees were inoculated in this manner, the blight germs having been carried on the knives from the diseased stocks.

Blight may also be introduced into the seedling block by means of insects that carry the bacteria to the tender shoots (Fig. 119). Occasionally entire trees become diseased in this manner. It is the opinion of the writer, however, that twig infections are seldom, if ever, so abundant in seedlings as to be the source of an epidemic. On the other hand, an attempt to bud any such infected stock would tend to favor the more rapid spread of the disease, the blight bacteria being carried on the budding-knives.

FIG. 119.—*Blighted shoot on apple seedling*

Special orchard considerations

In general, blight infections in the nursery occur through the twigs and blossoms; in the orchard, however, infections are frequently produced in a number of other ways. Jones ('11) has observed the work of a fruit bark-borer, *Scolytus rugulosus*, in spreading the blight in pear and apple orchards. In puncturing the diseased area the borer becomes infected, and later spreads the disease to healthy branches. In cuttings from a living branch of Bartlett pear, which was perforated by the fruit bark-boring beetle immediately below each of thirty leaf or fruit spurs, there was a beetle in every hole and the bark surrounding eight of these was developing blight.

Occasionally the bacteria are introduced into green fruit by such insects as curculio, causing what is known as fruit blight (Fig. 120).

FIG. 120.— *Blighted apple. Bacteria introduced into fruit by curculio. Note the wound and the oozing drops*

Waite (1896) has observed instances in which sap suckers, becoming infected by puncturing cankers of hold-over blight, spread the disease to healthy trees.

P. J. O'Gara is authority for a statement, published by Smith ('11) in his bulletin on crown gall, that fire blight cankers have been known to develop around

(1896) Waite, M. B. Cause and prevention of pear blight. U. S. Dept. Agr. Yearbook 1895 : 295–300. 1896.

('11) Jones, D. H. Scolytus rugulosus as an agent in the spread of bacterial blight in pear trees. Phytopath. 1 : 155–158. *pls. XXIII–XXIV*. 1911.

('11) Smith, E. F., Brown, Nellie A., and Townsend, C. O. Crown-gall of plants: its cause and remedy. Crown-gall followed by hold-over blight. U. S. Dept. Agr., Bur. Plant Indus. Bul. 213 : 186. 1911.

galls produced by the crown gall organism (*Bacterium tumefaciens*) on Esopus apple trees, the blight bacteria having gained an entrance through the gall.

Whetzel ('06) has also noted it to be a common occurrence for cankers to develop on the trunk or the collar of orchard trees, the bacteria having gained entrance through a water sprout or a tender young shoot (Fig. 121). This point is of interest, since in the West, especially, the use of Le Conte stocks in preference to French seedlings has been advocated, owing to the tendency of trees budded on Le Conte stocks to sprout less from the collar of the tree. When French seedlings are used the abundance of sprouts affords a means of entrance for bacteria, and losses from blight are increased.

FIG. 121.—*Blighted water sprouts on trunk of large pear tree*

Hold-over blight

The general opinion has prevailed that blight bacteria remain alive over winter only in those cankers that are more or less protected from drying out; also, that the number of hold-over cankers in which the organisms survive the winter is comparatively few. However, some evidence has been produced that under favorable conditions the parasite may live over in blighted shoots or twigs, as well as in larger diseased branches or limbs. Burrill (1882) cites a case in which a nurseryman experienced

(1882) Burrill, T. J. Have we any new light on pear blight or yellows? Rept. Michigan State Hort. Soc. 1881 : 133–139. 1882.

('06) Whetzel, H. H. The blight canker of apple trees. New York (Cornell) Agr. Exp. Sta. Bul. 236 : 104–138. 1906.

heavy loss due to the blight in grafts newly made that winter. Some of the scions stored for grafting purposes had evidently been cut from blighted trees. When the grafts were made with these scions the grafting-knives became infected, thus favoring the transmission of bacteria to the non-diseased grafts.

Sackett ('11) has recently shown that in Colorado the blight organism lives over winter in small blighted pear twigs. Numerous isolations were made from diseased pear twigs in February and March, and the parasite was frequently obtained in pure culture.

Isolations made in March by the writer from diseased twigs (less than one centimeter in diameter) of Bartlett pears, taken from an orchard near Newark, New York, gave about the same results as did those of Sackett. An attempt was made to isolate the organism from five blighted twigs, and a pure culture of *Bacillus amylivorus* was obtained from two of these. The organism isolated produced the characteristic blight when used for inoculating the tender twigs of quince trees growing in the greenhouse.

In the same month, the fire blight organism was isolated also from pear seedlings that had blighted the previous season. The trunks of the diseased seedlings were about one half inch in diameter.

Hold-over blight in budded seedlings is of special significance since it furnishes a source for early infection the following spring. More attention must also be given to hold-over blight in small twigs and branches, which until recently has been considered of little importance; for it is evident that these small cankers frequently furnish a means for existence of the bacteria over winter.

Influence of weather on blight

Weather conditions at certain times during the growing season are an important consideration in connection with the dissemination of blight in the nursery. Prolonged hot and dry weather in the early part of the season tends to check the rapid development of the young shoots, causing them to make a hard and woody growth. The terminal buds close up and cease growing. Such shoots are not so liable to infection, and usually epidemics of the disease subside somewhat during a hot, dry period. Later, with increased precipitation the growth of the trees is accelerated, and their tissues become tender and succulent and are naturally in a condition to be more susceptible to attacks of the causal organism.

The spread of blight is also more noticeable in the infected trees after abundant rainfall followed by periods of hot, cloudy weather. The

('11) Sackett, W. G. Hold-over blight in the pear. Colorado Agr. Exp. Sta. Bul. 177 : 2–8. 1911.

tissues are gorged with sap thus favoring increased activity of the bacteria, and the disease becomes more destructive.

Cultivation and manuring as affecting fire blight

Horticulturists and pathologists generally agree that cultivation, and the application of nitrogenous manures or of any material that tends to induce rapid and succulent growth, favor the serious development of blight, at least in pear trees. However, it seems that this general opinion is based on observation alone and that no carefully conducted experiments have been made in order to determine anything definite on this phase of the question.

Usually, blighted trees are more common among those growing in rich soil, and it is generally conceded that the condition of the tree has much to do with the amount of damage produced after the malady appears. As a rule, the more succulent the tree, the more severely it is attacked.

In the account of an experiment in orchard fertilization conducted by J. P. Stewart ('12) of the Pennsylvania Agricultural Experiment Station, certain observations with reference to fire blight are recorded. The trees in the manured plots, and those in general that had made the most rapid growth throughout the preceding four or five years, blighted more severely than did those that had not received such excessive manuring.

Period of growth-activity.— Observations and experiments made by the writer indicate that the most important factor influencing the spread of the disease is the period of growth-activity of the host plant. As shown by inoculation experiments subsequently discussed, succulence of the host tissue is essential in order to insure infection by the blight organism. For a period of time in early spring the new growth that develops shows practically no difference in its tenderness and succulence, regardless of the conditions under which the host exists. The young, tender shoots of trees growing in sod are as liable to infection as the twigs of cultivated trees. Later, with the lack of cultivation and fertilizers, trees in sod make a slower growth, and the new shoots become hard and woody and do not blight so readily as do those of trees that are well cared for, in which the period of growth-activity and succulence is extended throughout the greater part of the growing season. It is also natural to expect, under such conditions, that the damage to cultivated trees will be greater, when once attacked, than to trees that are less succulent. Abundant twig and blossom infection has been observed frequently on orchard pear trees growing in sod, but usually the blight does not progress so rapidly into the larger branches and limbs.

('12) Stewart, J. P. Factors influencing yield, color, size, and growth in apples. Relation of fertilization to fire blight. Rept. Pennsylvania Agr. Exp. Sta. **1910–1911** : 467. 1912.

The importance of the period of growth-activity as influencing blight infection is strongly emphasized by the experiments conducted throughout the past few years.

Experiment of 1910.— Thirty two-years-old Bartlett pear trees were set in the plant-disease garden on the university farm in the early spring of 1910. There were three plats with ten trees in each. Plat 1 was manured heavily with stable manure and kept well cultivated. Plat 2 was cultivated, but not manured. Plat 3 was in sod in Roberts' pasture, which has not been broken for about thirty years; this plat received no manure nor cultivation throughout the experiment.

During the summer of 1910 plats 1 and 2 were each cultivated three times, and at the end of the season there was a noticeable difference in growth between the cultivated trees and those in sod.

