SCAB DISEASE OF APPLES

A THESIS

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

DOCTOR OF PHILOSOPHY

BY

ERRETT WALLACE

[Reprinted from Cornell Agricultural Experiment Station Bulletin 335, September, 1913]

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THE HOST

Consideration of the origin, evolution, distribution, and methods of care and cultivation of the plants affected by a specific disease is often of assistance in reaching conclusions as to the origin and history of the disease, its possible distribution, and its economic importance. In the case of the apple these facts are rather generally known or are readily obtained from various horticultural books. To residents of New York State this information is especially accessible in the excellent work by Beach (1905) entitled "The Apples of New York." It is therefore not necessary, in this bulletin, to enter into an extended discussion of these features further than to indicate in a general way the distribution and importance of the apple industry.

THE APPLE IN THE UNITED STATES

Throughout the United States the apple is more generally cultivated than is any other fruit. The range of latitude in which it can be grown and the diversity of soil suitable for apple culture makes possible this wide distribution; while the universal demand for the fruit as a staple article of diet offers a special inducement for its production.

The census report for 1910 shows that apples are being grown in every state and territory in the Union except Alaska. In some of these localities, however, such small quantities are produced that the industry cannot be considered to be of commercial importance. Among these may be mentioned Florida, Louisiana, Wyoming, Arizona, Nevada, and North Dakota, in each of which States less than 100,000 bushels of apples were produced in 1909.

The accompanying table, compiled from the Thirteenth Census Report, shows the production of the leading apple-growing States in 1909 and in 1899, together with the total production in the United States for those years:

* Also presented to the Faculty of the Graduate School of Cornell University, June, 1911, as a major thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

(1905) Beach, S. A. The apples of New York. Vol. I. New York (Geneva) Agr. Exp. Sta. Rept. 1903:2:1–409.

TABLE I. PRODUCTION OF APPLES IN 1909 AND IN 1899

	1909		1899
	Production (bushels)	Value	Production (bushels)
United States	147,522,318	$83,231,492	175,397,600
New York	25,409,324	13,343,028	24,111,257
Michigan	12,332,296	5,969,080	8,931,569
Pennsylvania	11,048,430	5,557,616	24,060,651
Missouri	9,968,977	4,885,544	6,496,436
Kentucky	7,368,499	3,066,776	6,053,717
Iowa	6,746,668	3,550,729	3,129,862
California	6,335,073	2,901,662	3,488,208
Virginia	6,103,941	3,129,832	9,835,982
North Carolina	4,775,693	2,014,670	4,662,751
Ohio	4,663,752	2,970,851	20,617,480
Tennessee	4,640,444	2,172,475	5,387,775
West Virginia	4,225,163	2,461,074	7,495,743
Maine	3,636,181	2,121,816	1,421,773

THE APPLE IN NEW YORK

In New York State the apple has assumed an important place in recent years. It is the basis on which rests an industry that has made independent thousands of farmers throughout the State and has given to many communities a general air of prosperity and thrift, for which the rural sections of this State, as a rule, are noted. In western New York, particularly, the soil and the climate are so well adapted to apple-growing that the industry has assumed notably large proportions. In this State the two great commercial varieties, Baldwin and Rhode Island Greening, flourish; however, although taking the lead, these are by no means the only varieties of importance.

The Thirteenth Census shows that New York produced in 1909 more than twenty-five million bushels of apples, worth over thirteen million dollars. This production is more than twice that of any other State. The production of all orchard fruits in the State amounted to 29,456,291 bushels, with a value of $17,988,894. It is therefore evident that the apple is of much greater commercial importance in New York State than are all other orchard fruits combined.

THE DISEASE

NAMES APPLIED

The disease, which is known as scab, black spot, scurf, or the fungus, and which has in some cases been called rust, occurs on the leaves and the fruit, and occasionally has been found on the twigs, of the apple. The name "scab" is used almost exclusively in the United States and is the name that will be used in this account.

HISTORY

The scab disease apparently exists in every country where apples are grown. It was reported early in the nineteenth century by Fries (1819) from Sweden, and some years later by Wallroth (1833) from Germany. The first authentic record from America is by Schweinitz (1834), who reports scab on Newton Pippins in New York and Pennsylvania. The disease was first noticed in England in 1845, according to Berkeley (1855), and in Australia in 1862, according to McAlpine (1902). Its introduction into Australia was attributed to a Seckel pear imported from America; this is doubtful, however, since the scab disease of the pear has since been shown to be entirely distinct from that of the apple.

SYMPTOMS

On the leaves

The scab is likely to appear earliest on the lower side of the leaves. The diseased area usually appears first as an olive discoloration slightly darker than the normal surface of the leaf. The color deepens with age until dark brown or black is reached, the spot having a more or less velvet-like appearance. As noted by Aderhold (1896), on the lower side of the leaf there is a tendency for the lesion to extend along the veins and the midrib and to diffuse irregularly and indefinitely into the healthy area; whereas on the upper surface of the leaf the lesion appears first as a slight olive-green discoloration, of a lighter shade of green than the healthy surface of the leaf but dull and somewhat velvety. The natural luster characteristic of the upper surface of the leaf is destroyed. The spots may be few and scattered; or they may be so numerous as to coalesce, coating almost the entire surface. The diseased areas may be distinctly bordered or they may spread out irregularly and indefinitely into the healthy part of the leaf. In Plate I, Plate II, Fig. 1, and Plate III, Fig. 2, are shown various types of infestation, on both the upper and the lower surfaces of the leaves.

Later the scab spots become darker, changing to brown and finally, in some cases, to nearly black. In some cases the natural form of the leaf

(1819) Fries, Elias. Spilocæa Pomi Fr. Nov. fl. Suec. 5:79.
(1833) Wallroth, F. G. Cladosporium dendriticum W. Fl. crypt. Germ. 2:4:169.
(1834) Schweinitz, L. D. de. Spilocæa fructigena aut Pomi Lk. Syn. F. N. A., p. 297.
(1855) Berkeley, M. J. Why do pears and apples crack? Gard. chron. 1855:724.
(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25:881.
(1902) McAlpine, D. The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. 1:703-708.

is not destroyed; in other cases some distortion results. Very often the diseased surface protrudes, forming a convex surface with a corresponding concavity on the opposite side of the leaf. In time the tissue under many of the diseased spots is killed outright, forming dead areas, which often crack as shrinkage occurs. This condition is most common near the close of the season. In extreme cases considerable defoliation may result (Plate II, Fig. 2).

On the fruit

The lesion on the fruit usually appears from the first as a darker-colored spot than is produced by the disease on the leaves. Sometimes the spots are almost black when first visible; or they may be dark olive, changing to reddish brown or black. The spots are usually very small at first and they enlarge more slowly than do those on the leaves. They are more sharply bordered on the fruit than on the leaves (Plates IV and V).

As the scab spot on the fruit grows older its appearance changes markedly. The central and older part becomes bare, brown, and corky, while the margin is black. A more or less whitish band, due to the loosened cuticle, may surround the black margin (Plate VI, Fig. 2). Sometimes the scab spots may enlarge so as to cover rather large areas and cracking of the fruit results, due to excessive loss of moisture content from the underlying unprotected tissues (Plate III, Fig. 1).

Scab spots resulting from late autumn infection differ somewhat in appearance from those developing early while the fruit is very young. The spots as they first appear are more dense and black. Often they will have enlarged considerably before the cuticle is ruptured. They seldom reach the stage described above, in which the center becomes bare and brown (Plate VI, Fig. 1).

On the twigs

The disease rarely occurs on the twigs, at least in many localities. Affected twigs have, in general, a scurfy appearance. The bark becomes blistered and later ruptured in places, presenting an appearance similar to scabby pear twigs, which are very common. The occurrence of twig infection is discussed at greater length elsewhere in this bulletin.

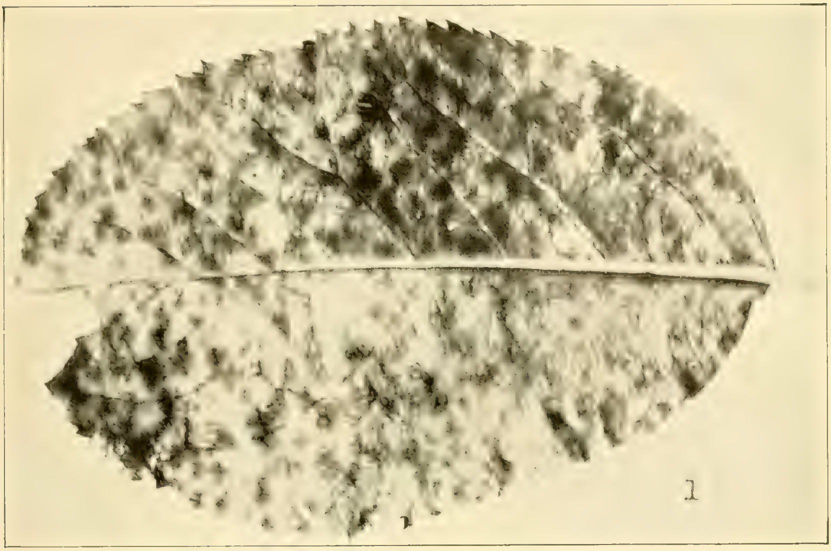
IMPORTANCE

General estimates of loss

McAlpine (1902) estimated the annual average loss due to apple scab in Victoria, Australia, at £40,000 (approximately $194,000), which is

(1902) McAlpine, D. The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. 1:705.

PLATE I.— *Apple-scab disease on leaves. Showing various types of lesions on both upper and lower sides. Photograph made in 1908. Somewhat reduced*



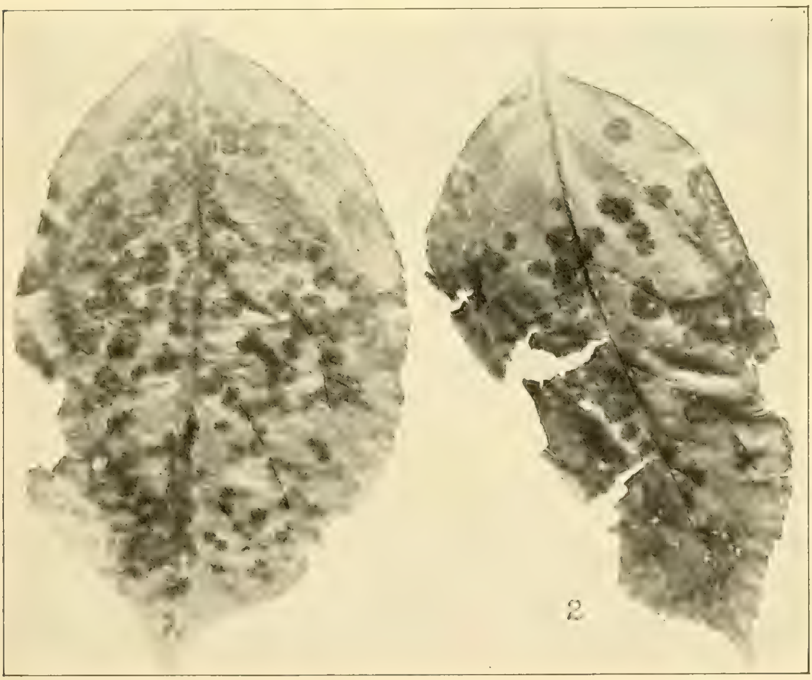


PLATE II. FIG. 1.—*A severe infestation of scab artificially produced by inoculation of protected foliage with ascospores of Venturia inæqualis. Photograph made twenty days after inoculation. Natural size*

FIG. 2.—*Badly infested leaves as they appear late in the season. Photograph made on August 15, 1908. Natural size*

PLATE III. FIG. 1.— *Severe infestation of scab. The fruit is cracked in places, while the old spots appear corky. Many of the spots are small, the result of late infection. Photograph made on October 14, 1908. Natural size*

FIG. 2.— *Scab lesions on upper surface of leaf only, producing a cup-like effect beneath. A common occurrence in cases of severe infestation. Photograph made by Fisher, August 7, 1912. Natural size*

PLATE IV.— *Cluster of badly scabbed apples showing typical lesions. Photograph made by Whetzel, July 31, 1906. Natural size*

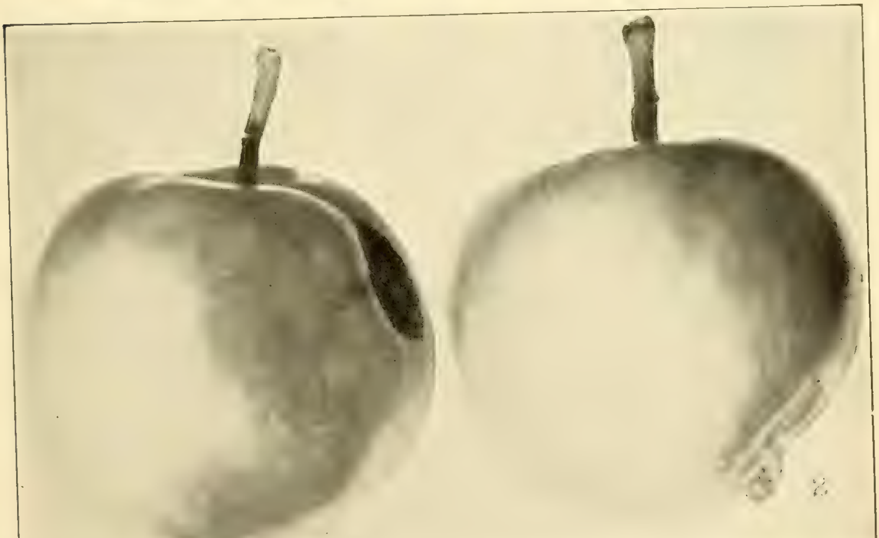


PLATE V. FIG. 1.— *Successive stages in the development of scab lesions. A photomicrograph of the lesion on the upper left apple is shown in Plate VIII, Fig. 6. Photograph made on July 1, 1908. Natural size*

FIG. 2.— *Showing the dwarfing effect of a single scab lesion on the side of an apple. Photograph made by Fisher, August 7, 1912. Natural size*

PLATE VI. FIG. 1.— *Scab lesions on fruit. Late, secondary infections are becoming prominent. Photograph made in the autumn of 1909. Natural size*

FIG. 2.— *Showing the action of the scab fungus in lifting the cuticle of the apple, thus allowing evaporation. Photograph made by Whetzel, July 31, 1906. Enlarged twice*

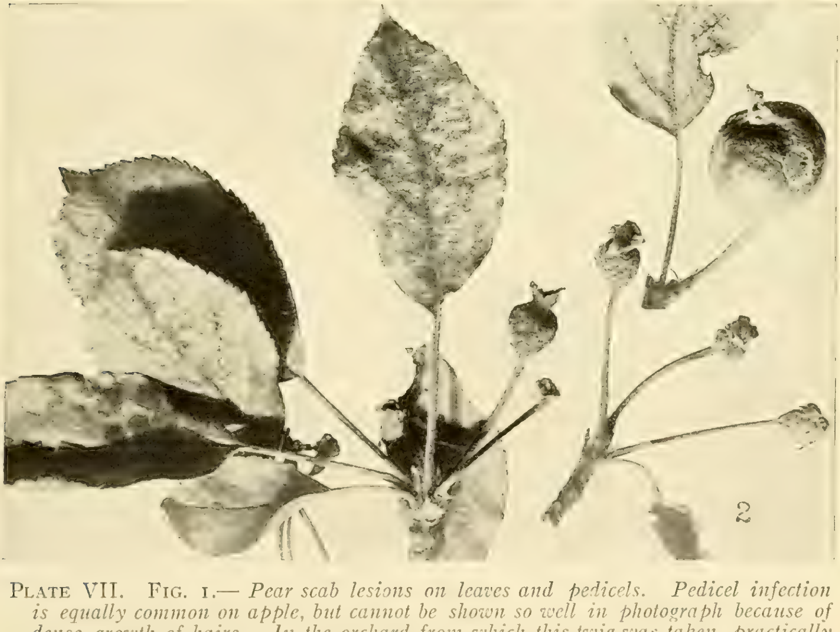


PLATE VII. FIG. 1.— *Pear scab lesions on leaves and pedicels. Pedicel infection is equally common on apple, but cannot be shown so well in photograph because of dense growth of hairs. In the orchard from which this twig was taken, practically no fruit set because of the attack on the pedicels. Photograph made on June 1, 1909. Natural size*

FIG. 2.— *Fruit pedicels and foliage severely infected at an early stage with the scab fungus. The apple in the upper right corner not so severely attacked. The fruit will never mature. Photograph made on August 15, 1908. Somewhat reduced*

equivalent to $48.50 an acre. Stevens and Sherman (1903) state that one grower reports an increase of $1000 in value of his crop due to spraying, at an outlay of $125 to $150; and that in the State of Illinois apple scab is estimated to have caused $6,000,000 damage in one year, or sixty per cent of the total loss through all enemies. Marlatt and Orton (1906) state that the loss from scab amounts to many million dollars each year. Scott and Quaintance (1907) estimate that scab often affects fifty to seventy-five per cent of the fruit over wide areas, and not infrequently causes total failure of the crop by killing the young fruit when in blossom or soon after. Gossard (1908) estimates a net profit of $3 to $7 for each tree, due to spraying for control of insects and disease, at a cost of 30 to 50 cents for each tree.

Estimates of loss in New York

Some interesting figures in regard to the importance of scab disease, as shown by the gain due to spraying apple orchards, are to be found in the reports on orchard surveys of Orleans and Niagara counties. Warren (1905) reports an average gain of $47 an acre, in 1904, in orchards sprayed three times over those not sprayed. This is included in a study of 564 orchards containing 4881 acres. Since it was thought that other forms of neglect might be correlated with that of omitting the spray, another count was made including only those orchards that were well cared for in other ways. The difference in this case was $81 an acre in favor of orchards sprayed three times. Evidently, then, the profit from spraying well-cared-for orchards is greater than that from spraying those otherwise neglected. This is what should be expected, since trees properly cared for are better able to produce a larger quantity of fruit than those not well cared for. The cost of spraying was estimated at $6.77 an acre, leaving an average net gain of $40.23 including all orchards and of $74.23 including only orchards otherwise well cared for.

Here, of course, it is impossible to separate the percentage of gain due to the control of scab from that due to the control of the codling moth, since the disease and the insect are controlled by a combination spray. An attempt was made to correlate the percentage of scab with the yield of fruit and the income for each acre. It was found that orchards having no scab to 5 per cent of scab gave an average income of $143 an acre, with a yield of 382 bushels; while those having 76 to 100 per cent of scab

(1903) Stevens, F. L., and Sherman, Jr., Franklin. Insect and fungus enemies of the apple, pear, and quince, with methods of treatment. North Carolina Agr. Exp. Sta. Bul. 183:66.
(1905) Warren, G. F. An apple orchard survey of Orleans county. Cornell Univ. Agr. Exp. Sta. Bul. 229:478.
(1906) Marlatt, C. L., and Orton, W. A. The control of the codling moth and apple scab. U. S. Agr. Dept. Farmers' bul. 247:12.
(1907) Scott, W. M., and Quaintance, A. L. Spraying for apple diseases and the codling moth in the Ozarks. U. S. Agr. Dept. Farmers' bul. 283:20.
(1908) Gossard, H. A. Spraying apples. Ohio Agr. Exp. Sta. Bul. 191:103–125.

gave an average income of only $88 an acre, with a yield of 248 bushels. This shows an apparent loss of $55 an acre where scab was abundant. It is probable, however, that the scabby orchards were unsprayed, and therefore suffered from the codling moth also. It is seen likewise from the figures given that these pests reduced the quantity of the yield 134 bushels an acre.

Cummings (1909) made similar estimates in his survey of Niagara county. Here unsprayed orchards gave an average yield of 261 bushels with an average income of $45 an acre, while three sprayings resulted in a yield of 577 bushels and an income of $171 per acre; a gain in yield of 316 bushels and in income of $126 an acre.

Cummings finds that there are in Niagara county about 24,190 acres in apples, and on this acreage about one fifth of the orchards are unsprayed. From this it may be estimated that the loss in the 4838 acres of unsprayed orchards in Niagara county would aggregate $609,588. An estimate similarly made from the figures already referred to by Warren for Orleans county shows that the loss suffered by unsprayed orchards in that county during the season of 1904 was about $287,616.

These are apparently very moderate estimates. Only the difference between orchards unsprayed and those sprayed three times was considered. Many orchards were ineffectively sprayed; they also suffered much loss and were not included in these estimates.

Taking Orleans county as a basis from which to work, the writer has attempted to estimate roughly what may be the total annual loss due to neglect of spraying in New York State and in the United States. As shown above, the loss in Orleans county in 1904 was $47 an acre. According to the census of 1900 there were in New York State at that time 15,054,832 apple trees of bearing age. Warren found that there are, on an average, slightly more than forty trees per acre, from which it may be estimated that there were about 376,370 acres of apple orchards in the State. Cummings found one fifth of the orchards in Niagara county unsprayed. Since that is one of the most progressive fruit-growing counties in New York, there is no doubt that it would be a conservative estimate to say that one fifth of the orchard area of the State is unsprayed, making a total of 75,274 acres on which a loss of $47 an acre would be suffered. This gives $3,537,878 as an estimate of the annual loss to this State through neglect of spraying. This estimate represents only the loss where no spraying is done. Many thousands of acres are ineffectively sprayed, and if the loss on these could be estimated it would add much to the aggregate.

(1909) Cummings, M. B. Apple orchard survey of Niagara county. Cornell Univ. Agr. Exp. Sta. Bul. 262:277–320.

Figuring on a similar basis for the United States, it is found in the same census that there were 201,704,764 apple trees on 5,044,869 acres. One fifth of this acreage gives 1,008,973.8 acres of unsprayed orchard, on which the loss at $47 an acre would amount to $47,421,768.60.

These estimates are based on by far the lower of the figures showing the average loss found to exist in the two cases cited above. According to figures of Cummings for Niagara county, in 1905 there was a gain of $126 an acre in the income from sprayed over that from unsprayed orchards. If this amount is considered as representing the average loss through neglect of spraying, the figures given here would be increased very materially. The writer has chosen the more conservative estimate, however, and believes he is safe in stating that New York alone loses over three million dollars annually through this one form of neglect on the part of its apple-growers, and that a corresponding loss of over forty-five million dollars is suffered by growers throughout the United States.

It is of course impossible to determine what proportion of this loss is due to scab. In the northern States scab is the all-important fungous disease of the apple and is the cause of a large proportion of the loss; while in some of the more southern States other diseases, such as bitter rot, blotch, and the like, outrank scab in importance. While the codling moth is generally distributed throughout the United States and is very destructive, a large percentage of wormy apples are also scabby and the disease alone would be responsible for great loss even if there were no codling moth.

Nature of the loss

Ordinarily the reduction in quality of scabby apples is considered to be the main cause of loss. This, while it is important, is only one of the several factors. It will be shown later that early scab infection, if not controlled, in some years almost entirely prevents the setting of fruit; it also very materially reduces the size of individual apples, while a single lesion retards growth on the affected side and causes unsymmetrical development (Plate V, Fig. 2). The unmistakable dwarfing effect has been apparent in experimental work during two epidemic years of apple scab, when it was noticed that apples from unsprayed trees were uniformly smaller than those from sprayed trees. Green (1891) determined that there was a loss in size of fifty per cent on scabby fruit as compared with sound fruit.

A fourth important factor of loss to be considered is the effect on the keeping qualities of the fruit. This effect is indirect, in that the disease furnishes a point of entrance for *Cephalothecium roseum*, the pink-rot organism, *Penicillium expansum*, the brown ripe-rot fungus, *Sphaeropsis malorum*, the black-rot fungus, and other organisms.

(1891) Green, W. J. The spraying of orchards. Ohio Agr. Exp. Sta. Bul. 4:9: 193–212.

In addition to the immediate effect on the crop of the current year, there is doubtless, in case of severe leaf infection, a devitalizing effect on the tree as noted by Bailey (1895, pp. 13–14). To some degree this prevents the formation of fruit buds for the following year and hinders the normal wood growth which is the basis for future crops.

