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The New York Botanical Garden

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A SERIOUS CHESTNUT DISEASE.

A serious disease of our native chestnut, which threatens the extinction of this valuable tree in and about New York City, was brought to my attention last summer by Mr. H. W. Merkel, of the New York Zoölogical Park, and has been under investigation here since that time.

The immense number of dead and dying chestnut trees in the Zoölogical Park first caused Mr. Merkel to suspect the presence of a destructive fungus. The ravages of this fungus among the young chestnut trees of the nursery were later observed by him and the trees sprayed with Bordeaux mixture, a treatment afterwards administered to the larger trees in the Zoölogical Park. The same disease has been found to exist among the chestnuts of New Jersey, Maryland and Virginia, and it is probable that the death of the chestnut in the lowlands of Alabama and Georgia, as noted by Mohr and Small, is largely due to this agency.

Inquiries from various sources regarding the disease and the hope that suggestions made now may be of service during the present season have led me to publish at this time a preliminary account of the disease, reserving a more technical and detailed description for a later paper.

Pure cultures from affected chestnut sprouts in the Botanical Garden were made last autumn, and transferred to agar, bean stems, and sterilized chestnut twigs; on all of which the fungus grew rapidly and fruited abundantly. Living chestnut twigs

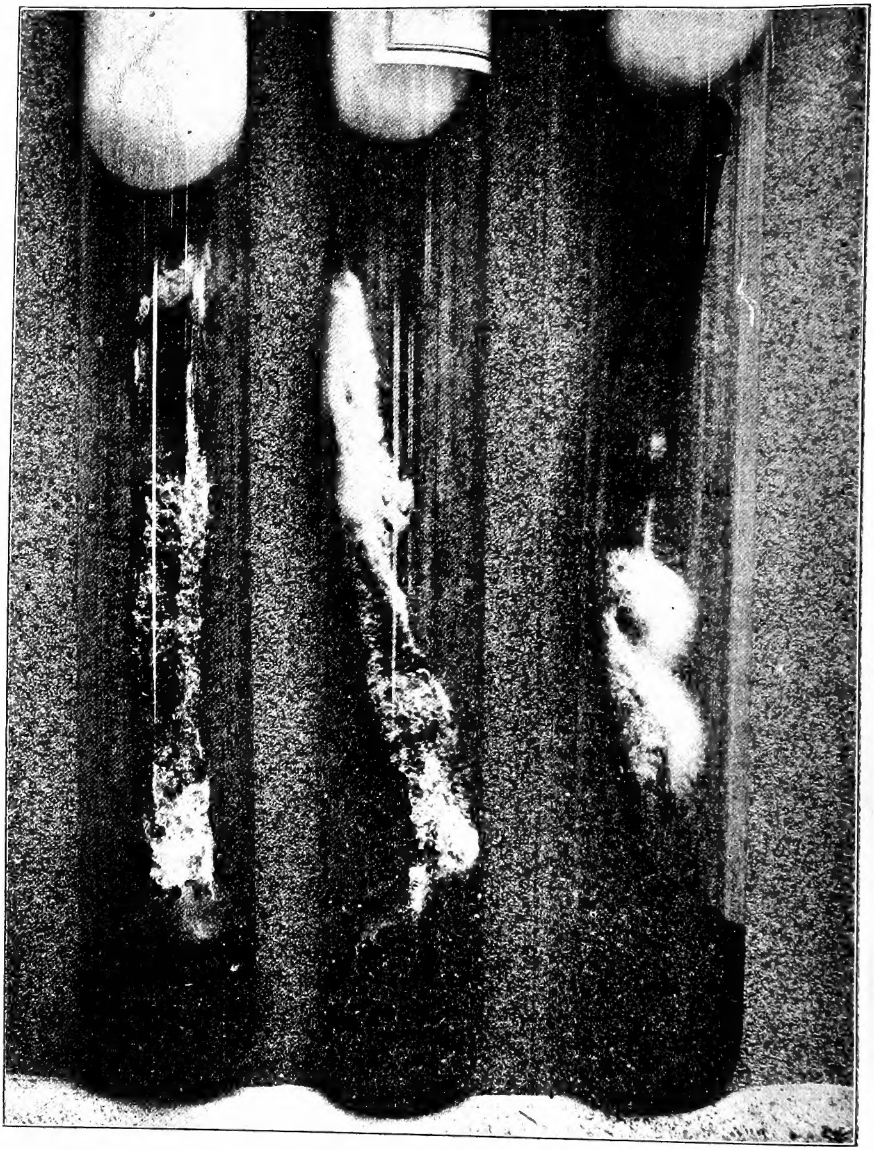

FIG. 13. Three generations of the fungus, on sterilized bean stems.

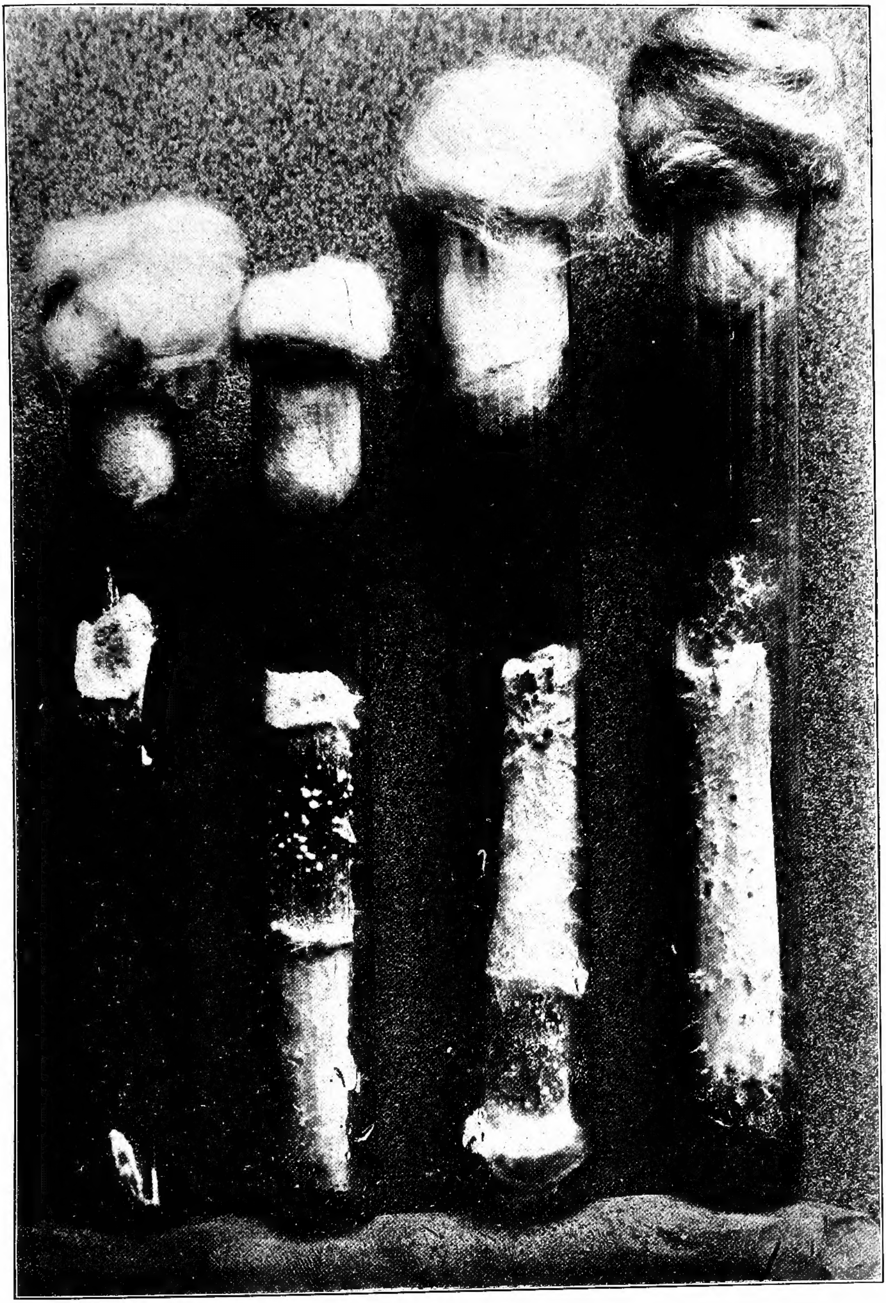

FIG. 14. Cultures of the fungus on sterilized chestnut branches, some with the cortex wholly or partially removed.

placed under belljars with one end of the twig in water were then infected and the growth of the fungus watched, as preliminary to field infections. These latter were made on a number of young chestnut trees in the propagating houses of the Garden as soon as growth commenced in the spring, experiments with dormant trees being carefully avoided. As the preliminary experiments had led me to expect, the actively growing fungus, when transferred from bean stems to the branches of the young trees, attacked them with vigor and soon caused their death by girdling.

The progress of the disease in infections through natural causes was observed in young trees transferred from the nursery of the Zoölogical Park and numerous older infected trees throughout Bronx Park. In all of these the fungus was found exceedingly active at the beginning of the season of growth, before the opening buds were able to use the large quantity of nourishment at hand.

The fungus works beneath the cortex in the layers of inner bark and cambium. Its presence is first indicated by the death of the cortex and the change of its color to a pale brown, resembling that of a dead leaf. Later the fruiting pustules push up through the lenticels and give the bark a rough, warty appearance; and from these numerous yellowish-brown pustules millions of minute summer spores emerge from day to day in elongated reddish-brown masses, to be disseminated by the wind and other agencies, such as insects, birds, squirrels, etc. In late autumn the winter spores are formed, which are disseminated from the dead branches the following spring.

When grown in artificial cultures, the mycelium of the fungus is at first pure white, changing to yellow with age, and the fruiting pustules are a beautiful yellow. Winter spores sown November 27 on agar and transferred to bean stems showed young pustules on December 8 and mature spores in process of discharge by December 17. Cultures transferred to sterilized chestnut twigs developed with equal rapidity, while those remaining on agar were considerably slower. Mycelium inserted beneath the bark of living chestnut twigs on December 13 developed a prominent spore-mass by December 27. Inoculations

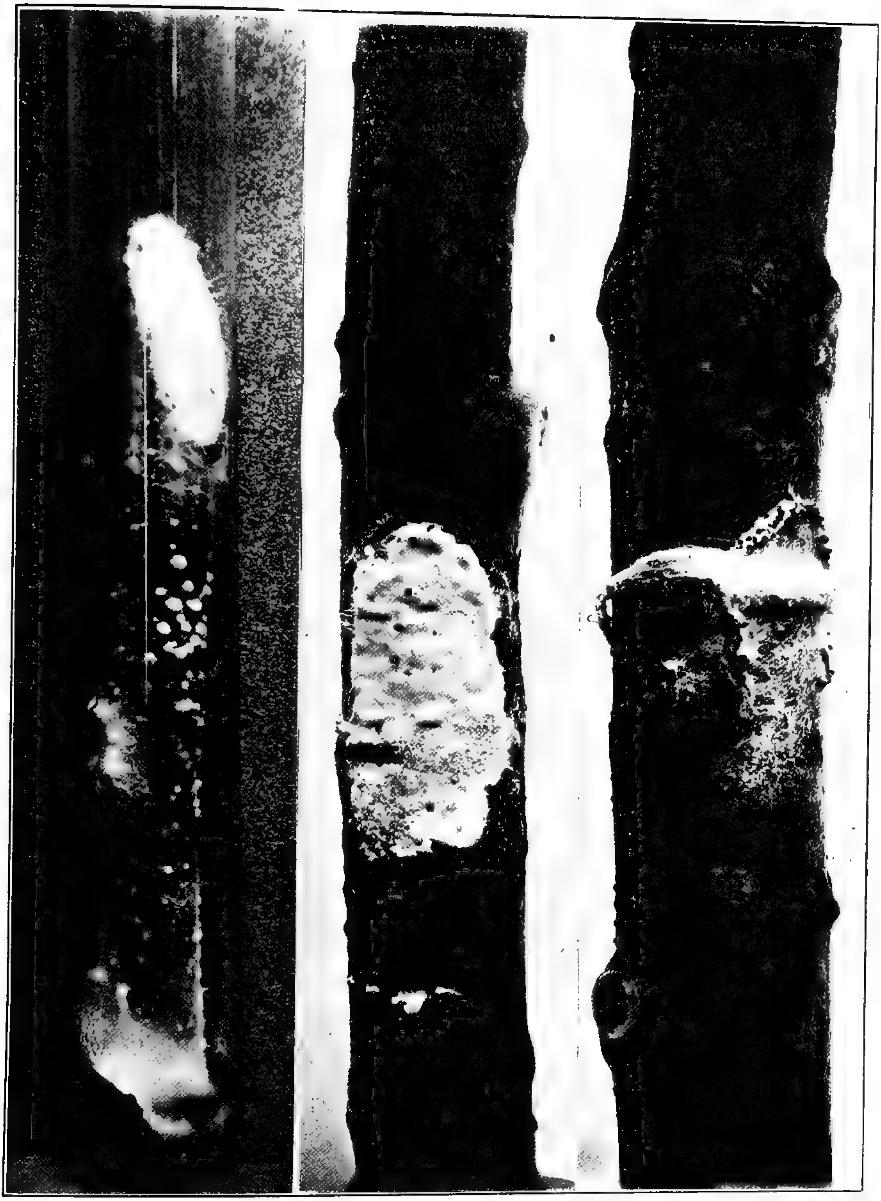

FIG. 15. Cultures of the fungus in sterilized and living chestnut branches. The central figure shows a large mass of yellow mycelium grown on the moist, cut surface of a living branch. The figure to the right shows fruiting pustules arising from mycelium introduced beneath the bark of a living branch. On the left is an enlarged view of numerous pustules grown on sterilized chestnut.

of growing mycelium into living trees in the propagating houses caused the death of infected branches and produced abundant fruit in from four to six weeks. One or two of these young trees appeared to be able to resist infection altogether, and a few of the older trees in the Garden are apparently immune, at least when in vigorous health.

In its effect on the host, this fungus may be classed with the most destructive parasites ; the parts attacked being so vital and

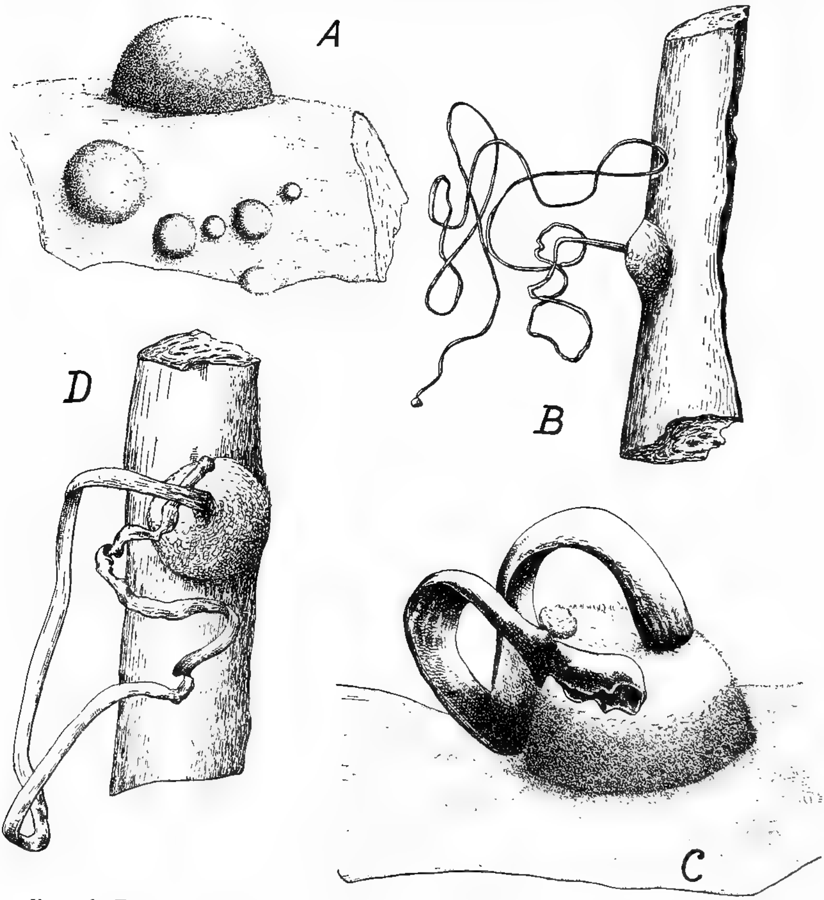

FIG. 16. Fruiting pustules and spore masses from chestnut cultures, × 16. *A*. Stages in the development of the pustules. *B*, *C*, *D*. Various forms of spore discharge in a moist atmosphere.

FIG. 17. Young chestnut trees at the propagating houses inoculated with the fungus in various ways. A dead branch which has been killed by girdling is shown on the extreme left.

the attack so vigorous that young trees often succumb in one or two years, and older ones soon lose branches of such size that the vigor of the entire tree is materially impaired and its beauty and usefulness practically destroyed. It is not the primary effect of the fungus on the living tissues of the tree, widespread as this effect often is, that causes the greatest damage; but the secondary effect of this injury on the remaining portions of the trunk or branch affected; for it is the habit of the entering mycelium to proceed in a circle about the affected portion until it is completely girdled. This girdling habit is due to the stoppage of the circulation up and down the stem at the infected point and the growth of the mycelium toward the current of water and food supply, which is more and more deflected by the invading fungus until finally cut off altogether.

This is well shown in Fig. 19, which represents a portion of a young tree being girdled by the fungus, viewed from three different directions. The fungus entered in 1905 through an undressed pruning wound, and grew nearly half-way around the trunk during last season. The first week in May, 1906, when the weather was warm and moist and the inner bark full of food, the mycelium began to grow again, and by May 11 it had covered that part of the trunk indicated by the light area in the figure. On May 15 the two growing borders had united and the girdling was apparently complete; though death did not ensue for several days, on account of tissues lying next to the sapwood that still remained uninjured. At this time the leaves of the opening buds were scarcely an inch in length; too young to have made use of much of the nutriment stored in the stem.

When the tips of branches are affected, the progress of the disease is of necessity slow, since the affected area is small and the food supply scanty. On the other hand, the base of the young tree is a point of special danger, since the abundance of moisture and food it supplies facilitates the speedy growth of the fungus and thus endangers the life of the entire tree.