Experiment of 1911.— In the spring of 1911 plat 1 was again heavily manured, and both plats 1 and 2 had received two cultivations up to July 1. At this time there were marked differences in the growth of the trees; those in sod had made but little growth and the new shoots were short, hard, and woody, with indications that the growth for the season was practically completed. In the cultivated plats the trees had made a rapid growth and the development of young, tender shoots had been abundant. Many of these were still very succulent, especially on the trees that had been manured and cultivated.

On July 5, under ideal conditions for blight infection — a hot, cloudy day following a heavy rain — all the trees were inoculated with a four-days-old bouillon culture of *Bacillus amylivorus*, recently isolated from a blighted quince tree. An effort was made to choose the tenderest twigs in every case and three shoots on each tree were inoculated.

Five days later, when some of the infections had become apparent, considerable differences were noticed. No infections had occurred in the trees in sod, in which it had been necessary to make the inoculations into hard, woody tissue. Inoculations of the trees cultivated but not manured showed about twenty-five per cent of the twigs infected. Practically all the inoculated twigs on the heavily manured trees showed infection, as yet indicated only by a water-soaked appearance and slight discoloration. Four days later the progress of the malady in the infected shoots was considerably advanced and about forty per cent of the inoculated twigs in plat 2 were diseased. Only two infections developed in the trees growing in sod.

It was strikingly noticeable that infections occurred only in twigs that were still making an active growth, indicating that succulence of the tissue is the primary factor in liability to infection by the bacteria. The hard and woody twigs of trees growing in sod were more resistant than were the tender shoots of cultivated trees. Judging from results obtained the following year, had the inoculations been made earlier in the season the number of infections for the trees in sod would have been greater.

Experiment of 1912.— Early in the spring of 1912 plats 1 and 2 were again cultivated and plat 1 was manured. On May 28 the inoculations as described above for 1911 were repeated. At this time the new shoots on all the trees were tender and succulent. But little difference was apparent, except that the shoots on the trees in sod were shorter and not so numerous.

After five days all the inoculated shoots in plats 1 and 2 were evidently diseased, and out of a total of twenty-eight inoculated shoots in plat 3 only three failed to blight. Later in the season (July 22) many of the trees that had been cultivated were badly blighted (Figs. 122 and 123), new infections had occurred, and the larger branches and limbs were diseased. On the other hand, the trees in sod (Fig. 124) were not so severely attacked, no new infections had appeared, and the blight had progressed only a short distance (about six inches) from the points of inoculation.

FIG. 122.— *Bartlett pear tree in plat 1, highly cultivated and manured. The blight practically ruined the entire tree*

In connection with the question of succulence as influencing the amount of blight in the nursery, it is of interest to note also certain differences in growth-activity for various kinds of pome fruits when grown under the same conditions. Pear trees especially make their most rapid development early in the season, and after the middle of July the shoots are, as a rule, too hard and woody for blight infections to occur. Infection experiments during the latter part of July in 1910 and in 1911 on the two-years-old pear trees in the nursery gave but few positive results. In the greater number of cases the inoculations were a failure. Inoculations were successful, however, when made as late as September 1 the same years on adjoining blocks of two-years-old apples and quinces. All trees had received the same amounts of cultivation and fertilizer.

FIG. 123.— *Bartlett pear tree in plat 2, cultivated but not manured. Such trees did not suffer so severely when inoculated with the fire blight organism as did those in plat 1*

It is believed that such a condition is a determining factor with reference to the dissemination of the blight bacteria by such insects as the tarnished plant bug. Serious outbreaks of the disease have occurred in blocks of apples and quinces where the rapid spread of the parasite was attributed to the presence of the tarnished bug. Although the same insects infested nearby and adjoining blocks of pears, practically no blight appeared. In the writer's opinion this is due to the fact that the shoots had passed their period of most rapid development and were not in a condition to be so readily attacked by the bacteria.

Varietal susceptibility

Opinions disagree considerably regarding the susceptibility of different varieties of pears to this disease. Bartlett and Flemish are generally reported as being most severely attacked and much more susceptible, in different sections of the country, than Kieffer and Seckel. Among apples, Esopus and certain crab varieties are known to blight somewhat readily; but the difference in resistance for other varieties is considered not so constant, most of them being more or less affected.

FIG. 124.— *Bartlett pear tree growing in sod in plat 3. The progress of the blight was very limited, only the tender growth of the inoculated shoots becoming diseased*

However, from observations and inoculation experiments the writer is inclined to believe that for nursery stock, at least, but little difference is shown by the several varieties in their ability to withstand the attacks of the blight. The enormous amount of conflicting data that have been accumulated on the question of varietal resistance of orchard trees to fire blight, indicate that only such factors as the source of infection, the abundance of disseminating agents such as insects, and the period of growth-activity of the host plants are the criteria to be considered in determining the difference in susceptibility. As far as is known, all varieties are attacked under conditions favorable for the development and propagation of the malady.

Inoculation experiments.— Believing that any differences manifested are governed more by external factors than by a natural immunity of certain varieties, a series of varietal inoculations was conducted on quinces, apples, and pears. From the results obtained it is conclusive that the varieties inoculated showed practically no difference in their resistance to attacks of the causal organism. All were susceptible.

In the table below are listed the varieties inoculated, the dates on which the infections appeared, and the total number of infections for each. A four-days-old bouillon culture of *Bacillus amylivorus* was used for all inoculations. This strain was isolated in August, 1911, from quince. An effort was made to choose the tenderest growth in every case and a single shoot on each of five different trees of each variety was inoculated by pricking the tip of the shoot with a needle that had been dipped into the bouillon culture.

TABLE 2. VARIETAL INOCULATIONS OF BACILLUS AMYLIVORUS ON TWO-YEARS-OLD QUINCES. STRAIN NO. 8. INOCULATIONS MADE AUGUST 13, 1912

Variety	Number of infections and dates on which they appeared			Total number of inoculations	Total number of infections
	August 17	August 18	August 19		
Bourgeat*..............	0	....	5	5	5
Champion..............	5	....	....	5	5
Meech..................	5	....	....	5	5
Rea.....................	5	....	....	5	5
Bentley................	0	1	4	5	5
Orange.................	0	5	....	5	5

*Nomenclature according to code adopted by the American Pomological Society in 1903.

TABLE 3. VARIETAL INOCULATIONS OF BACILLUS AMYLIVORUS ON TWO- AND THREE-YEARS-OLD APPLES. STRAIN NO. 8. INOCULATIONS MADE JUNE 18, 1912

Variety	Number of infections and dates on which they appeared								Total number of inoculations	Total number of infections
	June 23	June 24	June 25	June 26	June 27	June 28	June 30	July 2		
Two-years-old										
Gideon..................	....	....	2	....	2	....	....	....	5	4
Hyslop..................	5	....	....	....	....	....	....	....	5	5
Ontario..................	5	....	....	....	....	....	....	....	5	5
Late Strawberry.........	5	....	....	....	....	....	....	....	5	5
St. Lawrence............	5	....	....	....	....	....	....	....	5	5
General Grant...........	5	....	....	....	....	....	....	....	5	5
Fall Pippin..............	5	....	....	....	....	....	....	....	5	5
Transcendent............	5	....	....	....	....	....	....	....	5	5
Martha..................	....	....	1	....	2	....	....	1	5	4

TABLE 3 (*concluded*)