Loss of fruit set due to the disease

The majority of apple-growers have believed for years that the occurrence of cold rains during the blossoming period is the cause of failure of fruit to set. There is ample evidence, however, that the scab disease occurs abundantly on the pedicels in certain years — as in 1910 — and causes the blossoms or the young fruit to fall (Plate VII, Figs. 1 and 2, and cover-page figure). It is even claimed by Reddick (1913) that cold rains at blossoming time are not a factor in the setting of fruit, but that the scab disease is the factor involved. The following instances may be cited as showing that destruction of the blossoms and the young fruit by scab furnishes an important source of loss, which is often overlooked because of the inconspicuous character of the disease at this stage or is attributed to various causes such as poor pollination, bad weather, and the like:

A general failure of the apple crop apparently due to this cause is noted by Bailey (1895) to have occurred during the summer of 1894. In regard to the cause of this failure Bailey writes (on page 20 of the bulletin cited): "I have visited over twenty orchards in the western part of the State this year in which there were large crops of excellent quality, but all of these had been sprayed with paris green or bordeaux mixture, or both, all of them were pruned and the land was in 'good heart.'" In general the orchards were almost barren in that year, and the smallness of the crop was usually in proportion to the degree of neglect to which the orchards were subjected. In another place Bailey states (on page 10): "But the immediate cause of most of our apple failures of the last few years, is undoubtedly the apple scab fungus." Again (on page 18): "The best proof that the apple scab fungus is the immediate cause of the greater part of the apple failures of western New York is afforded by the fact that thorough spraying with bordeaux mixture is usually followed by a great increase in the productiveness of the orchard." While it is not stated here just how the disease so greatly decreased the productiveness of the orchards, there is no doubt that the decrease was brought about principally by the occurrence of scab on the pedicels of the blossoms or the young fruit at an early stage, causing them to fall.

(1895) Bailey, L. H. The recent apple failures of western New York. Cornell Univ. Agr. Exp. Sta. Bul. 84: 1–34.
(1913) Reddick, D. The apple scab situation. West. New York Hort. Soc. Proc. 58: 86–90.

Lodeman (1895) cites an instance in which the crop was entirely destroyed by this form of attack, as shown by the fact that unsprayed trees bore no fruit while there was a large crop on trees properly sprayed.

Marlatt and Orton (1906) state that "the yield of fruit per tree is greatly lessened whenever scab is present: (1) by the premature dropping of young apples, due to the attacks of the scab fungus on flowers, stems, and fruits soon after the blossoms fall; (2) by the smaller size of the scabby apples that mature; and (3) by the loss, just before picking, due to the fact that scabby fruit does not cling well to the tree."

Scott and Quaintance (1907) note that scab not infrequently causes total failure of the crop, by killing the young fruit when in blossom or soon after.

Gossard (1909) reports that scab disease caused a large proportion of the young fruit to fall from unsprayed Winesap trees almost as soon as it had set.

Taft and Wilken (1909), in their report for 1908, make the following statement: "If the early spraying was done at the proper time, the work of the fungus which attacks the blossom stem and causes the blossom to drop was prevented."

Selby (1910) states that scab often causes the young fruit to fall, and that often this falling or failure of the fruit to set, which is attributed to frost injury or poor pollination, is really due to scab.

Pink rot following scab

This is another important factor for consideration in connection with the causes of loss due to apple scab. The first serious outbreak of pink rot apparently occurred during the season of 1902 and was reported almost simultaneously by Eustace (1902) of Geneva and by Craig and Van Hook (1902) of Cornell University. The fungus causing the disease, *Cephalothecium roseum* Cda., was found to attack the apple almost entirely through wounds in the cuticle and in the epidermis caused by scab. The fungus had formerly been considered a saprophyte, although Aderhold (1899) had reported a case in which it caused rot of pears following scab infection.

(1895) Lodeman, E. G. The spraying of orchards. Cornell Univ. Agr. Exp. Sta. Bul. 86:119.

(1899) Aderhold, Rudolf. Arbeiten der botanischen abteilung der Versuchsstation des Kgl. pomologischen Instituts zu Proskau. Centbl. bakt. 2:5:522.

(1902) Eustace, H. J. A destructive apple rot following scab. New York (Geneva) Agr. Exp. Sta. Bul. 227:367–389.

(1902) Craig, John, and Van Hook, J. M. Pink rot, an attendant of apple scab. Cornell Univ. Agr. Exp. Sta. Bul. 207:157–171.

(1906) Marlatt, C. L., and Orton, W. A. The control of the codling moth and apple scab. U. S. Agr. Dept. Farmers' bul. 247:12.

(1907) Scott, W. M., and Quaintance, A. L. Spraying for apple diseases and the codling moth in the Ozarks. U. S. Agr. Dept. Farmers' bul. 283:20.

(1909) Gossard, H. A. Apple spraying in 1908. Ohio Agr. Exp. Sta. Circ. 95:4.

(1909) Taft, L. R., and Wilken, F. A. Annual report of the South Haven sub-station for 1908. Michigan Agr. Exp. Sta. Spec. bul. 48:16.

(1910) Selby, A. D. A brief handbook of the diseases of cultivated plants in Ohio. Ohio Agr. Exp. Sta. Bul. 214:371.

According to the three authors first named above, apple scab had been very common during the summer of 1902. Late in the season, in August and September while the fruit was yet on the trees, it was observed, as stated by Eustace, that on some of the scab spots there appeared a white or pinkish, mildew-like growth. A little later this growth produced a brown, sunken, bitter rotten spot. On very scabby apples these spots soon coalesced and the fruit became a mass of decay.

Some rot develops in the fruit while it is on the trees, as stated above, but the greater destruction occurs soon after the fruit has been stored or while it is in piles on the ground. The occurrence of this disease has been common to a greater or less degree since 1902. During the season of 1910 considerable pink rot developed in many sections of the State where scab was not kept well under control.

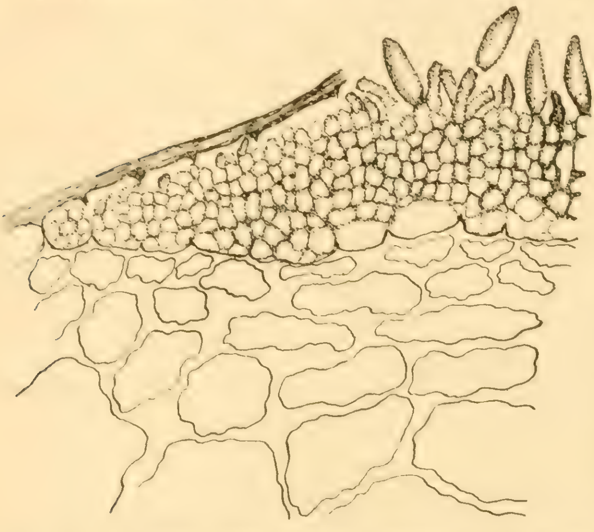


FIG. 182.— *Conidial stage of Venturia inæqualis. The section through a scab spot shows the fungus stroma located beneath the cuticle and in the epidermal cells, conidiophores, and the development of conidia. The growth of the fungus, especially the development of conidia, lifts the cuticle. A few of the conidiophores show the scars where spores were developed earlier in the season. (See also Plate VI, Fig. 2.) Camera lucida drawing*

ETIOLOGY

Morphology

The apple-scab disease is caused by the fungous pathogen *Venturia inæqualis*. The mycelium of the fungus is in some cases hyaline when young, but it soon becomes tinted and varies from olivaceous to reddish brown. It is septate, branches very irregularly, and is subject to modifications as influenced by environment, varying particularly in the different stages of the life cycle of the fungus. The hyphæ vary from 3 to 5 μ in diameter in the living host, but in the dead leaves they may be as much as twice this size (Plates IX and X). In the living host the mycelium will be found, in the early stages on leaves, confined to a region between the cuticle and the epidermal cells; on the fruit the epidermal cells are attacked and usually destroyed.

Previous to the formation of conidia this subcuticular mycelium divides into one or more layers of densely packed, rounded, and at first hyaline cells (stroma), from which the conidiophores are produced (Fig. 182). The outer layers later take on a brownish tint. On the leaves this stroma may consist of only one layer of cells, but more than one layer is likely

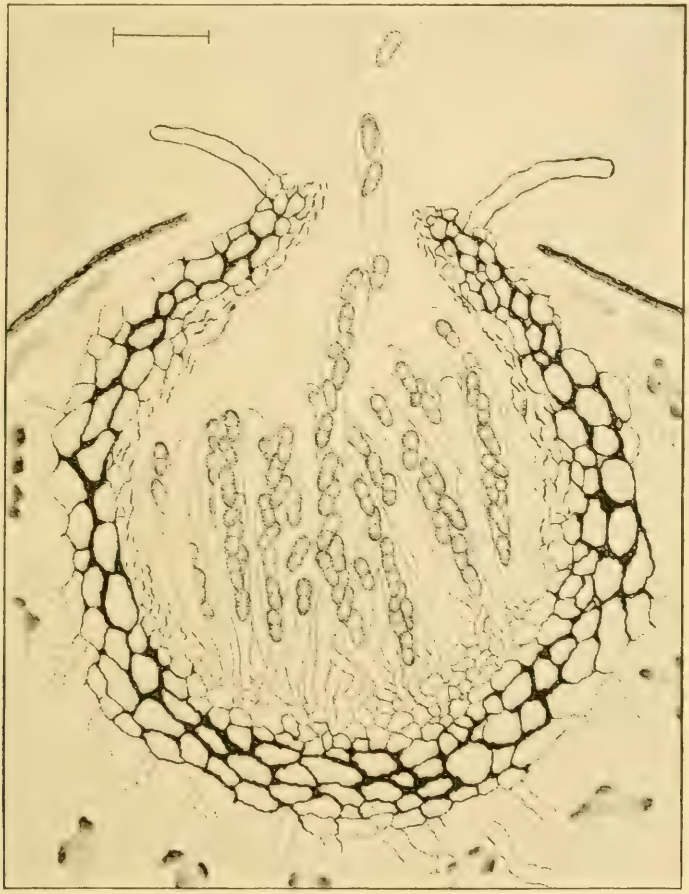


FIG. 183.— *Mature perithecium of Venturia inæqualis. The section shows the method of formation of asci, mature ascospores, the method of ejection of ascospores, and the bristles that sometimes occur about the ostiole. Outlined with a camera lucida*

to occur over the veins or the firmer parts of the leaves. On the fruit the number of layers is much greater, due apparently to the fact that the thicker cuticle offers a greater resistance which is not overcome until the time for the formation of more cells has elapsed. This resistance is apparently overcome partly by means of a solvent action of the fungus (as shown in Fig. 182, where the cuticle is found to have been eaten away from beneath, directly over the subcuticular mycelium), and partly by the pressure exerted which finally pries the cuticle loose. The conidiophores that arise from these cells are reddish brown in color and while young are somewhat ovate in form. They have an inner hyaline wall which protrudes from the apex to form the spore. At first the spores are hyaline and are rounded in a sac-like manner at the free end, but later they become reddish olive-colored and are mostly lanceolate but somewhat irregularly so and variable in form. They are mostly unicellular, but in the later stages a septum is often formed. They are rather variable in size, measuring 12 to 22 μ in length by 6 to 9 μ in breadth. The form and general appearance of the conidiophore changes with its age and the number of conidia that it has produced. The older conidiophores assume a more or less irregular form, showing a distinct knee and a change in the axis of growth at the point where each spore was borne. They are usually unicellular, but sometimes old conidiophores become septate.

The perithecia are imbedded in the tissue of the leaf, usually protruding sufficiently to form a small dome-shaped pimple (Fig. 183) which is sometimes large enough to be easily visible to the naked eye but at other times only discernible by the aid of a lens. They are spherical or subspherical, 90 to 160 μ in diameter, with a somewhat beak-like projection at the ostiole. Six or more simple tapering bristles 25 to 75 μ in length sometimes surround the ostiole. The perithecial wall is dark olive-green to brown in color, with polygonal reticulations. The asci are oblong to clavate, often somewhat curved, 55 to 75 μ by 6 to 12 μ, without paraphyses. The ascospores are olive-brown, two-celled, with the upper cell somewhat broader than the lower, 11 to 15 μ by 5 μ. There are eight ascospores in each ascus.

Nomenclature

As early as 1819 Fries (1819) applied the name *Spilocæa Pomi* to the conidial stage of the apple-scab fungus. Wallroth (1833) described the same fungus under the name *Cladosporium dendriticum*. Fuckel (1869) transferred the fungus to the genus Fusicladium and called it *Fusicladium dendriticum* (Wallr.) Fckl. Cooke (1866) described the ascigerous stages of the forms occurring on both apple and pear as *Sphærella inæqualis*. Clinton (1901) notes that Winter seems to have been the first to place the species under the genus Venturia, since the specimens on apple leaves distributed in 1880 in von Thümen's Mycotheca Universalis No. 1544 are

(1819) Fries, Elias. Spilocæa Pomi Fr. Nov. fl. Suec. 5: 79.
(1833) Wallroth, F. G. Cladosporium dendriticum W. Fl. crypt. Germ. 2:4:169.
(1866) Cooke, M. C. Sphærella inæqualis Cke. Journ. bot. 4:248–249.
(1869) Fuckel, L. Fusicladium dendriticum (Wllr.). Symb. myc., p. 357.
(1880) Winter, Georg. Venturia inæqualis Wint. Myc. uni., von Thümen, no. 1544.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:123.

PLATE VIII.— *Perithecial stage of Venturia inæqualis*

FIG. 1.— *Photomicrograph of the under surface of a leaf thickly dotted with perithecia of Venturia inæqualis*

FIG. 2.— *Same as Fig. 1, except that dehiscence has occurred in a circumscissile manner leaving cavities in the leaf. The saucer-shaped base of the perithecium was found in some of these*

FIG. 3.— *Same leaf as is shown in Fig. 1, showing perithecia on upper surface of the leaf*

FIG. 4.— *Photomicrograph of a perithecium in action. The perithecium was pricked out of the leaf with a needle and was placed in a drop of water on a glass slide. The photograph was made while spores were being discharged*

FIG. 5.— *Photomicrograph of a free-hand section through a perithecium. This shows the elongation of asci that occurs when moisture is present*

FIG. 6.— *Photomicrograph of the very young scab spot shown in the upper left apple in Plate V, Fig. 1. Shows how the cuticle is lifted by the growth of the fungus*

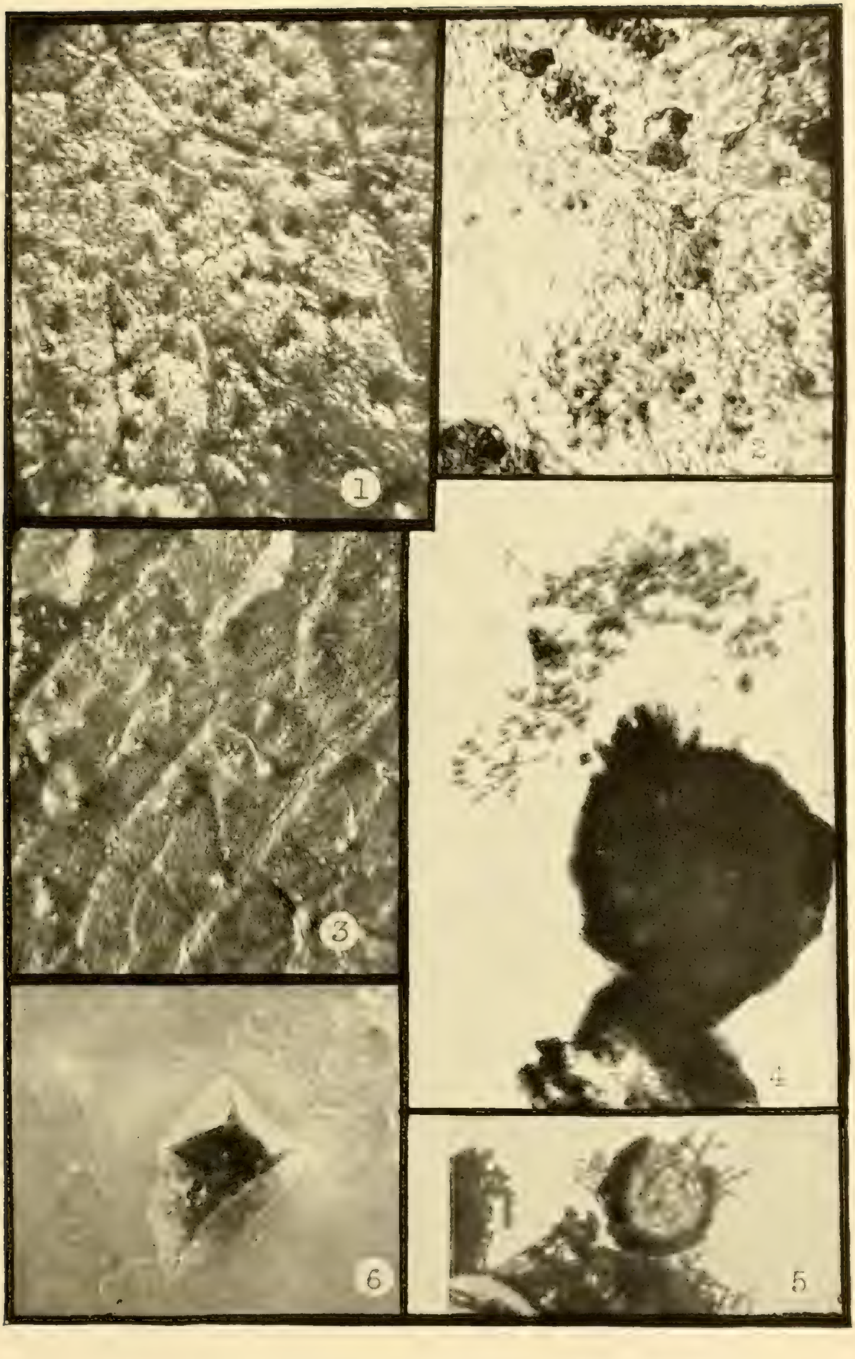


Plate VIII.— *Perithecial stage of Venturia inæqualis*

PLATE IX.— *Germinating ascospores of Venturia inæqualis. Ascospores discharged from perithecia in old leaves were caught on agar plates and allowed to germinate*

FIG. 1.— *Average germination after twelve hours*
FIG. 2.— *Average germination after thirty-one hours*
FIG. 3.— *Average germination after forty-two hours*

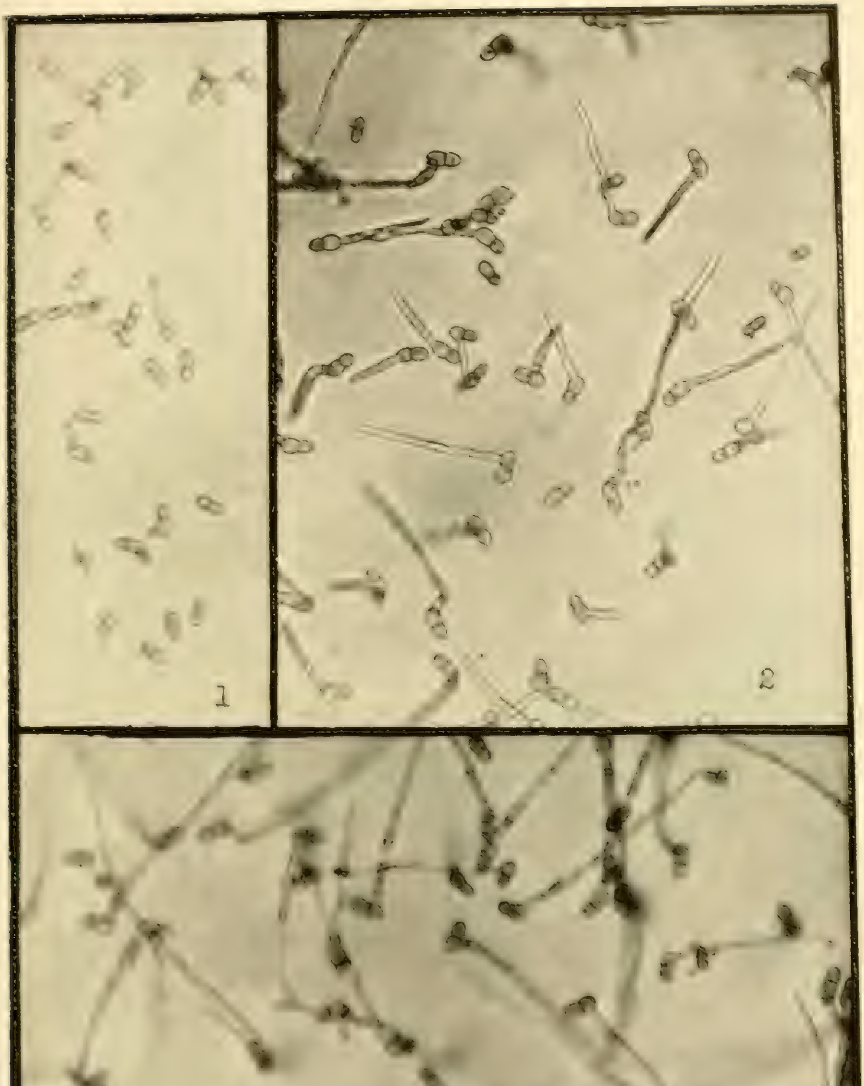


PLATE IX. — *Germinating ascospores of Venturia inaequalis*

PLATE X.— *Same as Plate IX*

FIG. 1.— *Average germination after fifty-one hours*
FIG. 2.— *Average germination after seventy-two hours*
FIG. 3.— *Average germination after one hundred and twenty hours*
FIG. 4.— *Mycelium and spores more highly magnified*

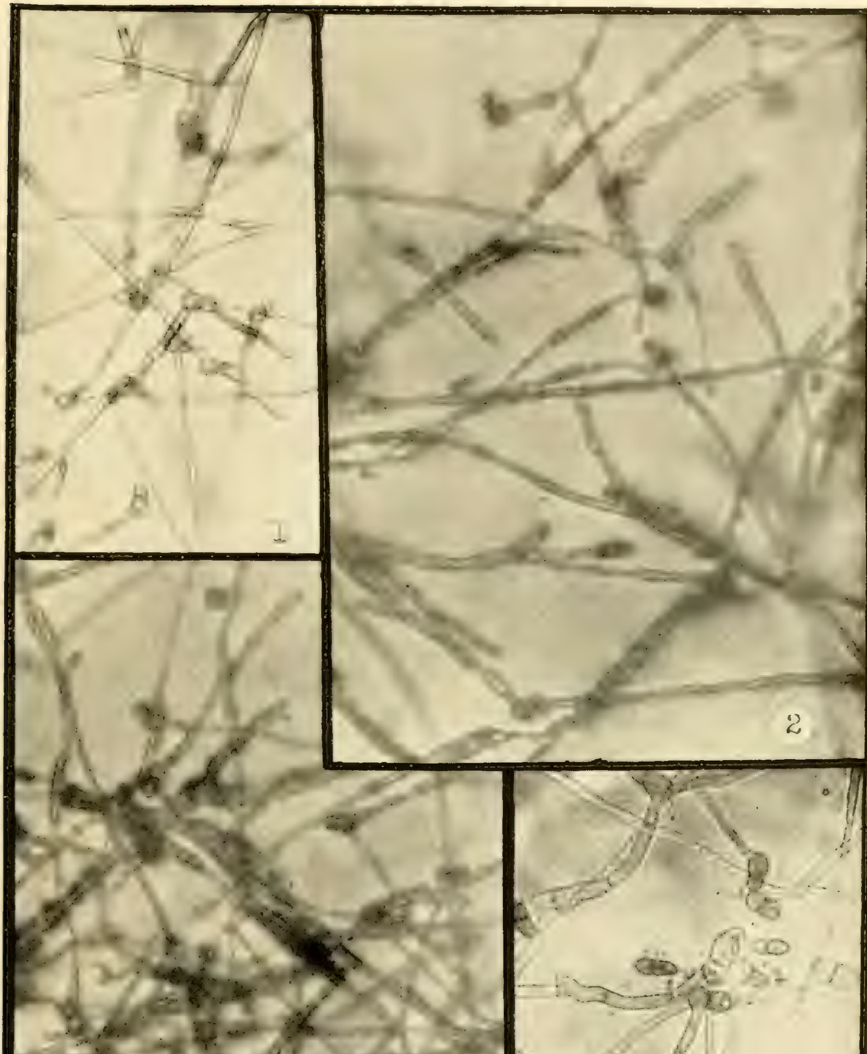


PLATE X.— *Germinating ascospores of Venturia inæqualis*

called *Venturia inæqualis* Wint. in litt. Aderhold (1897) also places this fungus in the genus Venturia, calling it *V. inæqualis* (Cke.) Ad., apparently not knowing that it had been listed previously by Winter.