The way in which the fungus in question first enters a chestnut tree is at present largely a matter of conjecture. Twigs, sprouts, nursery trees, branches of various sizes, and trunks a foot or more in diameter have been found infected, apparently irrespective of their size or position. So far as field observations show, the fungus might enter wherever a spore happened to find a resting place. All of my experiments, however, have failed to introduce the fungus into a branch while the thin brown layer of cortex remained intact; though it readily entered when this was scraped off or punctured. As the fungus does not attack the leaves, I was not surprised when repeated attempts failed to introduce the disease into green twigs, where, although no cortex is present, the quality of the food and the character of the bark

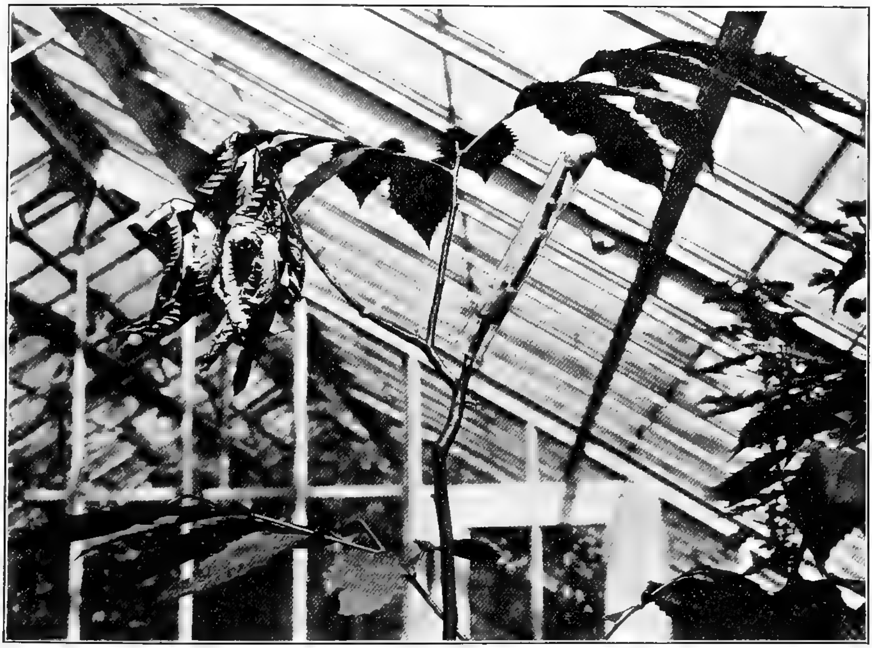

FIG. 18. A nearer view is here given of the dead branch mentioned under Fig. 17. The fungus was introduced by scraping off the cortex and applying active mycelium grown on bean stems.

is evidently not suited to its development. The present supposition is, therefore, that infection takes place only through wounds; or, possibly, through the lenticels.

Wounds are, unfortunately, only too frequent, especially in the case of a tender, rapidly-growing tree like the chestnut, which has the additional misfortune of attracting lumbermen and nut-gatherers. If it escapes winter injuries to its trunk, the spring storms are sure to break the smaller branches and abrade the surfaces of the larger limbs; if it is not disfigured by the green fly and twig-borer during summer, it is sure to be mutilated by

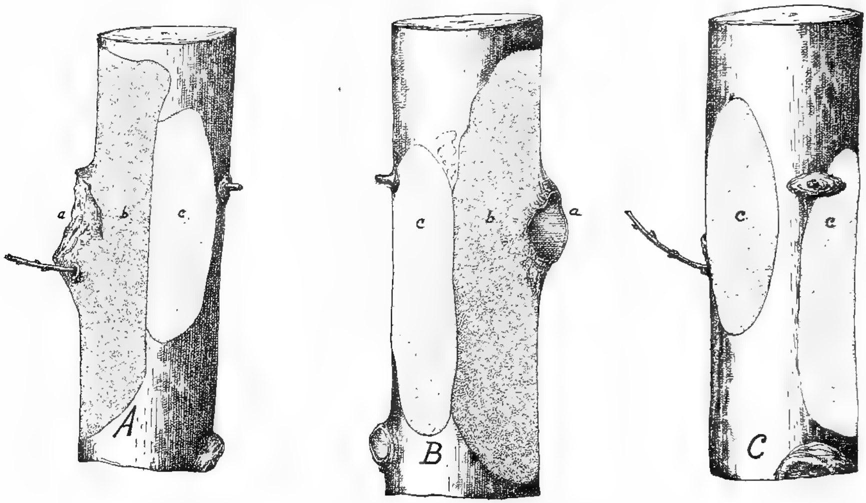

FIG. 19. The trunk of an infected nursery tree, shown natural size. *A*, *B* and *C* are views from different directions. The point of infection in each view is shown at *a*, the area killed by the fungus last year at *b*, and the development early in May of this year at *c*. Three days after this figure was drawn the girdling was complete.

savage hordes of small boys in autumn. Even the ubiquitous squirrel may spread the disease with tooth and claw while cutting off ripe burs and racing up and down the trunks; while every bird and insect that rests upon an infected spot is liable to carry the spores upon its feet or body to other trees. Mice, voles and rabbits often make wounds about the base of a tree and carry the spores in their fur. All during the growing season spores are being developed in countless numbers, and these are liable to fall into even the slightest abrasions of the bark and germinate.

The treatment of a disease of this nature must, of course, be almost entirely preventive. When once allowed to enter, it cannot be reached by poisons applied externally, nor can the spores, which issue continuously and abundantly through eruptions in the bark, be rendered innocuous by any coating applied at intervals. On the other hand, no poisonous wash, even though covering every part of the tree, can prevent the germination of the disseminated spores when they fall into a wound, since the wound opens up fresh tissues unprotected by the poison.

The spraying of young trees with copper sulfate solution, or strong Bordeaux mixture, in the spring before the buds open might be of advantage in killing the spores that have found lodgment among the branches during the winter, but the real efficacy of this treatment is so doubtful that it could not be recommended for large trees, where the practical difficulties and expense of applying it are much increased. Nursery trees should be pruned of all affected branches as soon as they are discovered, and the wounds carefully dressed with tar or paint or other suitable substance. Vigilance and care should largely control the disease among young trees. With older trees all dead and infected wood should be cut out and burned and all wounds covered without delay. Particular attention should be paid to water, soil and other conditions of culture affecting the vitality of the tree; since anything that impairs its health renders it less able to resist fungus attack.

It is possible that the conspicuous ravages of the disease about New York City are largely due to the severe and prolonged winter of 1903–'04, during which many trees of various kinds were killed or injured. The chestnut is peculiar, moreover, in its power to sprout from the stump almost indefinitely, and most of the trees now existing in this region are descendants of trees cut for lumber many decades ago. This repeated coppicing cannot fail at length to impair the vigor of each new generation of sprouts and render them peculiarly liable to speedy infection and vigorous attack.

W. A. Murrill.

THE FIRST DECADE OF THE GARDEN.

On the afternoon of May 23, 1906, the Torrey Botanical Club held a special meeting at the museum building in honor of the tenth anniversary of the commencement of work in the development of the New York Botanical Garden, planting having been commenced in the spring of 1896. The program consisted of an illustrated lecture by the President of the Club, Dr. Henry H. Rusby, who is also a member of the Board of Managers of the Garden, on "The History of Botany in New York City."

The lecturer presented a historical sketch of the development of botany in the city of New York, giving special attention to the history of local botanical gardens, of the botanical department of Columbia University, and of the Torrey Botanical Club. The earliest local work related to the botanical gardens of Colden, Michaux, and Hosack, and to the publication of local catalogues and floras. The second period was that of text-books, manuals, and other educational works. Out of the associations resulting from local work, the Torrey Botanical Club developed so gradually that it was impossible to fix the date of its actual beginning. Portraits of its early members were exhibited, and brief biographical sketches presented. Out of the activity of the Club, and of the botanical department of Columbia University, grew the demand for a great botanical garden, which was satisfied by the establishment of the present New York Botanical Garden. The contemporary botanical forces at work in the city were briefly described, and their most important present needs outlined. The complete address will be published in *Torreya* for June, 1906.

After the lecture an informal reception was held in the library, followed by an inspection of the laboratories, library, herbaria, and the museum and greenhouse exhibits.

C. Stuart Gager.

A LARGE OAK STRUCK BY LIGHTNING.

During the first thunderstorm of the season, which occurred on April 21, the largest pin oak (*Quercus palustris*) within the Garden was struck and cannot recover from the damage which

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THE AUTUMN LECTURES.

The lectures of the autumn course will be delivered in the lecture hall of the museum building on Saturday afternoons at 4:30, beginning early in October and closing the first week in December. They will be illustrated by lantern slides and otherwise. The program will be announced on a special card. The Garden is reached by the Harlem Division of the New York Central Railway to Bronx Park Station, or by the Third Avenue Elevated Railway to Bronx Park. Lectures will close in time for auditors to take the train arriving at Grand Central Station about 6 P. M.

FURTHER REMARKS ON A SERIOUS CHESTNUT DISEASE.

A preliminary account of this disease appeared in the June number of the Journal. At the time the account was written the disease was just beginning to spread on the twigs and branches from the infected areas in which it had spent the winter. On my return to New York in August, I found it very abundant and very destructive, the warm, moist summer having been exceedingly favorable to its development. Hardly a tree in the Garden had escaped infection and many dying and recently-killed branches were observed. I now know of very few chestnut trees in this portion of the city that appear to be worth trying to save and I do not consider any immune.

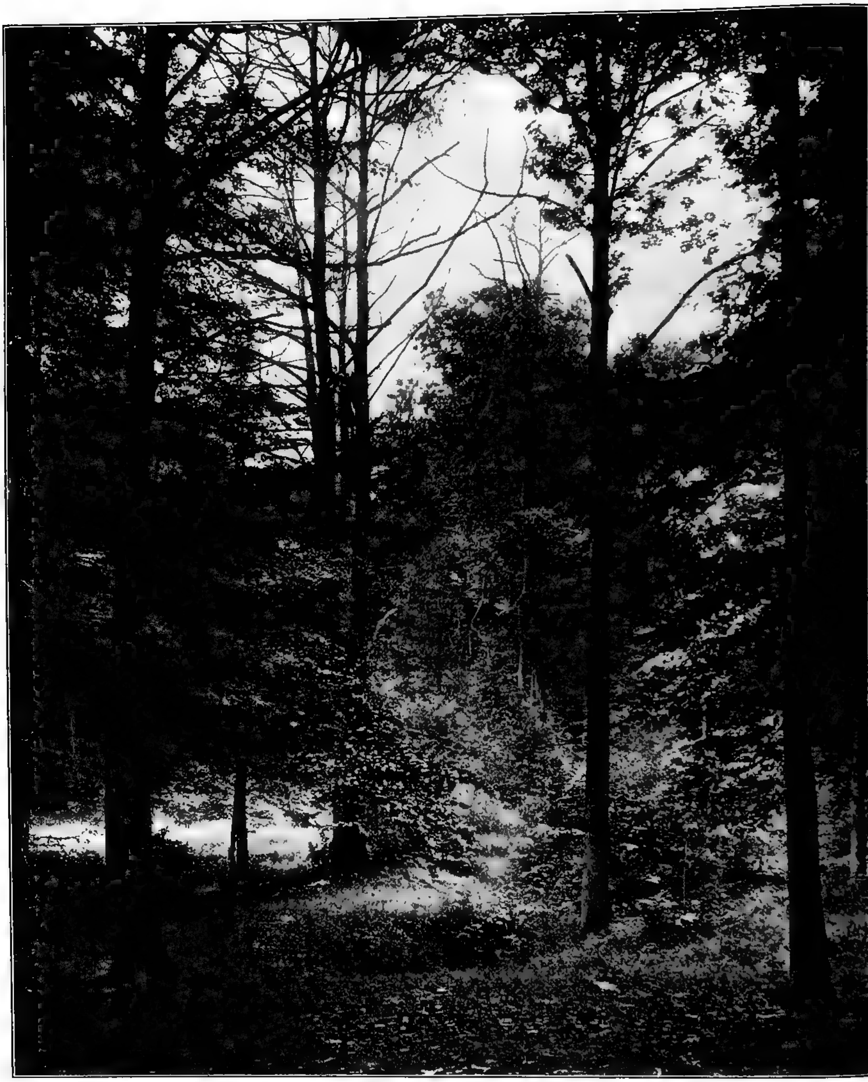

FIG. 25. Chestnut trees in the hemlock woods, New York Botanical Garden, killed by the disease. The clump of trees on the left near the center of the picture is entirely dead; those on the right in the background have almost succumbed.

An attempt was made by Mr. Merkel, * chief forester at the Zoölogical Park, to control the disease by spraying, but I believe he considers the condition quite hopeless. Practically all of the

FIG. 26. Young chestnut trees at the propagating houses used in the inoculation experiments. The tree on the right was not inoculated, being reserved as a check. The tree on the left shows two twigs killed. The top one was inoculated with the fungus March 21 and was completely girdled by April 14. By August 26 the fungus had reached a point nearly, an inch below the junction of this twig with the adjoining one and had extended an equal distance up the latter, girdling it completely. The dead twig near the base of the tree was inoculated in the same way as the top one, namely, by scraping off the cortex and applying the growing fungus to the fresh surface. The two tubes cover twigs inoculated April 3 at the ends after pruning. In both of these the fungus had reached the base of the twig by September 1.

The tree in the center was inoculated April 3 in a fresh wound near the top of the main stem and in another near its base. The principal side branch, treated in the same way, died May 11, and by the end of August the entire stem was dead, including the young twig below the lowest infection, which was girdled by the fungus in its progress down the stem.

* "A deadly fungus on the American chestnut." Annual Report of the New York Zoölogical Society 10: 97–103, *4 figs.* July 4, 1906.

FIG. 27. Other chestnut trees used in the inoculation experiments. The tree on the right was inoculated April 3 in three different places. The small twig near the middle of the stem died on May 6, the larger one near the top on May 19. By August 26 the fungus had girdled the trunk at the lowest inoculation, indicated by the tuft of cotton, and had spread downward to the two lowest twigs.

The experiments with cut twigs, covered with glass tubes, were repeated on the tree in the center, with the same result as before. Attempts were made to introduce the fungus into various buds and young twigs near the top of this tree without wounding the bark, but none of them were successful.

The tree on the left was treated on April 5 in the same way, several buds and young twigs from one to five inches in length being covered with the fungus for some time under glass; but all these attempts likewise failed. The dead branch at the top was inoculated through a wound.

chestnut trees within his jurisdiction appear to be dying rapidly. Even the young trees in the nursery there have been either entirely killed or rendered worthless by the fungus.

Mr. Levison reports all the chestnut trees of Forest Park, Brooklyn, to be either dead or dying, and many in Prospect Park to be seriously affected. Wherever he has found the chestnut tree in Brooklyn, he has found the disease.

The natural result must be the death of practically all the chestnut trees in the infected area, unless some exceedingly active enemy speedily appears; which is extremely unlikely. Dry summers and otherwise unfavorable conditions may delay the progress of the disease a few years, but not very long. After the disease has run its course and the dead trees have been cleared away, young healthy trees, grown from the seed, may be planted with some chance of success, especially if carefully cultivated and guarded against attacks by aphis and wounds of every description. In nearly all the new infections examined I have noticed a dead

FIG. 28. Inoculation experiments with young chestnut trees. Tree on the right killed to the base of the trunk by a body infection; tree on the left reserved as a check.

FIG. 29. Infected nursery trees removed from the Zoölogical Park to the Garden last autumn. The photograph was taken August 27, 1906. The dead tree on the right was apparently in perfect condition early in the season, but close inspection revealed a diseased spot near the base of the trunk, which later girdled it and killed the entire tree.

The tree on the left also leafed out vigorously and appeared healthy, but was girdled about halfway up the trunk by May 15 from a diseased spot near a wound made in pruning. On May 19 fruiting pustules began to appear on the diseased bark and the leaves began to die.

twig, or dead area of some kind on the bark, apparently not killed by the fungus, from which the infection appeared to spread. The end of the branch being killed, dead spots are sure to appear lower down, from lack of food, and the spores washed down by the rain find easy entrance. Thus it frequently happens that a small infected branch will often lead to a serious infection of the main stem even before the fungus has had time to grow down the whole length of the branch.

In the case of large branches, the ends of which are killed, one side of the branch may entirely die, thus affording an easy and speedy entrance of the fungus directly into the trunk. It is on this account that pruning large infected branches often fails of success.

In this connection it may be interesting to give a brief outline of the results of the infection experiments with young trees in the propagating houses mentioned in my former article. In one set of experiments, the fungus, taken from pure cultures, was introduced through wounds into the living tissues of the branch. As may be seen from the accompanying illustrations, the branches thus infected have all died. An attempt was made in another set of experiments to infect young twigs and unfolding buds without removing the cortex. No infections of this kind were successful. Other infections were made upon the cut ends of branches and the progress of the disease down the branch toward the trunk observed. A number of check trees were kept in each case and they have all remained perfectly sound.

Interesting observations were also made on the progress of the disease during the summer in young trees in the nursery outside. One of these in particular was mentioned and figured in the June Journal. A comparison of the condition of the tree early in May with its condition now, as seen in the accompanying illustration, will show how rapid and how deadly the work of this fungus may be.

I have no treatment to suggest further than the preventive measures already mentioned. I realize the extent of the calamity in New Jersey, Maryland, Virginia, and other states where the disease is known to occur, if it is as virulent as it is with us.

