The New York Apple Tree Canker

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THE HOST

The economic importance of the apple tree makes the disease in question well worth consideration. That the apple as an agricultural product has a vast relative value cannot be denied. We have only to turn to certain statistics to find fairly accurate figures regarding the absolute dollar value of a single crop. Gannett ('03)[1] estimates that the annual crop is worth above $175,000,000. As an orchard product, the apple comprises 55% of orchard trees and produces 82% of the total bushels of orchard fruit.

THE DISEASE

The term "canker" has come to be a general one, and is usually applied to any disease which causes the death of definite areas of bark on the limbs and trunks of trees. Consequently some modifying term is necessary in order to indicate which canker is under consideration. Paddock ('99)[2] first used the name New York apple tree canker, thus distinguishing it from the European canker, Illinois blister canker, fire blight canker, and others.

The disease frequently occurs on twigs, where it is usually called "twig blight," but this is confusing, since this term is applied to fire blight. When the disease occurs on leaves it is known as "frog eye." Black rot refers to the disease as it appears on fruit.

The earlier theories regarding canker lead us to believe that the diseases under consideration probably were not the New York apple tree

[1] '03, Gannett, H. Twelfth Census of the United States 1900: 74–78.

[2] '99. Paddock, W. The New York Apple Tree Canker. N. Y. (Geneva) Agr. Exp. Sta. Bull. 153:180. 1899.

canker, nevertheless, they are interesting. Parkinson (1629)[1] in a rare volume discusses canker after the following manner: "The canker is a shrewd disease when it happeneth to a tree; for it will eate the barke round, and so kill the very heart in a little space. It must be looked into in time before it hath runne too farre; most men do wholly cut away as much as is fretted with the Canker, and then dresse it, or wet it with vinegar, or Cowes dung and urine, etc., until it be destroyed, and after healed againe with your salve before appointed * * *." Hales (1732)[2] wrote in regard to the manner in which canker spreads. Marshall? (1799)[3] says: "The canker is a disease that originates chiefly in the soil, pervades the juices of the plant, and finally operates towards its dissolution."

Other workers have discussed canker, but Paddock ('98)[4] was first to present anything definite regarding the New York apple tree canker. Mangin ('02)[5] and Delacroix ('03)[6] described an apple disease. Until recent years there has been confusion as to the cause of the leaf-spot or "frog-eye" disease, but Scott and Rorer ('08)[7] proved its identity with the canker disease.

Geographical Distribution.—The disease is known to occur in England, France, Austria, Italy, probably in Scotland, South Africa and in America. In our country it is found in practically all apple growing districts.

Economic Importance.—From careful conservative estimates it has been determined that this disease is second in importance among the fungous diseases of the apple. The annual loss can be safely put at $10,000,000, which makes it apparent that the disease is a serious one.

Symptoms.—The first signs of canker are usually the dying out of the top of affected trees (Fig. 1). Upon approaching more closely, the bark is found to be roughened in more or less definite areas (Fig. 2).

[1] 1629. Parkinson, John. Pardisus Terrestris, London. 1629:550.

[2] 1732. Hales, Stephen. Statical Essays. 1732:264–265.

[3] 1799. Marshall? An Inquiry into the Cause of Diseases in Plants with Hints Respecting their Cure or Prevention. Edinburg (J. Ruthven and Sons). 1799:24.

[4] '98. Paddock, W. An Apple Canker. Science n. s. 8:595–596. 1898.

[5] '02. Mangin, L. Sur une nouvelle maladie des Pommiers causee par le "Diplodia pseudo-Diplodia." Jour. d'Agr. Prat. 2:138–139. 1902.

[6] 03. Delacroix, G. Sur un chancre du Pommier produit par le Sphaeropsis malorum Pk. Bull. Soc. Myc. France. 19:132–142. 1903.

[7] '08. Scott, W. M. and Rorer, J. B. Apple Leaf-Spot Caused by Sphaeropsis malorum. U. S. D. A., Bu. Pl. Ind. Bull. 121:48. 1908.