From the work of Aderhold (1894) it is known that *Fusicladium dendriticum* is merely a conidial stage of a perithecia-forming fungus of the genus Venturia. According to present rules of nomenclature, then, the fungus should be known as *Venturia inæqualis* (Cke.) Wint.

Relationships and host plants

Aderhold (1900) states that *Fusicladium dendriticum* occurs on many *Pyrus* species of the *Malus* group (*P. spectabilis* Ait., *P. Kaido* Sieb., *P. floribunda* Sieb., *P. baccata* L., *P. prunifolia* Willd., *P. rivularis* Hook., *P. divica* Mnch.). A variety, Aderhold states, is found to occur on species of Sorbus and apparently also on Crataegus. In regard to the two last named, however, Aderhold was convinced by later experiments that these forms are entirely distinct from *F. dendriticum.*

Previous to later work of Aderhold (1903) the Fusicladia on Crataegus and Sorbus were supposed to be varieties of the apple-scab fungus, and thus capable of infecting the apple. In this later article the author records cultural experiments in which the Venturia found on Crataegus was shown to produce the typical conidial stage of *Fusicladium crataegi* Adh., a species distinctly different from *F. dendriticum.* Aderhold concludes that the fungus on Crataegus is entirely distinct from that on the apple, and that there need be no fear of Crataegus as a means of infecting the apple. In the same article he records experiments designed to determine whether *Fusicladium orbiculatum* Denn. or *Sorbus torminalis*, which is closely related to *F. dendriticum* morphologically, can infect the apple. Inoculations were made with cultures derived from the form found on Sorbus, with the result that abundant infection followed on *S. torminalis*, but none on apple trees, on *S. domestica*, or on *Pyrus chamaemespilus.* Aderhold states, however, that negative proof is not entirely decisive and that the experiments should be repeated in order to obtain a positive decision. The writer has not attempted cross-inoculation.

Life history

Perithecial stage

It is well known to pathologists that *Venturia inæqualis* has two distinct stages in its life cycle. The writer's observations on the life history of

(1894) Aderhold, Rudolf. Die perithecienform von Fusicladium dendriticum Wal. (Venturia chlorospora f. Mali). Deut. Bot. Gesell. Ber. 12:338–342.
(1897) Aderhold, Rudolf. Revision der species Venturia chlorospora, inaequalis, und ditricha autorum. Hedw. 36:81.
(1900) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Centbl. bakt. 2:6:593–595.
(1903) Aderhold, Rudolf. Kann das Fusicladium von Crataegus und von Sorbus-arten auf den apfelbaum übergehn? Kaiserliches Gesundheitsamt, Biol. Abt. Land- u. Forstw. Arb. 3:436–439.

the fungus began with a study of the perithecial stage during the spring of 1908. L. F. Strickland, who was at that time a special student in the Department of Plant Pathology at Cornell University, located a crab-apple tree on the campus which furnished abundant material for a study of the ascigerous stage. After having become interested and having learned what to look for, the writer had no difficulty in finding perithecia in old leaves under apple trees in other localities Many investigators appear to have had considerable difficulty in finding this stage of the fungus; but the writer is convinced, from the experience of three seasons, that it can be found easily almost any spring following a year of foliage infection if looked for carefully at the right time. Material in abundance was found easily in 1909, 1910, and 1911.

The perithecia appear most abundantly on the exposed surface of the leaf as it lies on the ground. They are often not easily discernible with the naked eye, but appear under a lens as small, dome-shaped pimples on the surface of the leaf. They are sometimes confused with the fruiting bodies of other fungi which are very similar in external appearance to the perithecia of Venturia and which are frequently more abundant than the latter. However, by one who is familiar with their appearance they can usually be distinguished from other forms on examination with a hand lens (Plate VIII, Figs. 1, 2, and 3); the pimples commonly have more of a dome-like form and are plumper than those of other fungi that are likely to be confused with them.

Development of perithecia

The perfect stage of the fungus begins to develop in fall or early winter. After the scab-infected leaves have fallen and decay has set in, the mycelium, which during the summer does not penetrate deeper than the epidermis, permeates the entire leaf tissue and sometime during the fall or winter begins to form perithecia. This winter development has not been studied very carefully, but a few notes were made at various intervals during the winter and spring of 1908-1909. Scabby leaves were brought in during the latter part of November, 1908, and parts of these leaves were cooked in potassium hydroxid. This did not make it possible to separate the epidermis from the underlying tissue, as had previously been the case. It seemed as if the mycelium had already permeated the tissue and, as it were, sewed the epidermis fast.

On February 26, 1909, leaves were examined and found to contain immature perithecia. At this date the asci were filled with a homogeneous mass of protoplasm which had not yet become differentiated to form spores. When the perithecia were pricked out in water these immature asci would push out through any wounds in the perithecium, but they were not seen to push out through the ostiole which was probably not yet open. In some cases there was so much expansion of the asci, due to the absorption of water which was evidently admitted through the wounds, that dehiscence occurred, bursting off the upper half of the perithecium in a manner similar to that to be described as occurring in the case of mature perithecia. It would seem, then, that even at this early date the immature asci have the ability to absorb water and exert a pressure similar to that exerted later by means of which the discharge of spores is brought about. It is evident that in nature this premature action is in some way prevented.

Some of the leaves brought in on February 26 were kept in a moist chamber in the laboratory until March 20, when they were examined. The spores had been formed and some were evidently ripening at that date, since they were somewhat brown. Some shooting of spores also occurred. This, it will be noted, is almost one and one half month earlier than the same stage of development was reached under natural conditions; in leaves from out of doors the asci were much less mature at this date. In some asci the protoplasm had just begun to differentiate to form spores and the few spores formed were still hyaline; in other asci the protoplasm still existed as a homogeneous mass in the ascus. The perithecia were small and inconspicuous and were likely to be overlooked. It was especially noticeable during 1910 that the perithecia remained inconspicuous until near the end of their maturity, when they enlarged somewhat. It was difficult to find infested leaves until the apple blossoms were about ready to open.

Clinton (1901) found signs of perithecial formation in sections of fallen leaves made as early as October, and could occasionally connect these perithecia by mycelial thread with the subcuticular mycelium. He notes that the perithecia usually occur on the lower side of the leaf, especially along the veins, and believes that they usually originate from a late infection on the lower side of the leaf. In the writer's observations during the past three seasons, perithecia have been found to occur abundantly on both sides of the leaf. They seem to develop mostly on the side that faces upward as the leaf lies on the ground. There appears to be a negatively geotropic tendency.

Time of maturity of ascospores

In nature the ascospores usually begin to mature at or about the time when the apple blossoms are ready to open. In 1908 mature spores were found on May 4 and in 1910 on May 1; the blossoms were about to open in each case. The exact date for 1909 is not available but it did not differ

(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:121.

materially from those given for 1908 and 1910. The ascospores do not all mature at one time and the ripening process may continue for about one month. These points are discussed more in detail and the results of observations are tabulated elsewhere in this bulletin.

Discharge of ascospores

Turning now to a more detailed study of the mature perithecium, some interesting phenomena are found. During the spring of 1908 an attempt was made to study the mode of discharge of the ascospores. Several methods of observing this phenomenon were employed. First, leaves containing perithecia were sectioned and the discharge of spores from the asci in water on a glass slide was observed under the microscope. This was rather an unnatural condition, since the sectioning usually cut the perithecia open thus exposing the asci to free access of the water. A more natural method seemed to be to soften the leaves and prick out the perithecia with a needle, place them in water on a slide, and observe their method of discharge. A photomicrograph of a perithecium thus treated is shown in Plate VIII, Fig. 4. Even with this method the conditions are somewhat abnormal, since it is impossible to prick out the perithecia without inflicting certain wounds which seem to admit water prematurely and thus premature extrusion of the asci and dehiscence of the perithecia are sometimes caused. From a study of this nature, however, accompanied by a study of spore discharge *in situ* on the leaf, much can be learned.*

It was noticeable throughout the study that any wounding of the perithecium induces more rapid discharge of ascospores and even induces discharge of spores from perithecia that are immature. It would seem that the expansion and extrusion of the asci and the discharge of spores is due to the absorption of water by the asci, and that premature discharge of the spores is prevented only by the fact that the perithecia in some way prevent premature or too rapid admission of water.

Another point of interest along this line is that when the perithecia are wounded and the consequent abnormally rapid extrusion of the asci takes place, it sometimes happens that the number of asci thus forced into action at one time is greater than can be accommodated by the ostiole. Consequently a greater pressure is exerted than the perithecium can withstand, and the upper half is burst off thus exposing all the asci at once.

This was first noticed in studying perithecia pricked out of leaves and placed in water on the slide. In many cases these perithecia would be seen to dehisce as described above. In Fig. 184 is shown a camera lucida drawing made at different stages of the above-described process. The dehiscence is always circumscissile, occurring nearer to the base than to the ostiole of the perithecium, apparently just above the point of attachment of the asci so that the latter adhere to the basal part.

A subsequent examination of leaves containing perithecia revealed the fact that a circumscissile dehiscence similar to that observed under artificial conditions occasionally occurs also in nature. Certain leaves could be found in which the crowns of many of the perithecia had been burst off, carrying with them the adhering fragments of the epidermis of the leaf and leaving the saucer-shaped bases of the perithecia *in situ* in the

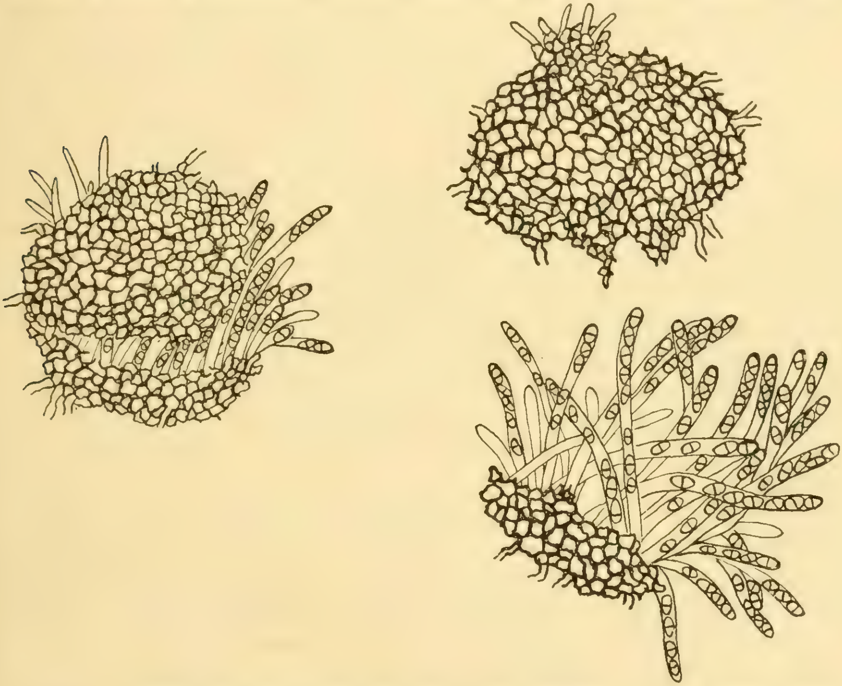


FIG. 184.— *Circumscissile dehiscence of the perithecium, showing two stages in the rupture of the same perithecium. Outlined with a camera lucida*

leaf. A photomicrograph of the surface of such a leaf is shown in Plate VIII, Fig. 2. This phenomenon was found to be fairly common in 1908 but has since been observed only occasionally. It is possible that some particular condition of the season of 1908 favored this method of spore discharge.

Clinton (1901) makes the following statement, which is suggestive when considered in connection with what is stated above: "When mature [perithecia] are more or less loosely imbedded in the leaf tissues and at the time of their disappearance infected leaves often show numerous small

(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:122.

holes where they have been imbedded." The writer has little doubt that the "small holes" thus observed were similar to those shown in Plate VIII, Fig. 2, and were the result of dehiscence as described above rather than of the mechancial removal of the entire perithecium.

McAlpine (1904), who studied this fungus in Australia, notes that "the perithecia or spore cases soon fall away from the dead leaves, so that by the middle of October scarcely a single one could be obtained from leaves still on the ground, though the minute holes showing where they had been were plainly visible." Here again it seems evident that these "minute holes" in the leaves were the result of such dehiscence. The perithecia are certainly not so loosely imbedded in the leaves that they fall out merely from their own weight.

Another method of studying ascospore discharge is to place glue-coated slides in an inverted position over moistened leaves containing perithecia. By this means a study was made in order to determine how high spores may be shot; how many may be discharged in a given time from a given area of leaf surface; how soon after wetting the leaves the discharge may begin; how long it may continue and how long a single perithecium may continue to discharge spores; and whether the continued discharge, covering a period of several weeks during the spring and early summer, is due to the ripening of new perithecia or of new asci in the same perithecium.

No spores were caught on slides placed higher than 1.1 centimeter above the leaf, and but few at this height. At .5 centimeter a large number were caught.

From a fragment of leaf 1 centimeter square 5630 spores were discharged in forty-five minutes. From this it is estimated that if the surface of the ground beneath trees set 40 by 40 feet apart were covered with old leaves well infested with perithecia, there might be 8,107,200,000 ascospores discharged for each tree in forty-five minutes in wet weather. Certainly this would be sufficient to account for abundant early infection, even though only a very small percentage of these ascospores would reach the trees and actually produce infection.

The discharge of spores begins very soon after the leaves are wet. Dry leaves were brought in and moistened and glue-coated slides were inverted above them. After five minutes the slides were removed and examined. A number of spores were found, showing that spore-shooting begins almost as soon as rain begins, or within five minutes after the leaves are wet.

In order to determine how long a single leaf or part of a leaf might continue to discharge spores if kept constantly wet, pieces of perithecia-bearing leaves were placed in a moist chamber under glue-coated slides and occasional examinations were made, new slides being supplied each time.

(1904) McAlpine, D. Black spot of the apple. Victoria Agr. Dept. Bul. 17: 10.

Four of these experiments were set up on May 21, 1908. On the next day spores were abundant on three slides and there were a few on the fourth. On the second day spores were abundant on one slide and there were a few on the others. On the third day they were abundant on one slide and there were a few on one other. The fourth day showed similar results. On the fifth day many spores could be found on the slide above one piece of leaf. On the tenth day a few spores had been discharged from the same specimen. On the eleventh day no spores were found.

These leaves were dried for eleven days and then rewet, in order to determine whether this might induce a reawakening of activities. The results were negative. No more spores were dischaiged from any of these leaves.

It is clear from this experiment, however, that under continuously wet conditions an uninterrupted discharge of spores can be expected for some time. Under these artificial conditions a single leaf continued to discharge ascospores abundantly for ten days. It is probable that in nature some leaves may be found that would continue even longer than this; and the fact that from some leaves operations would begin earlier than from others would lengthen the period still more. It is evident, then, that a rainy period sufficiently prolonged to exhaust the leaves of ascospores either temporarily or permanently would rarely, if ever, occur. It would seem probable, however, that a frequent succession of rainy periods would exhaust the supply earlier in the season by hastening the maturity and the discharge of ascospores. Judging from observations made during the spring of 1908, ascospore discharge continues for about one month or slightly longer. It was first noted on May 4, while leaves gathered on June 6 were found to contain only empty perithecia.

Further experiments were tried in order to determine whether the long-continued production of ascospores is due mainly to the continued ripening of immature asci in the same perithecium or to the ripening of immature perithecia. Pieces of leaves each containing a single perithecium were cut out with the aid of a razor and a dissecting microscope. These pieces were kept moist under a glue-coated slide, as described above. Thirteen perithecia were so treated, and in no case could it be found that spores were discharged continuously from a single perithecium for a longer period than one day. In one experiment including six perithecia, three were active on the first day and three others on the second day; the latter three were evidently not quite ripe on the first day. In another experiment including seven perithecia, two were active and for the first day only.

These experiments are not exhaustive. They seem to indicate, however, that individual perithecia mature at different times and thus extend the period of ascospore discharge over one month or more in the spring; but that when discharge from a given perithecium begins, if kept constantly wet its entire contents are discharged within twenty-four hours.

Cultural characters of the fungus

Aderhold (1896) grew the fungus successfully on a number of artificial media; among these he mentions leaf and stem infusions of various plants, such as apple, pear, cherry, birch, syringa, and pink. He grew it also on fresh cucumber sap and on gelatin. The cultural characters were alike whether the fungus was grown from ascospores or from conidia.

Appressoria were formed, which were at first club-shaped but the clubbed ends of which later enlarged irregularly, somewhat in the form of hands with the fingers reaching down into the substratum. The appressoria became somewhat brown in color, and from them developed colorless hyphæ corresponding to the infection tubes that occur when germination takes place on the host plant. Voges (1910), in describing the formation of appressoria, notes the presence of a gelatinous envelope which he believes to be important as a means of anchorage.

One point of special interest noted by Aderhold is that cultures of the fungus in spring or early summer form but little mycelium and many spores; while cultures made on the same gelatin in the fall produce but very few spores and abundant mycelial growth. This he found to hold true whether cultures originated from conidia or from cultures obtained directly from the conidia from leaves in the fall. In the hundreds of cultures made during the two years, only one exception to this rule was observed. The phenomenon is attributed to a difference in the age of the generation. In fall the mycelium penetrates deeply into the tissues of the dead leaf, forming an abundant mycelial development which in spring results in the formation of perithecia. Aderhold is also of the opinion that the first generation of the fungus which develops from ascospores forms conidia abundantly and quickly at the expense of mycelial development. Then, on the approach of fall, the conidial formation is retarded and mycelial development is increased for the purpose of favoring the formation of perithecia.

Aderhold was not able to develop the perfect stage to maturity in artificial cultures. He states, however, that there appeared very abundantly in the cultures, from exhausted conidial formations, bodies which he says are doubtless to be regarded as young perithecia.

The writer experienced no difficulty in obtaining pure cultures of the fungus by dilution plates from conidia and by inverting plates of agar about one half centimeter above moistened leaves containing perithecia.

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25:888.
(1910) Voges, Ernst. Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 20:385–393.

In the latter case the ascospores when discharged were caught by the agar. Germinated spores were later transferred to tubes. It was noted that these ascospores did not germinate so quickly as did others placed in water, but they grew more vigorously later.

Artificial inoculations

Aderhold (1896), in carrying out infection experiments, tried several methods of marking the point of inoculation so as to avoid confusion with natural infection. He used india ink and several coloring matters for this purpose, but found nothing else so successful as surrounding the point of inoculation with Von Stahl's cocoa-butter-wax mixture. When the leaf was all dried before applying it and the ring was not made too narrow, this mixture adhered well, and, if not applied too hot, did not injure the leaf nor prevent germination of the spores.

The inoculations were made on the young leaves and on the fruit. From ascospores on leaves Aderhold obtained about thirty-three per cent infection and from conidia about twenty-three per cent. From conidia on fruit he had less success; only about eight per cent of the inoculations were successful. According to Aderhold's tables conidia taken from fruit or from artificial cultures were less successfully used than those taken from scabby leaves.

The method of infection was studied also. Aderhold observed that the germ tube usually enters directly over the junction of two epidermal cells and often where several meet, in a corner so to speak. It broadens slightly at the point of entrance and bores directly through the cuticle. It was not observed to enter through wounds. Aderhold observed not only that the germ tube can bore directly through the cuticle, but also that the conidiophores sometimes bore their way out from beneath the cuticle. In other cases the cuticle may be ruptured by pressure from the mycelial growth beneath.

Clinton (1901) considered outdoor work unreliable because of the abundant natural infection. Accordingly he used one-year-old or two-years-old seedlings planted in crocks indoors and grown at a temperature higher than that outside. These seedlings were inoculated and kept in moist chambers. Inoculations made in this way were not very successful. Branches were cut off and artificially inoculated indoors. The leaves dropped in two weeks and therefore no results were obtained from this method.

The writer's inoculation experiments were performed mainly during the spring of 1908. For most of this work ascospores obtained from dead

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25:893.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:120.

leaves were used. It was desired to determine how readily ascospores may cause infection, what the period of incubation is, and how infection takes place.

Leaves containing an abundance of perithecia were chopped fine in water and this decoction was applied with a brush. The twigs were then inclosed in a moist chamber. This was made of a large test tube or a lamp chimney, having all openings closed with cotton and some moist cotton left inside.

On leaves inoculated on May 16, scab first appeared on May 24. The same leaves had been examined on May 23, when no infection was visible. It is evident that the period of incubation in this case was exactly eight days. By May 28 these leaves showed that many infections had taken place on each leaf (Plate II, Fig. 1), while only a few spots could be found on any uninoculated leaf. On May 31 ninety-eight distinct infections were counted on nine leaves that had been artificially inoculated, while only twenty-four infections could be found on twelve leaves from a branch that represented the most abundant natural infection found. There is no doubt, therefore, that the abundant infection was the result of inoculation. Further inoculations were made on May 26. By June 12 the leaves inoculated on May 26 were very badly infected. They had been examined three days previously and scab was not visible; its appearance, therefore, was rather sudden, and the period of incubation in this case must have been about fifteen days unless for some reason the infection did not take place as soon as the inoculation was made.

The writer would not like to infer, without further data, that the period of incubation increases in length as the season advances, but this may be possible. As the leaves become older and the cuticle thicker, a longer time may be required for the fungus to work its way out through the cuticle. This, however, is as yet only a suggestion. In each of the above experiments blossoms or young fruits were also inoculated, but they dropped before the time for the appearance of scab had arrived.

Artificial infection with conidia was also attempted. Both leaves and young fruit were inoculated with conidia from scabby leaves at three different dates — June 10, June 12, and June 15. The results were not nearly so striking as in the earlier experiments, when ascospores were used. A somewhat larger number of leaf infections followed than on the uninoculated leaves, but not enough more to permit safely the drawing of conclusions. Infection of fruit was not successful at this time.

In 1910 Rhode Island Greening and Baldwin apples were inoculated when almost full-grown. Conidia from scabby leaves were used and each apple was covered with moist cotton as soon as inoculated. Early in September a large proportion of the inoculated Rhode Island Greenings showed late infection. On one apple nine spots were counted, several others had three to five spots, and about four of the twelve inoculated were clean. It is true that some late infection had occurred on uninoculated fruit, but not nearly so generally as on the inoculated fruit. On the Baldwins some spots appeared, but the success of the inoculations was not so great as on the Rhode Island Greenings. These experiments were duplicated later with negative results.

Method of infection

In connection with the writer's infection experiments an attempt was made to determine how the germ tube pierces the cuticle of the host. Inoculated leaves were gathered at various dates. Some were put up in fixer and embedded in paraffin. Others were cooked for a short time in caustic potash, after which the epidermis could be peeled off and mounted on a slide. This being done, it was easy to locate some of the germinating spores and to trace the course of their germ tubes through the cuticle and for some distance between the cuticle and the epidermis. In Fig. 185 is shown a camera lucida drawing of an early stage of infection by an ascospore. In general it seems that the germ tube bores directly through the cuticle and continues to grow between the cuticle and the epidermis.

FIG. 185.—*Ascospore infection, showing the germ tube from an ascospore entering between the cuticle and the epidermis. Camera lucida drawing*

As noted above, Aderhold observed a slight broadening of the germ tube at the point of entrance, and the formation of appressoria. This did not occur in any of the cases observed by the writer. Fischer (1909) states that the fungus cannot enter an entirely sound fruit without a break in the epidermis. He believes that changes of temperature, by expanding or contracting the tissues of the fruit, may separate the cuticle from the epidermis, permitting the growth of the fungus in such places. The writer cannot see that there is much ground for this opinion. It seems that a germ tube from a spore is able to attack a perfectly sound fruit, although one cannot be sure that certain injuries which are not detectable might not be present.

Aderhold (1900) records experiments which lead him to believe that in the case of *Venturia pirina* the pectic compounds between the cuticle and the epidermal cells exert a chemotropic influence on the germ tube of the fungus and probably also supply nourishment.

(1900) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. **29**: 562–565.
(1909) Fischer, F. Über die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. **19**: 432–434.

Time of infection

From data recorded in Table 2 it seems evident that the first appearance of scab on leaves in 1908 and in 1910, undoubtedly due to ascospore infection as will be shown later, was directly traceable to certain rains which furnished conditions for infection; and that the dates of these rains are the dates of infection, thus giving approximately the period of incubation in each case.