Variety	Number of infections and dates on which they appeared								Total number of inocu- lations	Total number of infec- tions
	June 23	June 24	June 25	June 26	June 27	June 28	June 30	July 2		
Two-years-old										
Excelsior	....	....	I	....	I	....	....	3	5	5
Mann	5	....	....	....	....	....	....	....	5	5
Westfield	5	....	....	....	....	....	....	....	5	5
Early Strawberry	5	....	....	....	....	....	....	....	5	5
Bismarck	3	2	....	....	....	....	....	....	5	5
Whitney	I	I	....	....	3	....	....	....	5	5
Alexander	4	I	....	....	....	....	....	....	5	5
Roxbury	2	2	....	....	I	....	....	....	5	5
Sutton	3	....	....	....	....	....	....	I	5	4
Quebec	3	2	....	....	....	....	....	....	5	5
Tetofsky	2	2	....	....	I	....	....	....	5	5
Jersey Sweet	3	I	I	....	....	....	....	....	5	5
Sops-of-Wine	3	2	....	....	....	....	....	....	5	5
Smith Cider	4	I	....	....	....	....	....	....	5	5
Ralls	2	I	....	....	....	....	....	I	5	4
Longfield	4	I	....	....	....	....	....	....	5	5
Esopus	4	I	....	....	....	....	....	....	5	5
Winter Pearmain*	4	I	I	....	I	I	....	....	10	8
America	....	2	....	....	I	....	....	2	5	5
Wolf River	4	I	....	....	....	....	....	....	5	5
Red Astrachan	....	2	I	....	....	....	....	....	5	3
Tompkins King	2	3	....	....	....	....	....	....	5	5
North Star	....	3	....	....	2	....	....	....	5	5
Munson	I	I	....	....	....	....	I	....	5	3
Bethel	....	2	....	I	....	I	....	....	5	4
Peck	....	2	....	I	2	....	....	....	5	5
Missouri	2	2	....	....	I	....	....	....	5	5
Porter	....	5	....	....	....	....	....	....	5	5
Newtown Pippin	3	I	....	I	....	....	....	....	5	5
Haas	I	3	....	....	....	....	....	I	5	5
Red June	5	....	....	....	....	....	....	....	5	5
Peach	3	2	....	....	....	....	....	....	5	5
Oldenburg	I	3	....	....	I	....	....	....	5	5
Yellow Transparent	3	2	....	....	....	....	....	....	5	5
Rhode Island	2	3	....	....	....	....	....	....	5	5
Ben Davis	....	5	....	....	....	....	....	....	5	5
Gravenstein	....	....	....	I	....	I	....	2	5	4
Arkansas Black	....	5	....	....	....	....	....	....	5	5
Yellow Bellflower	....	3	....	2	....	....	....	....	5	5
Winter Banana	4	I	....	....	....	....	....	....	5	5
Baldwin	I	2	I	....	I	....	....	....	5	5
Wealthy	I	2	....	2	....	....	....	....	5	5
Bottle Greening	2	I	....	2	....	....	....	....	5	5
Jonathan	4	I	....	....	....	....	....	....	5	5
Opalescent	3	I	....	I	....	....	....	....	5	5
Walbridge	....	2	I	I	I	....	....	....	5	5
Red Canada†	....	....	....	....	3	....	....	....	3	3
Stayman	....	2	....	....	2	I	....	....	5	5
Black Gilliflower	2	2	....	....	I	....	....	....	5	5
Rolfe	I	2	I	....	....	....	....	....	5	4
Three-years-old										
McIntosh	I	3	....	....	I	....	....	....	5	5
Wagener	2	3	....	....	....	....	....	....	5	5
Bough	3	2	....	....	....	....	....	....	5	5
York Imperial	2	I	I	....	....	....	....	....	5	4
Pewaukee	....	2	I	....	....	....	....	....	5	3
Tolman	....	I	I	I	I	....	....	....	5	4
Golden Sweet	I	....	I	....	3	....	....	....	5	5
Boiken	....	2	2	....	I	....	....	....	5	5
Winesap	....	I	....	I	3	....	....	....	5	5
Golden Russet	....	I	....	3	I	....	....	....	5	5
Fameuse	....	4	I	....	....	....	....	....	5	5
Rambo	2	3	....	....	....	....	....	....	5	5
Rome	....	....	2	....	2	....	....	I	5	5
Northern Spy	....	I	2	....	2	....	....	....	5	5
Northwestern Greening	I	3	....	....	....	....	....	I	5	5
Gano	....	....	2	....	I	....	2	....	5	5
Maiden Blush	....	I	2	....	....	I	....	I	5	5
Pumpkin Sweet	....	2	2	I	....	....	....	....	5	5
Stark	I	4	....	....	....	....	....	....	5	5
Twenty Ounce	....	3	....	I	....	....	....	I	5	5

* Winter Pearmain. Two rows inoculated by mistake, making ten inoculations.
† Red Canada. Only three inoculations, by mistake.

TABLE 4. VARIETAL INOCULATIONS OF BACILLUS AMYLIVORUS ON THREE-YEARS-OLD PEAR TREES. STRAIN NO. 8. INOCULATIONS MADE JUNE 19, 1912

Variety	Number of infections and dates on which they appeared								Total number of inoculations	Total number of infections
	June 23	June 24	June 25	June 26	June 27	June 28	June 30	July 2		
Garber	....	....	2	....	3	....	....	....	5	5
Kieffer	....	....	1	1	3	....	....	....	5	5
Seckel	....	....	1	....	2	....	1	....	5	4
Anjou	....	1	1	3	....	....	....	....	5	5
Sheldon	....	1	....	....	....	....	1	....	5	2
Vermont Beauty	....	....	....	1	1	....	3	....	5	5
Angouleme	....	4	....	....	....	....	....	....	5	4
Clapp Favorite	....	....	....	1	....	....	....	3	5	4
Koonce	....	....	....	1	....	....	1	....	5	2
Flemish	....	1	1	....	....	....	....	....	5	2

In the above experiments the failure of some of the inoculated twigs to blight was attributed to the hard and woody condition of the tissues, rather than to any natural immunity on the part of the host. Varietal inoculations on pears later in the season did not yield such a high percentage of infections. Some of the varieties had made a slower growth than others and were not so readily attacked by the bacteria. In comparing tables 4 and 5, it is to be noted that the varieties included in both are practically the same and that in Table 4 all are shown to be susceptible.

The later inoculations were made on July 8, with a five-days-old bouillon culture of the same strain of *Bacillus amylivorus* as was used in other experiments. The tenderest growth was chosen in every case and the tip of a single shoot on each of three different trees was inoculated. The condition of the twig as to succulence and tenderness was also recorded.

TABLE 5. VARIETAL INOCULATIONS OF BACILLUS AMYLIVORUS ON TWO-YEARS-OLD PEAR TREES. INOCULATIONS MADE JULY 8, 1912

Variety	Condition of shoots	Number of infections and dates on which they appeared				Total number of inoculations	Total number of infections
		July 12	July 13	July 14	July 16		
Kieffer	Tender	3	0	0	0	3	3
Sheldon	Tender	0	1	2	0	3	3
Wilder Early	Medium tender	1	1	0	0	3	2
Angouleme	Medium tender	2	1	0	0	3	3
Bartlett	Medium tender	1	0	1	1	3	3
Clapp Favorite	Medium tender	0	1	0	0	3	1
Lawrence	Medium tender	1	0	0	0	3	1
Garber	Medium tender	1	0	0	0	3	1
Worden Seckel	Hard and woody	0	0	0	1	3	1
Seckel	Hard and woody	0	1	0	0	3	1
Anjou	Hard and woody	0	0	0	0	3	0
Flemish	Hard and woody	0	0	0	0	3	0

Natural resistance.— As determined by the experiments, all varieties of pome fruits tested were susceptible to blight when inoculations were made during the period of most rapid development of the trees. Instances may be cited, however, when certain varieties have shown to some degree a natural freedom from the disease. In the summer of 1912 the blight made its first appearance at one nursery during the first week in June, affecting two rows of Transcendent (crab) at one end of a large block of two-years-old apples. The disease was practically confined to this variety for several weeks, spreading gradually to the three rows of Fall Pippin adjoining the Transcendent. About the first part of July, with the appearance of the tarnished plant bug the blight became epidemic and was spread over one end of the block.

Bearing in mind that the varieties which suffered most were in the vicinity where the disease first appeared, a few comparisons may be made. Fall Pippin and Transcendent blighted badly. Other varieties severely attacked were General Grant, St. Lawrence, Late Strawberry, Ontario, Mann, and Smith Cider. The Martha (crab) immediately next to the Transcendent blighted to only a slight extent, and the same is true of Excelsior and Whitney. By virtue of their position, it is evident that these varieties were for some reason less liable to blight as brought about by natural infection.

Due to the fact that the other varieties were somewhat removed from the center of the epidemic, no definite statements can be made concerning their liability to infection. From previous observations at different times, it may be stated that in general the Yellow Transparent, Golden Russet, Sutton, Alexander, Ralls, Fameuse, Wagener, Tompkins King, Rhode Island, Baxter, and Rambo are more often affected than Baldwin, Ben Davis, Red Astrachan, Oldenburg, and Gravenstein.

It is not possible, however, to place much reliance on differences manifested by certain varieties in their liability to blight. The behavior of the trees toward the disease is no doubt greatly influenced by local conditions. This point is well illustrated from observations recorded by Crandall (1898) in Colorado. In a row of crabs, Martha and Whitney alternating, the Whitney trees were all severely attacked by the blight while not a single Martha tree blighted. It is interesting to note that in the nursery the Whitney variety was observed by the writer to be practically free from the disease. The Martha also blighted to only a slight degree, although this variety has been known to blight readily in other localities.