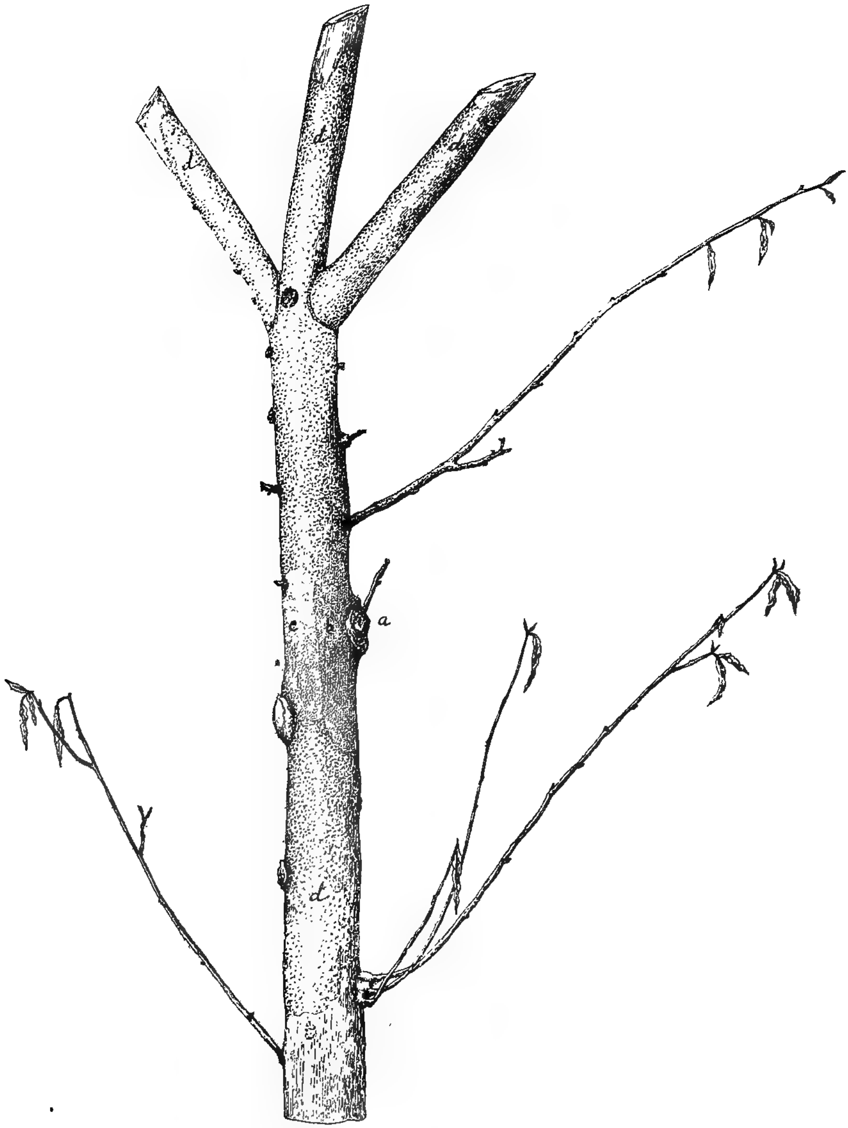

FIG. 30. A portion of the tree shown on the left in fig. 29. The point of infection is shown at *a*, the area killed last year at *b*, and the development of the fungus by May 15 of this year, when the girdling was complete, at *c*. Between May 15 and August 27 the fungus covered the area above and below the point of infection represented by *d*, a lineal distance of nearly ten inches, the progress downward being opposed by living tissue.

Owners of woodlands in these states should cut and use all large infected trees at once. Since the fungus affects the bark only, the wood is perfectly sound unless allowed to stand and be subjected to other agencies causing decay. Small trees with body infections will soon die, so they might as well be cut at the same time. Healthy young trees with only a few diseased twigs might be treated by pruning a foot or more below the discolored area and covering the wounds with coal-tar. Care should be taken not to make new infections with the hands or pruning implements while the work is being done.

Fortunately, the disease does not spread to other forest trees: nor has it been found on any other species of chestnut, either in this country or in Europe.

In *Torreya* of this month the fungus is described in detail, with figures showing its microscopic characters, as a new species under *Diaporthe*, a large genus of the pyrenomycetes.

W. A. MURRILL.

OBSERVATIONS IN ECONOMIC BOTANY MADE AT OSCODA, MICHIGAN.

During a stay of several days at Oscoda, Michigan, in the latter part of August, I was most impressed by the disastrous effects of the destruction of the great forests which once covered the surrounding region. These forests consisted of white pine (*Pinus Strobus*); red pine (*P. resinosa*), there called Norway pine, and presenting two distinct varieties to the lumberman, the "sap Norway," its wood almost all alburnum and of little value, and "cork Norway," with very little sap-wood, and highly esteemed; and jack-pine (*P. divaricata*), a pitch pine of little value. With these were associated more or less hardwood timber, chiefly white and black oak, sugar maple and birch, and, in the low grounds, other coniferous trees, chiefly spruce, tamarack and white cedar.

In the cutting of these forests, the usual American custom of indiscriminate and total destruction was followed. The removal of the larger trees, with judicious replanting, would have preserved not only the valuable lumbering industry, but also climatic conditions of the greatest importance. As it is, we have left only vast sandy wastes covered with jack-pines, and these of the smallest and meanest description. There is no shade, and the plains are arid and desolate, affording apparently no opportunities for even ordinary agricultural operations. In Oscoda and Au Sable, contiguous towns except for the intervening Au Sable River, the twenty-odd saw-mills are now reduced to four, and these are fed principally upon "dead-heads,"—snags dragged out from the bed of the river. A population of ten or twelve thousand has become reduced to two or three thousand, with a corresponding decline in general business.

This depressing picture is repeated a thousand times throughout the once rich lumbering regions of the United States, and marks one of the most brutal cases of looting of the property of a future generation that the world has ever witnessed. It is probably not too much to say that the reforestration that is now recognized as a necessity will cost a hundred fold what it would have done to preserve the existing forests, and many times the price that has been obtained for the lumber cut. A still worse feature is that this cannot be done at all until special methods are devised. Experimental work in this direction is now proceeding, especially under the direction of Mr. Carl Schmidt, of Detroit, who has bought Cedar Lake and a large area in its vicinity.

Other industries, except beyond the limits of the sand barrens, are unimportant. Great quantities of blueberries, chiefly the low sweet blueberry (*Vaccinium pennsylvanicum*) are exported, the picking being done chiefly by Chippewa Indians, who have a settlement near by and establish temporary camps from place to place, as the harvest proceeds. Both the large and small cranberry are found in the bogs, the latter being more common, but less esteemed. Some use is made of the high bush cranberry (*Viburnum Opulus*), which grows in the edges of the swamps. Checkerberries, bearberries and bunchberries abound, but are not commercial elements, the same being true of the choke-berry. The wild red cherry (*Prunus pennsylvanica*) is not uncommon.

B. P. I.—347.

THE IMMUNITY OF THE JAPANESE CHESTNUT TO THE BARK DISEASE.

By HAVEN METCALF, *Pathologist in Charge of the Laboratory of Forest Pathology.*

THE EXTENT OF THE BARK DISEASE.

The bark disease of the chestnut, caused by the fungus *Diaporthe parasitica* Murrill, has spread rapidly from Long Island, where it was first observed, and is now reported from Connecticut, Massachusetts, Vermont, New York as far north as Poughkeepsie, New Jersey, Pennsylvania, and possibly Delaware. It is no exaggeration to say that it is at present the most threatening forest-tree disease in America. Unless something now unforeseen occurs to check its spread, the complete destruction of the chestnut orchards and forests of the country, or at least of the Atlantic States, is only a question of a few years' time.

AN IMMUNE VARIETY.

Observations made by the writer during the past year indicate that all varieties and species of the genus Castanea are subject to the disease except the Japanese varieties (*Castanea crenata* Sieb. and Zucc.). All of the latter that have been observed in the field or tested by inoculations have been found immune. This fact can hardly fail to be of fundamental importance to the future of chestnut nut culture. Although the nuts are distinctly inferior in flavor to the European varieties, such as Paragon, the Japanese chestnut is already grown on a large scale as a nut-producing tree. There are, however, many trade varieties of dubious origin. Some of these may prove later to be subject to the disease. Immunity tests of all known varieties of chestnuts have been undertaken.

Attempts will also be made to hybridize the Japanese with American and European varieties, with the hope of combining the immunity of the former with the desirable qualities of the latter.

However excellent as a nut and ornamental tree, the value of the Japanese chestnut as a forest tree is doubtful. It can be recommended only experimentally at present for forest planting. It certainly will not take the place of the American chestnut. The tree is said to attain a height of 50 or 60 feet in Japan. As seen in this country it is a handsome tree, dwarfish and compact in habit, and rather slow growing. It has hardly had time to show how large it can grow.

The immunity of the Japanese chestnut, together with the fact that it was first introduced and cultivated on Long Island and in the very locality from which the disease appears to have spread, suggests the interesting hypothesis that the disease was introduced from Japan. So far, however, no facts have been adduced to substantiate this view.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 141, PART V.

B. T. GALLOWAY, *Chief of Bureau.*

THE PRESENT STATUS OF THE CHESTNUT BARK DISEASE.

BY

HAVEN METCALF, PATHOLOGIST IN CHARGE,

AND

J. FRANKLIN COLLINS, SPECIAL AGENT,
INVESTIGATIONS IN FOREST PATHOLOGY.

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THE PRESENT STATUS OF THE CHESTNUT BARK DISEASE.

By HAVEN METCALF, *Pathologist in Charge*, and J. FRANKLIN COLLINS, *Special Agent, Investigations in Forest Pathology.*

HISTORY OF THE CHESTNUT BARK DISEASE.

In 1904 Mr. H. W. Merkel, of the New York Zoological Park, observed a disease which was destroying large numbers of chestnut trees in the city of New York. This disease is what is now known as the chestnut bark disease. Even at that time it is certain that it had spread over Nassau County and Greater New York, and had found lodgment in the adjacent counties of Connecticut and New Jersey. No earlier observation than this is recorded, but it is evident that the disease, which would of necessity have made slow advance at first, must have been in this general locality for a number of years in order to have gained such a foothold by 1904. Conspicuous as it is, it is strange that the fungus causing this disease was not observed or collected by any mycologist until May, 1905, when specimens were received from New Jersey by Mrs. F. W. Patterson, the Mycologist of the Bureau of Plant Industry. In the same year Dr. W. A. Murrill began his studies of the disease, publishing the results in the summer of 1906. By August, 1907, specimens received by this Bureau showed that the disease had reached at least as far south as Trenton, N. J., and as far north as Poughkeepsie, N. Y., and was spread generally over Westchester and Nassau counties, N. Y., Bergen County, N. J., and Fairfield County, Conn.

PRESENT DISTRIBUTION.

The present distribution of the chestnut bark disease is shown on the accompanying map (fig. 2). By this it will be seen that infection is now complete in the general vicinity of the city of New York. Outside of this area the disease already occurs at scattering points in a number of States. In every case its occurrence has been definitely authenticated by specimens which have been examined microscopically. Reports have been received indicating that the disease is found at many other places, but not being substantiated by specimens these localities have not been shown on the accompanying map. It is only fair to state, however, that such reports have been received from points as remote as Cape Cod, Wellesley, and Pittsfield, Mass.; Rochester and Shelter Island, N. Y., and Akron, Ohio.

The bark disease is entirely different from a disease which during the past twenty years has caused the death of many chestnut trees on the Atlantic slope, particularly south of the Potomac River. The latter disease, which is now being studied by the Department of Agriculture, is associated with insects, is much slower in action than the bark disease, and produces a stag-headed condition of the tree. It can be quite confidently stated that the bark disease does not yet occur south of Virginia and at only a few points in that State.

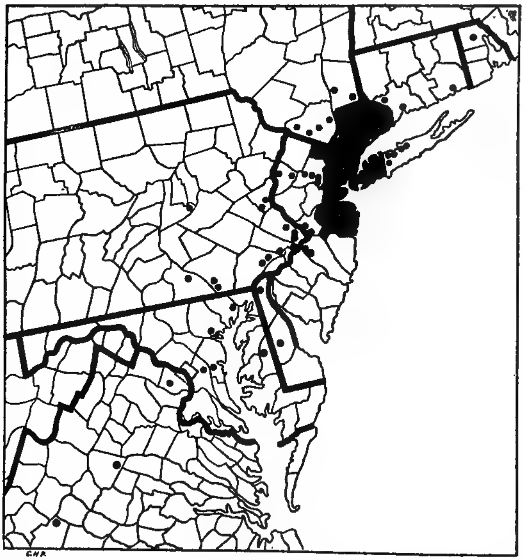

FIG. 2.—Map of the eastern portion of the United States, showing the distribution of the chestnut bark disease. The heavily shaded part shows the counties wherein infection is already complete. The round dots show other points where the disease is positively known to occur.

Investigations are in progress to determine the origin of the bark disease in America and the details regarding its spread. The theory advanced in a previous publication of this Bureau,[a] that the Japanese chestnuts were the original source of infection, has been strengthened by many facts. It yet lacks much of demonstration, however, and is still advanced only tentatively.

While the disease has spread principally from the vicinity of New York there is much to indicate that it occurred at other points at an early date. Chester's Cytospora on a Japanese chestnut, noted at Newark, Del., in 1902, may have been the bark disease. Observations by the junior writer indicate that this disease may have been present in an orchard in Bedford County, Va., as early

[a] Bureau of Plant Industry, U. S. Department of Agriculture, Bulletin 121, Part VI. 1908.

as 1903, and that in Lancaster County, Pa., it probably was present as early as 1905. All other points shown on the map outside of the area of general infection appear to have been infected only within one or two years.

The bark disease appears practically to exterminate the trees in any locality which it infests. A survey of Forest Park, Brooklyn, showed "that 16,695 chestnut trees were killed in the 350 acres of woodland in this park alone. Of this number about 9,000 were between 8 and 12 inches in diameter, and the remaining 7,000 or more were of larger size."

In a recent publication Dr. W. A. Murrill estimates the financial loss from this disease "in and about New York City" at "between five and ten million dollars." The aggregate loss throughout the whole area of country affected must be much greater.

The bark disease occurs on both chestnut and chinquapin, regardless of age, origin, or condition. It does not occur on any other tree so far as known. All reports of its occurrence on the chestnut oak (*Quercus prinus*) have proved to be unfounded. It is not yet known whether the goldenleaf chinquapin of the Pacific coast (*Castanopsis chrysophylla*) is subject to this disease.

According to Sudworth, the range of the native chestnut is "from southern Maine to northwestern Vermont (Winooski River), southern Ontario, and southern shores of Lake Ontario to southeastern Michigan; southward to Delaware and southeastern Indiana, and on the Allegheny Mountains to central Kentucky and Tennessee, central Alabama, and Mississippi." The range of the chinquapin is "from southern Pennsylvania (Adams, York, Franklin, and Cumberland counties) to northern Florida and eastern Texas (Neches River)." The bark disease may, therefore, be expected to occur at any point within these limits, as well as in any other localities where the chestnut is grown as an ornamental or orchard tree.

CAUSE AND SYMPTOMS.

The disease is caused by the fungus *Diaporthe parasitica* Murrill (also known as *Valsonectria parasitica* (Murrill) Rehm). The spores of this fungus, brought by some means from a previously diseased tree, enter the bark through wounds; possibly also in other ways. The leaves and green twigs are not directly affected. From the point of infection the fungus grows in all directions through the inner bark until the growth meets on the opposite side of the trunk or limb, which in this way is girdled. The wood is but little affected. Limbs with smooth bark attacked by the fungus soon show dead, discolored, sunken patches of bark covered more or less thickly with the yellow, orange, or reddish-brown pustules of the fruiting fungus.

In damp weather or in damp situations the spores are extruded in the form of long irregular "horns," or strings, at first greenish to bright yellow in color, becoming darker with age. Plate IV, figure 3, shows a part of a branch of a diseased chestnut tree magnified $3\frac{1}{2}$ diameters. In this illustration the typical appearance of the pustules in damp weather and the projection of the spores of the fungus in the form of "horns," or threads, are shown. These threads may be especially conspicuous near the edges of diseased areas. If the spot is on the trunk or a large limb with very thick bark there is no obvious change in the appearance of the bark itself, but the pustules of the fungus show in the cracks of the bark and, on account of the destruction of the layers beneath, the bark often sounds hollow when tapped. A patch usually grows fast enough to girdle the branch or trunk that it is on during the first summer.

The damage may not be immediately apparent, since the water supply from the roots continues to pass up through the comparatively uninjured wood to the leaves, but when in the following spring the new leaves are put out they are usually stunted and soon wither. The appearance of such trees is very characteristic. Plate IV, figure 1, shows large chestnut trees killed by the bark disease. In this illustration the trees to the left show the characteristic stunted foliage, which indicates that they were girdled during the previous year, while the tree on the right having no foliage was presumably girdled by the fungus at least two summers before the photograph reproduced was taken. Plate IV, figure 2, shows an orchard tree with recently girdled branches. Nothing else except an actual mechanical injury—breaking off of trunk or limb—produces such an effect as is shown in these illustrations. The imperfectly developed leaves often persist on the dead branches throughout the summer.

The great damage which the disease has done thus becomes most apparent in the last week of May or the first week in June, giving rise to the false but common idea that the fungus does its work at this time of the year, when in reality the harm is done during the previous summer. If the first attack is on the trunk, of course the entire tree dies. If, on the other hand, the small branches are first involved, the tree may live for several years.

It is very easy for a person not familiar with fungi to confuse this parasite with various other fungi which occur commonly on the dead wood of chestnuts and other trees, such as species belonging to the genera Calocera, Cytospora, and Cytosporina. The superficial resemblance is sometimes very strong, but a microscopical examination instantly reveals the true nature of the organism in question. On account of this common confusion no dependable diagnosis of the bark disease can be made in a new locality without a microscopical examination of specimens by an expert.

FIG. 1.—LARGE CHESTNUT TREES KILLED BY THE BARK DISEASE.

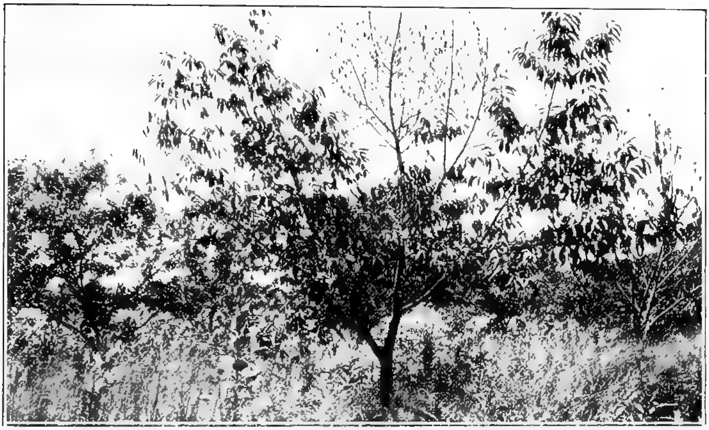

FIG. 2.—AN ORCHARD TREE, SHOWING RECENTLY GIRDLED BRANCHES.

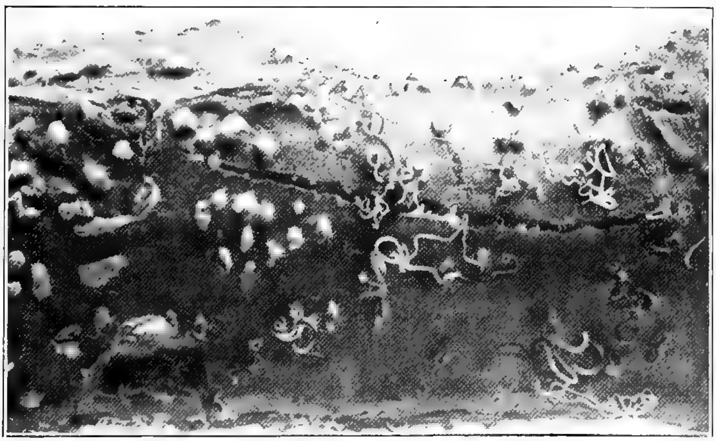

FIG. 3.—PART OF A DISEASED BRANCH OF A CHESTNUT TREE, SHOWING TYPICAL PUSTULES AND FORM OF SPORE DISCHARGE IN DAMP WEATHER.