Artificial inoculations recorded above show that the period of incubation may vary from eight to fifteen days. In the table, therefore, all rains are recorded which occurred within these time limits previous to the date on which scab appeared; and the limits are further broadened so as to include all rains occurring five to eighteen days previous to the appearance of the disease, in order to allow for any possible greater variations that may have occurred.

TABLE 2. DATES AND AMOUNT OF PRECIPITATION PREVIOUS TO THE FIRST APPEARANCE OF SCAB ON LEAVES DUE TO ASCOSPORE INFECTION, INCLUDING ALL CASES OF RAINFALL THAT COULD BE RESPONSIBLE FOR EACH INFECTION. THE DATES ON WHICH INFECTION PROBABLY OCCURRED ARE SET IN BLACK-FACE TYPE

1908 (first appearance on May 22)			1910 (first appearance on May 12)		
Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared	Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared
May 16	.15	6	May **2** to **3**	.75	9 to 10
May 15	.12	7	May 1	.25	11
May **14**	.30	8	April 29	.25	13
May **13**	.12	9	April 26	.25	16
May 11	.01	11	April 25		17
May 10	.03	12	April 24	1.25	18
May **9**	.36	13	April 23		19
May **8**	.33	14			
May **7**	.40	15			
May 6	.08	16			

In 1908 the first infection appeared on May 22. As the mature ascospores were found on May 4 it is safe to assume that some infection occurred during the rains of May 7, May 8, and May 9, since these furnished the first favorable conditions for infection after the spores had matured. This gives an incubation period of thirteen to fifteen days. Conditions favorable for infection also prevailed on May 13 and May 14, in which case the period of incubation would be eight to nine days; this period corresponds with inoculation experiments made early in the season. Since the spores were mature at the date of the earlier rains (on May 7 to May 9), there is no reason to believe that the infection did not occur at that time. Infections that appeared later probably occurred during the later rains (on May 13 and May 14). It is evident, therefore, that the infection appearing on May 22 occurred during one of the two rainy periods recorded above, probably the earlier period (May 7 to May 9).

In 1910, at Sodus, ascospores began to ripen about May 1. On April 29 and May 1 some rain fell; on May 2 and May 3 the precipitation was .75 inch, with good conditions for scab infection. The infection appeared on the leaves on May 12, giving a possible incubation period of nine to thirteen days. The table shows that there were weather conditions which would permit infection earlier than this date, but the following reasons exist for the opinion that there was no infection prior to April 29 and probably none before May 1: first, the ascospores were just beginning to ripen on May 1; and, second, spray applied on April 29 preserved the foliage from infection.

The abundant appearance of scab from secondary, or conidial, infection is shown in Table 3, which is constructed on the same plan as is Table 2:

TABLE 3. Dates and Amount of Precipitation Previous to Abundant Appearance of Scab on Leaves Due to Secondary (Conidial) Infection, Including All Cases of Rainfall that Could Be Responsible for Each Infection

1908 (abundant appearance at Ithaca on June 28)			1910 (abundant appearance at Sodus on June 7)		
Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared	Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared
June 15	.46	13	May 25	.54	13
June 14	T*	14	May 24		14
June 10	.01	18	May 22	.15	16
June 9	.13	19	May 20	.19	18
June 1	.01	27	May 18	.11	20
May 31	.41	28	May 10	.08	28
May 30	.16	29	May 9	.08	29
May 29	.05	30	May 8		30

*Trace; an amount less than .01 inch, too small to be measured.

In 1908, at Ithaca, abundant secondary infection appeared on June 28. In this case there is little doubt that the infection occurred on June 15, when .46 inch of rain fell. This gives a period of thirteen days for incubation. It is certain that the period of incubation was not less than thirteen days, since, excepting a trace on June 19, no more rain occurred until June 23, only five days previous to the appearance of lesions.

In 1910, at Sodus, the first production of conidia from which secondary infection could be expected appeared on May 12, as shown in Table 2. The first rainfall after this time occurred on May 18, with showers in the night and in the forenoon. Since these rains, however, consisted of intermittent showers, it is probable that the foliage did not remain wet long enough at one time to permit abundant infection to occur. It seems much more probable that the abundant appearance of scab on June 7 was the result of infections that occurred during the rain of May 24 and 25, when conditions were much more favorable for such an infection. In the latter case rain began to fall gently and steadily at 4 p. m. on May 24, with heavy rain during the following night, followed by a cloudy forenoon on May 25 with drizzling, or misting, showers, and a cloudy afternoon. Since this rain furnished the first really good infection weather after the conidia appeared — May 12 — and since abundant infection became evident on June 7, it may be concluded that the incubation period in this case was of thirteen to fourteen days duration.

In studying these tables, it must be borne in mind that the amount of precipitation is not necessarily the important factor in determining whether or not a certain rain permits infection. A more important factor is the length of time that the trees remain wet so as to allow spore germination (Plates IX and X). In fact it is theoretically to be expected that a heavy, beating rain would be less favorable to infection by the fungus, since constant washing would have a tendency either to keep many of the spores moving from place to place — not allowing sufficient time in any one position for them to become established in the tissues of the host — or to wash many of them to the ground. The ideal condition for infection is a gentle, continued rain followed by cloudy, calm weather and a saturated atmosphere, in which case the spores are kept wet for a long time while in one position.

Ascospores have been observed to germinate within a period of four hours, but it is probable that in order to produce abundant infection the trees must be kept wet for eight or ten hours or even longer. Any condition tending to favor the retention of moisture after rain has ceased tends to favor infection by the fungus. Several factors may be mentioned in this connection: dense foliage prevents prompt drying-out of the trees after rain has ceased; good air drainage favors rapid drying of trees, for which reason orchards located on hilltops are, in general, less likely to be seriously attacked by scab than are those in sheltered locations where there is poor circulation of air; showers occurring during the day, followed by winds or other drying conditions, are not likely to permit infection; showers occurring in the evening, followed by a calm night with a humid atmosphere, are likely to allow abundant infection. Conditions were favorable for infection on each of the dates mentioned above.

In Table 4 is shown the relation of the development of fruit buds and the maturity of ascospores to early scab infection. The data on infection are the same as those recorded in Table 2.

TABLE 4. CORRELATION OF THE FIRST APPEARANCE OF SCAB DUE TO PRIMARY INFECTION AND THE DATE ON WHICH THIS INFECTION PROBABLY OCCURRED, WITH THE DEVELOPMENT OF ASCOSPORES AND OF FRUIT BUDS

Year	Date of first appearance of scab	Condition of buds at date of first appearance of scab	Probable date of infection, as shown in Table 2	Condition of buds at probable date of infection	Date when mature ascospores were first found
1908	May 22......	Petals falling	May 7 to 9...	Almost opening	May 4
1910	May 12......	Mostly in bloom	May 2 to 3...	Ready to open	May 1

From Table 4 it appears that in 1908 the first infection on leaves and pedicels of crab-apple appeared as the petals were falling, on May 22. As is shown in Table 2 the period of incubation was evidently thirteen to fifteen days, making the dates of infection May 7, May 8, and May 9. This was several days before the blossoms opened. Ascospores were found to be mature on May 4 which would provide the necessary source of infection at the time when the rains referred to in Table 2 (on May 7 and May 9) occurred.

In 1910, on apple leaves at Sodus, it is evident that the early infection occurred just as the blossoms were ready to open (Plate XI), that is, on May 2 to May 3. In this case mature ascospores were first found on May 1.

From the above data it appears that the leaves and buds of the apple are susceptible to infection as soon as they are exposed, but that infection does not occur until the ascospores have matured or until the first appearance of weather conditions favorable for infection following the maturity of ascospores. According to observations during the past three years, the spores do not reach maturity until the blossoms are either opening or just ready to open. It seems, therefore, that there is little danger of abundant infection earlier than about the time when the blossom buds show pink.

Place of primary infection

The reason for blossom-bud leaves' becoming scabby earlier than others is another point relating to this early infection that is worthy of consideration. Many investigators have noticed that the leaves of blossom buds become scabbed earlier, and are often found to be infected worse, than those from leaf buds; others, who have not noticed this, have noted that flower-bud leaves are more easily burned by a spray mixture. This greater susceptibility to injury in many cases is the result of previous scab infection. These leaves are the first to open in spring; they are exposed to the earliest infection, while those from the leaf buds do not appear until later (ten days) and thus escape it. The leaves from fruit buds are exposed to both ascospore and secondary conidial infection, while those from leaf buds are, for the most part, subject only to the secondary attack.

In Table 5 is shown the same relation of the development of fruit buds and conidia to the secondary, or conidial, infection as appears in Table 4 to the primary, or ascospore, infection:

TABLE 5. CORRELATION OF THE FIRST ABUNDANT APPEARANCE OF SCAB DUE TO SECONDARY (CONIDIAL) INFECTION AND THE DATE ON WHICH THIS INFECTION PROBABLY OCCURRED, WITH THE DEVELOPMENT OF THE FIRST CROP OF CONIDIA AND OF FRUIT BUDS

Year	Date when secondary infection first appeared abundantly	Condition of buds at date of appearance of secondary infection	Probable date of infection, as shown in Table 3	Condition of buds at probable date of infection	Date when conidia from primary infection (source of secondary infection) appeared, as shown in Table 2
1908	June 28......	Apples ¾ to 1 inch in diameter	June 15......	Apples about ½ inch in diameter	May 22
1910	June 7......	Apples ½ inch in diameter	May 24 to 25	Petals falling	May 12

As intimated above, the ascospore infection is often not severe in itself. It is the original source, however, of this conidial infection, which is often much more abundant and which usually causes most of the scabby fruit as well as the most abundant leaf infection.

In Table 5 it appears that abundant leaf infection at Ithaca in 1908 appeared on June 28, when the young apples were about three fourths inch in diameter. In Table 3 it is shown that the infection probably occurred on June 15, thirteen days previous. On June 15 the young fruit was about one half inch in diameter. In 1910, at Sodus, secondary infection appeared on June 7, when the apples were about one half inch in diameter. In Table 3 it is shown that the infection in this case probably occurred on May 24 to 25, thirteen to fourteen days previous to the date of its appearance. At this time the trees were in full bloom and some blossoms were falling.

The writer has no satisfactory explanation to offer as to why the abundant secondary infection did not appear earlier in 1908, since the first crop of conidia, as shown in Table 2, was produced as early as May 22* while the infection did not take place abundantly until June 15. Weather conditions apparently favorable for infection occurred at intervals between May 26 and 31. It is probable, then, that some infection did occur at this time, but it is apparent that the abundant infection constituted the third generation of the season. In 1910, as shown in Table 3, this abundant infection occurred much earlier, evidently during the first continuously rainy period following the appearance of the first crop of conidia. In this case, then, the infection unquestionably represented the second generation of the season.

Another method of determining the date of infection and the period of incubation was attempted to a limited extent during the spring of 1908. On May 16 certain branches were inclosed tightly in paper sacks. The sacks were removed on May 26 and the leaves were found to be as badly scabbed as uncovered leaves, showing that this infection, which had already been visible about two days, had taken place previous to May 16, thus making the period of incubation more than eight days. Some of the sacks were not removed until later, and these prevented abundant secondary infection which appeared on the unbagged branches about June 28.

Clinton (1901) observed in 1898 that scab first appeared about May 2, at which time the oldest leaves had not reached full size. In 1899 the disease appeared first on May 5, a few days later than in the previous year. Clinton notes that the later leaves were the most infected in the latter year, while the earlier ones from flower buds were the most infected in 1898. The Venturia stage was later in developing in 1899. Clinton gives no data in either case. In 1900 scab was first found on May 11 and did not make a general appearance until the latter part of the month. Clinton observed further that in 1898 scab appeared more abundantly on the under surface of the leaf because this surface is exposed earlier than the upper surface. In 1899, when the infection occurred later, the leaves were mostly affected on the upper side.

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* Conidia were present as soon as infection appeared.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:114.

As an explanation of the more abundant infection of leaves from flower buds in 1898, Clinton suggests that infection is carried by insects and also that these leaves are probably the most affected because they are the first exposed. The same phenomenon was observed by the writer in 1909 and 1910. It was especially marked in 1910. The writer believes that the latter explanation is the more probable one. It is evident that this infection has occurred in some cases before the blossoms opened, as shown in Table 4, and therefore before insects are likely to visit the blossoms in very great numbers. While it is not to be doubted that insects may carry spores, the writer is of the opinion that scab infection results oftener from wind-blown or rain-washed spores.

The development of the two forms of this fungus as outlined by Clinton (1901) agrees in general with the writer's observations as recorded in the text. The following paragraphs are quoted from Clinton's bulletin:

May. Scab first appears on young apple leaves and fruit and during this month and June obtains its greatest foothold.

July to September. The warm, generally dry, weather is not very favorable for spreading the disease to the leaves, and fruit usually suffers but little from further infection.

September and October. Scab appears to develop somewhat more abundantly especially on the lower surfaces of the leaves, but not necessarily in vigorous fruiting condition.

October and later. On the fallen dead leaves there are signs of the formation of the perithecia of the Venturia stage.

October to April. Perithecia slowly develop as weather conditions prove favorable.

April and May. Perithecia with mature ascospores are now found.

June. Venturia stage disappears.

Late infection and scab development in storage

While the cycle indicated above may be regarded as the usual one, it is to be noted that seasonal variations markedly influence the development of the disease. In the case of abundant fall rains accompanied by fog, or the occurrence of excessive dew, a late infection of scab appears. The disease may not appear on infected fruit until the fruit is stored. This phenomenon has been called to the writer's attention recently by several investigators and growers. It is not new, however, for Goethe (1889) noted that scab developed in certain cases and new infections occurred after the fruit had been stored.

Brooks (1908) reports a case of late infection on McIntosh apples. The fruit when picked was apparently free from scab. Two weeks later the apples from an unsprayed tree were found to be very scabby. Brooks states further that during the winter of 1907–1908 much trouble was experienced in the Boston cold-storage plants and many commission men lost heavily because of scab. He considers it unlikely that the disease

(1889) Goethe, R. Zur bekämpfung des apfelrostes. Gartenflora **38** : 241.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67 : 121.
(1908) Brooks, Charles. Notes on apple diseases. New Hampshire Agr. Exp. Sta. Rept. **19–20** : 372.

spread through the storage plant, and thinks it resulted either from minute colonies that were not noticeable at picking time or from spores lodged on the apples.*

The writer was informed by B. J. Case, of Sodus, New York, of a similar occurrence on Rhode Island Greenings. Mr. Case stated that a succession of very heavy dews occurred shortly before harvest time and that this doubtless furnished conditions for the infection. It is probable that heavy dews or very gentle rains would be more effective in inducing late fruit infection than would washing rains, which would tend to keep the spores in motion over the smooth surface of the apple. At the time of the early infection the surface of the young fruit is sufficiently rough and hairy to furnish lodging-places for the spores.

Such weather conditions, with some very gentle rains, occurred during the fall of 1910 and considerable late infection was noted in some cases. This had appeared to a somewhat limited extent on the Rhode Island Greenings in the writer's experimental plats at Sodus which had not received the late application of spray. The percentage of scab on these plats was 17, as compared with 12 per cent on plats similarly treated but receiving a later application of a fungicide. The inoculation experiments reported earlier in this bulletin also indicated the possibility of this late infection and the time when it may occur.

Morse (1910) reports a very serious occurrence of late infection in Maine. During the winter of 1907–1908 hundreds of barrels of Maine apples, which were free from scab when placed in storage, were later found to be thoroughly covered with small black specks. Morse states that the entire growing and harvesting season was very wet and that the vegetative development of the fungus continued up to harvest time. Then the moist apples, covered with spores, were placed in rather warm cellars, resulting in the infection of the fruit and the formation of small scab spots on the apples in storage.

Morse and Lewis (1911) note an instance which would seem to indicate that scab infection has actually occurred in storage. It was found that apples lying adjacent to those that were scabby when placed in storage became infected. Morse notes also that Professor F. C. Sears, of the Massachusetts Agricultural College, has informed him that the development of scab on stored apples is not uncommon in Nova Scotia.

McAlpine (1904) reports late scab infection in Australian orchards. The disease is said to have appeared in December and January on apples

* Brooks gives no evidence that infection may not have taken place before the apples were gathered. That the fruit may have been gathered during the period of incubation is perhaps in most cases the explanation, rather than that infection occurs after harvesting.

(1904) McAlpine, D. Black spot of the apple. Victoria Agr. Dept. Bul. 17 : 6.
(1910) Morse, W. J. Notes on plant diseases in 1908. Maine Agr. Exp. Sta. Bul. 164 : 4.
(1911) Morse, W. J., and Lewis, C. E. Maine apple diseases. Maine Agr. Exp. Sta. Bul. 185 : 352–355, 390.

that had previously been fairly clean. This occurrence McAlpine attributes to unusually wet weather.

How the fungus passes the winter

Several possibilities have been suggested in answer to this question. One suggestion is that conidia which may lodge on the twigs or about the bud scales are able to retain their vitality and to germinate when favorable conditions arise in spring. Another suggestion is that the stroma of the fungus on twigs, or even on decayed leaves or fruit, may withstand the winter and produce in spring a new crop of conidia to start the infection.

Vitality of conidia.—Aderhold (1896) reports that, although the conidia of *Venturia inæqualis* germinate very readily and quickly, they soon lose their power of germination. Spores kept for eight weeks between glazed paper would not grow on gelatin. On the other hand, Aderhold notes that certain hyphal threads from cultures that had apparently been dormant for three months could awaken to renewed life when placed under favorable conditions. Further, he adds that it is not unusual to find the old hyphal cells rounded off, and these in suitable media produce mycelium by means of hyphal threads. Aërial threads may also be used in producing new cultures, and in the same way bits of stroma from old spots are agents of reproduction.

Ewert (1910) conducted experiments in order to determine the ability of conidia of various fungi to withstand low temperatures. Among these, conidia from the pear-scab and the apple-scab fungus, taken from diseased leaves and fruits, were tested. They were subjected to three periods of freezing, each of six hours duration at a temperature of 16° to 5° C. The freezing did not at all reduce the viability of the conidia of *Venturia pirina*, while only an occasional spore of *V. inæqualis* germinated after the second freezing. It would seem from these experiments that the conidia of *V. inæqualis* would probably be unable to survive the winter frost.

Hibernation of conidia.— McAlpine (1902) thought that the only source of infection worth taking into account, so far as Victoria (Australia) is concerned, is from the spores produced on the leaves or the fruit in one season, which may become entangled in the hairs or scales of the buds and may germinate when favorable conditions occur in the following spring. At that time McAlpine had not found in Australia any trace of the perithecial stage of the fungus. It is not probable that he would adhere to this view at present.

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25 : 892.
(1902) McAlpine, D. The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. 1 : 707.
(1910) Ewert, Dr. Die überwinterung von sommerkonidien pathogener ascomyceten und die widerstandsfähigkeit derselben gegen kälte. Zeitsch. pflanzenkr. 20 : 138–139.

Lawrence (1904) reports having found the scab fungus on the apexes of a number of fruiting spurs of both Baldwin and Rhode Island Greening trees. These spurs were noted in the following spring and a fungus was found which produced spores much like the conidia of Venturia. Lawrence remarks: "If these were summer spores of the scab fungus they are produced in such small numbers, and mature at such a time, that they will be killed by the spraying recommended below."

Lawrence believes that he found conidiophores in spring on old, dead leaves. Those kept in moist chamber in a decoction of dead leaves for twenty days produced conidia on the new growth identical with those produced on small stalks from germinating winter spores. Lawrence thinks there is little question but that these are true forms of the scab fungus. In examining many thousands of infected leaves in New York State, the writer has never been able to observe conidia produced on old, dead leaves in spring.

Persistence of stroma on twigs.—Apple scab has been observed by Stewart and Blodgett (1899) to occur on the twigs of Lady apples, which they report as being a variety very susceptible to this form of attack. Clinton (1901) notes having found scab on twigs but once, on a crab-apple tree. He regards the ascospores as the chief means of carrying the fungus over winter. He has since, however, reported to Professor H. H. Whetzel by letter that he has observed lesions frequently on twigs of Fall Pippin and certain other varieties of apples. Nevertheless he does not state that the fungus ever winters on the twigs.

According to Voges (1907 and 1910) it would seem that in some sections of Germany apple scab may grow abundantly on twigs; while in other sections it is at least very rare, since Aderhold, who has without doubt investigated the disease more carefully and thoroughly than has any other person, failed to find it on the twigs. Its occurrence must certainly have been very rare in the region where Aderhold conducted his investigations. However, Voges, as cited above, states that in his locality (in Hildesheim) scab was as common on apple twigs as on pear twigs. He names several varieties that have been badly affected in his garden, among which Ribston is mentioned.

The stroma of the scab spot on the twig, according to Voges, remains more or less dormant during the winter and produces a crop of conidia in spring. A section through such a spot, bearing conidia as found in March, is shown.

(1899) Stewart, F. C., and Blodgett, F. H. A fruit-disease survey of the Hudson valley in 1899. New York (Geneva) Agr. Exp. Sta. Bul. 167 : 283.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67 : 118.
(1904) Lawrence, W. H. The apple scab in western Washington. Washington Agr. Exp. Sta. Bul. 64 : 1–24.
(1907) Voges, Ernst. Ueber die schorfkrankheit der obstbäume. Deut. landw. presse 34 : 276–277.
(1910) Voges, Ernst. Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 20 : 385–393.

Salmon (1908) also reports finding scab on the young wood and shows photographs of infested twigs. In regard to the appearance of scab on young wood this author states: "According to the variety of apple attacked, its appearance varies considerably; in some cases e. g. on Coxe's Orange Pippin the diseased wood becomes somewhat swollen and prominently blistered. In other cases e. g. on Wellington the blistered appearance is less prominent, and the shoot is not swollen. In still other cases the scab produces isolated characteristic markings which give the wood a pocked appearance. Severely attacked young shoots may, as in the case of those of Lord Suffield, be blistered almost continuously over the surface, and the bark will then subsequently peal off in flakes." Salmon considers Coxe's Orange Pippin a susceptible variety.

The same author (1909) notes that twig infection was found to occur only on the following six varieties: Golden Noble, Ecklinville, Coxe's Orange Pippin, Blenheim Orange, Warner's King, and Peasgoods Nonesuch. It was very severe on Coxe's Orange Pippin and on Ecklinville.

Eriksson (1911) mentions having frequently observed the fungus on twigs of the current year's growth but not on older ones.

Considering all the evidence, the writer is convinced that the ascigerous stage is the principal agent involved in carrying the fungus over winter. It has been shown that twig infection is not of very common occurrence and that the conidia cannot withstand winter temperatures. Furthermore, evidence that the ascospores are the chief source of primary spring infection is furnished by the fact, noted more in detail in another part of the bulletin, that orchards the leaves of which have been plowed under or burned early in spring or late in fall are less seriously affected than are orchards in which the leaves are left exposed.

Formation of appressoria. There might remain the possibility of infection resulting from the germination of appressoria produced by the mycelium, as described by Aderhold and already referred to. Since Aderhold describes these enlargements as becoming more or less brown in color, it may be possible that they are able to function as resting spores.

Summary

The observations on scab infection given above lead in general to certain conclusions with reference to the time and source of infection under conditions existing in New York State:

1. The early infection is chiefly, if not entirely, from ascospores, and it may appear during the first period of weather favorable to infection

(1908) Salmon, E. S. Apple scab or black spot. London Bd. Agr. Journ. 15 : 182–195.
(1909) Salmon, E. S. Black spot or apple scab. Southeastern Agr. Col. (Wye, Kent). Journ. 18 : 207–270.
(1911) Eriksson, J. Die rote farbe der fruchtschale und die schorfkrankheit der obstsorten. Zeitsch. pflanzenkr. 21 : 129–131.

occurring after the ascospores have matured. Usually this does not take place until blossoming time or immediately before. There seems to be little danger that infection will occur much earlier; this is probably not because the leaves and buds are not earlier susceptible to scab, but rather because the ascospores have not matured in sufficient quantities to cause general infection.