Special inoculation experiments

Pathogenicity tests.— March 31, 1912. Inoculations of the nine cultures growing in bouillon which were used for the cultural studies were made

(1898) Crandall, C. S. Blight and other plant diseases. Colorado Agr Exp. Sta. Bul. 41:3-14. 1898.

into shoots of quince trees growing in the greenhouse. Two shoots were inoculated with each culture. After ten days all inoculated shoots showed infections except those inoculated with culture No. 2, on which infections appeared one day later. It is of interest to note that culture No. 7, from Colorado, appeared to be the most virulent, the infection appearing after eight days; this culture gave the slowest reactions on the cultural media. Practically no difference could be noticed in the virulence of numbers 1, 3, and 4, which were cultures isolated in different years from the same pear tree.

Blossom inoculations.—February 23, 1912. Ten blossoms on two-years-old Yellow Transparent apple trees growing in the greenhouse were sprayed, by means of an atomizer, with a bouillon culture of *Bacillus amylivorus*. The blossom parts were thoroughly moistened with the solution and the blossoms were then covered for thirty-six hours with lamp chimneys stoppered with cotton. Checks were run by spraying four blossoms with sterile water. The checks were covered in the same manner as were the other blossoms. After nine days the inoculated blossoms showed symptoms of the disease, and after thirteen days the blight had not only involved the pedicels but was apparent in the older and more woody tissue of the blossom spurs. All the inoculated blossoms blighted; none of the checks became diseased.

March 8, 1912. Inoculations into quince blossoms on trees growing in the greenhouse were made as follows: A small piece of absorbent cotton saturated with a bouillon culture of *Bacillus amylivorus* was placed in each of four blossoms. Care was taken in the manipulation not to injure any of the tissues. Two other blossoms were treated in the same manner except that the cotton was saturated with sterile water instead of with the culture of the organism. After ten days all the inoculated blossoms were blighted and the checks remained healthy.

Blossoms were also caused to blight by gently brushing the nectarial surfaces with a camel's-hair brush that had been dipped into a bouillon culture of *Bacillus amylivorus*.

Loss of virulence.— March 24, 1912. A culture of *Bacillus amylivorus* that had been isolated from pear in the spring of 1911 was used for inoculating some young pear shoots on trees in the greenhouse. When the infections appeared the organism was reisolated and obtained in pure culture. Bouillon cultures of the recent reisolation and also of the original culture isolated in 1911 were inoculated into different shoots on the same pear tree. After four days the reisolated culture had produced an infection, but the twigs inoculated with the old cultures did not show signs of the disease until nine days after the inoculations. From these results it appears that there is a tendency for the recently isolated cultures to be more virulent and that artificial propagation seems to reduce the virulence to some extent.

Pathological histology

Historical.— Burrill (1881) appears to have been the first to study the effects of *Bacillus amylivorus* on diseased tissues. He states that " the most conspicuous changes that can be observed by the aid of the microscope, in the tissues affected with the blight, is the disappearance of the stored starch." He further states that " the cell walls are not dissolved or altered in any way except by staining, which sometimes takes place through oxidation, in the later stages of the disease." He observed that the bacteria occupy the lumen of the cells in diseased tissue, but he found it difficult to explain how they penetrated the cell wall. He further observed that in the tips of apple twigs diseased with the blight, all the tissues, even the xylem and pith, are invaded; but that in older limbs only the bark is attacked and the outer bark, or cortex, is usually first affected. The bast fibres are never diseased and the cambium frequently escapes invasion.

Waite (1898) in more recent investigations, being unable to demonstrate the diastatic action of the organism on starch, holds that " its principal food consists of nitrogenous matter, sugars and probably, to some extent, organic acids, the very substances which occur in vigorous young growing tissues of the host." Bacterial cavities of considerable size are often formed, gorged with the viscid mass of the pathogen. Waite ('06) states further that " very often it has progressed much farther in the bark of the branches than appears on casual examination, for as a general rule it works only in the bark, leaving the mature wood at first unharmed. The sap, therefore, is able to continue to flow upward in the wood so that the leaves and branches, though girdled and doomed to destruction, may still carry their foliage or even mature their fruit." Such a condition as Waite describes may result in hyperplasia (Fig. 125) of the bark tissue above the lesion or diseased area, due to the accumulation of products formed in the metabolism of the tree. The girdling of the branch prevents the conduction of the products downward beyond the point of lesion.

Tissues affected.— A microscopic examination of sections of young diseased twigs shows a necrosis of the cells and a somewhat shrunken condition of the tissue. The cells are plasmolyzed and stained brown; the contents, having lost all semblance of organized cell contents, are thick and amorphous. The blight bacilli are present in great numbers

(1881) Burrill, T. J. Blight of pear and apple trees. Rept. Illinois Industrial Univ. **10** : 62–84. 1881.
(1898) Waite, M. B. Life history and characteristics of the pear blight germ. Proc. Amer. Assoc. Adv. Sci. **47** : 427–428. 1898.
('06) Waite, M. B., and Smith, R. E. Pear blight. Ann. Rept. California Fruit Growers Assoc. **31** : 137–161. 1906.

in the intercellular spaces and to some extent within the cells. The cortical parenchyma is most severely attacked. Sometimes the cambium layer is affected. This is especially true of twigs in the more advanced stages of the disease and in larger limbs and branches. The bacteria may invade the pith and also the xylem tissue of young, tender shoots, but apparently the organism does not migrate for any great distance through these tissues.

After their introduction into the tissues through a wound or an insect puncture, the organisms multiply rapidly and extend in all directions from the point of entrance. Although the lateral development is often sufficient to girdle and kill large limbs or even whole trees, the spread of the organism upward and downward is greater, often being several meters. There is a breaking and splitting apart of the cells, with the formation of pockets that are filled with bacteria suspended in a sticky substance. This gummy material is presumably a mixture of the cell sap and the decomposed substances of the tissues that have been formed in the metabolic processes of the bacteria.

FIG. 125.— *Pear limbs girdled by fire blight cankers, causing hyperplasia of the bark tissue above the lesion*

Frequently, with the active development of the bacilli, ruptures or fissures are produced and the gummy material laden with the organisms fills these cracks in the bark and oozes out as the characteristic exudation previously described (page 323). The tissues around the lenticels are also invaded and with the breaking down of the cells the bacterial exudation occurs through these openings. In newly affected shoots the bacteria may invade only a small area of the cortical parenchyma in their lateral development, but proceed for some distance downward. On reaching a lenticel, or with the formation of cracks or fissures, the exudation may occur before any marked external symptoms of the disease are apparent. This is especially true in young, tender shoots, when the progress of the bacteria downward is very rapid.

In a recent paper by Miss Bachmann ('13) the results are given of a careful examination into the histological relations of host and parasite, and several questionable points are cleared up with reference to the migration of the organisms in the tissues. For these studies inoculated blossoms of pear, water-shoots of apple, young pear seedlings, young shoots of pear and plum, and fruits of pear and apple were used.

Miss Bachmann states that " the first evidence of infection in the tissues of the fruit or shoot is a transparency around the point of inoculation, followed later by a browning in the same region." The transparency is attributed to the removal of air from the intercellular spaces, this being replaced by the liquid in which the bacteria live. By an examination of stained and unstained sections of inoculated tissues it was evident that the large intercellular spaces of the cortex provide a ready path for the migration of the organism. It was found also that the bacteria enter the xylem tubes very readily near the apex of young shoots, and frequently the tubes may be so packed with bacteria that transmission of sap in such a region is apparently impossible. From the author's observations it is to be assumed that the entrance of the bacteria into the xylem vessels is near the apex of the shoot and their presence in this tissue at some distance below is due to their migration downward. The greatest invasion of the xylem by the organism is always near the apex of the shoot.

A study of inoculated green fruits also indicated that the bacteria were most abundant in the intercellular spaces. The organisms seldom, if ever, enter the cells — at least, not before the death of the tissues. Miss Bachmann is of the opinion that the bacteria cause plasmolysis of the cellular contents and that the cells die owing to the extraction of water into the intercellular spaces, although chemical changes in the protoplast may accompany this loss of water. Bacteria were frequently observed between cells of tissue that still appeared perfectly normal. From this condition Miss Bachmann concludes " that the substances produced in the metabolism of the organisms are not at all strongly or quickly toxic in their effect on the cells." The film of liquid in which the bacteria move is not extracted in such amount that it precedes the bacteria to any extent. It is also considered possible to explain the broken walls and the formation of cracks or fissures on a purely physical basis, and Miss Bachmann suggests that " it may be that the osmotic pressure of the substance in which the bacteria are found is sufficiently great to rupture the cell walls."