These areas begin as slight discolorations, which become depressed, and a distinct crevice marks the line between the healthy and diseased bark. The bark may fall, exposing the wood, or it may adhere closely to the underlying wood. A plate of cork seems to limit for a time the extent

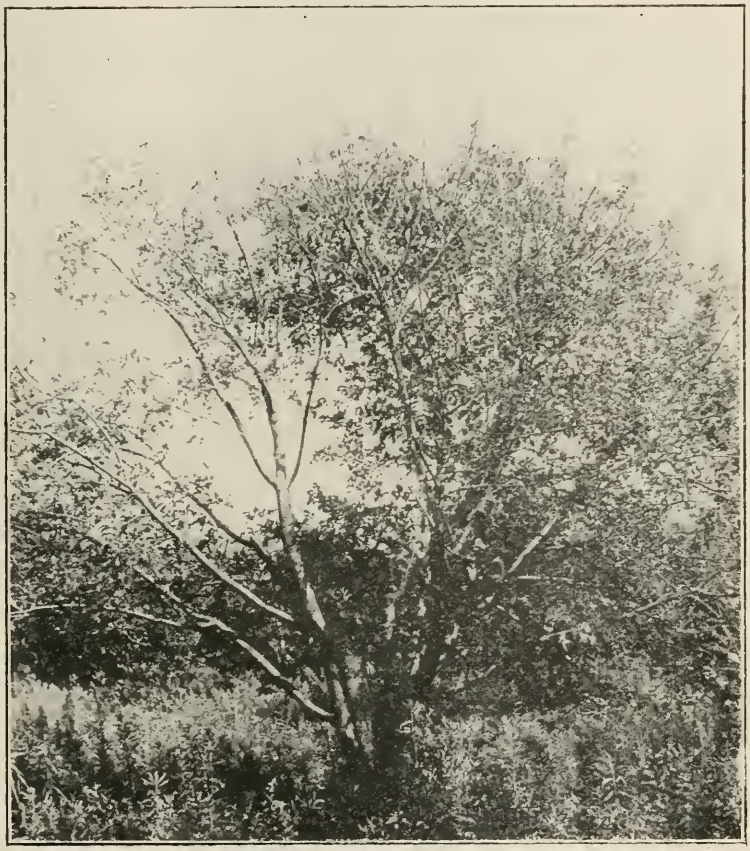

Fig. 1. Twenty Ounce apple tree dying from the attacks of New York apple tree canker. Note the characteristic dying out of the top.

of the diseased area, but this is pierced and the healthy tissue invaded. Soon the affected cells are killed; they shrink, and the healthy portion again is separated from the diseased by a crevice and by a second plate of cork. This process continues until we have concentric rings as shown

Fig. 2. Photograph of New York apple tree canker showing pycnidia in abundance. (After Whetzel.)

in the figure. The writer has not seen cases where healthy wood is invaded, and the cambium is attacked only rarely. In such cases where only the bark layer is attacked, the canker is not so destructive as when it is less superficial.

Fig. 3. Black rot of apple. Enlarged to show distribution of fruit bodies of the fungus. (After Whetzel.)

"Frog-eye" spots on leaves begin as small reddish brown spots with purple margins. Later the spots become brown, and if infection is bad they may coalesce, forming large brown patches which involve a larger portion of the leaf.

Black rot (Fig. 3) begins as small darkened area. After a few days alternating bands of lighter and darker colored brown appear, forming

concentric circles of uniform breadth about the point of infection. Finally the fruit is mummified, and according to Dandeno ('06)[1] there seems to be a distinct production of cellulose in the cell-wall of the apple, and also a production of starch in the invaded cells. The walls become thick and the fruit is temporarily in a state of preservation.

ETIOLOGY

The disease is caused by a fungous parasite, *Sphaeropsis malorum*. Its general nature is that of a wound parasite, though it frequently follows blight, thus acting as a saprophyte. Its pathogenicity has been established by Paddock ('00)[2] and by Scott and Rorer (l. c., p. 49). The writer has confirmed the work of these men, but at present the results are not entirely satisfactory. In few cases has the canker been produced by artificial inoculation even under the most favorable conditions. The only explanations at hand are that the fungus is strictly saprophytic or that the work was not done at the right season of the year. Where maximum sterile conditions were maintained and where the inoculations were made in early summer the writer has failed to reproduce the canker disease. Further experiments may show, however, that infection is possible if done at earlier seasons, perhaps at the time of the rise of sap. Leaves have been inoculated in all conceivable manner, but only where spores were sprayed on the under side were we able to produce "frog eye." In these cases abundant fruit bodies appeared. Extended discussion, as regards the pathogenicity of the organism cannot be taken up here, but it may be said that the present state of our knowledge is very unsatisfactory and many experiments will be necessary to clear up these points.