2. The period of incubation may vary from eight to fifteen days; so that after this length of time has elapsed subsequent to the date of the earliest ascospore infection a crop of conidia is produced, from which a second, and usually more abundant, infection may appear eight to fifteen days following the first period of weather favorable to infection that occurs after the above crop of spores has ripened. This generation may in turn produce another, and so on throughout the season. However, the various infections do not always occur only in successive jumps at intervals of eight to fifteen days, as the above discussion might lead one to believe. The crop of ascospores are not all matured and do not all discharge at one time. They begin to ripen at about the time indicated above and furnish a constant source of infection for a month or more. Thus the individual infections belonging to the first generation may be started at several different dates and consequently produce their first crops of conidia at different dates. It is possible also that individual infections occurring at the same time do not all have the same period of incubation. Thus there may be a more or less constant appearance of scab, with the more pronounced jumps at intervals as indicated above. In fact this is what usually occurs.

3. The earliest infections usually occur on the lower side of the leaves. This is due to the fact that the lower side is more exposed at that time, while the leaves are unfolding. The later infections occur more abundantly on the upper surfaces, which by that time have assumed a more exposed position.

VARIETAL SUSCEPTIBILITY

Perhaps the best method of obtaining data as to varietal susceptibility in case of this disease is to summarize the results that have been obtained and the observations that have been made by various investigators for years past. In reviewing this work it becomes evident that too much stress should not be laid on a single set of observations. It is found that certain varieties may be resistant in one year and susceptible in another year under conditions which for average varieties are as favorable to the disease in the one case as in the other. The experiments reported by Aderhold emphasize this point. The writer, on comparing his own results with those previously reported by others, finds the above statement to hold good.

Baldwin, for example, is usually listed among resistant varieties; yet on the check trees in the writer's experiments during 1910 Baldwin trees yielded ninety-eight per cent of scabby fruit, much of which was badly infected. In 1909, which was not an epidemic year, the Baldwins were as badly diseased as were the Rhode Island Greenings. The Ben Davis, which is usually reported as resistant, was as badly scabbed during both seasons as was the average variety.

It may be possible that the reputation of these varieties is due partly to their color. The scab is not so conspicuous on the dark-colored fruit as on that of the light-colored varieties. Many growers who had very scabby Baldwins in the season of 1910 considered them clean, while Rhode Island Greenings, which were really less diseased, were considered a scabby lot. However, as previously stated, it is possible that Baldwin and Ben Davis may be more or less resistant in some seasons, since it has been proved that such variations do occur.

There seems to be no satisfactory explanation for such variations, although several suggestions may be offered. They may be due to a relation of the weather conditions or of the time when weather favorable to infection occurs, to certain stages in the development of the fruit and the leaves of certain varieties. For example, a Baldwin may be just at its most susceptible stage at the time when weather favorable to infection occurs in this season, and in the next season may have passed this stage; while a Rhode Island Greening may so develop with respect to the weather as to give the opposite results each year. Therefore the Baldwin would be susceptible in one year in a certain locality, and the Rhode Island Greening in the next year. In some varieties the susceptible period may be reached sooner or may last longer than in other varieties; this explanation, however, is as yet only theoretical.

Another plausible explanation is suggested by a few statements made by Bailey (1892), from whom the following is quoted:

> One other important consideration must not be overlooked here, and that is the fact that enemies often progress or develop as rapidly as do the host plants. I imagine that by the time we are able to breed scab-proof varieties — from the present standpoint — our scab-fungus will have developed a capability to attack more uncongenial hosts. This is the common history of injurious insects and fungi; they take on new habits to accommodate themselves to new conditions. It is possible that a good market apple may spring up which is for the time scab-proof; but when we have learned how to produce such kinds with tolerable certainty, the enemy will have grown cunning too, I fear. How many are the pears which are sent out as blight-proof, and yet in a few years they suffer with the rest. We are in the habit of distrusting the originator who makes this claim if it turns out false in after years, but I am inclined to think that some of these varieties really are measurably blight-proof at first. If the histories of varieties of fruits could be written from the natural-history side, I fancy that many of our notions would be upset.
>
> I would not discourage Doctor Hoskins' efforts toward scab-proof apples, but I am not over-confident of success. For my generation, at least, I must pin my faith to the squirt-gun.

(1892) Bailey, L. H. Scab-proof apples. Garden and forest 5 : 442.

The above was written in connection with a discussion of the Baldwin apple. At that time this variety was considered fairly resistant to scab, yet Professor Bailey notes that in some cases it was attacked to some extent. It is significant to mention here that during the season of 1910 the unsprayed Baldwins in Mr. Case's orchard at Sodus, New York — one of the most carefully-cared-for orchards in the State — gave ninety-eight per cent of scabby fruit. Might it not be possible that the fungus has become better adapted to this host than in former years, as predicted by Professor Bailey in 1892? It is not necessarily true that the scab fungus in general has become able to attack more uncongenial hosts; but in this particular Baldwin orchard a strain of the fungus that is capable of flourishing under favorable weather conditions on the Baldwin apple may have been bred merely by means of natural selection. It should be possible for experimenters to breed fungi as well as higher plants; and in a Baldwin orchard in which the fungus is more or less harbored for years, those strains that are capable of attacking that variety persist and multiply until finally the disease is as prevalent as in other orchards of other previously susceptible varieties.

There is no reason to expect that any variety on which the fungus can grow, no matter to how small an extent, will remain resistant indefinitely if it is permitted to select, cultivate, and multiply those strains of the fungus that are capable of attacking it. Perhaps if an absolutely immune variety could be found there would be hope that such a variety could be kept immune until some particularly virulent strain of the fungus lodged on it by chance. Then, if the virulent character of the latter is perpetuated, there is no reason why its offspring would not be multiplied, in time even producing an epidemic on this previously immune variety.

Voges (1910) claims that red-skinned varieties are much more resistant to scab than are closely related white varieties. He offers the suggestion that the coloring substance in the skin may in some way be the cause of the resistance to infection of such varieties. Eriksson (1911) takes issue with this view and cites cases in which red-skinned apples were as badly attacked as others.

Aderhold (1896) made a study of varietal susceptibility and, while great difference was noted, none of the four hundred and fifty varieties of apples cultivated in Germany were found to be immune. Aderhold concludes also, on comparing his obervations with those of Goethe, that varietal susceptibility may vary in different localities.

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. **25** : 894.
(1910) Voges, Ernst. Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. **20** : 385–393.
(1911) Eriksson, J. Die rote farbe der fruchtschale und die schorfkrankheit der obstsorten. Zeitsch. pflanzenkr. **21** : 129–131.

The same author (1902) records the results of a five-years experiment on susceptibility of varieties and on the relation of weather to such susceptibility. One hundred and sixty-three varieties were kept under observation during the season from 1897 to 1901, inclusive. Notes were taken with reference to the disease on foliage. An elaborate tabulation was made showing the relative susceptibility of each variety in each season. Only a few varieties exhibited the same disease-resisting power throughout the five years, and almost without exception these were such varieties as suffered little during the great epidemic year of 1897. Some varieties, Aderhold notes, rose almost by bounds, so to speak, to a condition of relative freedom from disease; others were attacked very severely in 1900 and but slightly in 1901; while still others showed gradually less severe attacks each year. Aderhold notes further that not a few varieties which in 1897 — the epidemic year — were relatively immune, were very susceptible in 1898 and 1899. As a result of his investigations this author states that only those few varieties which were resistant every year can properly be considered resistant; and one can plainly see by examining his results that resistant varieties cannot be selected from the observations of a single season, even though that season be an epidemic one. This doubtless accounts for some of the conflicting reports on resistance of certain varieties to scab.

An anonymous author (1900) notes that certain varieties may appear to be immune in one season but may be very susceptible in another season, under different weather conditions. This author notes also that no variety can be considered entirely immune under all conditions. The same general sentiment is voiced by Fischer (1909), who states that no variety is immune and that many varieties may be practically free in certain seasons and yet suffer at other times.

CONTROL

SANITARY MEASURES

It should not be inferred from what has been said regarding infection by the perfect stage of the scab fungus that the disease can be controlled by sanitary measures alone. There will probably always be enough fallen leaves exposed to permit some infection, from which further spread may be rapid. It is doubtless true also that spores can be carried for considerable distances from neighboring orchards. If, however, the dead leaves are turned under, it is probable that much less danger will result from primary infection usually occurring about blossoming time. In most

(1900) Anonymous. Einige krankheiten und feinde der obstbäume und weinreben. Deut. landw. presse 27 : 721.
(1902) Aderhold, Rudolf. Ein beitrag zur frage der empfänglichkeit der apfelsorten für Fusicladium dendriticum (Wallr.) Fuckel und deren beziehungen zum wetter. Kaiserliches Gesundheitsamt, Biol. Abt. Land- u. Forstw., Arb. 2 : 560–566.
(1909) Fischer, F. Über die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 19 : 432–434.

cases the primary attack would probably be so light as to cause no serious results aside from furnishing convenient sources for more abundant secondary infection. Theoretically, then, it should be possible to dispose of many sources of primary infection by plowing the orchard in the previous autumn, or early in the spring before the ascospores have ripened.

A striking demonstration of this point was observed at Medina, New York, by the writer in 1909 and reported by Whetzel (1910). Several orchards in a certain locality were very severely attacked by the early infection. None of these orchards had been plowed and the leaves were found to contain perithecia in abundance. One orchard just across the road from one of those mentioned above had been plowed early in the spring and the old leaves were thus turned under. This orchard was comparatively free from scab on the leaves at the date when these observations were made.

Brooks (1909) also cites a striking demonstration of this point. He states: "The results were secured in two McIntosh orchards, which have been under observation for several years. Both have been seriously affected with scab each year, and the percentage of loss has been approximately the same in the two. Both orchards were in sod. About the middle of April a fire escaped from a sugar camp and swept over the entire area of one of these orchards. Not a scab spot could be found in this orchard the following summer, while the disease was quite common in the other orchard."

Other features of sanitation — such as the removal of rotted fruit and dead branches, and the like — although doubtless important in insect control, are probably not of importance so far as scab is concerned since the principal winter home of the fungus is in the leaves. Drainage, of course, should be considered a factor in case of very wet soils, since an excess of moisture favors development of the fungus by increasing atmospheric humidity; this hinders rapid drying of trees after rains and thus creates favorable conditions for the development of ascospores.

Pruning is an important factor. The denser the foliage of the tree, the more slowly it dries out after each rain. The longer the tree remains wet, the better is the opportunity for spores of the fungus to germinate and cause infection.

The location of the orchard with respect to air drainage is also important for the same reason. Trees situated on a hill, or otherwise located where there is free circulation of air, dry out much more quickly than do those growing in a pocket into which air currents commonly do not pass.

(1909) Brooks, Charles. Some apple diseases. New Hampshire Agr. Exp. Sta. Bul. 144 : 116.
(1910) Whetzel, H. H. Report of the committee on plant diseases. New York State Fruit Growers' Assn. Rept. 9 : 19–20.

SELECTION OF RESISTANT VARIETIES

This practice offers very little promise as a means of control. In the discussion of varietal susceptibility, it has been shown that no variety is likely to remain immune, or even very resistant, for many years. Further, even though a resistant variety could be obtained, the grower could not afford to sacrifice other desirable qualities for this one. Therefore it would seem better to select for quality of fruit and for productiveness, vigor, and hardiness of tree, and depend on some method of protecting the tree from scab.

SPRAYING

In view of the above discussion it will become evident that the most important method to be employed in controlling this disease is by timely applications of a protecting substance to the host. The early infection may be lessened by disposing of the dead leaves or by plowing them under. Proper pruning and good air drainage will aid in reducing danger of infection, and varieties may be selected that are somewhat less susceptible than others. But with all these precautions it is certain that clean fruit cannot be grown unless the trees are properly sprayed. This is now generally admitted and needs no argument. Much is yet to be learned, however, as to methods. The study of the habits of the parasite, which has already been dwelt upon in the text, is of importance chiefly as a means of learning how, when, and where it can be most effectively attacked without injury to the host plant.

The problem is to find the best fungicide and to learn how and, still more important, when it should be applied.

Fungicides

Some of the properties essential for a good protective fungicide may be enumerated as follows: first, the substance that goes into solution from the dried coating of spray material must have fungicidal value; second, this substance must go into solution in the presence of meteoric water, or it may be so brought into solution by the germinating spores of the fungus to be controlled, in sufficient quantity to prevent germination of the spores; third, it must not go into solution in such quantities or so rapidly that the material will all dissolve and be carried off with the first short rain, or in such quantities as to cause injury to the host if the resulting solution is caustic; fourth, the material, if applied as a solution, must change to a relatively insoluble form in drying on the plant, else the results will not be lasting as the substance will all be washed off with the first rain; and fifth, the material must adhere to the plant so that the solid particles will not be removed mechanically by rains or otherwise.

All these points must be considered in choosing a fungicide for the control of apple scab, as well as of other diseases of a similar nature when the principle involved is one of protection. There are many substances that are powerful antiseptics and have strong fungicidal properties but are not effective in controlling such diseases. Many such substances have been tested by reliable investigators and have proved to be inefficient.

McAlpine (1907) reports experiments in which were used certain proprietary sheep dips (Cooper's and Little's); also phenyl, phenylene, crude carbolic acid, and oil of tar, 1 part in 160 parts of water. None of these materials were at all effective in preventing scab.

There is no doubt that many of these substances possess fungicidal properties. Doubtless the reason why they do not succeed is that they are too easily soluble in water and do not change to an insoluble form after being applied. Since the fungicide protects from infection by forming a protective layer over the surface of the susceptible parts of the plant, there seems little reason to expect that a soluble preparation such as carbolic acid, which does not become relatively insoluble after drying on the plant, can be used in controlling such diseases as apple scab.

In the case of bordeaux, the mixture, of which copper is the essential fungicidal ingredient, is applied in the insoluble form and adheres to the plant like paint, forming a comparatively permanent protection. The copper is probably made effective by being very slowly brought into solution by means of certain agencies, either atmospheric conditions or the solvent action of spores, as needed. In the case of lime-sulfur solution, the sulfur, which is evidently the fungicidal ingredient, is applied in a soluble form. This would be almost, if not completely, washed off in the first few minutes of rain, leaving the plant unprotected even during the latter part of the same rain. During the drying process, however, certain chemical changes occur and the sulfur is deposited as a relatively insoluble precipitate, forming a protective and comparatively permanent layer as in the case of bordeaux mixture.

A third type of germicide, carbolic acid, may be compared with the two discussed above. This is applied in the soluble form. It dries on the plant without becoming insoluble; consequently it is dissolved and carried away in the first few minutes of rain and the plant is thereafter left unprotected. Carbolic acid may be a stronger germicide than lime-sulfur or bordeaux, but the lack of the one peculiar property, a proper balance of solubility, makes it worthless for this purpose.

Bordeaux mixture

Many fungicides and many combinations of fungicides have been tried in connection with the control of apple scab. Until very recently bordeaux

(1907) McAlpine, D. Experiments with black spot of apple. Victoria Agr. Dept. Journ. 5 : 362–363.

mixture has remained preeminently the standard, and the only spray used generally for the purpose. So much was this the case that the statement that bordeaux mixture is the best fungicide has become axiomatic. Most attempts at improvement in fungicides have been along the line of various modifications of bordeaux or by the use of other copper compounds. Many such combinations have been tried with varying success; the number of experiments of this kind is too great to permit of their mention here. Perhaps no one man has tried a greater number of such combinations than has McAlpine (1902), to some of whose very interesting experiments brief reference is here made.

In his report on control experiments in Australia during the season of 1901 and 1902 McAlpine records the use of many modifications of bordeaux mixture, with some suggestive results. Many substances were used, such as linseed oil, sal ammoniac, nitric acid, alum and salt, molasses, caustic soda, washing soda, permanganate of potash, bluestone, and rosin. In addition to these was a certain "Grant's mixture," with some unknown substance added. This gave much better control in every one of the three sets of experiments than did ordinary bordeaux or any other modifications tried. The addition of common salt seemed to increase somewhat the efficiency of bordeaux.

Dust sprays

Dust sprays, if efficient, can be applied with much less expense than other sprays, and can be used in orchards so located topographically that it is difficult to transport heavy spraying apparatus. In most cases in which comparative tests of dry spray and liquid spray have been made, a dry bordeaux preparation was used, which was applied with a special blowing apparatus.

The results in general have been decidedly discouraging for the dust spray, as will be shown by the following reports. In many cases the dust spray seemed to have no effect whatever in controlling the fungus, and in other cases but little effect. In one State, however, the dust spray seemed to give fairly good results in controlling scab.

Close (1905 and 1906) compared dust sprays with liquid sprays for the control of apple scab and other pests. The dust spray controlled apple scab very well in both seasons. The author concludes that the dust spray promises well for Delaware. No further experiments have been reported by him.

A series of experiments covering a period of three years, comparing

(1902) McAlpine, D. Experiments in the treatment of black spot of the apple and pear. Victoria Agr. Dept. Journ. 1:620–630.
(1905) Close, C. P. Dust spraying in Delaware. Delaware Agr. Exp. Sta. Bul. 69 : 1–7.
(1906) Close, C. P. Third report on dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 76 : 1–19.

dust sprays with liquid sprays, was conducted by Crandall (1906) of Illinois. In these experiments a dry bordeaux was used in combination with paris green. The test was repeated in each of the seasons 1903, 1904, and 1905. In every case the dust spray is reported as almost worthless so far as controlling apple scab is concerned. Even the foliage was not protected and it fell from the treated trees about as badly as from those untreated.

Faurot (1908) reports experiments in Missouri, where the use of home-made and commercial dust bordeaux resulted in only four to five per cent of scab-free fruit while the use of liquid bordeaux resulted in over ninety per cent.

Lawrence (1906) obtained eighty-eight to ninety-seven per cent of scab-free fruit with liquid bordeaux and only one to nine per cent with dust bordeaux. In another experiment reported by Lawrence, liquid bordeaux protected eighty-four to ninety-three per cent of the fruit and dust bordeaux protected only five to eight per cent.

The examples given are sufficient to indicate that under ordinary conditions little or no dependence can be placed on a bordeaux dust spray such as has been used up to the present time. These examples do not preclude the possibility of finding a satisfactory dry preparation, however, and if some form of dust spray can be devised that will be efficient the cost of spraying will be much reduced.

Lime-sulfur preparations

Lime-sulfur solution.— The use of lime-sulfur preparations as fungicides is discussed in detail by the writer in three bulletins recently published by the New York State College of Agriculture at Cornell University: Bulletin 288, Spray injury induced by lime-sulfur preparations; Bulletin 289, Lime-sulfur as a summer spray; Bulletin 290, Studies of the fungicidal value of lime-sulfur preparations. It is therefore not necessary to repeat that discussion here, further than to say that the work on this problem begun by Cordley (1908) — to whom belongs the credit of introducing on a practical basis in America the use of lime-sulfur solution as a summer spray — has progressed with increasing momentum each year since its beginning. The result is that to-day a large number of growers throughout the country have profited by the experience of the several investigators who have been working on the problem, and are using lime-sulfur solution combined with lead arsenate as a summer spray for apples.

(1906) Crandall, C. S. Spraying apples. Relative merits of liquid and dust applications. Illinois Agr. Exp. Sta. Bul. 106 : 205–242.
(1906) Lawrence, W. H. Apple scab in eastern Washington. Washington Agr. Exp. Sta. Bul. 75: 1–14.
(1908) Cordley, A. B. The lime-sulphur spray as a preventive of apple scab. Rural New-Yorker 67 : 202.
(1908) Faurot, F. W. Spraying versus dusting. Missouri Fruit Sta. Bul. 19 : 1–24.

The principal advantage of lime-sulfur over bordeaux mixture lies in the fact that the severe russeting of fruit often resulting under certain weather conditions from the use of the latter is avoided. The fruit sprayed with lime-sulfur usually has a much smoother, more highly colored skin and a more waxy finish than has that sprayed with bordeaux mixture. The occurrence of bordeaux injury has seemed to be more common within recent years than formerly, and the advent of an efficient substitute which promises to avoid the difficulty has been heartily welcomed by growers.

It must not be understood, however, that the use of lime-sulfur with lead arsenate is advised as the only summer spray for apples. This recommendation at present is safe for New York State, since here scab is the all-important fungous disease for which spraying must be done. Farther south, however, bitter rot and apple blotch are of vital importance, and Quaintance and Scott (1912) have determined that lime-sulfur solution cannot be relied on to control those diseases. Where they are present the lime-sulfur treatment for scab should be followed by later applications of bordeaux mixture.

Scott lime-sulfur.— In addition to the lime-sulfur solution which consists essentially of basic calcium sulfids, prepared by boiling together in water lime and sulfur in proper proportions and properly diluted, there has arisen the self-boiled lime-sulfur devised by Scott (1909) and used by him so successfully for the control of peach rot and peach scab. This, although highly effective for those diseases, seems rather inefficient for the control of apple scab, probably largely because it does not adhere so well as is desirable.

Waite's modification.— An interesting set of experiments is reported by Waite (1910) on results obtained by the use of several modifications of self-boiled lime-sulfur and bordeaux mixture. The most promising of these was prepared by adding iron sulfate to self-boiled lime-sulfur mixture. This seemed to increase the efficiency of the latter, which at the same time retained its freedom from injurious properties.

When to spray

First application

The fundamental principle on which this phase of the subject is based has already been discussed in connection with the study of infection. To know when infection occurs is to know when to spray. As has already been pointed out, the fungicide must be applied before the infection occurs

(1909) Scott, W. M. Lime-sulfur mixtures for the summer spraying of orchards. U. S. Agr. Dept., Plant Indus. Bur. Circ. 27 : 15–17.

(1910) Waite, M. B. Experiments on the apple with some new and little-known fungicides. U. S. Agr. Dept., Plant Indus. Bur. Circ. 58 : 1–19.

(1912) Quaintance, A. L., and Scott, W. M. The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Agr. Dept. Farmers bul. 492 : 23–26.

PLATE XI.— *The stage of development of the host reached at the time of first infection in 1910. This is the stage at which the first application of spray can be made effectively* in order to prevent it. The first infection usually occurs when the blossoms are about to open, or as soon thereafter as favorable weather conditions arise. Spraying for scab must be begun before this time if the trees are to be insured against early infection. Since the ascospores do not mature until about the time when the blossom buds show pink, the first application may be delayed until about that time. Spraying experiments in 1910 added evidence to this conclusion. Although the weather from the time when the leaf buds first opened was such as to furnish ideal conditions for fungous infection, the spray applied after the buds were showing considerable pink prevented the early infection.

The primary infection is often very light. In many cases it is not sufficient in itself to cause much loss. This accounts for the fact that in many cases the application before the blossoms open has been omitted without loss. Several factors may enter into the conditions governing this point. An abundance of dead leaves lying open under the trees, and the development of an abundance of perithecia in these leaves, furnish the source of infection, and wet weather at the right time furnishes the conditions.

Later applications

An application after the blossoms fall is necessary in order to protect the trees from later attacks, and it is also advisable, under ordinary conditions, to spray again two or three weeks later. By this time the apples will have grown considerably and new surfaces will have been exposed. Sometimes a fourth application in late July or in August is necessary in order to prevent late infection.

Not only should the grower watch the conditions of the fruit buds, but he should also watch the weather and attempt to get the spray on ahead of general storm periods if possible. Many growers delay the spraying until after the rain is over if rainy weather happens to be threatening at the time, thinking that the rain will wash off the spray. No worse mistake than this can be made. It is during wet weather that the spray is needed to protect the trees from infection, which occurs only in the presence of excessive moisture. The spray does not wash off so easily as is ordinarily supposed. If it has twenty-five minutes in which to dry before any washing rain occurs it will adhere well. Any spray that will not stand some washing after it has once dried on the tree cannot be considered an efficient preventive for this disease.

Dormant spraying

There appears to be an opinion prevalent that winter spraying is important in connection with the control of apple scab. Several persons have advocated the substitution of the dormant spray for the application just before the blossoms open.

The life history of the fungus in its relation to this point has already been discussed. Evidence presented in that discussion shows that the main source of early infection is the dead leaves. Spraying the trees before the leaves open cannot be expected to protect from this source of infection, because the leaves and the young buds which are to be protected are not yet exposed so that the spray can reach them.

It has been suggested that the conidia can live over winter on the twigs or the bud scales and that the spray applied during the dormant period kills them. It has been shown, however, that the conidia are not likely to live through the winter, and further that apple scab, unlike pear scab, is not of common occurrence on the twigs.

Even though it be admitted that some infection from either of the above sources may occur, it would not change the facts from the practical standpoint. It is known certainly that ascospores are responsible for at least most of the early spring infection, and that it is necessary to spray in order to protect trees from this source. It is further known that it is impossible to protect trees from this source except by coating the surface of the parts to be protected with the spray, and this cannot be done until those parts are exposed.