(Magnified 3 diameters.)

RESTRICTION OF SPREAD.

HOW THE FURTHER SPREAD OF THE BARK DISEASE MAY BE LIMITED.

BY THE INSPECTION OF DISEASED NURSERY STOCK.

It becomes more and more evident as this disease is studied that diseased nursery stock is the most important factor in its spread to distant points. In that part of the country where it is already well established in the native chestnuts its progress is rapid and sure, but there is no evidence at present that it is able to pass to remote districts, tens or hundreds of miles away, except on diseased nursery stock. Of course it is conceivable that the spores are carried by birds. Such distribution would, however, follow in general the great lines of bird migration north and south and hence would not be an important factor in the western spread, except locally. During the summer of 1908 nearly every chestnut nursery and orchard of importance in the Atlantic States north of North Carolina was visited, and very few were found free from the bark disease. Several cases were observed where the disease had obviously spread from the nursery to adjacent wild trees. This is the only way in which the disease is likely to spread beyond the Alleghenies.

It is therefore obvious that every State in which the chestnut or chinquapin grows should as speedily as possible pass a law putting the chestnut bark disease on the same footing as other pernicious diseases and insect pests, such as the San Jose scale, against which quarantine measures are taken. The Department of Agriculture will be glad to give detailed suggestions or advice regarding the framing of such laws. Inspectors who already have legal power to quarantine against this disease should now take special care that no shipment of chestnut stock escapes their rigid inspection.

A campaign of education should also be undertaken by pathologists and inspectors in every State in order to acquaint the public with the nature and appearance of the bark disease, so that it may be quickly recognized and stamped out in any particular locality in which it appears. The Department of Agriculture will cooperate in the following ways: Specimens from suspected trees sent in by any person will be promptly examined and the presence or absence of the disease reported. Typical specimens showing the disease (with the fungus previously killed by soaking in formalin to insure against any infection from this source) will be sent upon application to any inspector, forester, pathologist, or other State or experiment station officer, to any nurseryman or orchardist growing chestnuts, or to any botanist or teacher of botany. So far as the supply permits lantern slides and photographs will, upon application, be loaned for special lectures, exhibits, etc., to the officers of States, experiment stations, or colleges. By these means the inspectors first, and then the general public, may become familiar with the appearance and work of the disease in localities that it has not yet reached, and when it does appear may be able to recognize it before it is too late to take efficient measures against it.

Although its present distribution is that shown by the map (fig. 1), the bark disease may be confidently looked for in any orchard or nursery in the United States that contains chestnut trees. All such places should therefore be rigidly inspected at the earliest possible date.

By the Prompt Destruction of Diseased Trees.

When the bark disease is first noticed in any locality, all the affected trees should be immediately cut down, unless, as in the case of orchard and some few ornamental trees, they are of sufficient individual value to warrant special treatment. Diseased trees if untreated are doomed to death in any case. If permitted to stand, every such tree becomes a center of infection, certain to spread the disease to all neighboring trees, and so long as it will soon die if left to itself the sooner it is cut down the better.

When cut, the brush should be immediately gathered and burned in order to destroy the fungus in the bark. Whenever the bark is removed from the trunk, as, for example, when the trees are to be used for poles, it should be immediately burned with the brush. Even when the tree is to be used for firewood an effort should be made to cut off at least all the diseased patches of bark on the trunk and large limbs when the tree is cut and to burn this bark along with the brush; otherwise the brush and the piled wood will continue to spread infection, since it has been found that the fungus continues alive on dead bark for at least six months after cutting.

Sprouts arising from the stumps of cut trees will be free from the disease for the first year at least, but must then be carefully inspected to be sure that no infection has persisted.

By the Treatment of Diseased Trees.

During the past two years the Office of Investigations in Forest Pathology has been conducting certain experiments and collecting information in regard to the best methods of treating diseased trees.

At present it is impossible definitely to record general beneficial results from any of the sprayings which have been undertaken or have been under observation. This may in part be due to the fact that it is yet too early to judge satisfactorily all the results and in part, perhaps, to the infrequency of sprayings.

Observations and experiments seem to bear out the statement that it is very improbable that any method of spraying can interfere with the growth of the fungus if it has once established itself in the inner bark, but it may be of considerable importance in preventing the development of spores which come from other trees or from other parts of the same tree.

It has already been demonstrated that the crotches of branches and enlarged bases of sprouts are very susceptible to infection because they are favorable places for the lodgment of water, dust, spores, etc. In a large majority of cases infections are definitely known to have originated at a point where the outer bark had been injured in some way, leaving the inner living bark exposed, or where the entire bark over a more or less limited area had been stripped from the tree or cracked and split away from the wood. Certain injuries which are known to have afforded entrance for the disease have been of such a nature that they might easily be overlooked, while others have been quite obvious, even to the careless observer. Among the latter may be mentioned broken limbs, split limbs, branches which have been carefully cut but not properly treated with tar or paint, bruises from hames, plows, and cultivators; also poor grafts and diseased grafting scions. Among the former may be included bruises from boot heels, climbing spurs, holes made by borers and other insects, knife and saw cuts, and frost cracks.

Almost the only treatment that can at present be safely recommended as surely retarding the spread of the disease to a greater or less extent is one which will never be of practical use except in the case of orchard trees or certain valuable ornamental trees. It consists essentially in cutting out the infected branches or areas of bark and carefully protecting the cut surfaces from outside infection by means of a coat of paint or tar. This cutting must be thoroughly done and the bark of every infected place entirely removed for a distance of at least an inch (where the size of the branch permits) beyond the characteristic, often fan-shaped, discolored areas produced by the growing fungus in the inner bark. All small infected twigs or branches should be cut from the tree, the cut being made well back of the diseased area. A pruning knife with an incurved tip, a hollow gouge, or any other clean-cutting instrument will serve for cutting out diseased spots. So far as the exigencies of the case will permit, all borers' holes should be cut out. It has been repeatedly observed in the field that infection often starts where borers are at work, or even at the old holes made by them. The paint or tar may be applied by means of a good-sized brush, care being taken to cover every part of the cutting. Treatment should begin, or observations at least, at the base of the tree and the fact ascertained whether the disease has already girdled the trunk. If such is the case it will be a waste of time to attempt any treatment; instead, cut the tree down at once. A rigid watch must be kept, especially during the growing season, for new infections or infections which were overlooked in the earlier examinations, and if any are observed they must be treated promptly, as above mentioned. Constant vigilance is necessary to keep the disease in check. It is suggested that examinations be made about June 1, July 15, and September 1. During a very rainy or foggy season, when conditions are particularly favorable for the growth of fungi, it may be advisable to inspect as often as once a month.

In regions in which the disease is so widespread that almost every tree is infected, as, for instance, within 25 miles of the city of New York, it is extremely doubtful whether any individual treatment will pay. Under such conditions immediate reinfection is almost sure to occur at one or more of the small unnoticed abrasions or injuries which are quite certain to exist on most trees. In a region, however, where only isolated cases have yet appeared it is quite possible to stamp out the disease, or at least to prevent its rapid spread, by promptly cutting out and carefully burning all diseased bark and limbs, thus destroying these new sources of infection. If a tree is too badly infected to be worth treating it should not be left standing, for it will then become a continual menace to all surrounding chestnuts.

The Office of Investigations in Forest Pathology asks the cooperation of all persons who have observed the disease or experimented with it in any way. If such people will send in an early report of the kind of treatment used, time of treatment, methods employed, and results obtained (even if adverse), it may be possible to arrive at an earlier and more definite conclusion in regard to the possibilities or impossibilities of control than would otherwise be the case.

CONCLUSIONS.

It is to be hoped that in the economy of nature some limiting factor will arise to check the spread of the bark disease before it has wrought the same destruction throughout the country that it already has in the vicinity of New York. But at present there is nothing in sight that promises even remotely to check its spread into new territory except the general adoption of the measures advocated in these pages. It can not be argued that because of its apparently recent origin and rapid spread it will soon disappear of itself. Such diseases as pear-blight and peach yellows have been in the country for more than a century and yet show no sign of abating except when actively combated by modern quarantine methods. Nor can any conclusions be drawn from the fact that chestnuts in the Southern

States have suffered from a disease during the past twenty years, since, as already stated, that is a totally different thing from the bark disease.

Where the bark disease is already firmly established and has attacked 50 per cent or more of the chestnut trees, as in the vicinity of the city of New York, it is probably too late to try to do anything, but where the disease is just appearing there is no reason to doubt that strict quarantine methods will apply as well to this as to any other disease, whether of plants or animals. The question to settle is simply which is more costly—to use the methods recommended or to lose the trees. The people concerned must decide.

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THE CHESTNUT BARK DISEASE ON CHESTNUT FRUITS[1]

SINCE the chestnut bark disease has been so widely studied by the many investigators who have given attention to it within the last few years, numerous articles have been published calling attention to the various ways by which the infection is known definitely to be spread from place to place, as well as of some methods that have been assumed to contribute to its spread. The most prominent of those thus far mentioned have been due to the transportation of spores through the agencies of wind, rain, insects, birds, rodents, man, etc., or to the transportation of various fruiting and vegetative parts, or fragments of the fungus, by means of infected cordwood, poles, ties, bark, grafting scions, nursery stock, etc. So far as the writer knows, no one has called special attention to the danger of the disease being transmitted by means of infected chestnut fruits, yet infected nuts at times undoubtedly are capable of spreading the disease, as will be realized from what follows, which describes one case which has come to our notice.

In September, 1912, Professor R. Kent Beattie, Dr. T. C. Merrill and the writer found numerous nuts and burs, which had been lying on the ground in Lancaster county, Pennsylvania, for several months, upon which were many reddish brown pustules, in a buff or yellowish mycelium. These looked very much like the pycnidial pustules and mycelium of *Endothia parasitica*. Portions of the diseased fruits were inoculated by the writer into the bark of a grafted Paragon chestnut tree, while for comparison some inoculations were made at the same time from a typical canker. The infected nuts were collected on September 4, 1912, and the infected bark was collected and the inoculations made on the following day. The records and results of these inoculations are given below.

The limb selected for inoculation was healthy-looking, apparently free from disease, from one to two inches in diameter, but on a tree that was already diseased on some other limbs. Eighteen cuts through the bark were made with a sterile knife-blade, except as noted below in the case of two cuts. For convenience in referring to these cuts they have been numbered consecutively from 1 to 18. Nos. 1, 2, 5, 6, 7, 8, 11, 12, 13, 14, 17 and 18 were checks, all uninoculated in the ordinary sense, though cuts 13 and 14 were made with the knife-blade after it had been used to cut some of the infected bark to be inserted in cuts 15 and 16.

Cuts 3 and 4 were inoculated with pieces of the mycelium-covered shell of the nut after the pustules had been cut away; cuts 9 and 10 were inoculated with pieces of the shell to which pustules were still attached; and cuts 15 and 16 were inoculated with pieces of bark from a disease lesion on the bark of an American chestnut tree.

On July 22, 1913 (about ten and one half months after the inoculations were made), the inoculations and checks were reexamined and records made of their condition. Cuts 1 and 2 were uninfected. Cut 3 likewise was uninfected. Cut 4 had developed a characteristic lesion about 4 inches long. Cut 5 was sur-

[1] Published by permission of the Secretary of Agriculture.

rounded by disease, apparently from two confluent lesions, one of which started about midway between cuts 4 and 5, but on the opposite side of the limb, while the other started near cut 5 and on the same side of the limb. Judging only from the size of these lesions, they must have originated soon after the inoculations were made. There was no evidence that any infection had started at cut 5. Cut 6 was uninfected. Cuts 7 and 8 showed sunken areas but no fans, pustules, nor other symptoms of the disease. Cut 9 had developed a girdling lesion 7 inches long with very many pustules. Cut 10 had developed a lesion 4½ inches long and 3 inches wide. Cuts 11, 12, 13 and 14 were uninfected. Cuts 15 and 16 had produced confluent girdling lesions aggregating 11 inches in length. This probably indicated that each cut had produced a lesion about 6 inches in length, as the cuts were about 5 inches apart. Cuts 17 and 18 were uninfected.

The results of these inoculations may briefly be summarized as follows:

2 inoculations from typical canker on bark, both successful.
2 inoculations from pustules on nut, both successful.
2 inoculations from mycelium on nut, one successful.
10 checks cut with sterile knife, none infected.
2 checks cut with contaminated knife, none infected.

These inoculations indicate that the disease was present on or in the nuts and burs collected. Although the latter were not used in the inoculations, the nuts and burs were covered with the same fungus, judging only from an examination with a hand lens; and, moreover, the nuts and burs were in contact when collected.

Perhaps nuts infected in this manner are not likely often to reach the market, and presumably would be unsalable either for seed purposes or for eating if they did reach it. In the latter case an additional source of danger would be created by discarding the diseased nuts, perhaps in a new locality far distant from the place where they were grown. In any event, the possibility of the disease at times being disseminated through great distances in this manner can not be overlooked in summing up the evidence bearing on this phase of investigation.

J. Franklin Collins

Office of Investigation in Forest Pathology, Bureau of Plant Industry, Providence, R. I.,
October 20, 1913

THE CHESTNUT BARK DISEASE.

By Haven Metcalf,

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HISTORY AND DISTRIBUTION.

To Mr. H. W. Merkel, forester of the New York Zoological Park, belongs the credit of first clearly recognizing, in 1904, the potential seriousness of the disease now known as the chestnut bark disease or chestnut blight. Observations reported later by other persons indicate that the disease was present on Long Island some years earlier. Apparently the disease has spread from this general vicinity; at least no centers of infection have been found elsewhere which are as old as those about New York City.

The disease is now distributed from Merrimack County, N. H., and Warren County, N. Y., on the north, to Albemarle County, Va., on the south. In New York the western border of distribution, so far as known at present, is sharply delimited by an area without chestnut trees—a natural "immune zone"—which extends southward along the eastern borders of Fulton, Montgomery, and Schoharie Counties nearly to the Pennsylvania line in Delaware County. Consequently in New York the range of the disease is at present practically limited to the valley of the Hudson. In Pennsylvania the western limit of general infection is roughly along a curved line extending from the northwest corner of Susquehanna County to the eastern border of Clearfield County and on to the southwest corner of Fulton County. West of this line the advance infections have been cut out by the Pennsylvania Chestnut Tree Blight Commission. The disease has not yet been found in Ohio or North Carolina. The infections farthest west, most of which have now been cut out, are those in Livingston County, N. Y., Warren and Somerset Counties, Pa., and Randolph County, W. Va. All of these appear to owe their origin to diseased chestnut nursery stock.

It is difficult to estimate the financial loss which the above distribution represents, as we have no exact statistics on the value of standing chestnut timber. The estimate of $25,000,000 made in 1911 as representing the loss up to that time was probably much too conservative. But the total loss to date is insignificant compared with the loss which will ensue if the disease once attacks the fine chestnut timber of the South Appalachians. The bark disease has killed all the chestnut trees in those localities where it has been present long enough, and there is not now the slightest indication that it is decreasing in virulence or that the climate of any region to which it has spread is having any appreciable retarding effect upon it.

CAUSE AND SYMPTOMS.

The chestnut bark disease is caused by the growth in the bark and outer wood layers of a parasitic fungus, *Endothia parasitica* (Murr.) A. and A.

When any spores of this fungus gain entrance into a wound on any part of the trunk or limbs of a chestnut tree they commonly give rise to a concentrically spreading canker which soon girdles the tree. (Pl. XXXIV.) Not only is the bark and cambium destroyed, but the fungus quickly infects the outer layers of sapwood, penetrating more deeply at the center of the canker. If the part attacked happens to be the trunk, the whole tree is killed, sometimes in as short a time as a single season. If the smaller branches are attacked, only those portions beyond the point of attack are killed, and the remainder of the tree may survive for several years. In Plate XXXVI, figure 3, the lower large limb on the left-hand side is still healthy, as the canker which girdled and killed the rest of the tree is situated on the trunk immediately above this branch. Plate XXXVI, figure 1, shows the ragged appearance of the tree, due to the fact that some branches are not yet girdled and still have normal foliage, while others are dead.

Some of the symptoms are quite prominent. Limbs and trunks with smooth bark which are attacked by the fungus soon show cankers in the form of dead, discolored, sunken areas (occasionally with a raised margin), which continue to enlarge and soon become covered more or less thickly with yellow, orange, or reddish brown spots about the size of a pinhead. (Pl. XXXIV.) These spots are the pustules of the fruiting fungus. Following a rain, or in damp situations, masses of minute spores (conidia) are commonly extruded in the form of long, irregularly twisted strings or horns, which are at first bright yellow to greenish yellow, or even buff, becoming darker with age. If the canker is on the trunk or a large limb with very thick bark there is no obvious change in the external appearance of the bark itself, but the pustules show in the cracks, and the bark often sounds hollow when tapped. After the limbs or trunks are girdled the fungus continues to grow extensively through the dead bark, sometimes covering the entire surface with reddish brown pustules. These pustules produce mostly the type of spores called ascospores, although occasionally long strings of conidia are also produced, even on bark that has been dead at least a year. If the proper conditions of moisture are present the fungus will continue to grow on the bark of chestnut logs and even upon bare wood.

When a branch or trunk is girdled the leaves above change color and sooner or later wither. (Pl. XXXVII.) These prematurely killed leaves often remain on the branches, forming, together with the persistent burs, the most conspicuous winter symptom of the disease. The most conspicuous symptom at all times of the year is the occurrence of sprouts at the base of the tree, on the trunk, or on the branches. (Pl. XXXV; Pl. XXXVI, figs. 1 and 2; also Pl. XXXVII.) Sprouts may appear below every canker on a tree, and there are often many such cankers. These sprouts are usually very luxuriant and quick growing, but rarely survive their second or third year, as they in turn are killed by the fungus. The age of the oldest living sprout, as determined by the number of its annual rings, is an indication of the minimum age of the canker immediately above. The annual development of sprouts from the base of a tree sometimes continues vigorously for at least six years after the tree is dead, which fact affords clear evidence of the healthy condition of the roots. If infection of these basal sprouts could be prevented, they would develop into a much better type of coppice than is usually seen, since they are rooted in the ground. After the tree is dead the dead sprouts, together with the scars left by cankers on the outer layers of wood, serve to show what killed the tree long after the bark has completely decayed and fallen away.