Cavity formation.— The theory advanced by Miss Bachmann as an explanation for the splitting of the cell walls does not appear to be entirely

('13) Bachmann, Freda M. The migration of Bacillus amylovorus in the tissues of the host. Phytopath. 3 : 3–17. *pls. I–II. figs. 1–2.* 1913.

satisfactory. It is difficult to conceive of any great osmotic pressure being exerted in such tissues. By the killing of the protoplasm the plasma membrane would become functionless and exhibit no further ability to reject or permit the passage of certain substances through it. Under such conditions, owing to the permeability of the cell wall, any pressure exerted outside the cells, due to increased concentration of the solution or to the excess extraction of water from the cells, would only cause the solution to pass back into the dead cells until an equilibrium would be established, the pressure outside and inside becoming practically equal. There might be a tendency to force the medium containing the bacteria farther along in the intercellular spaces; but it does not seem to the writer that a pressure due to osmosis could be created which would be strong enough to rupture the cell walls.

In a general discussion of bacterial actions on the plant, Smith ('11) states that "the gum diseases rupture the bark and ooze extensively on the surface. Pear blight does this also to a lesser degree. Some, perhaps all, of this class of bacteria reach the surface through fissures due to surface tensions set up in dead tissues by the parts still alive and growing." Pressure of sap in the tissues might be transmitted to diseased parts and favor the exudation of the gum; or, due to increased growth of surrounding healthy tissues, a tension might be developed sufficient to cause rupturing of the dead cell walls. Such a tension could not, however, be correctly called surface tension. Surface tension, as such, could scarcely be said to have any influence on the splitting apart of the cell walls. The chief activity that could be attributed to it might be the rounding up of the cell contents of the individual cells as they shrink and dry up after plasmolysis.

It is probable that the above phenomenon of rupturing of the tissue may be more closely associated with some toxic or enzymic reaction which as yet is unknown. In view of some of the recent work on enzymes it seems natural to incline toward the enzymic theory.

Toxins.— With present knowledge it is impossible to state exactly how the killing of the tissue is brought about. Arthur (1886) has shown that solutions in which the bacteria were grown caused no rotting of green fruits when filtered. He used the sterile filtrate of a strong solution of blighted tissue for inoculating green pears. However, there always remains the possibility that the toxin, or substance which affects the tissues, may be destroyed (that is, absorbed by the filter or actually filtered out) in the process of separation, and by the removal of the toxin no deleterious effect on the tissue would be expected.

(1886) Arthur, J. C. Report of Botanist. Pear blight. Rept. New York (Geneva) Agr. Exp. Sta. 4 : 242–248. 1886.

('11) Smith, E. F. Bacteria in relation to plant diseases 2 : 69. 1911.

Following the method of study as outlined by L. R. Jones ('10) in his work on the enzymic production of *Bacillus carotovorus*, an attempt was made by the writer to isolate the enzymes produced by *Bacillus amylivorus*. But all tests for the production of diastase and the cell-wall-dissolving enzymes, pectinase and cellulase, proved negative.*

An aqueous solution of the substance isolated apparently had no effect on sections of pear and quince shoots. It is to be noted, however, that the extractions were made only from bouillon cultures of the organism, and under such conditions it is possible that the toxins or enzymes that act on the tissues were not produced. It has been shown that the nature of the culture medium in which an organism is grown exerts an important influence in the production of certain enzymes. This point is especially emphasized by the work of Knudson ('11) on the production of the enzyme tannase.

Miss Bachmann ('13), having observed fire blight bacteria in the intercellular spaces of apparently normal tissue, concludes that the toxic action of the products formed by the organisms is at least very slow. It seems evident, however, that with the presence of the bacteria in the intercellular spaces some toxic action is necessary in order to cause plasmolysis of the protoplast, with resulting extraction of water from the cells. The plasma membrane must be acted on in some way by a product formed in the metabolism of the organisms. The phenomenon could hardly be brought about by the action of the bacteria with products of the host outside the cells, resulting in such an increased concentration of a substance that would cause plasmolysis of the protoplast. If there were a tendency for increased concentration in this manner, the process would be very gradual; and under such conditions, presumably the protoplasm of the plant would be able to adjust itself to the change and there would be no permanent plasmolysis. It is well known that the protoplasm is often able to overcome partial plasmolysis caused by increased concentration of solutions outside the cell. This is evident in the case of cells of Tradescantia, which are able to recover when partially plasmolyzed by a solution of glucose sugar. If allowed to remain in this solution, the protoplasm will gradually adjust itself to the concentration and revert to its normal condition. The writer is of the opinion that, in view of the fact that only a limited amount of work has been done along this

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* As previously mentioned (page 337), the cane-sugar-reducing enzyme, invertase, was isolated by the above method.

('10) Harding, H. A., Morse, W. J., and Jones, L. R. The bacterial soft rot of certain vegetables. Vermont Agr. Exp. Sta. Bul. 147 : 243–360. 1910.

('11) Knudson, Lewis. Regulatory formation of the enzyme tannase. Science n. s. **34** : 219–220. 1911.

('13) Bachmann, Freda M. The migration of Bacillus amylovorus in the tissues of the host. Phytopath. **3** : 3–17. *pls. I–II. figs. 1–2.* 1913.

line of investigation, sufficient evidence has apparently not been produced to warrant drawing definite conclusions as to exactly how the bacteria affect the tissue.

Penetration of cell.— Although in the majority of cases the greatest invasion by the bacteria is in the intercellular spaces, they do occur in the cells to some extent. As with many other bacterial diseases, it has been impossible to demonstrate how the organism gains an entrance into the cell. With no apparent openings in the cell wall that would permit the passage of the bacteria, it may be assumed that the bacteria push or dissolve their way through thin places in the wall or through pits by mass action. In support of this view the following is quoted from Smith ('11) in his discussion of the bacteria in the cells: " The most striking example, perhaps, is the voluminous intracellular occupation in the root nodules of Leguminosae. Here the cells are often crowded with bacteria with no visible opening for entrance. They seem to enter by mass action, the bacteria being compacted into strands. Often there is a trumpet-like expansion where the strand touches the cell wall. The writer has seen what appears to him to be a similar dense occupation of unruptured cells in the bark of the pear attacked by *Bacillus amylovorus*. The particular tissue which shows this to best advantage is the pitted collenchyma toward the outer part of the bark. In a few cases it has seemed as if bacteria could actually be traced from one cell into another across a narrow pit, but of the absolute correctness of this view I have not yet fully satisfied myself."

In sections of quince and apple bark the compacted masses of bacteria as mentioned by Smith have been observed also by the writer, but it has not been possible to determine whether this is the manner in which the bacteria enter the cell. There still remains the possibility that their entrance is due to some toxic or enzymic action which as yet has been overlooked.

CONTROL

From the time that fire blight first became known, many recommendations have been given and experiments tried for control of the disease; but previous to the discovery of the causal organism, little advancement was made in checking the malady. When all was conjecture, with no direct evidence available, no sharply defined treatment could be expected; but with the classical works of Burrill, Arthur, Waite, and others, better knowledge of the disease was obtained, and since the appearance of these works more rapid advancement has been made in control of fire blight.

('11) Smith, E. F. Bacteria in relation to plant diseases 2 : 77. 1911.

TREE-FEEDING

Feeding the trees in order to make them immune, by the introduction of various solutions into the sap, has not as yet been definitely proved to be successful despite the claims of many manufacturerers of blight remedies. Bolley ('04 and '07) also claims to have cured trees suffering from blight by feeding them formalin and various other materials. It is to be regretted, however, that no definite statements with regard to the work have been published, except that positive results have been obtained and that the treatment requires too careful manipulation to be recommended to the general public.

SPRAYING

Spraying the trees with a fungicide is generally not considered effective. The very nature of the method of introduction of the causal organism into the trees precludes this in most cases as an effective means of prevention. Apparently the bacteria are unable to penetrate the cuticle of the host tissue, and can produce infection only when a means is afforded for their entrance into the bark tissue through a wound or puncture.