Spraying fallen leaves

The question is sometimes asked, will the spray falling on the dead leaves beneath the tree kill the ascospores or prevent them from being discharged? A study of the mechanism by means of which the spores are discharged will answer this question. The spores, being borne in a closed perithecium as shown in Fig. 183 (page 555), are protected from the fungicide until their discharge takes place. It will be seen further, from the same figure, that the asci containing the spores protrude beyond the surface of the leaf, passing the spores safely through any coating of spray material that may be present without even necessitating their contact with it.

Summary

Thus far mainly the theoretical side of the question as to the time of spraying has been presented. If the facts show that winter spraying can be depended on to control, or even to prevent, early infection the theory must be wrong. Some persons have considered that the amount of scab is decreased by a winter spray; but that the winter spray cannot be depended on to replace any of the summer applications seems clear. During the seasons of 1909 and 1910 certain trees were given this application only, a strong lime-sulfur wash being used. In both these cases it was impossible to detect any difference in the amount of scab on sprayed trees and on unsprayed trees.

It is impossible to say what might happen in some cases, but it is certain that in the two cases mentioned above the dormant spray did not materially reduce the amount of scab. The methods that are most likely to be successful must be adopted. A method that has failed during two consecutive years is certainly not to be relied on. It should be understood that good results may be obtained for many seasons or under certain conditions when the application before the opening of the blossoms is omitted. In many cases a single spraying after the blossoms have fallen gives excellent results. The point to be emphasized is that in cases in which the early summer spraying is important, the dormant spray cannot be substituted for it.

Before leaving the discussion of the time for spraying, the writer wishes to emphasize the importance of making each application at the proper time and of being prepared to do so. Any grower having fifty to one hundred acres of mature apple orchard, who expects to do all his spraying with a single outfit, will find it absolutely impossible to comply with the above requirements, since, as can be seen, the time limit for the most effective application of each spraying usually does not exceed four or five days. The rule for every grower, therefore, should be to provide sufficient spraying equipment to thoroughly spray his entire orchard within four or five days at the most. This is much more important than is generally supposed, since the spray may entirely fail to control scab if delayed one or two days too long, thus permitting the infection to occur before the application is made.

Effect of continued spraying

While, as has already been pointed out, spray applied to even the badly diseased orchards during the first year may be expected to result in clean fruit it is doubtless true that continued spraying year after year has a cumulative effect on the vigor of the trees and thus enables them to set a larger crop of fruit than they could if left unsprayed. The foliage, being protected from the attacks of the fungus, remains healthy and vigorous; consequently the trees are able to produce a larger number of strong fruit buds than would otherwise be possible.

This point is already emphasized by experiments reported by Chester (1898) of Delaware. In experiments conducted with the same trees for three successive years, those unsprayed gave remarkably small yields

(1898) Chester, F. D. Report of the Mycologist. Experiment in the treatment of apple scab upon the farm of S. H. Derby, Woodside, 1897. Delaware Agr. Exp. Sta. Ann. rept. **10**: 39–45.

in the third year while the sprayed trees maintained the same quantity as well as quality of yield. In this connection Crandall (1906) notes that when the foliage of the season is lost as a result of severe scab infection, the trees are likely to attempt to repair the loss by pushing out leaves from buds that should remain dormant until spring in order to form the fruit crop of the next year.

There may be exceptions, however, to the above rule. If trees have over-borne in one season and consequently have not set fruit buds for the next season, it may happen that a severe early attack of scab, by thinning the fruit during the season of over-production, may enable the tree to set more fruit in the following season. An instance of interest in this connection, in the case of pears, is reported by Beach (1895). Eight Seckel trees that were sprayed six times in 1893 were compared with eight other trees of the same variety, under similar conditions except that they were not sprayed in 1893, as to production in 1894. Very little difference in yield was noted, and also very little difference in quality. The yield of the trees sprayed in 1893 was slightly greater, and the quality of the fruit was slightly better, than of those not sprayed in that year. The author comments on the results as follows: " It will be remembered that the sprayed trees in 1893 yielded at harvest nearly three times as much fruit as did the unsprayed trees, so that on further reflection it is not amazing that they did not greatly excel the latter in yield in 1894. That they were enabled to excel them in quantity and nearly equal them in quality of yield in 1894 after the heavy crop of 1893 is really strong evidence of the permanent beneficial effect of spraying. The permanent injurious effects of the scab fungus on the unsprayed trees in 1893 was no greater, if as great, as the permanent injurious effects of excessive yield of the sprayed trees even though their foliage was kept in good condition by the spray." Beach concludes that " even when trees are sprayed, large annual crops of fruit ought not to be expected unless they are well fed and not permitted to overbear."

This, then, was a case in which the permanent injury due to scab practically balanced that due to an over-production of fruit. In the latter case the injury was accompanied by the remuneration of the crop of 1893, while in the former case it resulted in total loss.

(1895) Beach, S. A. Spraying pear and apple orchards in 1894. New York (Geneva) Agr. Exp. Sta. Bul. 84 : 33-35.
(1906) Crandall, C. S. Spraying apples. Relative merits of liquid and dust applications. Illinois Agr. Exp. Sta. Bul. 106 : 240.

BIBLIOGRAPHY

In preparing this bibliography the writer has attempted to make it as nearly as possible complete up to date. Since the writer believes the bibliography published by Clinton in 1901 to be adequate to that date, a few of the earlier references have been accepted as given by him and have not been verified. The writer believes that all later papers of importance have been consulted and are listed below.

Aderhold, Rudolf

1894 Die perithecienform von Fusicladium dendriticum Wal. (Venturia chlorospora f. Mali). Deut. Bot. Gesell. Ber. **12**:338–342.

Shows the relationship between *F. dendriticum* on living apple leaves and *V. chlorospora* f. *Mali*, the permanent stage on dead leaves.

1895 Litterarische berichtigung zu dem aufsatze über die perithecienform von Fusicladium dendriticum Wall. Deut. Bot. Gesell. Ber. **13**:54–55.

Speaks of earlier investigations connecting *F. dendriticum* with Venturia stage.

1896 Die Fusicladien unserer obstbäume. Landw. jahrb. **25**:875–914.

Detailed accounts of the scabs of apple, pear, and cherry, and their relation to Venturia stage on dead leaves of these hosts.

1897 Revision der species Venturia chlorospora, inaequalis, und ditricha autorum. Hedw. **36**:80–83.

Describes the different species of Venturia and gives their hyphomycetous stages, placing *Fusicladium dendriticum* under *Venturia inaequalis* (Cooke) Ad.

1899 Arbeiten der botanischen abteilung der Versuchsstation des Kgl. pomologischen Instituts zu Proskau. Centbl. bakt. 2:**5**:521–522.

Notes *Cephalothecium roseum* following pear scab. Evidently first note of parasitism of this fungus. Summarizes experiments at Proskau on varietal susceptibility.

1900 Die Fusicladien unserer obstbäume. Landw. jahrb. **29**:541–588.

Same as is briefly summarized in Centbl. bakt. 2:**6**:593–595. Aderhold notes that the perithecia are ripe before the blossoms open and that the first infestation appeared about the middle of May, which would make an application after blossoms fall too late for sure protection.

1900 Die Fusicladien unserer obstbäume. Centbl. bakt. 2:**6**:593–595.

Gives list of host plants and relationships. Also recommends certain measures for control.

1901 Arbeiten der botanischen abteilung der Versuchsstation des Kgl. pomologischen Institutes zu Proskau. Centbl. bakt. 2:**7**:661–662.

Finds that summer spraying, if given while leaves were young, was as effective as both winter and summer spraying. Winter spraying alone apparently gave some results.

1902 Ein beitrag zur frage der empfänglichkeit der apfelsorten für Fusicladium dendriticum (Wallr.) Fuckel und deren beziehungen zum wetter. Kaiserliches Gesundheitsamt, Biol. Abt. Land- u. Forstw. Arb. **2**:560–566.

Results of five years investigation of varietal susceptibility to scab. Marked difference noted for some varieties in different seasons.

1903 Kann das Fusicladium von Crataegus und von Sorbus-arten auf den apfelbaum übergehn? Kaiserliches Gesundheitsamt, Biol. Abt. Land- u. Forstw. Arb. **3**:436–439.

Cultural and cross-inoculation experiments.

Allen, W. J.

1911 Black spot of the apple and pear. Agr. gaz. N. S. Wales **22**:915.

Popular directions for treatment.

Alwood, W. B.

1893 Injurious insects and diseases of plants, with remedial measures for the same. Virginia Agr. Exp. Sta. Bul. 24:24.

Mentions *Fusicladium dendriticum* as cause of one of the serious apple diseases in this State.

André, Ed.

1888 Les Fusciciadium et nos vergers. Revue horticole **60**:246–247.

Short description of apple scab.

(Anonymous)

1895– Apple scab. U. S. Agr. Dept. Yearbook **1894**:577; **1895**:587;
1898 **1896**:625; **1897**:673.

Treatment for prevention of scab.

Arthur, J. C.

1885 Apple scab and leaf blight. New York (Geneva) Agr. Exp. Sta. Ann. rept. **3**:370.

Short note on damage caused by this fungus.

Atwood, G. A.

1907 Apple scab. New York State Agr. Dept., Hort. Bur. Inspection bul. 1:12.

Brief note on scab.

Bailey, L. H.

1892 Scab-proof apples. Garden and forest **5**:442.

States that there is no marketable scab-proof variety. Baldwin perhaps the least susceptible.

1895 The recent apple failures of western New York. Cornell Univ. Agr. Exp. Sta. Bul. 84:1–34.

Attributes to apple scab the chief cause of failures, and discusses the fungus and methods of combating it.

Ballou, F. H.

1910 Apple culture in Ohio. Ohio Agr. Exp. Sta. Bul. 217:527–559.

The scab was found to be the cause of withering and dropping of blossoms in unsprayed orchards. Records of spraying experiments.

1910 The rejuvenation of orchards. Ohio Agr. Exp. Sta. Bul. 224:117–150.

Reports experiments favoring the use of lime-sulfur as a summer spray for apples.

Beach, S. A.

1897 Wood ashes and apple scab. New York (Geneva) Agr. Exp. Sta. Bul. 140:665–690.

Reports experiments of applying wood ashes to the soil as not preventing scab.

Beach, S. A., and Bailey, L. H.

1900 Spraying in bloom. New York (Geneva) Agr. Exp. Sta. Bul. 196:399–460.

Spraying as soon as blossoms open seems to prevent set of fruit. If blossoms have been opened several days spraying seems to have no bad effect. Laboratory studies showed that poisons or bordeaux, or even lime alone, prevent germination of pollen.

Beach, S. A., and Little, E. E.

1907 Spraying calendar. Iowa Agr. Exp. Sta. Bul. 89:4.

General directions for spraying for scab.

Beach, S. A., Lowe, V. H., and Stewart, F. C.

1899 Common diseases and insects injurious to fruits. New York (Geneva) Agr. Exp. Sta. Bul. 170:385–387.

Short account of life history, and methods of prevention.

Beach, S. A., and Paddock, Wendell

1896 Apple scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. 14:345–347.

Brief discussion of apple scab and prevention by bordeaux mixture.

Berkeley, M. J.

1855 Why do pears and apples crack? Gard. chron. 1855:724.

States that this is due to *Spilocæa Pomi*, the fructigenous form of *Helminthosporium Pyrorum*, but does not recognize specific difference between the forms on apple and pear.

Bethune, C. J. S.

1910 Apple scab (Venturia inaequalis) and commercial lime-sulphur. Ontario Agr. Col. and Exp. Farm. Ann. rept. 35:34–35.

Used lime-sulfur for apple scab with good results.

1911 Spraying experiments. Ontario Agr. Col. and Exp. Farm. Ann. rept. 36:31.

Reports successful use of lime-sulfur and lead arsenate. Other arsenicals used with lime-sulfur are likely to cause burning.

Bizzozero, G.

1885 Fusicladium dendriticum var. minor Sacc. Fl. Ven. crittog. 1:510.

Follows Saccardo in giving form on apple as variety of that on pear.

Blair, J. C.

1899 Spraying apple trees, with special reference to scab fungus. Illinois Agr. Exp. Sta. Bul. 54:181-204.

Results of spraying, directions for making fungicide, description of machinery, and like information.

1907 Fruit and orchard investigations. Illinois Agr. Exp. Sta. Circ. 107:1-58.

Note on relative merits of liquid and dust sprays for apples. Reports experiments of three years, 1903-1905. Dust sprays were inefficient in every case.

Bonns, W. W.

1911 Orchard spraying problems and experiments. Maine Agr. Exp. Sta. Bul. 189:33-80.

Reviews past work on sulfur compounds for the control of apple scab, and records results of additional experiments, with notes and observations on spray injury.

Bonorden, H. F.

1851 Fusicladium virescens. Handbuch der allgemeinen mykologie, p. 80.

Describes this as a new genus and species and says in part, " Kommt in Gärten auf veredelten Apfelbäumen vor." Winter gives this as a synonym of the pear-scab organism, and Bonorden's figures certainly more nearly resemble that species than the one on the apple.

Brefeld, O.

1891 Venturia ditricha f. Piri. Unter. gesammt. mykol. 10:221.

Shows similarity of a stage produced from above fungus to the scab of pear and apple.

Briosi and Cavara

1892 Fusicladium dendriticum (Wallr.) Fckl. Fung. par., no. 140.

Illustrations and specimens of this fungus, together with a short description.

Brooks, Charles

1907 Diseases of the apple. New Hampshire Agr. Exp. Sta. Rept. 17-18:267-269.

Note containing brief description of apple scab.

1908 Report of the Department of Botany. New Hampshire Agr. Exp. Sta. Rept. 19-20:330-389.

Notes on apple scab. Late infection. Bordeaux injury. Substitution of lime-sulfur for bordeaux.

1909 Some apple diseases. New Hampshire Agr. Exp. Sta. Bul. 144:111–116.

Popular description and discussion of treatment. Spray injury. Evidence as to ascospore infection.

1910 Report of the Department of Botany. New Hampshire Agr. Exp. Sta. Bul. 151:21–22.

Lime-sulfur likely to require more frequent application in wet seasons than bordeaux. Notes on late infection and importance of spraying before blossoms open.

Burrill, T. J.

1882 Notes on parasitic fungi. Agr. rev. **2**:4:86–88.

Account of apple scab.

1883 An orchard scourge. Mississippi Valley Hort. Soc. Trans. **1**:202–207.

Account of apple scab and the damage caused by the disease in Illinois.

1901 The apple scab fungus. Illinois Hort. Soc. Trans. **34**:86–97.

A popular article on present knowledge of apple scab.

Butz, G. C.

1898 Apples in Pennsylvania. Pennsylvania Agr. Exp. Sta. Bul. 43:13, 16.

Treats of apple scab and its prevention by spraying.

Card, F. W.

1895 Apple-scab in Nebraska. Garden and forest **8**:28.

Writer thinks the small amount of scab found in this State is due to dry weather.

Chandler, W. H.

1909 Combating diseases and insects of the orchard. Missouri State Bd. Hort. Ann. rept. **3**:348, 374–379.

Popular description and directions for control of scab.

Chester, F. D.

1888 The scab of the apple and pear. Delaware Agr. Exp. Sta. Bul. 3:6–7.

Short note on above, including preventive measures.

1895 Experiments in the treatment of peach rot and of apple scab. Delaware Agr. Exp. Sta. Bul. 29:18–24.

Favorable results from spraying with bordeaux mixture.

1897 The treatment of plant diseases in 1896. Delaware Agr. Exp. Sta. Bul. 34:14–19.

Favorable results from spraying with bordeaux mixture.

1898 Report of the Mycologist. Experiment in the treatment of apple scab upon the farm of S. H. Derby, Woodside, 1897. Delaware Agr. Exp. Sta. Ann. rept. **10**:39–45.

1899 Report of the Mycologist. Continuation of the work on the treatment of apple scab upon the farm of S. H. Derby, Woodside, 1898. Delaware Agr. Exp. Sta. Ann. rept. **11**:27–30.

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Describes successful spraying experiments with bordeaux mixture.

Churchill, G. W.

1891 Apple and pear scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. **9**:337–339.

Describes effect of this on leaves and fruit and suggests prevention.

Clark, J. W.

1891 Spraying for the codling moth and apple scab. Missouri Agr. Exp. Sta. Bul. 13:6.

Favorable results from spraying with bordeaux mixture.

Clinton, G. P.

1901 Apple scab. Illinois Agr. Exp. Sta. Bul. 67:109–156.

Botanical studies of the fungus. Studied perfect stage, and demonstrated its connection with Fusicladium thus confirming the work of European investigators.

1904 Diseases of plants cultivated in Connecticut. Connecticut Agr. Exp. Sta. Ann. rept. **27**:301–302.

Brief description of the disease and directions for treatment.

Clinton, G. P., and Britton, W. E.

1910 Tests of summer sprays on apples and peaches in 1910. Connecticut Agr. Exp. Sta. Bienn. rept. **33–34**:584–618.

Reports on experiments using bordeaux, lime-sulfur solution, sulfocide, one-for-all, self-boiled lime-sulfur.

Close, C. P.

1900 Plant diseases and insect pests. Utah Agr. Exp. Sta. Bul. 65:67–68.

Note on appearance of scab and remedy.

1905 Dust spraying in Delaware. Delaware Agr. Exp. Sta. Bul. 69:1–7.

Found hydrated lime with copper sulfate, pulverized, and paris green successful. Results very promising.

1906 Third report on dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 76:1–19.

Dusting bordeaux with arsenicals versus spraying. Scab entirely controlled by either method. Bitter rot not well controlled by dusting.

1906 Dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 72:1–23.

Cobb, N. A.

1892 Apple scab. Agr. gaz. N. S. Wales **2**:216, 492.

Reports disease on the increase and suggests use of fungicides.

1893 Apple scab, "Tasmanian black spot." Agr. gaz. N. S. Wales **3**:276–278.

Short botanical account of the fungus and best fungicides for prevention.

Comes, O.

1891 Fusicladium dendriticum Fckl. Crittogamia agraria, pp. 394–397.

Short account of this fungus.

Cooke, M. C.

1866 Sphærella inæqualis Cke. Journ. bot. **4**:248–249.

Describes this as a new species and lists it on apple, pear, and the like.

1873 Spilocæa pomi Fr. Grev. **2**:64.

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1877 The hyphomycetous fungi of the United States. Buffalo Soc. Nat. Sci. Bul. 3:198.

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1891 Apple scab. Grev. **20**:27–29.

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1903 Pests of orchard and fruit garden. Roy. Hort. Soc. [London]. Journ. **28**:6–8.

Brief popular description of disease and fungus. Advises early spring application of iron sulfate, followed by bordeaux after fruit has set.

1904 Apple and pear scab. Roy. Hort. Soc. [London]. Journ. **29**: 91–92.

Habit and life history of fungus. Methods of control. Estimate of losses.

Corbett, L. C.

1900 Fruit diseases and how to treat them. West Virginia Agr. Exp. Sta. Bul. 66:204–206.

Gives characters of apple scab and best preventive treatment.

1900 Spraying. West Virginia Agr. Exp. Sta. Bul. 70:354–355.

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Cordley, A. B.

1904 Apple scab. Oregon Agr. Exp. Sta. Rept. **16**:38–40.

Spraying experiments with bordeaux mixture.

1908 Lime-sulphur spray to prevent apple scab. Better fruit **3**:3:26.

Report of Cordley's first work on apple scab, using lime-sulfur solutions.

1908 The lime-sulphur spray as a preventive of apple scab. Oregon agriculturist **17**:178.

Account of Cordley's first use of lime-sulfur for scab.

1908 The lime-sulphur spray as a preventive of apple scab. Rural New-Yorker 67:202.

Reports successful experiments with lime-sulfur solution. Account of writer's first experiments with same for this purpose.

1909 Lime-sulphur spray preventive of apple scab. Better fruit 3:10:33-35.

Records experiments demonstrating the superiority of lime-sulfur over bordeaux mixture for scab.

Cordley, A. B., and Jackson, H. S.

1911 Orchard spraying. Oregon Agr. Exp. Sta. Circ. 13:13-15.

Directions for the use of lime-sulfur solution.

Costantin, J.

1888 Fusicladium. Les mucédinées simples, pp. 69-71.

Gives figures and short account of apple scab.

Craig, John, and Van Hook, J. M.

1902 Pink rot, an attendant of apple scab. Cornell Univ. Agr. Exp. Sta. Bul. 207:157-171.

Cephalothecium roseum gains entrance through wounds caused by the scab fungus.

Crandall, C. S.

1906 Spraying apples. Relative merits of liquid and dust applications. Illinois Agr. Exp. Sta. Bul. 106:205-242.

An elaborate set of experiments comparing dust and liquid sprays for scab.

1909 Bordeaux mixture. Illinois Agr. Exp. Sta. Bul. 135:199-296.

An extensive investigation of bordeaux mixture as used for apple scab and other plant diseases.

Crawford, F. S.

1886 Report on the Fusicladiums, the codlin moth, and certain other fungus and insect pests attacking apple and pear trees in South Australia. Part I. The apple and pear scab fungi, pp. 7-31.

A popular discussion of the disease, estimates of losses, notes on varietal susceptibility, and the like. Notes on spraying experiments. Suggests use of carbolic acid vapor by placing vessels of the acid in the orchard, as was reported by Mr. Storck to successfully control coffee-leaf disease.

Cuboni, G.

1892 Sulla forma ibernante del Fusicladium dendriticum. Soc. Bot. Ital. Bul. 1892:287-288.

Describes a hibernating condition or stroma found on twigs that under proper conditions of moisture and heat gave rise to the characteristic conidia.

Cummings, M. B.

1909 Apple orchard survey of Niagara county. Cornell Univ. Agr. Exp. Sta. Bul. 262:277–320.

Curtis, M. A.

1867 Spilocaea Pomi Fr. North Carolina Geol. and Nat. Hist. Survey. Rept. 3:121.

Lists fungus as common on skin of apples.

Detmers, Freda

1891 Apple scab. Ohio Agr. Exp. Sta. Bul. 4:9:187–192.

Short description of apple-scab fungus and its injury.

Dickens, A., and Headlee, T. J.

1911 Spraying the apple orchard. Kansas Agr. Exp. Sta. Bul. 174:253–292.

Extensive spraying experiments.

1911 Spraying apples. Kansas Agr. Exp. Sta. Circ. 15:1–8.

Spraying experiment comparing lime-sulfur and bordeaux mixture. Lime-sulfur treatment recommended where blotch is not present.

Duggar, B. M.

1909 Apple scab and pear scab. Fungous diseases of plants, pp. 264–271.

A brief account of the disease, including life history, distribution, economic importance, varietal susceptibility, and treatment.

Ellis, J. B.

1892 Dothidea pomigena Schw. The North American Pyrenomycetes, p. 605.

States after examination of Schweinitz' specimen that this is apparently the fructigenous form of *Fusicladium dendriticum*. An examination by Clinton, however, shows this not to be the case.

Emerson, R. A.

1905 Apple scab and cedar rust. Nebraska Agr. Exp. Sta. Bul. 88:1–21.

Results and discussion of spraying experiments. Notes on varietal susceptibility.

1907 Spraying demonstrations in Nebraska apple orchards. Nebraska Agr. Exp. Sta. Bul. 98:1–35

Spraying experiments in six Nebraska apple orchards. Notes on cost and income.

Emerson, R. A., Howard, R. F., and Westgate, V. V.

1911 Spraying as an essential part of profitable apple orcharding. Nebraska Agr. Exp. Sta. Bul. 119:1–26.

Commercial spraying experiments.

Eriksson, Jakob

1885 Bidrag till kaennedomen om vara odlade vaxters sjukdomar. K. Landtbr. Akad. Exptlfält. Meddel. **1**:61.

1886 Der schorf der obstbäume. Bot. centbl. **26**:345-347.

Abstract of an article published by Erikkson the year before, on scab fungus and damage caused by it in Sweden.

1903 Om fruktträdsskorp och fruktträdsmögel samt medlem till dessa jukdomars bekampande (1. Apfelradszkorp Venturia dendritica) och parontradsskorp (V. pirina). K. Landtbr. Akad. Handl. och Tidskr. **42**:53-71.

Gives description of disease and of fungus, and suggests method of control.