Synonomy.—In literature we find the fungus referred to as *Sphaeropsis malorum* Berk. and *S. malorum* Pk. Other names have been applied to the same species, so that it is only by making a careful outline of the work done, tracing it from its discovery to the present time, that the situation may become clear.

Berkeley ('36)[3] found a fungus which he called *Sphaeria malorum*. He described it as follows: "Globose or subglobose, covered with a blackened cuticle; stroma blackish, cuticle erumpent, more or less strongly

[1] '06. Dandeno, J. B. A Stimulus to the Production of Cellulose and Starch. Rept. Mich. Acad. Sci. 8:40–44. 1906.

[2] '00. Paddock, W. The New York Apple Tree Canker (Second Report) N. Y. (Geneva) Agr. Exp. Sta. Bul. 185:205–213. 1900.

[3] '36. Berkeley, M. J. English Flora 5:257. 1836.

papillæ form. On apples lying on ground, Winter King's Cliffe, Norths, Rev. M. J. Berkeley. Asci broadly elliptic, septate filled with yellowish green granular. . . . . ." Why he should say "Asci septate," etc., is not known. In his Outlines ('60)[1] he changed the name to *Sphaeropsis malorum* Berk. listing *Sphaeria malorum* in synonomy.

Since the spores of *Sphaeropsis malorum* are brown when mature, and those of *Phoma* are greenish, Saccardo ('84)[2] used the name *Phoma malorum* (Berk.) Sacc. for Berkeley's fungus. In 1886, the genus *Phoma* was divided, the basis of separation being the size of the spores. Species of the genus *Phoma* with spores less than 15 microns long were retained in that genus, while those species with longer spores were placed in the genus *Macrophoma*. Consequently, Saccardo's *Phoma malorum* (Berk.) Sacc. was renamed by Berlese and Voglino ('86)[3] as *Macrophoma malorum* (Berk.) Berl. and Vogl. Meanwhile Dr. Peck ('78)[4] found a black rot fungus on apples which had brown spores. He believed it to be Berkeley's fungus, and so called it *Sphaeropsis malorum* Berk. But Saccardo ('84)[5] believed that, since the spores were brown, Peck's fungus was new and used the name *Sphaeropsis malorum* Pk.

Paddock ('99)[6] points out that *Sphaeropsis mali* Westd. and *S. cincrea* (C. & E.) Sacc. are identical with *S. malorum* Pk. In his second report (l. c., pp. 211-212) he states, as a result of inoculation work, that *S. malorum* Pk. occurs on apple trees, pear trees and hawthorn trees, and on apple, pear, and quince fruits. From this it seems that the species of *Sphaeropsis* on these different hosts are all identical with *S. malorum* Pk. O'Gara ('02)[7] records that *Sphaeropsis rhoina* (Schw.) Starb. on *Rhus glabra* is identical with *S. malorum* Pk.

Unfortunately it seems that species of *Sphaeropsis* have been confused with species of *Diplodia*. The two genera are almost identical, the chief distinction being that the spores of the former are usually 1-celled, while the latter embraces species with 2-celled spores. But both genera fail in their chief distinction, so that mycologists have frequently been

[1] '60. Berkeley, M. J. Outlines of British Fungology (Lovell Reve, London). 1860:316.
[2] '84. Saccardo, P. A. Sylloge Fungorum, 3:152. 1884.
[3] '86. Berlese, A. N. and Voglino, P. Atti. Soc. Veneto-Trentina 1886:184.
[4] '78. Peck, C. H. Report N. Y. State Mus. Nat. Hist. 31:20. 1878.
[5] '84. Saccardo, P. A. Sylloge Fungorum, 3:294. 1884.
[6] '99. Paddock, W. The New York Apple Tree Canker. N. Y. (Geneva) Agr. Exp. Sta. Bull. 163:202. 1899.
[7] '02. O'Gara, P. J. Notes on Canker and Black Rot. Science n. s. 16:434–435. 1902.

misled on this point. Fuckel ('62)[1] described *Diplodia malorum* and *D pseudo-Diplodia* on the branches of apple, and according to his description *S. malorum* is identical with these. Delacroix ('03)[2] states that, since *S. malorum* Pk. is only a species, which was formerly observed by Fuckel and described by him under the name *Diplodia pseudo-Diplodia*, the name *S. malorum* Pk. should disappear. As a substitute for all previous names he says that the logical name should be *Sphacropsis pseudo-Diplodia* (Fuckel) Delacroix.