It is to be noted, however, from the experiments in blossom infection previously described, that no injury to the host tissue was necessary when the bacteria were sprayed with an atomizer into the open blossoms. Waite (1898) makes the following statement with reference to blossom blight: " Beginning in the spring the germs on the new growth of the season first appear on the nectar disks of the blossoms. The bacilli live and multiply in the nectar and are able to enter the nectar glands without a puncture or injury and thus normally get inside their host."

It has been suggested that spraying into the blossoms * might tend to decrease the amount of blossom blight, the fungicide serving as a means of prevention when the bacteria are carried to the blossom by insects. Unpublished observations made by Dr. Donald Reddick, of this Department, seem to indicate that spraying might possibly be effective in reducing the amount of blossom blight. On the other hand, apple blossoms on trees growing in the greenhouse were susceptible to blight when sprayed with lime-sulfur solution, 1-40, and the following day sprayed with a bouillon culture of *Bacillus amylivorus*.

* In the State of New York it is a penal offense to spray when the trees are in blossom. This law was enacted on the assumption that spraying at this time was harmful to the bee industry: Section 1757. Penal Law. Spraying fruit trees with poison. Any person who will spray with, or apply in any way, poison or any poisonous substance to fruit trees while the same are in blossom, is guilty of a misdemeanor, punishable by fine of not less than ten dollars ($10) or more than fifty dollars ($50) for each offense."

(1898) Waite, M. B. Life history and characteristics of the pear blight germ. Proc. Amer. Assoc. Adv. Sci. **47** : 427–428. 1898.

('04) Bolley, H. L. Tree feeding and tree medication. Ann. Rept. North Dakota Agr. Exp. Sta. **14** : 55–58. 1904.

('07) Bolley, H. L. Tree feeding and tree medication. Ann. Rept. North Dakota Agr. Exp. Sta. **16** : 35. 1907.

PATENT NOSTRUMS

Certain manufacturers have placed blight remedies on the market, but as yet none of these have proved of value; in fact, in most cases those tested have been injurious to the trees themselves. The experiments of Whetzel ('09) with Callahan's blight specific proves conclusively that this substance is worthless as a blight remedy and even causes injury to the trees.

During the summer of 1910 three blight remedies were tried in the nursery, by the writer. California pear blight remedy, Warnock's tree paint, and Leffler's insecticide and blight remedy were the substances used. All were applied according to the directions given. Although the experiment was not carried to completion and the treated trees were not inoculated with the blight organisms in order to test their immunity, it suffices to state that in every case the remedies proved injurious to the trees. With the California pear blight remedy and the Leffler's insecticide and blight remedy applied in solution form to the soil, the two-years-old Bartlett trees treated were stunted at the end of the season as compared with untreated trees. In some cases part of the foliage fell prematurely. The Warnock's tree paint caused a splitting and cracking of the bark and the trees were unsalable when dug in the autumn.

It is suggested that the general use of commercial blight remedies, at least on nursery stock, be avoided except when tried experimentally on a small scale in order to test the value of the remedy.

GENERAL PLAN OF CONTROL

For the most satisfactory means of controlling fire blight, reference is made to the plan of operation outlined in a bulletin by Whetzel and Stewart ('09). Strict sanitation and an attempt to eradicate the disease from the locality affected are believed to be the most essential factors in the control of the malady. All sources of infection should be destroyed. A systematic inspection of all apple, pear, and quince stock should be made early in the spring, and trees with hold-over blight should be promptly removed and burned.

Old orchard trees of pear, apple, and quince in the vicinity of the nursery usually favor the blight, in that frequently these large trees become diseased and for years are sources of infection for nursery stock. Unless such trees are given special attention and kept free from disease by strict control methods, their presence is usually a menace to the nursery. Judging from the experiences and observations of the writer, old neglected orchard

('09) Whetzel, H. H. Fire blight remedies. Proc. West. New York Hort. Soc. 54 : 119–126. 1909.
('09) Whetzel, H. H., and Stewart, V. B. Fire blight of pears, apples, quinces, etc. New York (Cornell) Agr. Exp. Sta. Bul. 272 : 31–52. 1909.

trees should be removed from the vicinity of the nursery and every effort should be made to keep the surroundings clean and free from sources of disease. Old hawthorns and wild crab-apple trees along fence rows or in near-by pastures frequently harbor the blight. Such trees should be destroyed. Too much emphasis cannot be laid on the necessity for a thorough and systematic cleaning-up of all diseased trees before growth starts in the spring.

A regular inspection of all orchard trees should be made at least once each week during the summer, beginning as soon as the blossoms fall. Cut out all blighted twigs, shoots, and water sprouts, disinfect the cuts with corrosive sublimate 1–1,000, and burn the prunings. If all cut surfaces are disinfected, any bacteria left on them by the tools or any brought to them subsequently by insects will be destroyed.

A thorough cleaning-up and removal of all sources of disease in the early spring naturally reduces the possibility of blight infection in the nursery. However, as previously pointed out, bees and other insects frequently carry the bacteria from oozing hold-over cankers to the blossoms that often appear on the two-years-old quince stock. Since the production of fruit by such trees not only causes a stunted growth for the tree, but also furnishes a source of infection at blossoming time, it is considered good practice to pinch off or remove before they open all blossom buds from the two-years-old quince trees.

CONTROL IN NURSERY STOCK

Inspection

The plan of operation described above was successfully performed in two large nurseries in 1912. By the removal of the blossom buds it is believed that an early epidemic of the disease was prevented. This opinion is based on the fact that through oversight an occasional blossom bud was missed and was allowed to open. Later several of these blossoms were blighted. The amount of blossom blight would doubtless have been much greater if the blossom spurs had not been removed.

With the presence of the disseminating agents that greatly favor the spread of twig blight, thorough and frequent inspections of all susceptible stock become necessary in order to keep the disease under control. It is often necessary to inspect certain blocks daily, the diseased twigs being cut out as fast as they appear. In every case the cut surface should be disinfected with corrosive sublimate 1–1,000. For the work of inspection the equipment illustrated in Fig. 126 has proved very convenient. An ordinary pruning knive is used for removing the diseased twigs, which are carried away in a sack and burned. The supply of corrosive sublimate can be carried in a bottle, and the sponge used for swabbing the wound can be moistened from time to time.

With thorough and systematic inspections the number of new infections can be reduced greatly, and often by prompt and careful work in removing the first infections an epidemic can be averted completely. In cutting out new infections it is advisable to remove the entire twig, making a clean cut at the trunk; this gives greater likelihood that all the blighted tissue has been removed. Severe pruning of the young twigs of nursery trees leads to a bushy growth rather than to the ordinary development of long, unbranched shoots. When the infections have progressed rapidly down the twig, extending into the trunk of the tree, the removal of the entire tree is advisable.

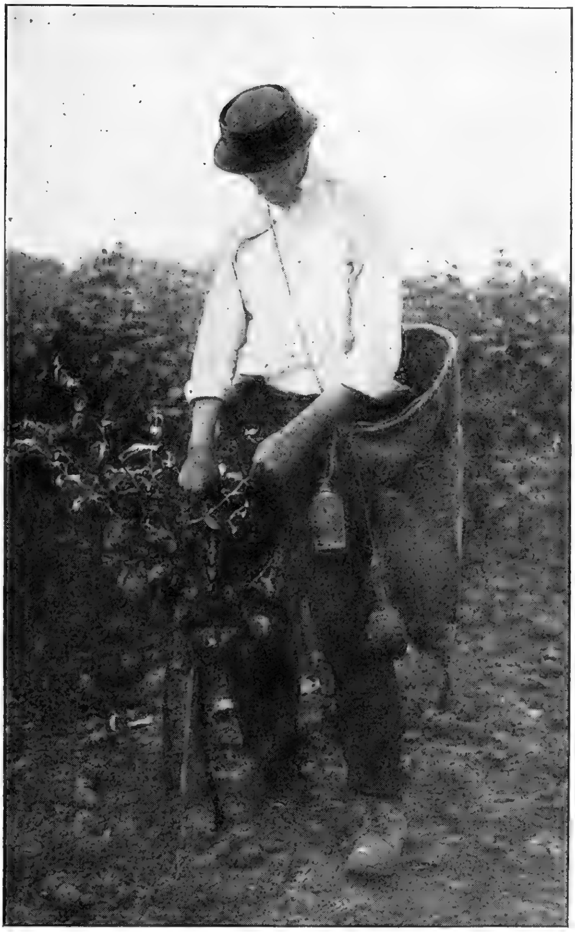

FIG. 126.— *Cutting blight from nursery stock. Note the bag for holding the blighted shoots, the bottle of corrosive sublimate, and the sponge at the end of a string*

When budded stock of the first year becomes diseased the blighted trees should be immediately grubbed out. Usually the bacteria are extremely active in such tender growth and the greater part of the tree is soon involved by the disease. Cutting back below the diseased area causes a crook in the trunk of the tree and such stock can seldom be put on the market.