1911 Die rote farbe der fruchtschale und die schorfkrankheit der obstsorten. Zeitsch. pflanzenkr. **21**:129-131.

Takes issue with Voges, who claims that red-skinned apples are more resistant to scab than are green-skinned ones. Notes having frequently observed the fungus on twigs of the current year's growth but not on older ones.

Eustace, H. J.

1902 A destructive apple rot following scab. New York (Geneva) Agr. Exp. Sta. Bul. 227:367-389.

Cephalothecium roseum following scab, causing pink rot. Proved its parasitism by inoculation.

1908 Investigations on some fruit diseases. New York (Geneva) Agr. Exp. Sta. Bul. 297:47-48.

Scab spots enlarged under coating of bordeaux mixture.

Evans, W. H.

1893 Apple scab. Handb. exp. sta. work **1893**:18.

Short description of scab and means for its prevention.

Ewert, Dr.

1910 Die überwinterung von sommerkonidien pathogener ascomyceten und die widerstandsfähigkeit derselben gegen kälte. Zeitsch. pflanzenkr. **20**:138-139.

Subjected conidia of *Fusicladium pirinum* and *F. dendriticum* to low temperature (16° to 5°) three times, six hours each time. Spores of the pear-scab fungus retained their normal vitality, while but very few of the apple-scab spores germinated after the second freezing.

Fairchild, D. G.

1892 Treatment of apple scab at Brockport. U. S. Agr. Dept., Veg. Path. Div. Bul. 3:62.

Records negative results from spraying with different fungicides because of the absence of scab.

1894 Bordeaux mixture as a fungicide. U. S. Agr. Dept., Veg. Path. Div. Bul. 6:43-44.

Brief historical account of the use of bordeaux mixture for apple scab.

Farrand, T. A.

1905 Report of South Haven sub-station for 1904. Michigan Agr. Exp. Sta. Spec. bul. 30:474–475.

Dust sprays inferior to liquid.

Faurot, F. W.

1903 Report on fungous diseases on cultivated fruits. Missouri Fruit Sta. Bul. 6:4.

Brief note on apple scab.

1906 Demonstration spraying for bitter rot and codling moth. Missouri Fruit Sta. Bul. 15:16.

Note on apple scab and combination treatment for scab, bitter rot, and codling moth.

1908 Spraying versus dusting. Missouri Fruit Sta. Bul. 19:1–24.

Dusting was not effective.

Fischer, F.

1909 Über die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 19:432–434.

Considers infection occurs through wounds in epidermis. Advises first application of bordeaux before leaves open. Notes on infection and varietal susceptibility.

Frank, A. B.

1880 Fusicladium dendriticum Fckl. Die krankheiten der pflanzen, pp. 587–589.

Short description of this fungus.

Fries, Elias

1819 Spilocæa Pomi Fr. Nov. fl. Suec. 5:79.

Names this fungus here for the first time rather than in Syst. Myc.

1825 Spilocæa. Syst. orb. veg. 1:198.

Describes this genus and gives host as living apple.

1829 Spilocaea epiphylla. Syst. myc. 3:504.

Describes a fungus on leaves from France that to all appearance is leaf form of apple (and pear?) scab.

1829 Spilocaea Pomi. Syst. myc. 3:504.

Describes the form of apple scab found on the fruit.

Fuckel, L.

1869 Fusicladium dendriticum (Wllr.). Symb. myc., p. 357.

Renames *Cladosporium dendriticum* (Wallr.) as above.

Funk, J. H.

1910 Spraying, the sheet-anchor of success. Pennsylvania State Agr. Dept. Bul. 197:85–94.

Practical directions for spraying apple orchards.

Galloway, B. T.

1887 Diseases of the apple caused by fungi. Missouri State Hort. Soc. Ann. rept. **29**:297–299.

Discusses scab and the use of the fungicides then known.

1889 Apple scab. U. S. Agr. Dept. Ann. rept. **1889**:405–412.

Reports on spraying experiments conducted under the writer's direction by Goff and Taft.

1890 Notes on the fungus of apple scab. Michigan Agr. Exp. Sta. Bul. 59:28–29.

Brief description of the fungus.

1892 Treatment of apple, pear, peach, plum, cherry, and quince diseases in the orchard. U. S. Agr. Dept. Ann. rept. **1891**:362–364.

Brief description of spraying experiments conducted under the writer's direction by Goff, bordeaux mixture proving more efficient than copper carbonate.

1892 Experiments in the treatment of apple scab in Wisconsin. U. S. Agr. Dept., Veg. Path. Div. Bul. 3:31–36.

Reports more fully experiments of Goff in 1891.

Galloway, B. T., and Southworth, E. A.

1889 Treatment of apple scab. Journ. myc. **5**:210–214.

Results of spraying experiments conducted in Wisconsin and Michigan with six fungicides, of which eau celeste and ammoniacal solution of copper carbonate were the most effective.

Garman, H.

1890 The apple scab fungus. Kentucky Agr. Exp. Sta. Ann. rept. **2**:46–49.

Description of fungus and discussion of fungicides.

1893 Bordeaux mixture for apple pests. Kentucky Agr. Exp. Sta. Bul. 44:25–26.

Favorable results from spraying with bordeaux mixture for apple scab.

1894 Apple-scab. Kentucky Agr. Exp. Sta. Ann. rept. **6**:53–54.

Very favorable results from spraying a Janet apple tree with bordeaux mixture.

1908 Apple orchard pests in Kentucky. Kentucky Agr. Exp. Sta. Bul. 133:66, 70–71.

Advises spraying before leaves expand, in bad cases. Note on bordeaux and bordeaux dust.

Goethe, R.

1887 Weitere beobachtungen über den apfel und birnenrost. Gartenflora **36**:293–299.

Notes the relationship of Fusicladium stage of scab on apples and pears to mature stage on the dead leaves.

1888 Zur bekämpfung des apfelrostes. Gartenflora 37:263.

Treats of the use and strength of bordeaux mixture as fungicide for apple scab.

1889 Zur bekämpfung des apfelrostes. Gartenflora 38:241.

Notes that scab developed on apples in storage. Suggests the use of sulfur in the storeroom.

Goff, E. S.

1886 An experiment for the prevention of apple scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. 4:260.

Favorable results from spraying a crab-apple tree with hyposulfite of soda.

1888 Applications for the prevention of apple scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. 6:99–101.

Very beneficial results from spraying parts of a crab-apple and a pear tree.

1889 Experiments in the treatment of gooseberry mildew and apple scab. Journ. myc. 5:35–37.

Results of spraying against apple scab with several fungicides.

1890 Treatment of apple scab. Journ. myc. 6:19–21.

Recommends the use of ammoniacal solution of copper carbonate.

1890 Report on the treatment of apple scab. U. S. Agr. Dept., Veg. Path. Div. Bul. 11:22–28.

Results of spraying with different fungicides, of which ammoniacal copper carbonate proved the most effective.

1890 Prevention of apple scab. Wisconsin Agr. Exp. Sta. Bul. 23:1–11.

Description of scab, and results of spraying experiments under the direction of the United States Department of Agriculture, recommending ammoniacal solution of copper carbonate.

1891 Experiment in the treatment of apple scab. Journ. myc. 7:17–22.

Reports favorably on ammoniacal solution of copper carbonate and ammoniacal copper sulfate.

1892 Experiment in the treatment of apple scab. Wisconsin Agr. Exp. Sta. Ann. rept. 8:160–161.

Summarizes results of spraying experiments conducted in 1890.

1893 Preventive treatment for apple scab, etc. Wisconsin Agr. Exp. Sta. Bul. 34:1–13.

Recommends bordeaux mixture.

1893 Experimental treatment for apple scab. Wisconsin Agr. Exp. Sta. Ann. rept. 9:264, 270–271.

Summarizes the results of spraying experiments conducted in Wisconsin.

1894 The apple scab and its prevention. Wisconsin Agr. Exp. Sta. Ann. rept. 10:228–240.

Gives note on scab and results of spraying experiments conducted during several years, especially those of 1892. Recommends bordeaux mixture.

Gossard, H. A.

1908 Spraying apples. Ohio Agr. Exp. Sta. Bul. 191:103–125.

Concludes that "orchards sprayed with lime-sulfur wash in winter do not need treatment with bordeaux mixture before blossoming, unless this ingredient is omitted from the spray applied just after blooming."

1909 Apple spraying in 1908. Ohio Agr. Exp. Sta. Circ. 95:1–8.

When lead arsenate alone was used for the first application, Winesaps fell almost as soon as set, due to scab disease.

1911 Commercial apple orcharding in Ohio. Ohio Agr. Exp. Sta. Circ. 112:1–15.

Reports successful control with lime-sulfur solution.

Green, W. J.

1891 The spraying of orchards. (1) Spraying to prevent apple scab. Ohio Agr. Exp. Sta. Bul. 4:9:193–212.

Records extensive spraying experiments.

1898 Fruit notes. Ohio State Hort. Soc. Ann. rept. 31:11–12.

Shows very beneficial results from spraying with bordeaux mixture for the control of scab.

Green, W. J., Selby, A. D., and Gossard, H. A.

1911 Orchard spraying suggestions for 1911. Ohio Agr. Exp. Sta. Circ. 109:1–3.

Brief directions for spraying.

Halsted, B. D.

1894 Decays of mature apples. New Jersey Agr. Exp. Sta. Ann. rept. 14:369–370.

Brief note on appearance of apple scab.

1895 Some of the more injurious fungi to fruits in 1894. New Jersey Agr. Exp. Sta. Ann. rept. 15:324.

Notes scab as abundant in New Jersey.

Hamilton, J.

1903 Black spot. Queensland agr. journ. 13:555.

Reports good results with the following formula: copper sulfate 4 pounds, alum 2 pounds, lime 3 pounds, water 50 gallons.

Harvey, F. L.

1889 Apple scab or black spot. Maine Agr. Exp. Sta. Ann. rept. 1888:149–151.

Short account of apple scab and means of prevention by spraying.

1890 Apple scab. Maine Agr. Exp. Sta. Ann. rept. 1889:182–184.

Notes on spraying experiments conducted by the United States Department of Agriculture.

Hatch, A. L.

1891 Experiments in treating apple scab. Journ. myc. 7:26.

Speaks of necessity of early spraying and suggests more dilute solutions than were then used.

Henderson, L. F.

1899 Apple scab in the Potlatch. Idaho Agr. Exp. Sta. Bul. 20: 77–95.

Favorable results from the use of bordeaux mixture.

1904 Some experiments with fungus diseases in 1903. Idaho Agr. Exp. Sta. Bul. 39:263–271.

Spraying experiments reported.

1906 Incomplete experiments for 1905. Idaho Agr. Exp. Sta. Rept. **1905**:14–16.

Spraying experiments reported.

1907 Mixed sprays for apple scab and codling moth. Idaho Agr. Exp. Sta. Bul. 55:1–27.

Includes studies concerning times for application of spray.

Hoffman, H.

1863 Cladosporium dendriticum. Index fungorum, p. 37.

Gives references to scab under this name.

Hoskins, T. H.

1892 Orchard spraying. Garden and forest **5**:370–371.

Speaks of need of selection in order to obtain a more hardy variety of apple, resistant to scab.

Huber, Karl

1908 Fusicladium-bekämpfung durch kupperkalkbrühe oder karbolineum. Deut. obstbäume ztg. **1908**:382–387.

Found carbolineum much inferior to bordeaux for controlling scab.

Jackson, H. S.

1913 Apple diseases. Oregon Agr. Exp. Sta. Bienn. crop-pest and hort. rept. **1911–1912**:238–241.

Jarvis, C. D.

1911 Apple growing in New England. Connecticut (Storrs) Agr. Exp. Sta. Bul. 66:256–261.

Advises caution in the use of lime-sulfur for scab; tested on susceptible varieties such as Fall Pippin and Fameuse. Directions for treatment.

Johnston, T. Harvey

1910 Notes on some plant diseases. (C. A scab on apples.) Agr. gaz. N. S. Wales **21**:563–566.

The author refers to a scab due to *Coniothecium chromatosporum*. The accompanying illustration shows typical frost-banding.

Jones, L. R.

1892 The prevention of apple and pear scab by spraying. Vermont Agr. Exp. Sta. Ann. rept. **5**:132–133.

Reports somewhat favorable results from spraying Greening apples with bordeaux mixture and ammoniacal copper carbonate.

1892 Plant diseases. Vermont Agr. Exp. Sta. Bul. 28:30–34.

Reports strong bordeaux mixture more effective than ammoniacal solution of copper carbonate, but injuring the foliage somewhat.

1893 Apple scab. Vermont Agr. Exp. Sta. Ann. rept. **6**:82–83.

States that spraying experiments were failures, due to excessive rains.

1895 Spraying orchards and potato fields. Vermont Agr. Exp. Sta. Bul. 44:83–93.

Describes scab and gives favorable results from spraying with bordeaux mixture.

Jones, L. R., and Morse, W. J.

1902 Scabbing and russeting of apples in 1902. Vermont Agr. Exp. Sta. Ann. rept. **15**:230–231.

Wet season of 1902 gave serious scab infection and induced much russeting of fruit and some spotting of foliage.

1903 Occurrence of plant diseases in Vermont in 1903. Vermont Agr. Exp. Sta. Ann. rept. **16**:154.

Practically no loss from scab. Early season very dry, followed by rainy season.

Jones, L. R., and Orton, W. A.

1898 Spraying for the prevention of apple scab in 1897. Vermont Agr. Exp. Sta. Ann. rept. **11**:195–198.

Report very favorable results from spraying with bordeaux mixture, and show that sprayed trees hold fruit better than do unsprayed trees.

1899 Spraying for the prevention of apple scab. Vermont Agr. Exp. Sta. Ann. rept. **12**:156–159.

Favorable results from the use of bordeaux mixture.

Keffer, C. A.

1894 Spraying apple trees. Missouri Agr. Exp. Sta. Bul. 27:1–24.

As result of numerous experiments, bordeaux mixture reported as largely preventing apple scab.

Kinney, L. F.

1892 The use of fungicides in the treatment of the apple scab. Rhode Island Agr. Exp. Sta. Bul. 15:21–22.

Quotes from Green as to methods and results of spraying.

1895 The scab of the apple and pear. Rhode Island Agr. Exp. Sta. Ann. rept. **7**:185–187.

Brief report on nature of scab.

Kirk, T. W., and Cockayne, A. H.

1908 Plant pathology. Apple scab (Fusicladium dendriticum) and apple Coniothecium (C. chromatosporum). New Zealand Agr. Dept. Ann. rept. **16**:110–111.

Notes on apple scab and a disease often confused with it, said by the authors to be caused by *Coniothecium chromatosporum*. The latter is illustrated, and is apparently identical with russeting of fruit as caused by bordeaux mixture or weather conditions.

Kock, G.

1911 Schorf, Monilia, und weissfleckigkeit auf verschiedenen obstsorten. Oesterr. Landw. Versuchsw. Zeitsch. **14**:209–213.

Varieties resistant and varieties susceptible to scab.

Lamson, H. H.

1892 Spraying against pear and apple scab. New Hampshire Agr. Exp. Sta. Ann. rept. **3–4**:217–218, 238–239.

Gives short description of scab and reports favorable results from spraying with bordeaux mixture and ammoniacal solution of copper carbonate.

1894 Some fungus diseases of plants and their treatment. New Hampshire Agr. Exp. Sta. Bul. 19:7–11.

Describes scab and gives favorable results from spraying with bordeaux mixture.

1895 Spraying experiments in 1894. New Hampshire Agr. Exp. Sta. Bul. 27:5–7.

Favorable results from use of bordeaux mixture.

1903 Fungous diseases and spraying. New Hampshire Agr. Exp. Sta. Bul. 101:59–60.

Brief description of disease and directions for spraying. Notes on susceptibility.

Lawrence, W. H.

1904 The apple scab in western Washington. Washington Agr. Exp. Sta. Bul. 64:1–24.

Description of fungus. Notes on twig infection and wintering over of conidia. Also production of conidia from mycelium in dead leaves. Distribution, varietal susceptibility. Inoculation experiments not successful. Spraying experiments.

1906 Apple scab in eastern Washington. Washington Agr. Exp. Sta. Bul. 75:1–14.

Liquid bordeaux versus dust.

1907 Some important plant diseases of Washington. Washington Agr. Exp. Sta. Bul. 83:25–28.

Popular description and methods of control.

Link, H. F.

1825 Spilocaea Pomi. Species plantarum, Linné, **6**:2:86–87.

Description of the fructigenous form of apple scab.

Lloyd, J. W.

1907 Spraying for the codling moth. Illinois Agr. Exp. Sta. Bul. 114:377–429.

Investigations on combined spraying for scab and codling moth.

Lochhead, William

1903 Some injurious insects and fungous diseases of the year 1902. Ontario Agr. Col. and Exp. Farm Ann. rept. **28**:26.

Brief note on prevalence of scab and directions for spraying.

1905 Insects and fungus diseases. Ontario Agr. Col. and Exp. Farm. Ann. rept. **30**:43.

Key to the fungous diseases of the apple.

1909 Three important fungous diseases of the orchard. Quebec Society for the Protection of Plants from Insects and Fungous Diseases. Ann. rept. **1**:53–55.

Popular description of disease and fungus.

Lodeman, E. G.

1892 Spraying apple orchards in a wet season. Cornell Univ. Agr. Exp. Sta. Bul. 48:357–393.

Gives results of spraying with bordeaux mixture, a table of varieties showing their susceptibility to scab, and the chemistry of bordeaux mixture.

1893 The spraying of orchards. Cornell Univ. Agr. Exp. Sta. Bul. 60:265–286.

Results of spraying experiments against apple scab.

1895 The spraying of orchards. Cornell Univ. Agr. Exp. Sta. Bul. 86:101–125.

Gives suggestions concerning and results of spraying apples, chiefly against scab.

Lounsbury, C. P.

1905 Fusicladium of the apple and pear. Cape Good Hope agr. journ. **27**:169–174.

Notes on distribution and injury in Australia and South Africa. Author thinks disease was introduced by nursery stock; possibly by diseased apples, but not so likely. Author thinks disease is carried over mostly on twigs. Old leaves not important.

1908 The Fusicladium disease of the pear and apple. Cape Good Hope agr. journ. **33**:16–32.

Conditions favoring disease and effect on host are described. Author notes that apple scab has a much more limited distribution in South Africa than has pear scab. Notes burning of foliage by use of copper soda spray.

Lovett, A. L.

1911 Spray calendar. Oklahoma Agr. Exp. Sta. Bul. 92:1–16.

Directions for spraying.

McAlpine, D.

1902 Experiments in the treatment of black spot of the apple and pear. Victoria Agr. Dept. Journ. **1**:620–630.

Tests of bordeaux with addition of several other substances.

1902 The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. **1**:703–708.

First observation, and history, of scab in Australia. Life history of fungus, symptoms of disease, and varietal susceptibility are discussed briefly.

1902 Report of the Vegetable Pathologist. Victoria Agr. Dept. Journn. **1**:803–804.

Notes on spraying for control of black spot of apples and pears.

1902 Experiments in the treatment of apple and pear scab during 1901–1902. Victoria Agr. Dept. Journ. **1**:525–528.

Results of spraying experiments, and notes on varietal susceptibility.

1902 Spraying experiments in 1901–1902 for black spot. Victoria Agr. Dept. Journ. **1**:432.

A preliminary report on the spraying experiments for the seasons 1901 and 1902.

1903 Report of the Vegetable Pathologist. Black spot of apple and pear. Victoria Agr. Dept. Journ. **2**:250–251.

Tests of various combinations of bordeaux with other substances used on apple and pear. Some experiments are reported more briefly in Bulletin 17 of the department.

1903 Spraying for black spot of the apple. Victoria Agr. Dept. Journ. **2**:354–360.

Addition of common salt slightly increased the efficiency of bordeaux, but McAlpine considers it not necessary. Spraying in bloom apparently did not prevent setting of fruit, but the author thinks it advisable to spray earlier.

1904 Black spot of the apple. Victoria Agr. Dept. Bul. 17:1–32.

Appearance of scab in Australia. Varietal susceptibility, and symptoms of attack. Losses. Conditions favoring disease. Spraying experiments.

1907 Experiments with black spot of apple. Victoria Agr. Dept. Journ. **5**:362–363.

Compared bordeaux with several proprietary sheep dips, and with phenyl, carbolic acid, and the like. None of the latter gave good results.

1910 Report of the Vegetable Pathologist. Victoria Agr. Dept. Rept. **1907–1910**:47–48.

Experiments with lime-water bordeaux.

McCarthy, Gerald

1891 Plant diseases and how to combat them. North Carolina Agr. Exp. Sta. Bul. 76:15.

Short note on scab and means for prevention.

M'Cormack, E. F.

1910 Apple scab (*Venturia pomi*). Indiana State Entomologist. Ann. rept. **3**:145–147.

Popular description of disease and directions for control.

McCready, S. B.

1911 Spraying for apple scab. Ontario Agr. Col. and Exp. Farm. Ann. rept. **36**:42.

Macoun, W. T.

1901 Apple culture. Canadian Agr. Dept., Cent. Exp. Farm. Bul. 37:67–68.

Notes this fungus as being very troublesome during recent years.

1902 Spraying. Canadian Exp. Farms. Rept. 1901:109.

Notes on spraying apples for scab.

1903 Spraying. Canadian Exp. Farms. Rept. 1902:110–111.

Notes loss due to omission of late spraying. Note on bordeaux russeting of apples.

Malley, C. W.

1909 Spraying for apple scab or black spot. Cape Good Hope agr. journ. 35:202–211.

Spraying experiments. At least half the fruit dropped from unsprayed trees. Third spraying caused some injury. Bordeaux injury found to occur as seriously when a small quantity of copper sulfate was used as when the quantity was large. A few trees were sprayed while in blossom and most of the blossoms were killed.

Marchal, E.

1907 Les principaux maladies du pommier. Brussels agr. bul. 23: 56–58.

Short description of disease and directions for treatment.

1907 Rapport sur les observations effectives par le service pathologique de l'Institute Agricole de l'État en 1906. Brussels agr. bul. 23:41.

Reports occurrence of apple scab.

Marlatt, C. L., and Orton, W. A.

1906 The control of the codling moth and apple scab. U. S. Agr. Dept. Farmers' bul. 247:12–21.

Discussion of the disease and methods of control.

Massee, G.

1899 Apple scab. A text-book of plant diseases, pp. 302–304, 435.

Short botanical description of this fungus, together with preventive measures.

1907 Apple scab. A text-book of plant diseases, pp. 302–304.

Brief description of disease, giving authorized methods of control.

Massey, W. F.

1893 The culture of orchard and garden fruits. North Carolina Agr. Exp. Sta. Bul. 92:87–88.

General information concerning scab, and list of varieties most and least liable to attack.

1900 The diseases and insects affecting apple trees in North Carolina, with suggestions for their destruction. North Carolina State Bd. Agr. Bul. 21:28–39.

Discussion of treatment for apple diseases in general.

Maynard, S. T.

1891 Fungicides and insecticides on the apple, pear, and plum. Massachusetts (Hatch) Agr. Exp. Sta. Bul. 11:12–16.

Reports various spraying experiments, which were not very successful in preventing apple scab.

Mohr, Karl

1900 Bericht über die im sommer 1899 angestellten versuche behufs bekämpfung pflanzlicher schmarotzer auf reben und kernobst. Zeitsch. pflanzenkr. **10**:270–274.

Reports the use of basic calcium sulfid as a summer spray for apple and pear scab and for grape mildews.

1901 Versuche über die pilztötenden eigenschaften des sulfurins. Zeitsch. pflanzenkr. **11**:98–99.

Reports successful use of sulfurin (chemically calcium polysulfid) for apple and pear scab and also for several other fungous diseases.

Morris, O. M., and Nicholson, J. F.

1908 Orchard spraying. Oklahoma Agr. Exp. Sta. Bul. 76:27–28.

Brief account of apple scab.

Morse, W. J.

1910 Notes on plant diseases in 1908. Maine Agr. Exp. Sta. Bul. 164:1–28.

Notes on self-boiled lime-sulfur as a substitute for bordeaux mixture for apple scab. Notes on late infection.

Morse, W. J., and Lewis, C. E.

1911 Maine apple diseases. Maine Agr. Exp. Sta. Bul. 185:352–355, 390.

Description of the disease and notes on the life history of the fungus. Storage infection noted.