The fungus apparently does not penetrate to any considerable distance below the ground; nor does it attack the green leaves or the greenest of the young wood. Late in the season it will readily attack wood of the current year. This is observed, however, most commonly on sprouts.

Regarding the virulent parasitism of *Endothia parasitica* there is no possible question. It is easy to demonstrate this by making artificial inoculations in healthy trees. Plate XXXVII shows such an inoculated tree. The conidia, or so-called summer spores of the fungus, were put into a slit in the bark near the base of this little potted chestnut tree and a canker promptly developed. The typical symptoms of the bark disease, as they occur in large trees, followed—girdling of the trunk, withering of the leaves above, and prompt development of sprouts from below the canker. Some weeks after the photograph (Pl. XXXVII) was taken the sprouts were all killed by the downward growth of the canker.

MEANS OF SPREAD AND INFECTION.

Recent investigations show that the ascospores are commonly ejected during and after a rain, and on account of their small size may be blown by the wind for a distance of at least 50 feet, in spite of their sticky character. The strings of sticky conidia are instantly dissolved by rain, and are washed down over the surface of the tree. It is conceivable that they may be blown by the wind as far as rain or spray is blown or, mingling with dust at the foot of the tree, be blown about with the dust. There is strong evidence that the sticky conidia and ascospores may become attached to the various forms of animal life—insects, birds, squirrels, etc.—which frequent the diseased trees, and so be carried by them to other trees. That the disease is carried bodily for great distances in diseased chestnut nursery stock, unbarked ties, poles, or other timber, tanbark, etc., is a demonstrated fact.

When the spores have once been carried to a previously uninfected tree they may develop in any sort of wound or injury in the bark that is reasonably moist, and produce a canker. There is, indeed, some slight evidence that under certain conditions the fungus may gain entrance through apparently uninjured bark; but it is not necessary to assume that such entrance is common in nature, for the bark of the typical chestnut tree is covered with all sorts of injuries through which the fungus can readily find entrance.

No evidence has been adduced up to the present time to show that a tree with reduced vitality is more susceptible to infection or that the cankers develop more rapidly in such a tree than in a perfectly healthy and well-nourished tree of either seedling or coppice growth, except in those cases where such reduced vitality is accompanied by bark injuries through which spores can gain entrance. Nor has any evidence yet been adduced to show that weather or soil conditions within the present range of the disease exert any appreciable effect upon it, beyond the fact that wet weather in general favors the distribution of the spores.

The American chestnut, the chinquapin, and the cultivated varieties and hybrids of the European chestnut are all subject to the bark disease, although apparently varying in susceptibility. The Japanese, Korean, and Chinese varieties appear to show decided resistance. Unfortunately, these varieties are, so far as known, too small to be of value except as lawn and nut-producing trees. In America true examples of these varieties are rarely seen. What passes in the market as the Japanese chestnut, for example, is almost invariably a hybrid between the Japanese and some American or European variety.

Recently *Endothia parasitica* has been reported on three species of oaks. Although such occurrence appears to be rare, the spread of the bark disease to oak trees presents an unpleasant possibility.

LINES OF INVESTIGATION AND CONTROL.

The history of the investigation of the chestnut bark disease with reference to its control is a long story of procrastination. Undoubtedly present on Long Island in the nineties and doing conspicuous damage in the largest city of the United States as early as 1904, the disease is, nevertheless, not mentioned in scientific literature until 1906. It is not mentioned in any economic publication until 1908, and then without any appreciation of its seriousness. The impression was allowed to prevail that the disease was due to weather conditions and would soon disappear of itself, and hence was not worthy of serious attention. So in attempting control of the disease we find ourselves handicapped at every step by lack of knowledge, although there would have been ample time to secure this knowledge if practical investigations had been begun even as late as when Merkel noted the serious character of the disease.

CUTTING OUT ADVANCE INFECTIONS.

Many scattered advance infections have been cut out, including all of those in Pennsylvania. That State has taken the lead not only in cutting out advance infections and utilizing dead chestnut trees, but also in all lines of investigation of the disease. The results of this work are awaited with profound interest, not only by such States as Ohio and West Virginia, which are in part protected by the action of Pennsylvania, but also by those more distant Southern States that still have time to profit by the experience of Pennsylvania.

UTILIZATION OF DEAD AND DYING TREES.

The utilization of dead and dying trees is a forestry problem of the utmost importance. In the neighborhood of New York City all chestnut trees are dead; as we go from there in any direction we find areas of dead trees, corresponding to old points of advance infection, surrounded by more recently infected trees. Between these areas are occasional "islands" of still healthy trees. But the number of trees that should be immediately utilized is enormous and will increase annually. They should be used to save the timber, to reduce infection, and to prevent possible increase of injurious insects. Since the wood of a diseased tree is rotted only immediately under the cankers, a tree that is cut promptly may be expected to make practically as good timber as a sound tree. However, if cutting is delayed until long after the tree is girdled, the timber will necessarily be open to the same objections as that from any dead tree.

The Pennsylvania Chestnut Tree Blight Commission has induced certain railroads in that State to make a discrimination in freight rates in favor of products from diseased chestnut trees, which enables these products to be used more cheaply than those of other species. Unless some such plan can be brought about in other States also, it is difficult to see how a great glut in the market for chestnut products can be avoided.

IMPROVEMENTS IN FOREST MANAGEMENT.

The work on the bark disease in certain States has been made the occasion of a general forest survey. Everywhere it will result in more careful management of the surviving trees. In localities where the chestnut is already past saving, this species must be discriminated against. While change of management of chestnut woodland may not affect the course of the disease, except in so far as it involves the cutting out of infected trees, constructive forestry is bound to be stimulated by the work done on this disease. Methods of control of this and other forest diseases, which are visionary now, will be in daily use in 20 years. We do not now realize how rapidly forestry in the Eastern States is becoming as intensive as that of Europe.

TREE MEDICATION.

The possibility of controlling disease in trees by special fertilization or by direct chemotherapy, that is, by the introduction of chemicals or immunizing substances directly into the tree, has long been a fascinating ideal. The method has been discredited by the number of " fake " remedies which are supposed to be applied in this way. Nevertheless, the basal idea is fundamentally sound. The Pennsylvania Chestnut Tree Blight Commission, in cooperation with the United States Department of Agriculture, is making extensive experiments along this general line. From this work very valuable scientific results are to be expected, whether the method becomes a practical success or not, and the results obtained may be expected to be in some measure applicable to other species of trees, including fruit trees.

BREEDING RESISTANT TREES.

The apparent resistance of various Asiatic chestnuts suggests that if resistant individuals of these varieties are crossed with the American and European chestnuts, hybrids might be produced with the desirable nut characters of one parent and the resistance of the other. So far no resistant individuals of the American chestnut have been found. Trees of both American and Asiatic species of the genus Castanopsis could possibly also be used as resistant parents, at least

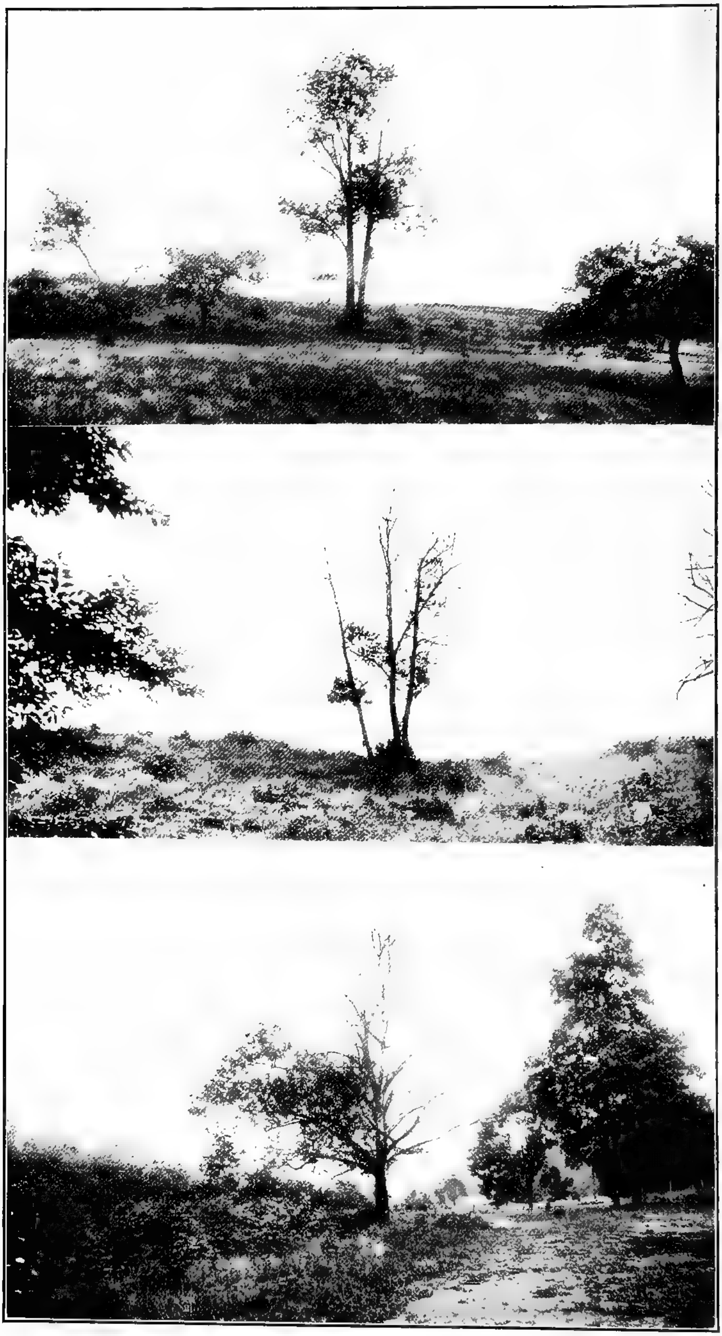
A Typical Girdling "Canker" of the Chestnut Bark Disease.

Julius Bien Co. Lith. N.Y.

FIG. 1.—COMPLETE DESTRUCTION OF CHESTNUT TREES IN MIXED STAND.

FIG. 2.—CHESTNUT TREES KILLED BY THE BARK DISEASE.

[Note healthy condition of trees of other species.]



ORNAMENTAL CHESTNUT TREES DYING WITH THE BARK DISEASE.

SMALL CHESTNUT TREE IN POT ABOUT THREE MONTHS AFTER ARTIFICIAL INOCULATION WITH SUMMER SPORES FROM A PURE CULTURE OF THE FUNGOUS PARASITE.

[Tree girdled at base, leaves above withered; vigorous suckers growing up from below girdled point.]

for trees to be grown in the South. Resistant timber trees, as well as nut trees, could doubtless be produced. Many experiments along this line are already in progress. In the long run the results of breeding will probably be the most profitable outcome of the struggle against the bark disease. Sooner or later we must begin to breed forest trees systematically, and the chestnut is on many accounts a good tree to start with.

INSPECTION OF DISEASED NURSERY STOCK.

As has been indicated, diseased chestnut nursery stock in the past has been an important factor in the spread of the bark disease. On account of a well-grounded fear of this disease much less chestnut nursery stock is being moved now than formerly, but there is still enough to constitute a serious source of danger. It is therefore obvious that every State in which the chestnut grows, either naturally or under cultivation, should as speedily as possible pass a law putting the chestnut bark disease on the same footing as other pernicious diseases and insect pests, such as peach yellows and the San Jose scale, against which quarantine measures are now taken. Many inspectors already have the legal power to quarantine against the bark disease on chestnut nursery stock, and they should now take special care that no shipment, however small, escapes their rigid inspection.

The most serious practical difficulty in inspecting nursery stock for this, as for other fungous diseases, lies in the fact that practically all State inspectors are necessarily entomologists and are usually not trained in recognizing the more obscure symptoms of fungous diseases. Nursery trees affected by the bark disease rarely show it prominently at the time when they are shipped; the threads of conidia or the yellow or orange pustules are rarely present, and usually all the inspector can find is a small, slightly depressed, dark-colored area of dead bark, usually near the ground, which is easily overlooked or mistaken for some insignificant injury. Upon cutting into such a spot the inner bark shows a most characteristic disorganized "punky" appearance quite different from that of any other bark injury. Occasionally a yellowish brown or reddish band or blotch, either girdling or partly girdling the young tree, may be seen, which is very characteristic.

If infected trees are set out they develop the disease with its characteristic symptoms the following spring. On account of their small size such trees are girdled and die before the end of the summer. Meanwhile they become a source of danger to neighboring orchard and forest trees. Orchardists and nurserymen purchasing chestnut trees are therefore warned to watch them closely during the first season, no matter how rigidly they may have been inspected.

INDIVIDUAL TREATMENT OF DISEASED TREES.

Where valuable ornamental, shade, or orchard chestnut trees become infected in one or more spots their life and usefulness can be prolonged for several or for many years, depending largely upon the thoroughness with which the recommendations herein given for cutting out the cankers are carried out. Better results will be obtained with small, thin-barked trees than with large ones.

The essentials for the work are a gouge, a mallet, a pruning knife, a pot of coal tar or good paint, and a paint brush. In the case of a tall tree a ladder or rope, or both, may be necessary, but tree climbers should not be used, as they cause wounds which are very favorable places for infection. Sometimes an ax, a saw, and a long-handled tree pruner are convenient auxiliary instruments, though practically all the cutting recommended can be done with a gouge having a cutting edge of 1 or 1½ inches. All cutting instruments should be kept very sharp, so that a clean and smooth cut may be made.

By cutting with the gouge into a diseased area a characteristically discolored and mottled middle and inner bark is revealed. All of this diseased bark should be carefully cut out for an inch or more beyond the discolored area, if the size of the branch will allow it. This bark should be collected in a bag or basket and burned. If the cutting is likely to result in the removal of the bark for much more than half the circumference of the branch or trunk it will probably be better to cut off the entire limb or to cut down the tree, as the case may be, unless there is some special reason for attempting to save the limb or tree. The fungus usually, though not always, develops most vigorously in the inner bark next to the wood. When the disease has reached the wood not only all the diseased bark and an inch of healthy bark around it must be removed, but three or more annual layers of wood beneath the diseased bark must also be gouged out. Special care should be taken to avoid loosening the healthy bark at the edges of the cut-out areas. Except in the early spring, this is not difficult after a little experience in manipulating the gouge and mallet, provided the gouge is kept sharp. Small branches which have become infected should be cut off, the cut being made well back of the diseased spot.

All cut-out areas and all the cut ends of stubs should be carefully and thoroughly painted with coal tar. A good grade of paint has been recommended by some authorities as superior to tar, but it is more expensive. If the tar is very thick the addition of a little creosote will improve it for antiseptic purposes as well as for ease in applying. If the first coat is thin a second one of fairly thick tar should be applied within a few weeks or months. Other coats should be applied later whenever it becomes necessary.

The entire tree should be carefully examined for diseased spots and every one thoroughly cut out and treated in the way described. In case suspicious-looking spots appear, a portion of the outer bark can be cut out with the sharp gouge as a test. If this cut shows the characteristically discolored bark, the spot is diseased and should be cut out accordingly; if the cut shows healthy bark, it need merely be treated with tar or paint, as other cuts are treated. In examining a tree for diseased spots it is always best to begin at the base of the trunk and work up, for if the trunk is girdled at the base it is useless to work anywhere on the tree.

A tree which is being treated for individual infections must be carefully watched and the diseased spots promptly cut out as they appear. For this purpose each tree should be examined very carefully two or three times at least during the growing season. If all the mycelium in the bark and wood has not been removed reinfection is certain to follow.

ADVICE TO CHESTNUT ORCHARDISTS.

In view of the uncertain future of the chestnut tree the United States Department of Agriculture advises against planting chestnuts anywhere east of Indiana, at least for the present.

West of the natural range of the American chestnut, however, the situation is quite different. Obviously the western chestnut orchardist has before him a great opportunity. No matter how successful efforts to limit the bark disease may be, the nut crop will be reduced for some years, and the business of growing fine orchard chestnuts in the East will be depressed for the same length of time. There is no apparent reason why, with rigid inspection of purchased stock and of the orchards themselves, all chestnut orchards and nurseries from Indiana to the Pacific coast can not be kept permanently free from the bark disease; therefore, all persons interested in growing the chestnut in the West are earnestly advised to be sure that stock from any source is rigidly inspected, to watch continually and with the utmost care their own nurseries and orchards, and to destroy immediately by fire any trees that may be found diseased.

ADVICE TO OWNERS OF ORNAMENTAL CHESTNUT TREES.

Until the future of the chestnut tree is better known, the owners of chestnut-timbered land available for building should pursue a very conservative policy. Houses should not be located with sole reference to chestnut groves or to isolated ornamental chestnut trees. Buyers of real estate should discriminate against houses so located in so far as the death of the chestnut trees would injure the appearance of the place.

When ornamental trees become diseased they had better be cut down at once and, if practicable, large trees of other species moved in to take their places. In expert hands the moving of large trees is a perfectly practicable and successful procedure and, although more expensive, is much more satisfactory than waiting for nursery trees to grow.

ADVICE TO OWNERS OF CHESTNUT WOODLAND.

Owners of chestnut woodland that is thoroughly infected are advised to convert their trees into lumber as soon as possible. The trees which are not already killed will soon die in any case, and the timber rapidly deteriorates in quality. Such trees are a continual source of infection.

Owners of chestnut woodland outside the area of general infection are counseled to watch for the first appearance of the disease and when it appears to cut down immediately all affected trees, bark them, and burn the bark and brush, over the stump if practicable. Such procedure will distinctly retard the spread of the disease in that particular woodland, even if no concerted efforts at elimination are made by neighboring owners or by the State.

It is almost needless to add that with the present outlook chestnut woodland is a poor investment. Furthermore, in forest management, as in improvement cuttings, etc., there should be discrimination against the chestnut.

THE OUTLOOK.

Disease is expected in cultivated plants, grown as they are under unnatural conditions and usually in a strange environment; but a fungous disease as serious as this, attacking a hardy native tree over hundreds of square miles in the heart of its natural range, is, so far as known, without precedent. It is, then, idle to attempt to prophesy what will be the future course of the disease. But whatever the outcome is, we may be sure that the results of the study of this disease will in the end justify all present efforts. We may be certain that this is not the last devastating disease of forest trees to appear, and in the future we shall need all the knowledge and experience that can be gained from this malady. With the increase in the value of timber and with the rapid development of intensive forestry, methods now impracticable for controlling tree diseases will come into regular use, and the practicable methods of the future can only be developed by years of scientific research and field experience on a large scale.

Issued October 28, 1911.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 467.