Scheweinitz ('34)[3] in his treatment of the North American Fungi described a fungus which he called *Sphaeria Sumachi*. Cook and Ellis ('76)[4] evidently recognized this organism as a *Sphaeropsis*, for they listed it as *Sphaeropsis Sumachi* (Schw.) C. & E. giving *Sphaeria Sumachi* Schw. as a synonym. According to their description and figures, this organism is identical with *S. malorum* Pk. If this is true, then *Sphaeropsis Sumachi* (Schw.) C. & E. is most ancient, and should stand.

Schweinitz (l. c., p. 218) described a fungus, calling it *Sphaeria rhoina*. Starback evidently considered this fungus as a *Sphaeropsis* for Saccardo ('95)[5] lists it as *Sphaeropsis rhoina* (Schw.) Starb.; but we have not seen Starback's original description. O'Gara (l. c., pp. 434-435), as we have pointed out, has shown that *S. rhoina* (Schw.) Starb. and *S. malorum* Pk. are identical. We find again that Schweinitz (l. c., p. 219) described a fungus which he called *Sphaeria pomorum*. Cooke ('92),[6] after having examined Schweinitz's collection, states that it should be classed with the species of *Sphaeropsis*, and that it is probably identical with *S. malorum* Pk.

At this point it might be stated that the writer has collected species of *Sphaeropsis* on several different hosts, all of which agree morphologically with the *Sphaeropsis malorum* of Peck; so that in order to clear up this confusion, these different specific names may also have to be considered in the synonomy. This will be determined by cross-inoculation work. The hosts follow: Apple (wood, bark, leaf, and fruit), *Rhus*

[1] '69. Fuckel, L. Symbolae Mycologicae. 1869:395.

[2] '03. Delacroix, G. Sur l'identite reelle Sphaeropsis malorum Peck. Bull. Soc. Myc. France 19:350–352. 1903.

[3] '34. de Schweinitz, L. D. Synopsis Fungorum America boreali media degentium. Trans. Amer. Phil. Soc. n. s. 4:205. 1834.

[4] '76. Cook, M. C. and Ellis, J. B. New Jersey Fungi. Grev. 5:31. 1876.

[5] '95. Saccardo, P. A. Sylloge Fungorum. 11:512. 1895.

[6] '92. Cooke, M. C. Sphaeriaceae Imperfectae Cognitae. Grev. 20:86. 1892.

typhina; Peach twigs; Pear (bark and fruit); Quince (fruit and leaf); *Tilia americana; Morus alba; Ulmus americana; Sambucus canadensis; Hamamelis virginiana* and Crab apple (bark).

With regard to this whole situation it may be said that the suggestion made by Dr. Peck ('81)[1] should have prevented any such confusions. He states that *Diplodia* and *Sphaeropsis* are merely form genera, and that both fail in their chief distinction. Accordingly the oldest generic name should be selected for species like this one, where spores are such that it may be classed either as *Sphaeropsis* or *Diplodia*, and further the separation of the two genera on the basis of the presence or absence of a septum in the spores seems little warranted. It seems that Saccardo was little justified in changing the name *Sphaeropsis malorum* Berk. to *Phoma malorum* (Berk.) Sacc., for it is quite possible that Berkeley described an immature organism. It is quite common to find spores greenish in black rot of apples. After maturing they are brownish.

The discussion of such a situation in regard to the name of a fungus may seem somewhat unimportant, yet it serves as a good example of some of the lack of thorough investigation and the mere guessing at details, which lead to just such confusion. As yet the writer is not wholly satisfied with any of the names. The types of several species will have to be carefully compared before any name can be accepted.

In concluding this phase of the subject there are listed a number of species with citations to literature, which it seems to the writer must be considered in determining the correct name of this fungus, and which names should appear in synonomy.

Sphaeria Samachi Schw.
Trans. Amer. Phil. Soc. n. s. 4:205. 1834.

Sphaeria rhoina Schw.
Trans. Amer. Phil. Soc. n. s. 4:218. 1834.

Sphaeria pomorum Schw.
Trans. Amer. Phil. Soc. n. s. 4:219. 1834.

Sphaeria malorum Berk.
Eng. Flora. 5:257–258. 1836.

Podosporium demersum Bon.
Handb. 1851:227.

[1] '81. Peek, C. H. Report of the Botanist, N. Y. State Mus. Nat. Hist. 34:36. 1881.

Sphaeropsis malorum Berk.

Outlines Brit. Fung. **1860**:316.