Munson, W. M.

1892 Spraying experiments. Maine Agr. Exp. Sta. Ann. rept. **1891**:110–118.

Account of scab and results of favorable spraying experiments with eau celeste and ammoniacal solution of copper carbonate.

1892 Spraying experiments. Maine Agr. Exp. Sta. Ann. rept. **1892**:92–98.

Favorable results from spraying with eau celeste against scab.

1894 Notes of spraying experiments. Maine Agr. Exp. Sta. Ann. rept. **1893**:124–128.

Favorable results from spraying with bordeaux against scab.

1903 Experiments in orchard culture. Maine Agr. Exp. Sta. Bul. 89:16–18.

The use of an excess of potash as fertilizer did not ward off attacks of scab.

1905 Summary of experiments in practical horticulture. Maine Agr. Exp. Sta. Bul. 113:26–27.

Ammoniacal copper carbonate was less satisfactory than bordeaux.

1906 Orchard notes. Maine Agr. Exp. Sta. Bul. 128:69–71.

Notes on and directions for spraying for scab. Notes on pink rot following scab.

1908 Orchard notes, 1907. Maine Agr. Exp. Sta. Bul. 155:143.
Notes on spraying for scab, and directions for same.

1909 Apple enemies and how to fight them. West Virginia Agr. Exp. Sta. Bul. 121:353–366.
General directions for spraying apple trees.

Niessl, G. von

1881 Didymosphæria inæqualis (Cke.) Nssl. Fung. Eur., Rabenhorst, no. 2663.
Changes to above name from *Sphærella inæqualis* Cke.

1898 Bemerkung über "Venturia" inæqualis (Cooke) und verwandte formen. Hedw. beiblatt **37**:1–2.
Criticises Aderhold for placing above species under genus Venturia because of presence of bristles around ostiolum.

Norton, J. B. S., and Norman, A. J.

1910 Controlling fungous diseases. Maryland Agr. Exp. Sta. Bul. 143:177–187, 200.
Compares self-boiled lime-sulfur, bordeaux, and sulfocide. Finds bordeaux the most satisfactory of the three.

Norton, J. B. S., and Symons, T. B.

1907 Control of insect pests and diseases of Maryland crops. Maryland Agr. Exp. Sta. Bul. 115:176–177.
Contains alphabetical list of cultivated crops, with notes on their pests and diseases including apple scab.

Paddock, Wendell

1901 Plant diseases of 1901. Colorado Agr. Exp. Sta. Bul. 69:9.
Note on bordeaux injury. Serious on Ben Davis apples.

Pammel, L. H.

1885 Apple scab and leaf blight. Prairie farmer **57**:746.
Gives abstract of article by Trelease.

1891 Treatment of fungus diseases. Iowa Agr. Exp. Sta. Bul. 13:48–49.
Gives copper carbonate as fungicide for this disease.

Peck, C. H.

1873 Spilocæa Pomi Fr. New York State Cabinet Nat. Hist. Rept. **23**:55.
Reports scab common on apples in New York in 1869.

1881 Fusicladium dendriticum Wallr. New York State Mus. Nat. Hist. Rept. **34**:32–33.
Gives short account of above, including with it forms on pear and other hosts.

Persoon, C. H.

1822 Fumago Mali. Myc. Eur. **1**:9.
Brief description of above fungus, which may possibly be apple scab.

Pickett, B. S.

1908 Spraying apple orchards for insects and fungi. Illinois Agr. Exp. Sta. Circ. 120: 1-36.

General directions for spraying, with spray calendar.

Piper, C. V.

1893 Common fungous diseases and methods of prevention. Washington Agr. Exp. Sta. Bul. 8: 138.

Writes briefly about apple scab and its prevention by spraying.

1902 Orchard enemies in the Pacific Northwest. U. S. Agr. Dept. Farmers' bul. 153: 33-34.

Notes on distribution of apple scab in the Northwest, description, and directions for treatment.

Powell, G. H.

1894 The apple-scab. Garden and forest **7**: 297.

List of varieties most and least affected by scab, as determined at Cornell University Horticultural Experiment Station.

Quaintance, A. L., and Scott, W. M.

1912 The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Agr. Dept. Farmers' bul. 492: 23-26.

Quinn, G.

1907 Seasonable notes on some orchard pests. South Australia Agr. Dept. Journ. **10**: 14.

Brief notes on apple scab. Directions for spraying.

Reddick, D.

1913 The apple scab situation. West. New York Hort. Soc. Proc. **58**: 86-90.

1913 Factors influencing successful orchard spraying. New York State Fruit Growers' Assoc. Proc. **12**: 51-54.

Roberts, J. W.

1911 The dilute lime-sulphur sprays versus bordeaux mixtures for apple diseases. Is bordeaux to be abandoned? Indiana Hort. Soc. Trans. **1910**: 82-93.

Control experiment.

Roumeguère, C.

1890 Fusicladium dendriticum forma microsperma. Fungi sel. exs., no. 5592.

Describes briefly this new form, of which a specimen is given.

Ruggles, A. G., and Stakman, E. C.

1911 Orchard and garden spraying. Minnesota Agr. Exp. Sta. Bul. 121: 1-32.

Brief description of scab and methods of treatment.

Saccardo, P. A.

1881 Fusicladium dendriticum (Wallr.) Fckl. var. minor. Fungi Italici, f. 782.

Gives form on apple as variety of that on pear.

1886 Fusicladium dendriticum (Wallr.) Fckl. Syll. fung. **4**:345.

Botanical description of above species.

1886 Fusicladium dendriticum (Wallr.) Fckl. var. Soraueri (Thüm.). Syll. fung. **4**:346.

Reduces von Thümen's *Napicladium Soraueri* to variety of apple-scab fungus.

Salmon, E. S.

1908 Apple scab or black spot. London Bd. Agr. Journ. **15**:182-195.

Scab said to cause considerable damage in England. Susceptibility of varieties discussed. Directions for bordeaux treatment. For late infection ammoniacal copper carbonate should be used. Suggests winter washing of trees with strong copper-sulfate solution when twigs are infected. Notes finding scab on twigs. First time reported in England.

1908 Apple scab or black spot and its treatment. Southeastern Agr. Col. (Wye, Kent). Journ. **17**:304-315.

Importance of the disease in England.

1909 Black spot or apple scab. Southeastern Agr. Col. (Wye, Kent). Journ. **18**:267-270.

Control experiments. Twig infection.

1910 A lime-sulphur wash for use on foliage. London Bd. Agr. Journ. **17**:184-189.

Used lime-sulfur wash of a density of 1.01 for hop mildew (*Sphaerotheca humuli*), gooseberry mildew (*S. mors-uvae*), and apple scab. Results good on all, so far as tested.

1910 Injury to foliage by bordeaux mixture. London Bd. Agr. Journ. **17**:103-114.

Discusses bordeaux injury on both fruit and foliage. Notes injury due to previous attack by the fungus. Russeting of fruit due to weather conditions. Recommends spraying susceptible varieties very lightly. Advises that no other spray than bordeaux be used for scab. Lime-sulfur is unquestionably inferior to bordeaux, although some success has attended its use in the United States.

Sanderson, E. D., Headlee, T. J., and Brooks, Charles

1907 Spraying the apple orchard. New Hampshire Agr. Exp. Sta. Bul. 131:9-56.

Popular descriptions of apple scab and results of spraying experiments. A net profit of eighty per cent for the first year is reported, as a result of spraying for scab and codling moth.

Scalia, G.

1901 Intorno ad una nuova forma di Fusicladium dendriticum (Wallr.) Fckl. Accad. Gioenia d. Catania. Boll. **70**:1-5. 1901. Abs. in Bot. centbl. **89**:398. 1902.

Fusicladium on Japanese loquat seems to have affinities with *F. dendriticum* and *F. eriobothryae*, and the name *F. dendriticum eriobothryae-japonicae* is given it. (Abstract consulted.)

Schander, R.

1909 Zur karbolineumfrage. Deut. landw. presse 36:63–64.

Reports spraying experiments, testing carbolineum which failed to control scab.

Schroeter, J.

1894 Fusicladium dendriticum Wallroth. Krypt.-fl. von Schles. 3:352.

Describes scab on apple and pear as a conidial stage of *Venturia chlorospora.*

Schweinitz, L. D. de

1834 Spilocaea fructigena aut Pomi Lk. Syn. F. N. A., p. 297.

Reports above not rare on Newton Pippin. Seems to have originated the specific name *fructigena.*

Scott, W. M.

1906 The control of apple bitter-rot. U. S. Agr. Dept., Plant Indus. Bur. Bul. 93:33.

Directions for combined treatment for scab and bitter rot.

1908 Self-boiled lime-sulfur mixture as a promising fungicide. U. S. Agr. Dept., Plant Indus. Bur. Circ. 1:12.

Reports no definite data, but favorable indications as to the control of apple scab by self-boiled lime-sulfur.

1909 Lime-sulfur mixtures for the summer spraying of orchards. U. S. Agr. Dept., Plant Indus. Bur. Circ. 27:15–17.

Commercial and self-boiled lime-sulfur used for control of scab, in comparison with bordeaux mixture.

1910 The substitution of lime-sulphur preparations for bordeaux mixture in the treatment of apple diseases. U. S. Agr. Dept., Plant Indus. Bur. Circ. 54:1–15.

Results of experiments in Virginia, Michigan, and Arkansas, during the season of 1909. Lime-sulfur solution seemed the more promising.

1910 The use of lime-sulphur sprays in the summer spraying of Virginia apple orchards. Virginia Agr. Exp. Sta. Bul. 188: 1–16.

Lime-sulfur was as effective as bordeaux for apple scab, and caused no russeting of fruit as did bordeaux.

1911 The use of dilute lime-sulphur for the control of apple diseases. Illinois Hort. Soc. Trans. 44:138–145.

Summarizes results of experiments favoring the use of lime-sulfur for scab.

Scott, W. M., and Quaintance, A. L.

1907 Spraying for apple diseases and the codling moth in the Ozarks. U. S. Agr. Dept. Farmers' bul. 283:1–42.

Combined treatment for apple scab, bitter rot, apple blotch, and codling moth. Description of apple scab, and brief life history of the fungus.

Scribner, F. L.

1885 Fungous diseases of plants. U. S. Agr. Dept. Ann. rept. 1885:81.

Suggests raking and burning leaves as of possible benefit in preventing apple scab.

1888 Apple scab. U. S. Agr. Dept. Ann. rept. 1887:341-347.

Botanical account of scab, with reference to literature. Recommends winter treatment with iron sulfate and early spring spraying with bordeaux mixture.

1890 The treatment of certain fungous diseases of plants. Tennessee Agr. Exp. Sta. Spec. bul. C:6.

Recommends certain fungicides.

1890 Fungus diseases of the grape and other plants, and their treatment, pp. 90-96.

Short botanical account of the fungus and methods for combating it.

1890 Apple-scab and its treatment. Orchard and garden 12:113-114.

General article on the subject.

Secretan, L.

1833 Spilocæa pomi. Mycographie Suisse 3:594.

Selby, A. D.

1897 Some diseases of orchard and garden fruits. Ohio Agr. Exp. Sta. Bul. 79:129-132.

Gives short description of apple scab and assigns it as the cause of the dropping of very young apples.

1899 Investigations of plant diseases. Ohio Agr. Exp. Sta. Bul. 111:95-115.

Results of various spraying experiments made at different times by persons in Ohio.

1910 A brief handbook of the diseases of cultivated plants in Ohio. Ohio Agr. Exp. Sta. Bul. 214:371.

Notes on scab and on profit due to spraying. Directions for control. Notes on iron sulfate as a sticker for bordeaux.

Sherman, Franklin

1904 Spraying apples and pears. North Carolina Agr. Dept. Ent. circ. 6:1-7.

General directions for spraying apples for insects and fungous diseases.

Smith, E. F.

1894 Apple scab. Journ. myc. 7:373-374.

Speaks of 1892 as an unusually bad year for scab in western New York and southwestern Michigan, because of wet spring.

Smith, W. G.

1885 Cracking of apples and pears caused by Cladosporium dendriticum. Gard. chron. n. s. 24:691.

Notes that the fungus attacks petals, anthers, and pistils of flowers, in some cases causing abortion of the fruit. Extremely difficult to suggest method of control.

(Anonymous)

1891 Some of the most common fungi and insects — with preventives. New York (Geneva) Agr. Exp. Sta. Bul. 35:606–607.

Describes briefly the effect of fungus and recommends preventive treatment by spraying.

Sorauer, Paul

1874 Entstehung der sogenannten rostflecken auf den früchten des kernobstes. Vers. Deut. Naturf. u. Aerzte. Verhandl. 1874:84–85.

1875 Entstehung der sogenannten rostflecken auf den früchten des kernobstes. Bot. ztg. 33:50–51.

Botanical account of apple scab on leaves and fruit.

1875 Die entstehung der rostflecken, auf äpfeln und birnen. Ver. Beförd. Gart. Kgl. Preuss. Staaten. Monatsschrift 18:5–15.

Description of *Fusicladium dendriticum* and disease caused by the fungus. The conidial stage is well illustrated.

1882 Fusicladium dendriticum. Die obstbaumkrankheiten, pp. 100–103.

Account of the gross and microscopical appearance of scab on leaves and fruit.

1886 Die rostflecke der äpfel und birnen. Handbuch der pflanzenkrankheiten, p. 392.

Describes apple scab briefly.

1888 Fusicladium dendriticum. Die schäden der kulturpflanzen, p. 224.

Short note on this fungus.

Sprague, C. J.

1856 Contributions to New England mycology. Boston Soc. Nat. Hist. Proc. 5:329.

Lists *Spilocæa fructigena* from New England but does not give host.

(Anonymous)

1895 Spraying pear and apple orchards in 1894. New York (Geneva) Agr. Exp. Sta. Bul. 84:19–20, 31–33.

Recommends time for spraying and notes varieties injured by bordeaux mixture.

Stene, A. E.

1910 Some suggestions on apple growing in Rhode Island. Rhode Island State Bd. Agr. Rept. 25:151–153, 155.

Brief notes on scab and control methods.

Stevens, F. L., and Sherman, Jr., Franklin

1903 Insect and fungus enemies of the apple, pear, and quince, with methods of treatment. North Carolina Agr. Exp. Sta. Bul. 183:64–66.

Stewart, F. C.

1909 Recent investigations on plant diseases. West. New York Hort. Soc. Proc. **54**:77–81.

Includes note on lime-sulfur solution for apple scab.

Stewart, F. C., and Blodgett, F. H.

1899 A fruit-disease survey of the Hudson valley in 1899. New York (Geneva) Agr. Exp. Sta. Bul. 167:283.

But very little scab during the dry season of 1899. Notes occurrence of scab on twigs of the Lady apple.

Stewart, F. C., Rolfs, F. M., and Hall, F. H.

1900 A fruit-disease survey of western New York in 1900. New York (Geneva) Agr. Exp. Sta. Bul. 191:295.

Stewart, J P.

1910 The apple in Pennsylvania: varieties, planting, and general care. Pennsylvania Agr. Exp. Sta. Bul. 106:11–13.

Brief notes on apple scab and its control.

Stinson, J. T.

1892 Apple scab, codling moth, and plum curculio. Arkansas Agr. Exp. Sta. Bul. 21:57–59.

Directions for spraying with bordeaux mixture.

1894 Apple scab. Arkansas Agr. Exp. Sta Bul. 26:23–33, 37–44.

Favorable results from spraying with bordeaux mixture. Notes on damage caused by scab over the State.

1896 Spraying experiment. Arkansas Agr. Exp. Sta. Bul. 39:20–22.

Notes that spraying experiments were not profitable because of the lack of scab that year.

1900 Preliminary report on bitter rot or ripe rot of apples. Missouri Fruit Sta. Rept. **1900**:15–17.

Results of spraying for scab with bordeaux. Scab was more easily controlled by bordeaux than was bitter rot.

Stone, G. E.

1907 Potato and apple scab. Massachusetts State Bd. Agr. Nature leaflet 7:3–4.

Popular description of disease and directions for treatment.

Streinz, W. M.

1862 Nomenclator fungorum, pp. 187, 280, 308.

Gives *Fumago mali* Pers. and *Helminthosporium pyrorum* Tib. as synonyms of *Cladosporium dendriticum* Wallr.

Sturgis, W. C.

1892 Scab. Connecticut Agr. Exp. Sta. Bul. 111:3–4.

Briefly describes scab and its prevention by spraying.

1893 Scab. Connecticut Agr. Exp. Sta. Bul. 115:3–4.

Short note on apple scab.

1894 Spraying for scab of apple and pear. Connecticut Agr. Exp. Sta. Ann. rept. **17**:72–73.

Results of spraying experiments including winter and summer treatments.

1901 Scab [Fusicladium dendriticum (Wallr.) Fckl.]. Connecticut Agr. Exp. Sta. Ann. rept. **24**:258.

A few references to literature.

Taft, L. R.

1890 Report on experiments with remedies for the apple scab. U. S. Agr. Dept., Veg. Path. Div. Bul. 11:30–38.

Experiments in spraying with different fungicides, of which modified eau celeste and ammoniacal copper carbonate gave the best results.

1890 Report on the experiments made in 1889 in the treatment of apple scab in Michigan. Michigan Agr. Exp. Sta. Bul. 59:30–42.

Obtained best results from use of modified eau celeste.

1892 Insecticides and fungicides. Michigan Agr. Exp. Sta. Bul. 83:12–14.

Short description of the fungus, with recommendations for spraying.

1907 Orchard spraying. Michigan Agr. Exp. Sta. Spec. bul. 37:25–26.

Brief directions for spraying for scab and codling moth.

Taft, L. R., and Davis, G. C.

1895 The pests of the orchard and garden. Michigan Agr. Exp. Sta. Bul. 121:19–21.

Writes briefly about scab and recommends use of bordeaux mixture.

Taft, L. R., and Smith, C. D.

1907 Spraying calendar. Michigan Agr. Exp. Sta. Spec. bul. 36:266–274.

General directions for spraying for scab.

Taft, L. R., and Wilken, F. A.

1909 Annual report of the South Haven sub-station for 1908. Michigan Agr. Exp. Sta. Spec. bul. 48:16–24.

Note on scab as affecting set of fruit, and report of use of lime-sulfur and calcium benzoate as summer sprays. Rex and Niagara lime-sulfur solutions, diluted 1–25, used on foliage of apples, pears, cherries, and plums.

Tetzner, ———

1910 Die schwefelkalkbrühe und ihr einfluss auf die kupfernen spritzen. Deut. obstbäume ztg. **14**:179–180.

Note suggesting use of lime-sulfur on apple trees.

Thümen, F. von

1875 Napicladium, eine neue hyphomyceten-gattung. Hedw. **14**: 3-4.

Describes scab fungus on apple fruit as belonging to a new genus.

1875 Napicladium Soraueri Thuem. Myc. uni., no. 91.

Gives specimen and description of his new genus.

1891 Ueber einige besonders beachtenswerte durch parasitische pilze hervorgerufene krankheiten der apfelbaumblätter. Zeitsch. pflanzenkr. **1**: 167-169.

Discusses apple scab and gives *Fusicladium dendriticum* var. *Soraueri* and *Napicladium Soraueri* as synonyms.

Tillinghast, J. A., and Adams, G. E.

1899 Suggestions as to spraying. Rhode Island Agr. Exp. Sta. Bul. 52:20-21.

Appearance of apple scab described and remedy suggested.

Trelease, William

1884 The apple scab and leaf blight. Wisconsin Agr. Exp. Sta. Ann. rept. **1**:45-56.

Gives extended account of scab and of varieties of apples attacked, and recommends raking together and burning leaves.

1884 Fusicladium dendriticum (Wallr.). Prel. list par. fungi Wisconsin, p. 15.

Lists this as very destructive and on following hosts: *Pryus malus*, *P. coronaria*, *P. prunifolia*.

Voges, Ernst

1907 Ueber die schorfkrankheit der obstbäume. Deut. landw. presse **34**:276-277, 284-285, 290-291.

Organisms described at length. Methods of entrance to host, effect on host, methods of propagation. Varietal susceptibility. Infection of twigs.

1910 Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. **20**: 385-393.

Red apples considered resistant. Twig infection. Life history.

Waite, M. B.

1910 Experiments on the apple with some new and little-known fungicides. U. S. Agr. Dept., Plant Indus. Bur. Circ. 58:1-19.

Used iron sulfid, prepared by adding iron sulfate to self-boiled lime-sulfur; tested various modifications of bordeaux mixture.

Walker, Ernest

1906 Suggestions upon the care of apple orchards. Arkansas Agr. Exp. Sta. Bul. 91:166-168, 204.

Dust sprays proved inefficient. Directions for spraying apple orchards.

Wallace, Errett

1909 Apple scab. Niagara Sprayer Company. Fellowship rept. **2**:1–10.

Popular description of disease and fungus. Comparison of bordeaux and lime-sulfur solution for control of apple scab.

1909 The value of lime-sulphur solutions as fungicides. Amer. Pomol. Soc. Proc. **1909**:112–113.

Control experiments with lime-sulfur.

1910 Spray injury induced by lime-sulfur preparations. Cornell Univ. Agr. Exp. Sta. Bul. 288:101–137.

Notes on spray injury to fruit and foliage. Explanations and methods of avoiding such injury are suggested. Scab infection previous to the application of the spray is found to favor injury.

1910 Venturia inæqualis, ascospore dissemination and infection. Science n. s. **31**:753–754.

Brief notes on method of ascospore discharge and infection.

1911 Lime-sulfur as a summer spray. Cornell Univ. Agr. Exp. Sta. Bul. 289:139–162.

Popular account of experiments in the control of apple scab. Various modifications of lime-sulfur preparations are compared with one another and with bordeaux mixture. Early attack of scab was found to be largely cause of poor set of fruit in 1910.

Wallace, Errett, Blodgett, F. M., and Hesler, Lex R.

1911 Studies of the fungicidal value of lime-sulfur preparations. Cornell Univ. Agr. Exp. Sta. Bul. 290:163–207.

Records laboratory tests, verified by field experiments, of the fungicidal value of many modifications of lime-sulfur solution and other fungicides.

Wallroth, F. G.

1833 Cladosporium dendriticum W. Fl. crypt. Germ. 2:**4**:169.

Describes this as a new species on apple, with queried reference to identity with Persoon's *Fumago mali.*

Warren, G. F.

1905 An apple orchard survey of Orleans county. Cornell Univ. Agr. Exp. Sta. Bul. 229:475–481.

Notes on spraying. Estimate of profit due to spraying.

1906 Spraying. New Jersey Agr. Exp. Sta. Bul. 194:12–15.

Popular notes on spraying apples, with directions.

1909 Elements of agriculture, p. 253.

Brief note on apple scab.

Warren, G. F., and Voorhees, J. A.

1907 Report of the Horticulturist. New Jersey Agr. Exp. Sta. Rept. **27**:225.

Attributes cloudiness on pears to an attack of the apple-scab fungus (*Venturia inæqualis*).

Watkins, O. S.

1911 Summary of various spraying experiments for the summer of 1910. Illinois Hort. Soc. Trans. 44:145–169.

Bordeaux mixture considered more effective than lime-sulfur.

Weed, C. M.

1890 Apple scab. Ohio Agr. Exp. Sta. Bul. 14:188.

Reports injury to fruit from spraying with bordeaux mixture.

Whetzel, H. H., and Stewart, F. C.

1908 The control of plant diseases. Cornell Univ. Agr. Exp. Sta. Bul. 252:190.

Brief directions for controlling scab.

Whitten, J. C.

1895 Spraying orchards and vineyards. Missouri Agr. Exp. Sta. Bul. 31:1–19.

Favorable results from spraying with bordeaux mixture.

Wilcox, E. M.

1905 Diseases of the apple, cherry, peach, pear, and plum, with methods of treatment. Alabama Agr. Exp. Sta. Bul. 132:97–102.

Brief description, with directions for control.

Williams, T. A.

1893 Common fungous and insect foes of farm and garden. South Dakota Agr. Exp. Sta. Bul. 35:79.

Gives short note on apple scab.

Winter, Georg

1875 Ueber Napicladium soraueri Thümen. Hedw. 14:35–36.

Shows that above fungus is not distinct from *Fusicladium dendriticum* (Wallr.).

1880 Venturia inæqualis Wint. Myc. uni., von Thümen, no. 1544.

Gives this name for first time to specimens on apple leaves.