THE CONTROL OF THE CHESTNUT BARK DISEASE.

BY

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AND

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 14, 1911.

Sir: I have the honor to transmit herewith and to recommend for publication as a Farmers' Bulletin a manuscript entitled "The Control of the Chestnut Bark Disease," by Dr. Haven Metcalf, Pathologist in Charge, and Prof. J. Franklin Collins, Forest Pathologist, of the Office of Investigations in Forest Pathology. The writers describe their method of restricting the spread of this dangerous disease by destroying advance infections, a method which is already being applied on a large scale by the State of Pennsylvania. It is hoped to perfect plans whereby through general cooperation the disease may be kept within the territory where infection is already general and the largest and best chestnut forests of the country, especially those of the south Appalachians, be kept permanently free from the disease.

The experimental data upon which the recommendations contained in this publication are based will be published in full in a forthcoming bulletin of the Bureau of Plant Industry.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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ILLUSTRATIONS.

THE CONTROL OF THE CHESTNUT BARK DISEASE.

THE DISEASE.

HISTORY AND DISTRIBUTION.

The chestnut bark disease was first recognized as a serious disease in the vicinity of New York City in 1904, and the first publication regarding it appeared in 1906. There is reliable evidence, however, that it was present on Long Island at least as early as 1893. Its origin is unknown, but there is some evidence that it was imported from the Orient with the Japanese chestnut. This view is not, however, held by all investigators. But whatever may have been its time or place of origin, it is certain that it has now spread into at least 10 States, as is shown by the accompanying map (fig. 1). In the vicinity of New York City and through adjacent counties it has killed practically all chestnut trees. Throughout a much larger neighboring area, as shown in figure 1, practically all chestnut trees are infected. Outside of this area, throughout the country from the northern border of Massachusetts and from Saratoga County, N. Y., to the western border of Pennsylvania and the southern border of Virginia, scattering areas of infection are known to occur and may be expected at any point.

So far as is now known, the bark disease is limited to the true chestnuts—that is, to the members of the genus Castanea. The American chestnut, the chinquapin, and the cultivated varieties of the European chestnut are all readily subject to the disease. Only the Japanese and perhaps other east Asian varieties appear to have resistance. In spite of popular reports to the contrary, it can be quite positively stated that the bark disease is not now known to occur on living oaks, horse-chestnuts, beeches, hickories, or the golden-leaf chinquapin (*Castanopsis chrysophylla*) of the Pacific coast.

FINANCIAL LOSSES.

The bark disease appears ultimately to exterminate the chestnut trees in any locality which it infests. A survey of Forest Park (Brooklyn) showed "that 16,695 chestnut trees were killed in the 350 acres of woodland in this park alone. Of this number, about 9,000 were between 8 and 12 inches in diameter, and the remaining 7,000 or more were of larger size." Three years ago the financial loss from this disease "in and about New York City" was estimated at "between five and ten million dollars."

The writers regard $25,000,000 as a conservative estimate of the financial loss from this disease up to 1911. In many localities the greatest damage has been among chestnuts grown for ornamental purposes, which have a value greatly in excess of their value as lumber.

Depression in the value of real estate, especially suburban or near-suburban, owing to the death of the chestnut trees, must be taken into account in an estimate of this kind, as well as the loss of the trees themselves.

CAUSE AND SYMPTOMS.

The chestnut bark disease is caused by a fungus parasite known under the technical name of *Diaporthe parasitica* Murrill. When any of the microscopic spores (reproductive cells) of this fungus gain

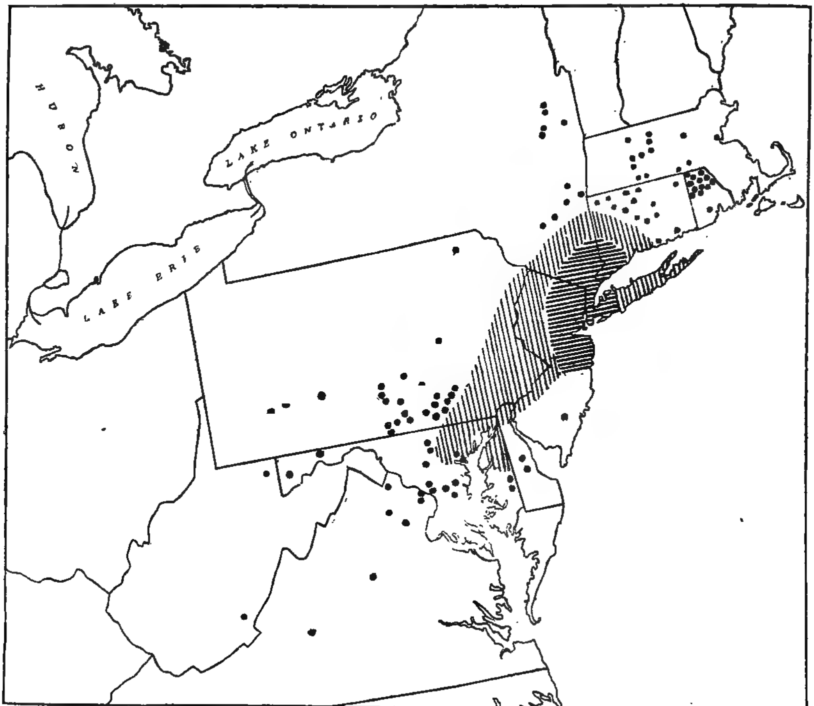

FIG. 1.—Map of the northeastern part of the United States, showing the distribution of the chestnut bark disease. The horizontally lined part shows the approximate area wherein the majority of chestnut trees are already dead from the bark disease. The part marked by vertical lines shows the approximate area wherein infection is already complete. The round dots show the location of advance infections of the disease. Many of these have already been eradicated. The map has been compiled from both observations and correspondence. The writers are under especial obligations to Dr. Perley Spaulding, Prof. A. H. Graves, Mr. I. C. Williams, Mr. W. H. Rankin, Mr. J. F. O'Byrne, Mr. F. W. Besley, Dr. Ernest S. Reynolds, and Mr. H. G. MacMillan, for data along this line. According to Dr. G. P. Clinton (Connecticut Agricultural Experiment Station, Report of the Botanist, 1909 and 1910) there are many more points of infection in Connecticut than are shown on this map.

entrance into any part of the trunk or limbs of a chestnut tree they give rise to a spreading "sore" or lesion, which soon girdles the tree. If the part attacked happens to be the trunk, the whole tree in consequence is killed, perhaps in a single season. If the smaller branches are attacked, only those branches are killed, or only those portions of branches beyond the point of attack, and the remainder of the tree may survive for several years (fig. 2).

Some of the symptoms are quite prominent. Limbs with smooth bark attacked by the fungus soon show dead, somewhat discolored, sunken areas (occasionally with a raised margin), which continue to

FIG. 2.—Large chestnut tree partly killed by the bark disease. Note the sprouts with leaves near the top, the dwarfed leaves on the lower right-hand limb, and the healthy lower branches with leaves.

enlarge and soon become covered more or less thickly with yellow, orange, or reddish-brown spots about the size of a pinhead. These spots are the pustules of the fruiting fungus. In damp weather or in damp situations, masses of summer spores are extruded in the

FIG. 3.—Diseased chestnut bark showing pustules and form of discharge of summer spores in damp weather. (Magnified 3 diameters.)

form of long, irregularly twisted strings or "horns," which are at first bright yellow to greenish yellow or even buff, becoming darker with age (fig. 3). If the lesion is on the trunk or a large limb with very thick bark there is no obvious change in the appearance of the bark itself, but the pustules show in the cracks and the bark often sounds hollow when tapped. After smooth-barked limbs or trunks are girdled the fungus continues to grow extensively through the bark, sometimes covering the entire surface with reddish-brown pustules (fig. 4). These pustules produce mostly winter spores (ascospores), although occasionally the long strings of summer spores (fig. 3) are also produced, even on bark that has been dead at least a year.

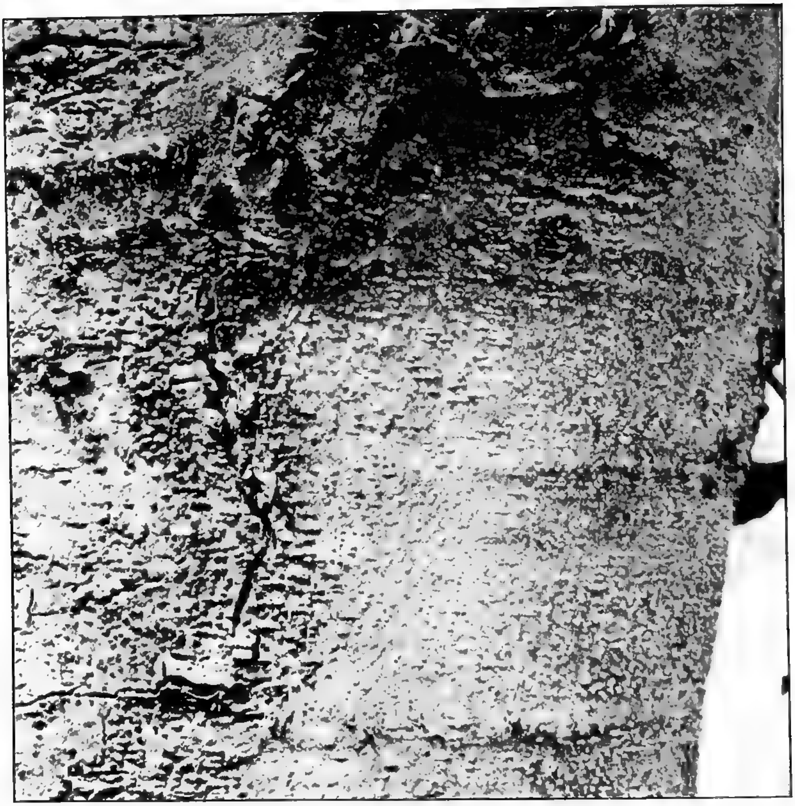

FIG. 4.—Dead chestnut bark showing pustules of the parasitic fungus bearing winter spores.

After a branch or trunk is girdled, the leaves change color and sooner or later wither. Such branches have a very characteristic appearance and can hardly be mistaken for anything else, except in certain localities where the work of twig-girdling insects may produce a similar appearance in the spring. In case the girdling by the fungus is completed late in the season, the leaves of the following spring assume a yellowish or pale appearance and do not develop to their full size (fig. 2). If the girdling is completed between spring and midsummer the leaves may attain their full size and then turn a somewhat characteristic reddish-brown color, which can easily be detected at a long distance. Later this leaf coloration changes to a more brownish tinge and the leaves are commonly persistent for a considerable time. The chestnut fruits (burs) on a spring-girdled branch may or may not attain full size, according to whether the girdling by the disease was completed late or early in the spring. These burs commonly persist on the tree during the following winter, thus producing the only symptom which is at all conspicuous during the leafless season. The great damage which the disease has done in the late summer thus becomes most evident at the beginning of the next season, and that done in the spring becomes evident later in the same season, giving rise to the false but common idea that the fungus does its work at the time of year that the leaves change color, when in reality the harm was done much earlier.

Perhaps the most easily seen as well as the longest persistent symptom of the bark disease is the prompt development of sprouts, or "suckers," on the trunk of the tree (fig. 2) and at its base, or somewhat less frequently on the smaller branches. Sprouts may appear below every girdling lesion on a tree, and there are usually many such lesions. These sprouts are usually very luxuriant and quick growing, but rarely survive the second or third year, as they in turn are killed by the fungus. The age of the oldest living sprout, as determined by the number of its annual rings, is an indication of the minimum age of that portion of the infection immediately above it. Sprouts are sometimes produced as a result of other injuries; for instance, trees girdled by borers may develop sprouts, but these are generally less rapid in growth and are distributed with greater uniformity over the trunk.

MEANS OF SPREAD AND ENTRANCE.

The disease is spread by the spores of the fungus, of which there are two kinds. As both kinds of spores appear to be sticky, there is no evidence that they are transmitted by wind except where they may be washed down into the dust and so blown about with the dust. The spores are spread easily through short distances by rain; particularly they are washed down from twig infections to the lower parts of the tree. There is strong evidence that the spores are spread extensively by birds, especially woodpeckers, and there is also excellent evidence that they are spread by insects and by various rodents, such as squirrels. The disease is carried bodily for considerable distances in tan bark and unbarked timber derived from diseased trees. One of the most prolific sources of general infection has been the transportation of diseased chestnut nursery stock from infected to uninfected localities.

When the spores have once been carried to a healthy tree, they may develop in any sort of hole in the bark which is reasonably moist. These may be wounds or mechanical injuries, but by far the most common place of infection is a tunnel made by a borer. Borers' tunnels are moist, even in dry weather, and in them the spore finds surroundings favorable to its development. In many parts of the country where the disease is prevalent there is very direct evidence that bark borers, and particularly the two-lined chestnut borer (*Agrilus bilineatus*), are directly associated in this way with 90 per cent or more of all cases of this disease. We are informed that the Bureau of Entomology will issue a circular on the insects associated with the chestnut bark disease.

The writers have no definite evidence, experimental or otherwise, to show that a tree with reduced vitality is more susceptible to infection, or that the disease spreads more rapidly in such a tree, than in a perfectly healthy and well-nourished tree of either seedling or coppice growth, provided that such reduced vitality does not result in or is not accompanied by bark injuries through which spores can gain entrance.

THE CONTROL OF THE DISEASE.

ELIMINATION AND QUARANTINE.

FUNDAMENTAL OBSERVATIONS AND EXPERIMENTS.

No method of immunizing individual trees against the bark disease is yet known, and no method of treating or curing them when once attacked is certain in its results. While this is unfortunate from the standpoint of the owner of orchard trees and large ornamental trees of great individual value, no method of dealing with single trees—surgery, medication, spraying, etc.—however successful in itself, would meet the demands of the present situation. It is not practicable at present to apply any individual method of treatment to forest trees; the individual tree is not worth it, and will not be for many years. Therefore, so far as the chestnut forests are concerned we do not need to regret particularly that no individual treatment has yet been discovered that is entirely effective.

Fortunately, however, there is a method of dealing with the situation which is applicable to the country as a whole and which, so far as tested, is practicable. Early in the course of the writers' investigations it became evident that the disease advances but slowly in a solid line, but instead spreads from isolated centers of infection, often many miles in advance of the main line of disease. That such is the case is evident from a glance at figure 1. It therefore seemed probable that if these advance infections could be located at a reasonably early stage, they could be eliminated at relatively little expense, thus preventing further spread from these points at least. Accordingly, the country within approximately 35 miles of Washington, D. C., was chosen in the fall of 1908 as preliminary territory in which to test this method of control. This section has since been gone over fairly thoroughly once a year. As will be seen by figure 1, 14 points of infection were located, and the infected trees destroyed. Most of this work was done by the senior writer. The largest infection was a group of nursery trees that had been imported from New Jersey; the smallest, a single lesion on a small branch of a large forest tree. In one case 11 forest trees in a group were infected, the original infection having been two trees, dating apparently from as early as 1907. Up to the present time (June, 1911) the disease has not reappeared at any point where eliminated and the country within a radius of approximately 35 miles from Washington is apparently free from the bark disease, although new infections must be looked for as long as the disease remains elsewhere unchecked. It is therefore believed that this method of attack will prove equally practicable in other localities, and if carried out on a large scale will result ultimately in the control of the bark disease.

LEGAL CONSIDERATIONS.

In carrying such a scheme of control into effect on a large scale, however, legal difficulties are at once encountered. The bark disease threatens the extinction of the chestnut throughout its range. As it has already been found in at least 10 States and the District of Columbia, it is essentially a national issue, but there is no law whereby the Federal Government can attempt to cope with the emergency. Each State must act on its own initiative and control the disease or let it go as its officers and legislative bodies see fit. Herein lies one of the most serious aspects of the matter; for if one State elects to undertake control of the disease it will be seriously handicapped if neighboring States do not. Any method of elimination, isolation, or quarantine in dealing with any disease of plants, domestic animals, or human beings necessitates general cooperation. It is not practicable to try to control the bark disease solely by the cooperation of individual owners of chestnut woodland, since a single indifferent or obstinate person can nullify the efforts of an entire community. The control of the chestnut bark disease must therefore be undertaken by the separate States under special legislation. Possibly in certain States the crop and woodland pest laws, which ordinarily apply only to nursery stock, may be broad enough to include this disease, but in most States the first thing to be done is to obtain the necessary legal authority and an appropriation for action along the following lines, as has already been done in Pennsylvania.

THE METHOD IN DETAIL.

Locating advance infections ("scouting").—The first thing to be done in each State is to determine the exact range of the disease in that State, and particularly to locate the advance points of infection. This is by far the most difficult feature of the entire program, because the work must be directed and in large measure carried out by experts; otherwise diseased trees will be left, and the results can not be depended upon. It is best intrusted to professional plant pathologists or at least to botanists familiar with fungi and the collecting of fungi, and even these must have some preliminary knowledge of this particular disease. The symptoms of the disease are too obscure and the means of locating it too intricate to make it possible for a person without a professional knowledge of plant diseases to deal successfully with the situation, no matter how well informed in agriculture or forestry or how experienced in the care of trees. It is suggested that in most States this part of the work would be best handled by the pathologists of the State agricultural experiment stations.

For assistants the pathologists having this work in charge should choose the best scientific observers obtainable, regardless of other considerations, but persons with some knowledge of plant pathology are to be preferred. College students trained in these lines are usually available, for the summer vacation at least, and make in many respects the most desirable "scouts" for this work. But all "scouts" must be carefully and individually trained by the expert in charge.

Attention should first be directed to the advance spots of infection already known to exist, and when found the diseased trees should be destroyed or marked for destruction. No difficulty will be experienced in locating infections 2 years old or more, but the greatest difficulty will be met in locating infections of the current year. Every tree in the immediate vicinity of older infected trees must be carefully gone over. Many dubious cases will be found, and from such trees samples of the suspected bark must be taken and sent to some laboratory for expert judgment. It is absolutely necessary to have arrangements with some laboratory whereby such work can be done and the results promptly reported.

After the spots already known to exist have been delimited and the trees destroyed or marked for destruction, the search should be continued. It is best next to clearly define the location of the main line of advance of the disease, back of which infection is general. Working away from this line as a base, a complete survey of the remainder of the State must be made, until it is reasonably certain that all spots have been located.

Scouting is best discontinued as soon as the leaves change color in the fall, since from October to April, inclusive, the symptoms are very obscure. Practically no sign of the disease is visible from a distance, except in those cases where the burs persist on the older trees. Even the pustules of the fungus become weathered, so that even a close examination of a tree may not yield visible results. But the destruction of trees already marked can continue through the winter.