The plan of blight control as discussed with reference to the removal of new infections under orchard conditions, as fast as they appear throughout the summer, has been questioned by some investigators. O'Gara ('09) has offered special criticism to this procedure. He is of the opinion that summer cutting is advisable where there is only a little blight in the orchards, but under other conditions the work is only half satisfactory. He makes the statement, apparently copied from a previous article by Waite ('06), "that summer cutting is generally a failure for the reason that new infections, invisible at the time the work is done, may develop in a few days, so that a week after the most thorough cutting out of the blight a new crop of infection is found appearing."

If badly blighted trees are given only occasional attention during the summer, practically no satisfactory results in blight control can be expected.

Data are presented in Bulletin 272 of the Cornell University Agricultural Experiment Station, which indicate that thorough, frequent, and systematic inspections of the pear orchard throughout the summer, with immediate removal of any diseased parts, will prove effective, under western New York conditions, in the control of fire blight. Observations made by various members of the Department of Plant Pathology at Cornell University, of practical attempts in control of fire blight, indicate that when the above recommendations are closely followed pear orchards may be saved.

The experience of Gammon ('12) indicates, further, that cutting out the blight in summer is practicable also in the West, despite the claims of some investigators who have worked in that section of the country. The results of active effort for seven years in the control of the disease in a large orchard in California were highly satisfactory. Careful pruning and thorough disinfection throughout the summer greatly reduced the annual loss of trees.

When the disease is once established its eradication is, as a rule, impossible. However, by inspection, as previously described, the blight can be held in check not only in orchard trees but also in nursery stock. Frequently the removal early in the season of a single blighted shoot will prevent the loss of an entire tree. Cutting out infections not only protects the remainder of the tree, but also eradicates a source of infection for neighboring trees.

In tables 6 and 7 are included a careful estimate of the number of infections occurring in apples, quinces, and pears, and also the number

('06) Waite, M. B., and Smith, R. E. Pear blight. Ann. Rept. California Fruit Growers Assoc. 31: 137–161. 1906.
('09) O'Gara, P. J. Control of pear blight on the Pacific coast. Ann. Rept. Washington State Hort. Assoc. 5 : 36–55. 1909.
('12) Gammon, E. A. Pear blight control. California Hort. Com. Mo. Bul. 1: 37-41. 1912.

of blighted trees removed, in two of the larger nurseries in New York State. In each nursery were about 150 acres of apple, quince, and pear stock. This work in nursery control was conducted during the summer of 1911, which was an epidemic year for the blight over the entire State. Frequent inspections were made and a record was kept of the number of infections cut out and the number of trees removed on each inspection. In blocks where the disease was very abundant — as, for example, among the two-years-old quinces — daily inspections were made until the blight subsided. Some blocks of two-years-old apples and pears were not inspected more than once every four or five days.

The greater abundance of blight in nursery A, as recorded in Table 6, is attributed to the fact that, with the presence of a large number of hold-over cankers on trees that had blighted in the previous year, a greater amount of blossom infection occurred in the two-years-old quinces. On the first day of inspection over two thousand blighted blossom spurs were removed. This condition naturally furnished an abundant source of infection for the blocks of apples and pears near by. In nursery B all hold-over blight had been cleaned up and the blossom infection of the quinces was not so abundant. Under such conditions the possibilities of checking the malady were more favorable.

TABLE 6. NUMBER OF INFECTIONS AND NUMBER OF TREES REMOVED, NURSERY A

Kind of stock	Number of infections	Number of trees cut out
Apple (2 years old)	540	40
Apple (1 year old)	1,700	800
Quince (2 years old)	3,500	290
Quince (1 year old)	None	None
Pear (standard 2 years old)	95	None
Pear (dwarf 2 years old)	524	10
Pear (1 year old)	None	None
Total	6,359	1,140

TABLE 7. NUMBER OF INFECTIONS AND NUMBER OF TREES REMOVED, NURSERY B

Kind of stock	Number of infections	Number of trees cut out
Apple (2 years old)	10	3
Apple (1 year old)	69	30
Quince (2 years old)	236	25
Quince (1 year old)	145	40
Pear (2 years old)	None	None
Pear (1 year old)	45	12
Total	505	110

It is evident from the above figures that a large percentage of the infected trees were saved by prompt pruning and disinfection before the disease involved the entire tree. This, of course, does not include the large number of other trees that were entirely protected from the disease by removal of the blighted trees and shoots that would have served as sources of infection had they been left.

The four years of work for blight control in the nursery lead the writer to believe that it is highly profitable to give careful attention to fire blight. Eradicating the hold-over blight, removing quince blossom buds, and inspecting diseased areas systematically will reduce the abundance of the disease, without question.

Destruction of insect agents

The elimination of certain disseminating agents is an important consideration. It has been demonstrated that controlling the aphids is frequently an essential step in preventing the spread of the blight bacteria. The greatest necessity at the present time, however, is a means of eradicating from the nursery the numerous sucking insects that occur on stock that is susceptible to fire blight. Of these blight disseminators the tarnished plant bug (*Lygus pratensis*) appears at the present time to be the most important.

BIBLIOGRAPHY

The following bibliography is by no means complete. However, it includes practically all articles that are of importance. A large number of citations have been omitted because, on consultation, they have been found to be of slight consequence or to contain no points of advance in the knowledge of the disease.

Adametz, L. Mikrococeen. Mikrococcus amylovorous Burrill. Mitt. Œst. Vers. Stat. Brau. u. Mälz. **1**: 30. 1888.

Arthur, J. C. Diseases of pear. Pear blight. Rept. New York (Geneva) Agr. Exp. Sta. **3**: 357–367. 1885.

——— Pear blight and its cause. Amer. Nat. **19**: 1177–1185. 1885.

——— Proof that bacteria are the direct cause of the disease in trees known as pear blight. Proc. Amer. Assoc. Adv. Sci. **34**: 295–298. 1885.

——— Pear blight, cause and prevention. Ann. Rept. New Jersey Hort. Soc. **1885**: 1–16. 1886.

——— Report of Botanist. Pear blight. Rept. New York (Geneva) Agr. Exp. Sta. **4**: 242–248. 1886.

——— History and biology of pear blight. Proc. Philadelphia Acad. Nat. Sci. **38**: 322–341. 1887.

——— Pear blight. Rept. New York (Geneva) Agr. Exp. Sta. **5**: 275–289. 1887.

——— Important articles on pear blight. Rept. New York (Geneva) Agr. Exp. Sta. **5**: 300–315. 1887.

Bachmann, Freda M. The migration of Bacillus amylovorus in the tissues of the host. Phytopath. **3**: 3–17. *pls. I-II. figs.* 1–2. 1913.
Barry, Patrick. Insect blight. Genesee Farmer **8**: 218. 1847.
Beecher, H. W. The blight in the pear tree: its cause and a remedy for it. Mag. Hort. **10**: 441–456. 1844.
Bolley, H. L. Tree feeding and tree medication. Ann. Rept. North Dakota Agr. Exp. Sta. **14**: 55–58. 1904.
——— Tree feeding and tree medication. Ann. Rept. North Dakota Agr. Exp. Sta. **16**: 35. 1907.
Burrill, T. J. Pear blight. Trans. Illinois State Hort. Soc. **11**: 114–116. 1878.
——— Fire blight. Trans. Illinois State Hort. Soc. **12**: 77–81. 1879.
——— Anthrax of fruit trees: or the so-called fire blight of pear and twig blight of apple trees. Proc. Amer. Assoc. Adv. Sci. **29**: 583–597. 1881.
——— Pear and apple tree blight. Trans. Illinois State Hort. Soc. **14**: 157–167. 1881.
——— Bacteria as a cause of disease in plants. Amer. Nat. **15**: 527–531. 1881.
——— Blight of pear and apple trees. Rept. Illinois Industrial Univ. **10**: 62–84. 1881.
——— Have we any new light on pear blight or yellows? Rept. Michigan State Hort. Soc. **1881**: 133–139. 1882.
——— New species of Micrococcus (Bacteria). Amer. Nat. **17**: 319. 1883.
——— Pear blight and peach yellows. Trans. Illinois State Hort. Soc. **17**: 46–49. 1884.
Chester, F. D. Notes on pear blight. Ann. Rept. Delaware Agr. Exp. Sta. **12**: 38–46. 1901.
——— Pear blight and pear canker. Delaware Agr. Exp. Sta. Bul. 52: 2–7. 1901.
——— Treatment of pear blight cankers and inoculations. Ann. Rept. Delaware Agr. Exp. Sta. **14**: 40–43. 1903.
Cook, A. J. Pear blight and bees. California Cultivator **17** : 83–84. 1901.
Cooke, S. S. Pear blight. Gardeners Monthly **9**: 73–78. 1867.
Coxe, William. Cultivation of fruit trees. Pear blight, 175–176. 1817.
Craig, J. Diseases of fruits. Apple and pear blight. Rept. Canada Exp. Farms **1896**: 168–171. 1897.
Crandall, C. S. Blight and other plant diseases. Colorado Agr. Exp. Sta. Bul. 41: 3–14. 1898.
Denning, William. On the decay of apple trees. Trans. New York Soc. Prom. Agr. Arts and Manfr. $\mathbf{1}^2$: 219–222. 1794. [Second edition $\mathbf{1}^2$: 185–187. 1801.]
Eaton, L. C. Review of opinions of pear tree blight. Hort. **1**: 459–463, 495–500. 1846.
Edwards, S. F. Bacterial diseases of fruits and vegetables. Bacterium amylovorus. Ann. Rept. Ontario Agr. Col. **32**: 136–137. 1907.
Ernst, A. H., and Downing, A. J. Fire blight in pear trees. Hort. **2**: 328–332. 1848.