Diplodia pseudo-Diplodia Fckl.

Sym. Myc. **1869**:393.

Diplodia malorum Fckl.

Sym. Myc. **1869**:395.

Sphaeropsis Sumachi (Schw.) C. & E.

Grev. **5**:31. 1876.

Macroplodia cinerea C. & E.

Grev. **6**:2. 1877.

Sphaeropsis cydoniae C. & E.

Grev. **6**:84. 1878.

Phoma malorum (Berk.) Sacc.

Syll. Fung. **3**:152. 1884.

Sphaeropsis demersa (Bon.) Sacc.

Syll. Fung. **3**:298. 1884.

Sphaeropsis cinerea (C. & E.) Sacc.

Syll. Fung. **3**:293. 1884.

Macroplodia mali Westd.

Lamb. Fl. Myc. Belg. **3**:66.

Sphaeropsis Mali (West) Sacc.

Syll. Fung. **3**:293. 1884.

Sphaeropsis malorum Pk.

Syll. Fung. **3**:294. 1884.

Macrophoma malorum (Berk.) Berl. et Vogl.

Atti. Soc. Myc. Veneto-Trentina **1886**:184.

Sphaeropsis pseudo-Diplodia (Fckl.) Delacr.

Bull. Soc. Myc. France, **19**:350–352. 1903.

LIFE HISTORY

Upon examination of a cankered limb, especially if comparatively young, pycnidia will be found. Occasionally, too, they are developed on leaves, and very abundantly on the fruit. They are borne beneath the cuticle, which is ruptured at their maturity, and a papillate ostiolum

protrudes (Fig. 4). The size of pycnidium varies from 200-270 microns in the vertical diameter, by 180-210 microns in the horizontal diameter. Typically, there is a unilocular spore-bearing cavity and an ostiole; however, certain conditions of culture have developed pycnidia which lack the ostiole (Fig. 5). This has been observed by Walker ('08)[1] who regarded the character as sufficient to call it a "new form." Whether or not this is so to be regarded cannot be said, but the strain which produced pycnidia in our culture lacking the ostiole, originally possessed an ostiole in nature. Isolations were made from unilocular pycnidia and when mature fruit bodies had developed in culture, they were larger, measuring 400-600 microns x 660-720 microns, and were multilocular. Just how we are to interpret these variations is yet a question, but it seems

Fig. 4. Camera lucida drawing of a typical pycnidium of *Sphaeropsis malorum*.

that they are not to be taken too seriously when questions of taxonomy are involved. If these characters were constant they would be more important, but since they are only variations, little importance should be attached to the absence of an ostiole or to the number of conceptacles.

The pycnidial wall is thick, but not uniformly so. The reason for any variation in thickness may be that less protection is needed at the base, or that its thickness, there, is determined by purely mechanical pressure brought about by the resistance offered to the apex of the pycnidium by the epidermal and cuticular layers of the host tissue. It is made up of two distinct layers, the pseudo-cells of which are very thick-walled and black, and an inner layer of thin-walled cells.

Conidiophores arise from all points of the inner layer and extend entad. They are variously shaped and each is terminated by a conidium

[1] '08. Walker, L. B. A New Form of Sphaeropsis on Apples. Nebr. Agr. Exp. Sta. Rept 21:31-44. 1908.

or pycnospore. A spore arises as a swelling at the tip of the stalk which bears it and after it has reached a certain size, is cut off by a septum. Spores vary in color, size, and shape. When young they are hyaline, later becoming greenish, and when mature are brownish. They may or may not become septate; just what determines this is not understood. One-celled spores in some cases develop two-celled spores in culture. The sporophore is binucleate (Fig. 4) and as the swelling begins at the terminal end, one nucleus passes into the swelling. About this time, a con-

Fig. 5. Photomicrograph of a pycnidium in median section, developed on fruit of apple by artificial inoculation. Note the absence of an ostiole.

striction begins to appear a short distance from the spore-end of the stalk. This marks the line of detachment of the spore from the sporophore. Further development cannot be given at present, except to say that the mature spore is binucleate. The most noteworthy difference in size of spores is that they are larger on fruit and in culture than on limbs or leaves. There is also slight variation with host-plants.

Spores readily germinate in water (Fig. 6), about six hours being required, though we have observed germination after three hours. The tube first appears as a slight swelling at one end or the side. Two-celled

spores frequently put out two germ tubes. Those kept in the laboratory for a year have been found capable of germination.