Destroying advance infections.—Many of the advance infections will be found to consist of single trees or of less than half a dozen trees. These may perhaps be destroyed by the person who finds them, especially if remote from other infections; but the greater part of the work of elimination is best handled by other persons under separate direction. Undoubtedly this work can be best directed in each State by the State forestry officials.

The work of elimination should be done as soon as possible after the diseased trees are located, but may be done at whatever time of year is most convenient, since new infections will be detected by the scouting of the following year. The marked trees should be cut down. So far as is now known, the timber may be safely utilized in various ways, *provided it is barked.* The bark and brush should be piled over the stumps and, as soon as practicable, burned. If it is not practicable to have the fire over the stumps, the stumps should be barked to the ground; but in any case the bark and brush must be burned.

It will be readily seen that the task of locating the disease, and the subsequent one of eliminating it, call for very different talents. The "scouting" calls for carefully trained and absolutely accurate scientific observers working under the most highly specialized direction that can be obtained. The work of elimination calls not for scientific knowledge, but for executive ability, tact in dealing with owners and in otherwise administering the law, and a knowledge of forestry and of lumbering, market, and transportation conditions. In a word, the first is a task for pathologists, the second for foresters. Another advantage of thus dividing the work is that a certain rivalry will usually develop, resulting in more thorough work on both sides. It is, moreover, of the utmost importance to have as many different forces and interests as possible in any given State working toward the common end of controlling this disease.

Establishing the "immune zone."—After all advance spots of infection are eliminated, attention must be turned to the main line of advance—the edge of the area of general infection. Here the problem will present local differences. It may prove necessary in some States to destroy all chestnut trees, diseased or healthy, in a belt 10 to 20 miles wide, or possibly less. Advantage must be taken of natural barriers to infection, such as unforested areas or wooded areas without chestnuts. In this way an "immune zone" will be established, across which the disease can not easily be transmitted by merely local agents. Back of this line the chestnut trees may be abandoned to the disease. Every effort should be made, however, to have them cut down and the timber utilized as soon as possible, since they remain sources of distant infection as long as any spore-laden bark or diseased sprouts remain on them.

Quarantine.—Whether any restrictions are placed upon the movement of chestnut products from the area of complete infection to the protected territory will depend largely on local conditions and must be left to the judgment of State authorities. Barked timber can probably be moved with comparative safety. It will always be desirable to limit the movement of unbarked chestnut timber and firewood and of chestnut tan bark. An inspection of local conditions will readily determine whether the danger from these sources is sufficiently great to warrant the business inconvenience which would be caused by the quarantine of any or all chestnut products.

Program for the second year.—The work for the second year will consist mostly of reïnspection of the advance spots where the bark disease has been eradicated the previous year and of general scouting to locate new spots. If the work of the first year has been thoroughly done and there has been time to complete the elimination of all spots located, only scattering infections may be expected. From this time on the persons in charge of scouting will have the bulk of work and responsibility.

THE EXAMPLE OF PENNSYLVANIA.

Pennsylvania enjoys the distinction of being the first and so far the only State to undertake in any way the control of the chestnut bark disease. In the summer of 1910 the Main Line Citizens' Association—an organization of citizens residing along the main line of the Pennsylvania Railroad near Philadelphia—appointed a committee of seven, under the chairmanship of Mr. Harold Peirce, to determine the status of the disease in that locality and to see what could be done toward controlling it. An extensive local survey of the disease was made under the direction of Mr. I. C. Williams, deputy State forest commissioner. The committee soon became convinced that the problem was of State and even national importance, and could only be solved by legislation and by the broadest cooperation. Accordingly they devoted their energies to securing the passage by the Pennsylvania Legislature of the following bill, which has now become a law. This law is almost unique in conservational legislation, and on account of its important bearing as precedent for similar laws in other States it is here reproduced in full.

AN ACT To provide efficient and practical means for the prevention, control, and eradication of a disease affecting chestnut trees, commonly called the chestnut-tree blight; providing for the destruction of trees so affected; creating a commission to carry out the purpose of this act; fixing penalties for violation of the provisions hereof; and making an appropriation therefor.

SECTION 1. *Be it enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania in General Assembly met; and it is hereby* *enacted by the authority of the same:* That a commission to consist of five members, to be appointed by the Governor for a period of three years from the date of the approval of this act, and to be called "The Commission for the Investigation and Control of the Chestnut-Tree Blight Disease in Pennsylvania," is hereby created, with power to ascertain, determine upon, and adopt the most efficient and practical means for the prevention, control, and eradication of a disease of the chestnut tree commonly known as the chestnut-tree blight disease; and for this purpose, in collaboration with the department of forestry, or otherwise, to conduct scientific investigations into the nature and causes of such disease and the means of preventing its introducton, continuance, and spread; to establish, regulate, maintain, and enforce quarantine against the introduction and spread of such disease; and, from time to time, to adopt and prescribe such regulations and methods of procedure as to it may seem necessary and proper for carrying into effect the purpose of this act, and exercising the powers and authority hereby conferred: *Provided*, That in the work of collaboration by the commission with the Department of Forestry said department may employ such means, and make detail of such men, and do such other things, as may seem to be necessary or expedient to accomplish the purpose of this act.

Sec. 2. Any member of the commission, or any of its duly authorized agents or employees, shall have the right, at any time, to enter upon any premises, wild lands, farms, fields, private grounds, and inclosures for the purpose of examining into the condition of any chestnut tree or trees thereon, and determining whether or not such trees, or any of them, have been attacked or infected by the chestnut-tree blight; and whenever this disease is found to exist, such commissioners, their duly authorized agents and employees, shall, in all practicable ways, cooperate with the owners of such trees in and for the removal, cure, control, and eradication of such disease, and the prevention of its spread to other chestnut trees upon adjoining and other properties; shall specifically advise and direct such owner how he shall proceed for the accomplishment of these ends; and shall leave with such owner, his agent, tenant, or other representative having charge of such trees, a notice, in writing, containing a description or plan specifically designating the trees so found to be diseased, and full and specific instructions for the treatment of such trees, or for the removal and destruction of designated parts thereof or of an entire tree or trees, as the case may require.

Sec. 3. If any owner of such trees, so found to be diseased by the said commission, its duly authorized agents or employees, shall neglect or refuse to cooperate in applying the necessary remedies for the removal, cure, control, and eradication of such disease, and the prevention of its spread to other chestnut trees upon adjoining and other properties; or shall neglect or refuse to comply with the requirements of the notice aforesaid, prescribing the treatment which shall be applied to such trees, so found to be diseased, within twenty days from the time such notice shall have been served, the said commission may at once proceed, through its duly authorized agents and employees, to do whatever may be found by it to be necessary and proper to accomplish the cure, control, or eradication of such disease and the prevention of its spread to other chestnut trees; and for this purpose, whenever it may be found necessary may remove, cut down, and destroy, or cause to be removed, cut down, or destroyed, any trees or parts of trees so found to be infected with such disease; and shall immediately thereafter duly certify to the owner of such trees, so treated or destroyed, or to his tenant, agent, or other representative in charge of such trees, the amount of the cost or expenses actually incurred by the commission in the treatment, removal, or destruction of such trees; and if the amount of such expense, so certified, shall not be paid by such owner of said trees, so treated, removed, or destroyed within sixty days after it shall have been so certified, the same may be recovered by the said commission, from such owner, by an action in the name of the Commonwealth, in the same manner as debts of like amount are now recoverable, and when recovered may be used by said commission in carrying out the purposes of this act.

Provided, however, That any owner or owners of trees, his or their tenants, agents, or representatives, who may be dissatisfied with any decision, order, or notice of any member of the commission, or any of its agents or employees, directing or prescribing the treatment, removal, or destruction of trees belonging to or controlled by them, shall have the right within ten days from the time of the service upon them of such order or notice to appeal therefrom, in writing, to the commission, which shall thereupon, without avoidable delay, direct a re-examination of the premises or trees in question, by competent experts, who shall make report of their findings to the commision; which shall then fix a time and a place for a hearing before it, upon such appeal, and notify the person making appeal thereof. All further proceedings under such order or notice shall be suspended until the decision of the commission shall have been formally rendered.

Sec. 4. Whenever, in the judgment of the commission, it may be necessary to destroy chestnut trees not affected by the chestnut-tree blight, for the purpose of establishing a quarantine to prevent and control the spread of the disease, the owner of such trees shall be reimbursed for the loss of all the good and unaffected trees so destroyed; the amount to be paid therefor to be not greater than the stumpage prices of such trees, prevailing at the time in the locality where such trees grew; such value to be determined by the commission, by such method or procedure as it may adopt, and payment therefor to be made from the fund hereinafter specifically appropriated for the use of the said commission in performing the duties required by this act. Should any owner of trees be dissatisfied with the amount awarded to pay for the destruction of such good and unaffected trees, said owner shall have all the remedies now existing, or which may hereafter be provided by law, for the protection of his interests.

Sec. 5. Any person who shall wilfully violate any of the provisions of this act, or any of the regulations of the commission intended to assist in carrying this act into effect, or shall wilfully resist or interfere with any agent or employee of the said commission in the performance of his duties in accordance with the regulations and orders of the commission, under the provisions hereof, shall be deemed guilty of misdemeanor, and shall upon conviction thereof be punished by a fine not exceeding one hundred dollars, or by imprisonment not exceeding one month, either or both, at the discretion of the court. The word "person," as used in this act, shall include not only individuals or natural persons, but as well artificial persons, existing only in contemplation of law, and shall be construed to mean partnerships, limited partnerships, joint-stock companies, and corporations, and the officers, agents, and employees of the same.

Sec. 6. The members of the commission shall serve without pay, but shall be reimbursed for all actual expense incurred by them in exercising the powers conferred upon them and performing the duties required by this act. The employees of the commission shall receive such compensation for their services as the commission shall determine will fairly compensate them for the work to be done. The commission shall be furnished with suitable rooms in the Capitol building at Harrisburg, or elsewhere, by the Superintendent of Public Grounds and Buildings. The sum of twenty-five thousand dollars is hereby specifically appropriated, to be immediately available upon the approval of this act, for the payment of such expense as may be incurred by the commission, for such scientific research and for office expenses, as in their judgment may be necessary to comply with the provisions hereof, said appropriation to be available until the first day of June, Anno Domini, one thousand nine hundred and thirteen; and the further sum of two hundred and fifty thousand dollars, or so much thereof as shall be necessary, is hereby specifically appropriated, to be available only upon the approval of the Governor, for the performance of all other duties herein required to be done; as, for quarantine, removal of diseased trees or other trees, conducting outside investigations and operations, and every other means of eradication and control, as to it may seem necessary in complying with the provisions hereof.

SEC. 7. All acts or parts of acts inconsistent herewith are hereby repealed.

The commission authorized by the bill has been appointed by the governor of Pennsylvania and consists of the following persons: Mr. Winthrop Sargent, chairman; Mr. Harold Peirce, secretary; Messrs. Samuel T. Bodine, George F. Craig, and Theodore N. Ely. Persons desiring information regarding the work on this disease in Pennsylvania should address the executive officer of the commission, Mr. Samuel B. Detweiler, 1112 Morris Building, Philadelphia, Pa.

INSPECTION OF DISEASED NURSERY STOCK.

As has been indicated, diseased chestnut nursery stock has in the past been a most important factor in the spread of the bark disease. On account of a well-grounded fear of this disease much less nursery stock is being moved now than formerly, but there is still enough to constitute a serious source of danger. It is therefore obvious that every State in which the chestnut grows, either naturally or under cultivation, should as speedily as possible pass a law putting the chestnut bark disease on the same footing as other pernicious diseases and insect pests, such as peach yellows and the San Jose scale, against which quarantine measures are taken. Many inspectors already have legal power to quarantine against the bark disease on chestnut nursery stock, and they should now take special care that no shipment, however small, escapes their rigid inspection.

The most serious practical difficulty in inspecting nursery stock for this as for other fungous diseases lies in the fact that practically all State inspectors are necessarily entomologists, and are not trained in recognizing the more obscure symptoms of fungous diseases. Nursery trees affected by the bark disease rarely show it prominently at the time when shipped; the threads of summer spores or the yellow or orange pustules are rarely present, and usually all the inspector can find is a small, slightly depressed, dark-colored area of dead bark, usually near the ground, which is easily overlooked or mistaken for some insignificant injury. Upon cutting into such a spot, the inner bark shows a most characteristic disorganized "punky" appearance, quite different from that of any other bark injury; but it is impossible to adequately describe this appearance without recourse to colored illustrations. Occasionally a yellowish-brown band, either girdling or partly girdling the young tree, may be seen; this is very characteristic, but is so prominent a symptom that it may be noticed at the nursery, and presumably trees so affected will not be shipped.

If infected trees are set out they develop the disease with its characteristic symptoms the following spring. But on account of their small size such trees are girdled and die before the end of the summer, often in two or three weeks. Meanwhile they are spreading the disease to neighboring orchard and forest trees. Orchardists and nurserymen purchasing chestnut trees are therefore warned to watch them closely during the first season, no matter how rigidly they may have been inspected.

INDIVIDUAL TREATMENT OF DISEASED TREES.

Where valuable ornamental, shade, or orchard chestnut trees become infected in one or more spots, the life and usefulness of such trees can be prolonged for several or for many years, depending largely upon the thoroughness with which the recommendations herein given for cutting out the diseased areas (lesions) are carried out. These recommendations are based upon the results of extensive experiments with hundreds of lesions during the past four years. These experiments were performed for the most part by the junior writer.

The essentials for the work are a gouge, a mallet, a pruning knife, a pot of coal tar, and a paint brush. In the case of a tall tree a ladder or rope, or both, may be necessary, but under no circumstances should tree climbers be used, as they cause wounds which are very favorable places for infection. Sometimes an ax, a saw, and a long-handled tree pruner are convenient auxiliary instruments, though practically all the cutting recommended can be done with a gouge with a cutting edge of 1 or 1½ inches. All cutting instruments should be kept very sharp, so that a clean and smooth cut may be made at all times.

By cutting with the gouge into a diseased area a characteristically discolored and mottled middle and inner bark is revealed. All of this diseased bark should be carefully cut out for at least an inch beyond the discolored area if the size of the branch will allow it. This bark should be collected in a bag or basket and burned. If the cutting is likely to result in the removal of the bark for much more than half the circumference of the branch or trunk, it will probably be better to cut off the entire limb or to cut down the tree, as the case may be, unless there is some special reason for attempting to save the limb or tree. The fungus usually, though not always, develops most vigorously in the inner bark next to the wood. When this is the case, not only all the diseased bark and an inch of healthy bark around it must be removed, but at least two or three annual layers of wood beneath the diseased bark must also be gouged out. Special care should be taken to avoid loosening the healthy bark at the edges of the cut-out areas. Except in the early spring this is not difficult after a little experience in manipulating the gouge and mallet, provided the gouge is kept sharp.

Small branches which have become infected should be cut off, the cut being made well back of the disease—at least 2 or 3 inches, if possible.

All cut-out areas and all the cut ends of stubs should be carefully and completely painted with coal tar. A good grade of paint has been recommended by some authorities as superior to tar, but it is more expensive. If the tar is very thick, the addition of a little creosote will improve it for antiseptic purposes as well as for ease in applying. If the first coat is thin, a second one of fairly thick tar should be applied within a few weeks or months. Other coats should be applied later whenever it becomes necessary.

The entire tree should be carefully examined for diseased spots and every one thoroughly cut out and treated in the way already described. In case of suspicious looking spots a portion of the outer bark can be cut out with the sharp gouge as a test. If this cut shows the characteristically discolored bark the spot can be considered as diseased and cut out accordingly; if the cut shows healthy bark, it need merely be treated with tar or paint, as other cuts are treated. In examining a tree for diseased spots it is always best to begin at the base of the trunk and work up, for if the trunk is girdled at the base it is useless to work anywhere on the tree.

When the spores of the fungus are present, especially in the form of threads, or "horns," they are readily washed down the branches and trunk by every rain, and are thus carried down to or toward the base of the tree. As a result the base of a tree, the crotches, and other places which afford easy lodgment for the spores are particularly subject to infection.

Although spraying with any of the standard fungicides appears to have no effect whatever in stopping the progress of the disease after it has once started in the inner or middle bark, there is little doubt that it is of use in preventing infection from spores washed down by rain from the upper part of a tree or from spores which have been transported from other trees. For this reason the spraying, after each rain, of the parts of a tree below a spore-bearing lesion is recommended, but only on an experimental basis. If no spore-bearing lesions occur on the tree, there is less apparent reason for spraying. The scattering of slaked lime about the base of a tree and the whitewashing of the trunk and larger limbs have shown apparently beneficial results in preventing infections and perhaps also depredations of borers.

A tree which is being treated for individual infections must be carefully watched and the diseased spots promptly cut out as they appear. For this purpose each tree should be examined very carefully two or three times at least during the growing season.

The Department of Agriculture asks the cooperation of all persons who have experimented with the disease in any way, and in return is ready to give specific advice, based upon extensive experience with the disease, as to the best methods of attempting its control or as to what are likely to be the most profitable systematic observations or experiments.

ADVICE TO CHESTNUT ORCHARDISTS.

In view of the uncertain future of the chestnut tree, the Department of Agriculture advises against planting chestnuts anywhere east of Ohio, at least until it is settled what efforts will be made by the individual States to control the bark disease. The only exception is that Japanese chestnuts may be grown if raised from imported seeds and not grafted on American stocks. If the seed is raised in America, the trees are more than likely to be hybrids with the American chestnut and to vary greatly in resistance to the bark disease. If grafted on American stocks, the stocks readily succumb to the disease, and so the whole tree is killed, no matter how resistant the scion may be. However, the nut of the true Japanese chestnut is of poor quality at best, and it is an open question whether it can ever be made a commercial success.

West of the natural range of the American chestnut, however, the situation is quite different. Obviously the western chestnut orchardist has before him a great opportunity. No matter how successful efforts to limit the bark disease in the East may be, the nut crop will be reduced for some years, and the business of growing fine orchard chestnuts in the East will be depressed for the same length of time. There is no apparent reason why, with rigid inspection, both of any purchased stock and of the orchards themselves, all chestnut orchards and nurseries from Ohio to the Pacific coast can not be kept permanently free from the bark disease; therefore all persons interested in growing the chestnut in the West as an orchard tree are earnestly advised not to secure any chestnut nursery stock from eastern nurseries; to be sure that stock from any source is rigidly inspected; to watch with the utmost care their own nurseries and orchards; and to destroy immediately by fire any trees that may be found diseased.