Fulton, H. R. The persistence of Bacillus amylovorus in pruned apple twigs. Phytopath. **1**: 68. 1911.

Gammon, E. A. Pear blight control. California Hort. Com. Mo. Bul. **1**: 37–41. 1912.

Gookins, S. B., and Downing, A. J. Remarks on pear blight of the West. Hort. **1**: 253–256. 1846.

Halsted, B. D. Report of Botanist. Experiments with pear blight. Rept. New Jersey Agr. Exp. Sta. **19**: 352–354. 1899.

——— Report of Botanist. Experiments with pear blight. Rept. New Jersey Agr. Exp. Sta. **20**: 414–417. 1900.

——— Report of Botanist. Experiments with pear blight. Rept. New Jersey Agr. Exp. Sta. **22**: 430–433. 1902.

Hull, E. B. Cryptogamous diseases and root pruning of the pear, a preventive of blight. Trans. Illinois State Hort. Soc. **1868**: 35–37. 1869.

Isaac, John. Pear blight in California. Rept. California State Board Hort. **8**: 53–65. 1902.

Jackson, H. S. Fire blight of pear and apple. Oregon Agr. Exp. Sta. Cir. 7: 2–16. 1910.

James, J. H. Blight in pear trees. Mag. Hort. **15**: 13–23. 1849.

Jones, D. H. Bacterial blight of apple, pear, and quince trees. Ontario Agr. Col. Bul. 176: 1–63. 1909.

——— Scolytus rugulosus as an agent in the spread of bacterial blight in pear trees. Phytopath. **1**: 155–158. *pls. XXIII–XXIV.* 1911.

Jones, L. R. Studies on plum blight. Centbl. Bakt. u. Par. 2, **9**: 835–841. 1902.

Jones, L. R., and Morse, W. J. Orchard diseases and their remedies. Plum blight. Rept. Vermont Agr. Exp. Sta. **15**: 231–239. 1902.

Lawrence, W. H. Important diseases of Washington. Fire blight. Washington Agr. Exp. Sta. Bul. 83: 19–21. 1907.

Lowell, John. Pear blight. New England Farmer **5**: 17–18, 42. 1826.

Meehan, Thomas, and Hunt, J. G. Pear blight. Gardeners Monthly **17**: 245. 1875.

Morse, W. J. Diseases of plants. Crotch injury caused by weather conditions. Maine Agr. Exp. Sta. Bul. 164: 18–19. 1908.

O'Gara, P. J. Control of pear blight on the Pacific coast. Ann. Rept. Washington State Hort. Assoc. **5**: 36–55. 1909.

——— Control of pear blight on the Pacific coast. Better Fruit $\mathbf{5}^2$: 49–51, 54–56; $\mathbf{5}^5$: 30–43, 52–57. 1910.

Orton, W. A. Plant diseases in the United States in 1901. Pear blight. U. S. Dept. Agr. Yearbook **1901**: 669. 1902.

——— Disease resistance in plants. Ann. Rept. Amer. Breeders Assoc. **1**: 202–207. 1905.

Paddock, Wendall. An apricot blight. Colorado Agr. Exp. Sta. Bul. 84: 5–14. 1903.

——— An old orchard disease in a new role. Fire blight of apricot. Ann. Rept. Colorado Board Hort. **15**: 75–77. 1904.

Pierce, Newton B. Pear blight in California. Science n. s. **16**: 193–194. 1902.

Sackett, W. G. Bacterial diseases in plants. Pear blight. Michigan Agr. Exp. Sta. Bul. 230: 205–210. 1905.

——— Some bacterial diseases of plants. Pear blight. Colorado Agr. Exp. Sta. Bul. 138: 6–14. 1909.
——— Hold-over blight in the pear. Colorado Agr. Exp. Sta. Bul. 177: 2–8. 1911.
Salisbury, J. H. Pear, apple, and peach trees affected with blight. Ohio Agr. Rept. **1863:** 450–460, 469. 1864.
Shear, F. C. Apple twig blight. Garden and Forest **9:** 467–468. 1896.
Smith, E. F. Bacteria in relation to plant diseases **1:** 1–285. 1905; **2:** 1–368. 1911.
Smith, E. F., Brown, Nellie A., and Townsend, C. O. Crown-gall of plants: its cause and remedy. Crown-gall followed by hold-over blight. U. S. Dept. Agr., Bur. Plant Indus. Bul. 213: 186. 1911.
Smith, R. E. Report of Plant Pathologist. Pear blight. California Agr. Exp. Sta. Bul. 184: 221–232. 1906.
——— Report of Plant Pathologist. Pear blight. California Agr. Exp. Sta. Bul. 203: 18–24. 1909.
Smith, R. E., and Smith, Elizabeth H. California plant diseases. Pear blight. California Agr. Exp. Sta. Bul. 218: 1154–1155. 1911.
Snyder, Lillian. A bacteriological study of pear blight. Proc. Amer. Assoc. Adv. Sci. **47:** 426–427. 1898.
Stewart, J. P. Factors influencing yield, color, size, and growth in apples. Relation of fertilization to fire blight. Rept. Pennsylvania Agr. Exp. Sta. **1910–1911:** 467. 1912.
Taylor, W. A. Pear blight. Science n. s. **15:** 990–991. 1902.
Trevisan di Saint-Leon, Vittore. I generi e le specie delle batteriaceae, prodromo sinottico. Milano, 1–36. 1889.
Waite, M. B. A remedy for pear blight. Science n. s. **1:** 721. 1895.
——— Cause and prevention of pear blight. U. S. Dept. Agr. Yearbook **1895:** 295–300. 1896.
——— Fungous diseases of the apple and pear. Proc. Michigan Hort. Soc. **1897:** 186–191. 1898.
——— Life history and characteristics of the pear blight germ. Proc. Amer. Assoc. Adv. Sci. **47:** 427–428. 1898.
——— Relation of bees to the orchard. California Cultivator **18:** 390–391. 1902.
——— A new native host for pear blight. Science n. s. **25:** 286–287. 1907.
Waite, M. B., and Smith, R. E. Pear blight. Ann. Rept. California Fruit Growers Assoc. **31:** 137–161. 1906.
Whetzel, H. H. The blight canker of apple trees. New York (Cornell) Agr. Exp. Sta. Bul. 236: 104–138. 1906.
——— Fire blight and apple tree canker. Ann. Rept. Wisconsin Hort. Soc. **36:** 215–226. 1906.
——— Fire blight remedies. Proc. West. New York Hort. Soc. **54:** 119–126. 1909.
Whetzel, H. H., and Stewart, V. B. Fire blight of pears, apples, quinces, etc. New York (Cornell) Agr. Exp. Sta. Bul. 272: 31–52. 1909.
Whipple, O. B. Pear blight. Colorado Agr. Exp. Sta. Bul. 118 : 7–9. 1907.
Woods, A. F. The wastes of the farm. Pear blight. U. S. Dept. Agr. Yearbook **1908:** 209. 1909.

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