Micro-conidia have been found frequently in cultures. They are produced near the tips of young mycelial threads and will reproduce the fungus when sown in pure culture. They are colorless and measure 3.6–6.3 x 7–14.5 microns.

Fig. 6. Spores. Germinated in water after a few hours.

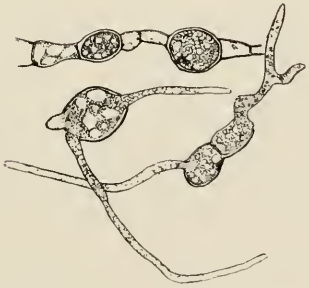

Fig. 7. Chlamydospores produced in culture after four months. Germinated in water after a few hours.

Chlamydospores are also quite common (Fig. 7). The first notice of these bodies was made in agar cultures about three months old. Their formation seems to be brought about as a result of certain mycelial cells becoming rich in protoplasm and becoming delimited by transverse walls to form the chlamydospore, which later acquires a thick membrane. In older cultures, oil drops have been seen in the chlamydospores. These germinate readily in water (Fig 5).

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The Mycelium.—The germ-tube as it branches to develop the mycelium is at first hyaline, but soon becomes darker. In old cultures it is very dark brown. The contents are granular, glycogen frequently being present. Its diameter ranges from 4-10 microns; averaging about 7 microns.

The ascogonous form has been reported by Shear ('10),[1] who sowed ascopores of *Melanops quercuum* (Schw.) Rehm *forma vitis* Sacc. and obtained brown pycnospores which agree morphologically with those of *S. malorum* Pk. and *Diplodia pseudo-Diplodia* Fckl.

Pure Cultures.—The fungus grows and fruits well on any of the media which we have used, including several vegetable and fruit decoction agars. Growth is at first cottony, the colonies effuse and radiating. The brown color characteristic of the older threads soon spreads through the aerial hyphae until only the extreme surface threads remain a light gray color. The production of pycnidia in culture has never failed in our experience, and at present we have about fifty different strains growing. Whether or not certain strains will not fruit in culture remains to be tested.

CONTROL

Preventive measures have not been carefully worked out, though a few general suggestions can be given.

So far as an immediate remedy is concerned it seems that eradication, protection and immunization are points most worthy of consideration. Clean culture should be practiced along with surgical measures. Cankers should be cleaned out and this done carefully. Whether this is practicable or not depends upon the energies of the grower. In one orchard of about 400 trees which we call to mind, the work was done effectively at a cost of about twenty-five cents per tree. In removing cankered spots, all diseased bark should be removed, the wounds disinfected with corrosive sublimate (1-1000) and painted with coal gas tar. Tools which we have found convenient are those which any farmer has, namely, a draw-shave, a farrier's knife for trimming the margin of the wound, and the necessary coal tar and disinfectant. In performing these operations, as well as when picking the fruit, it is recommended the workmen use care about breaking the bark. Any such wounds are only an open door for the fungus.

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[1] '10. Shear, C. L. Life History of *Melanops quercuum* (Schw.) Rehm, *forma vitis* Sacc. Science n. s. 31:748. 1910.

Spraying for canker is practiced; but do not misunderstand what is meant. If the organism is established then it is likely that spraying will not be effective, but trees can be protected against infection. It is often stated that canker is not found in well managed orchards, but this has not been our observation. Even in some of the best cared for orchards we have found the most cankers. In these cases, either the fungus gained entrance to the cambium in only a few instances, or if it did pierce this layer, the limbs were cut off just back of the diseased area and a new shoot allowed to form.

It has been noticed for a number of years that not all varieties are attacked. We have in mind an orchard in which three rows were the Twenty Ounce variety. Other varieties on either side were unaffected. Just why this difference? Is it due to the virulence of the fungus or does it depend upon increased susceptibility of the host, this in turn to be attributed to some subtle change in nutrition, soil condition, or some other overlooked factors of environment? Soil conditions were apparently uniform, so that some more remote factor must have contributed to this phenomenon.

Is it possible to inject into a tree a substance which would render it immune? It is claimed by some that such a thing is possible. After all, then, just how far is the canker fungus responsible for the destruction of the host? May not its invasion be the result of changes from some of the causes suggested rather than the direct work of the parasite? The questions are only to be answered by hoping that future investigation will reveal some of these remote, yet interesting, questions to such an extent that economic conditions generally will be benefited.

Wabash College,
Crawfordsville, Ind., June 1911.