There is presumptive evidence that the bark disease was introduced into America on the Japanese chestnut, but until this point is definitely settled orchardists west of Ohio are advised not to import nursery stock of this variety. Seed can probably be imported with a reasonable degree of safety, however.

ADVICE TO OWNERS OF CHESTNUT WOODLAND.

Owners of chestnut woodland anywhere within the area of complete infection are earnestly advised to convert their trees into lumber as quickly as possible. The trees that are not already killed will soon die in any case and the timber will quickly deteriorate in quality. Such trees are a continual source of further infection, and, moreover, large areas of dead chestnut trees, by harboring bark and wood inhabiting insects, are likely to start some insect epidemic. Indeed, with the quantity of dead chestnut timber now standing it will be remarkable if some serious infestation of insects extending to sound trees does not follow.

Owners of chestnut woodland outside the area of general infection are counseled to watch for the first appearance of the disease, and when it appears to cut down immediately all affected trees, bark them, and burn the bark and brush, over the stump if practicable. Such procedure will distinctly retard the spread of the disease in that particular woodland, even if no concerted efforts at elimination are made by neighboring owners. It is to be expected, however, that in all cases of this kind the owner will have the cooperation of the State authorities in a general quarantine movement.

It is almost needless to add that until we know what action is to be taken in all the chestnut-growing States and what the results are likely to be, chestnut woodland is a poor investment. Furthermore, in forest management, as in improvement cuttings, etc., there should be discrimination against the chestnut.

ADVICE TO OWNERS OF ORNAMENTAL CHESTNUT TREES.

Until the future of the chestnut tree is better known, or at least until we know what legalized action is going to be taken in the States concerned, the owners of chestnut-timbered land available for building should pursue a very conservative policy. Houses should not be located with sole reference to chestnut groves or to isolated ornamental chestnut trees. Houses so located should be discriminated against in purchasing homes in so far as the death of the chestnut trees would injure the appearance of the place.

When ornamental trees become diseased they had better be cut down at once and, if practicable, large trees of other species moved in to take their places. In expert hands the moving of large trees is a perfectly practicable and successful procedure and, although more expensive, is much more satisfactory than waiting for nursery trees to grow.[1]

All owners of diseased ornamental chestnut trees are specifically warned against "fake" tree doctors. Large sums of money have been paid out in many cases for treatment that has been worse than useless. Reliable tree specialists will have nothing to do with trees affected with the chestnut bark disease, or, if they do anything, do it with the distinct understanding in advance that it is entirely at the

[1] In case such action is not immediately desirable or possible, a very good, though temporary, scenic effect can be obtained by lopping off the ends of the larger branches of the dead and dying chestnut trees, removing the bark, and planting some rapid-growing vine at their foot, which soon covers them. One of the best for this purpose is the Japanese kudzu vine (*Pueraria thunbergiana* (S. and Z.) (Benth.), on account of its extraordinarily rapid growth. Such vine-covered stumps must be carefully watched, however, for in a very few years they decay and are liable to be blown over.

owner's risk. Of course, if an owner desires to employ tree surgeons to experiment, that is another matter.

ADVANCING POPULAR KNOWLEDGE OF THE DISEASE.

In the localities where infection is general or complete (fig. 1) everyone knows what the chestnut bark disease is and what its symptoms are and everyone appreciates its seriousness; but in these localities it is too late even to attempt its control. On the other hand, in Delaware, Virginia, West Virginia, western and southern Maryland, western Pennsylvania, central and northern New York, Massachusetts, and Rhode Island very few people know the symptoms of the disease. On this account no one notices it until it is thoroughly established, and by the time public sentiment is sufficiently aroused to authorize the necessary legislation and bring about united action for public protection it is too late for such action to be of service. Obviously, then, every effort should be made by all State and other officials having such matters in charge to acquaint every citizen with the prominent symptoms of the bark disease and to familiarize him with the fact that unless prompt and united action is taken there is every indication that the chestnut tree in the States above mentioned will become practically extinct within 10 years.

COOPERATION OF THE DEPARTMENT OF AGRICULTURE.

In this campaign of education the Department of Agriculture will cooperate in the following ways: *Copies of this bulletin or of other publications of this Department relating to the bark disease, and also typical specimens of the disease, will be sent to any person applying for them.* Two specimens will be sent to each person—one showing the appearance of the disease on smooth bark, and the other the later development of the fungus on thick bark. In both these specimens the fungus will have been killed by soaking in formalin, to insure against any infection from this source.

So far as the supply permits, lantern slides and photographs will, upon application, be loaned for special lectures, exhibits, etc., to the officers of States, experiment stations, colleges, and schools where agriculture is taught, as well as to tree wardens and other officials whose work may bear directly upon local campaigns of publicity.

This Department will always examine any suspected specimens of this disease sent to Washington by mail, and will report the findings as promptly as possible. Before sending specimens, however, all persons are urged to read the paragraphs on symptoms on pages 6 to 9 in order to select the specimens intelligently. For example, if the end of a girdled and withered branch is sent, it is not possible to make a dependable diagnosis unless a portion of the girdling area happens to be included. This is the only part where the fungus is surely present, and the fungus itself must be seen in order to be absolutely sure of the disease. Portions of the bark that show the small orange or reddish-brown pustules, about the size of the head of a pin, should always be sent, if these can be found. These commonly occur near the lower edge of the girdling area.

PUBLIC COOPERATION.

With many people familiarized with the appearance of the chestnut bark disease and its possibilities of harm, the disease will be noticed and stamped out by private effort in many places when it first appears and the public will understand and be ready to cooperate in any official measures of control as soon as these become necessary in any locality.

All possible forces must be enlisted in a campaign of publicity. The cooperation of all newspapers, particularly local papers, can be easily secured in all the States where the chestnut is an important tree. A portion of the program for Arbor Day, 1912, should be devoted to a consideration of this disease. Teachers of nature study, botany, or agriculture in the public schools can do great service by teaching their pupils how to recognize the disease and by training them to be on the lookout for its first appearance in the home community. Such a body as the "Boy Scouts" can, if properly trained, become in every community a most efficient force for locating the disease. The boys will readily appreciate that such work is real "scouting" against a most insidious and destructive public enemy. And, finally, many private owners of chestnut trees will be eager to cooperate with the State authorities in the early elimination of advance infections if only they are able to recognize such infections.

THE PROTECTION OF THE SOUTHERN STATES.

It must be remembered that the bark disease has as yet done only a small fraction of the damage that it is undoubtedly capable of doing. The best chestnut timber of America is south of the Potomac River and there the bark disease is present in only a few spots. For this reason it is of extraordinary importance that these few spots be eradicated and that the disease be soon controlled immediately north of the Potomac. If the bark disease once becomes well established in the chestnut forests of the South, it will be well-nigh impossible to control it, on account of the sparsely settled and mountainous condition of much of that country and for other reasons which do not obtain farther north.

SUMMARY.

(1) The chestnut bark disease was first noted near New York City in 1904 and is now present in at least 10 States. It attacks the American chestnut, the European chestnut, the chinquapin, and, rarely, the Japanese chestnut.

(2) The total financial loss from this disease is now estimated at $25,000,000.

(3) The disease is caused by a fungus, and the entrance of a spore at any point where the bark is broken may cause infection. The

disease spreads primarily in the inner bark and produces characteristic lesions which girdle the tree at the point attacked.

(4) Conspicuous symptoms are the development of bunches of sprouts below the girdling lesions; the half-formed yellowish leaves in the spring on the previously girdled branches; the reddish-brown leaves on branches girdled in summer, and the yellow, orange, or reddish-brown pustules of the fruiting fungus on the bark. It is practically useless to attempt systematic location of the disease from October to April, inclusive.

(5) The spores may be carried considerable distances on chestnut nursery stock, tan bark, and unbarked timber; also by birds, insects, squirrels, etc., which have come in contact with the sticky spore masses. Water quickly dissolves these spore masses and the minute spores are in this way carried along with water, as, for instance, with rain water running down a tree. Borers' tunnels form the most common places of entrance for spores.

(6) The only known practical way of controlling the disease in a forest is to locate and destroy the advance infections as soon as possible after they appear and, if the disease is well established near by, to separate the area of complete infection from the comparatively uninfected area by an immune zone. Advance infections should be located by trained observers and destroyed by cutting and burning. As the disease develops almost entirely in the bark, this must be completely destroyed (burned).

(7) In order to carry out the above methods it is essential that the several States concerned secure necessary legislation and appropriations, following the example of Pennsylvania, as no law exists whereby the Federal Government can undertake such work and cooperation among private owners without State supervision is impracticable.

(8) Chestnut nursery stock should be rigidly inspected for the disease and only perfectly healthy plants passed.

(9) The life of valuable ornamental trees may be greatly prolonged by promptly cutting out all diseased areas and removing all disease-girdled branches and then covering the cuts with tar. Spraying is of no use in stopping the fungus after it has once started growth in the bark.

(10) It is recommended that owners of infected woodland cut down and utilize the diseased chestnut timber as soon as possible.

(11) For the present the planting of chestnuts anywhere east of Ohio is not advised, but there is no apparent reason why chestnut orchards west of Ohio may not be kept free from the disease.

[A list giving the titles of all Farmers' Bulletins available for distribution will be sent free upon application to a Member of Congress or the Secretary of Agriculture.]

62D CONGRESS } SENATE { DOCUMENT
2d Session } { No. 653

CHESTNUT TREE BLIGHT

LETTER FROM THE
SECRETARY OF AGRICULTURE

TRANSMITTING

IN RESPONSE TO SENATE RESOLUTION OF APRIL 30, 1912, INFORMATION RELATIVE TO THE STUDY AND INVESTIGATION OF THE SO-CALLED CHESTNUT TREE BLIGHT

MAY 9, 1912.—Referred to the Committee on Agriculture and Forestry and ordered to be printed with illustrations

WASHINGTON
1912

UNITED STATES OF AMERICA
GOVERNMENT PRINTING OFFICE

CHESTNUT TREE BLIGHT.

Department of Agriculture,
Office of the Secretary,
Washington, May 8, 1912.

The President of the Senate.

Sir: In accordance with the resolution of the Senate, under date of April 30, directing that the Secretary of Agriculture "submit to the Senate, at the earliest practicable day, the results thus far secured in the study and investigation of the so-called chestnut-tree blight, and the amount of money thus far expended in said study and investigation," I have the honor to report as follows:

Observations on the disease known as the chestnut-tree blight, or the chestnut-bark disease, were begun in this department in the summer of 1907, as soon as any office was organized to do this class of work. The results secured in the study and investigation of this disease have been set forth in detail from time to time in the following publications, which are inclosed herewith, and constitute a part of this report:

Bureau of Plant Industry Bulletin No. 121, Part VI, The Immunity of the Japanese Chestnut to the Bark Disease, February 10, 1908.

Forest Service, unnumbered circular: Extent and Importance of the Chestnut Bark Disease, October 21, 1908.

Bureau of Plant Industry Bulletin No. 141, Part V, The Present Status of the Chestnut Bark Disease, August 30, 1909.

Farmers' Bulletin No. 467, The Control of the Chestnut Bark Disease, October 28, 1911.

A series of 34 photographs, mounted on 20 sheets, with explanatory legends, illustrating various phases of the disease, are also appended, and constitute a part of this report. (Pls. I–XVI.)

A summary of results follows:

(1) The disease is caused by a parasitic fungus which kills the tree by girdling it at various points. Trees of all ages and conditions are attacked without discrimination.

(2) A tree once attacked never recovers. It takes from two months to four years to kill a tree, according to the size of the tree and the point of attack. The average length of life of a diseased tree is three years. Trees killed by this disease sprout readily from the trunks and roots, but the sprouts are in turn infected and killed.

(3) All species and varieties of chestnut now grown in this country are subject to the disease, except the Japanese and Korean varieties, which are resistant. The Japanese and Korean chestnuts are small trees, fair nut producers, but probably valueless for timber. No other species of trees have as yet been parasitized by the fungus, but it is not impossible that other species, such as oaks and walnuts, may later become attacked.

(4) The disease is spread by the spores of the fungus, which are sticky in character. They are probably not diffused by wind to any appreciable extent, but are spread by rain, insects, probably also by birds, small mammals such as squirrels, and by man. Unbarked timber and cordwood from diseased trees and diseased chestnut

nursery stock may carry the disease bodily for great distances. The majority of infections take place through wounds made by bark-borers. The relation of insects to the disease appears to be very intimate.

(5) The origin of the disease is unknown. Its obvious spread from a center—the vicinity of New York City—suggests that it is not a native disease; and the resistance of Asiatic species of chestnut to the disease suggests that it may have been imported from Asia with the Japanese chestnut. No evidence has been secured to connect the considerable losses of chestnut timber in the Southeastern States in past years with this disease; these losses were more probably due to attacks of insects.

(6) The disease was first called to public attention in 1904, but it probably had already been present on Long Island for some years.

(7) The value of the chestnut stand is variously estimated at between three hundred and four hundred million dollars. This disease has already caused an estimated minimum damage of $25,000,000.

(8) Judging by the history of the disease to date, it may be expected to spread throughout the range of the chestnut tree during the next two years, unless checked by human effort. Whatever is done to control the disease by any methods known at present must be attempted immediately, else the disease will be beyond control by any effort ever likely to be put forth.

(9) As shown on the accompanying map (Pl. I), the disease is now known to occur in at least 10 States, viz: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, and Virginia. In all of Connecticut, New Jersey, and Delaware, and in western Massachusetts, eastern New York, eastern Pennsylvania, and northeastern Maryland, the chestnut trees are already generally infected, and a large per cent are already dead.

(10) Outside of this area of general infection the disease occurs at scattered points ("advance infections"). These consist mostly of single infected trees, or small groups of trees, often many miles apart.

(11) Analogy with pear blight and peach yellows and with animal and human diseases that are controlled by destruction or isolation of the foci of infection suggests early destruction of the advance infections as the only possible means of controlling the disease or limiting its range. There is no contagious disease known that does not yield to sanitation and quarantine. The destruction of diseased trees can not possibly be an effective means of control, however, in localities where the disease has already become general.

This method of destroying advance infections has been employed extensively by private owners to check the progress of the disease in their own holdings. But since general cooperation is necessary to make any sanitation finally effective, it appears necessary to organize private effort under State control. This has already been done in Pennsylvania under special law, and is about to be done in Virginia under special law; and under the general laws now existing, in West Virginia and probably some other States. This department indorses the work of these States, and particularly the early and vigorous action of Pennsylvania.

(12) Results to date indicate the following lines of activity as desirable and necessary to be carried out by this department and the various States in cooperation:

(*a*) The determining of the exact range of the disease, and the locating and cutting out of all advance infections. This work to be done in Virginia, West Virginia, western and probably southern Maryland, Ohio, western Pennsylvania, central and western New York; possibly also in Kentucky, Tennessee, and North Carolina, following the methods now employed by the Chestnut Blight Commission of Pennsylvania. In all localities, and particularly in those States where no State quarantine of any sort is contemplated, it will be necessary to instruct private owners regarding the disease in order that they may take such measures as they see fit to protect their own property.

(*b*) The careful inspection of all nurseries containing chestnut trees, and all chestnut nursery stock.

(*c*) Determining by extensive local investigation the best methods of rapidly utilizing and marketing the timber of trees dying and dead from this disease, in order to protect timber owners against total loss, and to reduce infection. This work to be done in all localities where infection is already general.

(*d*) Determining what changes in general forest management are necessary in those localities where the chestnut tree is already doomed, and so far as practicable putting such changes immediately into practice.

(*e*) Continuing experiments on tree surgery and tree medication, in the hope of saving valuable orchard and ornamental trees. Any positive results from this line of work will also be applicable to other tree diseases, including those of fruit trees.

(*f*) Continuing search for a resistant American stock, and breeding from resistant Asiatic stock, in order particularly to rehabilitate the chestnut-orchard industry; at the same time breeding also for timber trees. Results of the greatest value to the chestnut-orchard industry can not fail to be secured from this line of work.

(*g*) Making careful studies of the many unsolved scientific problems involved in the disease. Some of the more important of these are: The relation of the disease to climate; the relation of the parasite to the varying tannin content of the tree; the origin of the disease; the relation of birds and insects to the distribution of the disease; the nature and degree of resistance in the Asiatic varieties.

(*h*) Determining in detail the relation of the disease to the future of the chestnut timber in the proposed Appalachian Forest Reserves, and making special effort to keep the disease out of this territory.

With the exception of about $400, expended by the Forest Service in 1908 in the work set forth in the inclosed circular by E. R. Hodson, all expenditures have been made in the Bureau of Plant Industry. The amount thus far expended in this study and investigation is $14,885.96 (estimated), which is itemized as follows:

For the fiscal year ending June 30, 1908 (estimated)	$350.00
For the fiscal year ending June 30, 1909	1,365.81
For the fiscal year ending June 30, 1910	1,814.27
For the fiscal year ending June 30, 1911	2,210.51
For the fiscal year 1912, to date (estimated)	9,145.37
Total	14,885.96

I have the honor to be, sir, your obedient servant,

JAMES WILSON, *Secretary.*

[Reprint of Bureau of Plant Industry Bulletin No. 121, Pt. VI, issued Feb. 10, 1908.]

THE IMMUNITY OF THE JAPANESE CHESTNUT TO THE BARK DISEASE.

By Haven Metcalf, *Pathologist in Charge of the Laboratory of Forest Pathology.*

The Extent of the Bark Disease.

The bark disease of the chestnut, caused by the fungus *Diaporthe parasitica* Murrill, has spread rapidly from Long Island, where it was first observed, and is now reported from Connecticut, Massachusetts, Vermont, New York as far north as Poughkeepsie, New Jersey, Pennsylvania, and possibly Delaware. It is no exaggeration to say that it is at present the most threatening forest-tree disease in America. Unless something now unforeseen occurs to check its spread the complete destruction of the chestnut orchards and forests of the country, or at least of the Atlantic States, is only a question of a few years' time.

An Immune Variety.

Observations made by the writer during the past year indicate that all varieties and species of the genus Castanea are subject to the disease except the Japanese varieties (*Castanea crenata* Sieb. and Zucc.). All of the latter that have been observed in the field or tested by inoculations have been found immune. This fact can hardly fail to be of fundamental importance to the future of chestnut nut culture. Although the nuts are distinctly inferior in flavor to the European varieties, such as Paragon, the Japanese chestnut is already grown on a large scale as a nut-producing tree. There are, however, many trade varieties of dubious origin. Some of these may prove later to be subject to the disease. Immunity tests of all known varieties of chestnuts have been undertaken.

Attempts will also be made to hybridize the Japanese with American and European varieties, with the hope of combining the immunity of the former with the desirable qualities of the latter.

However excellent as a nut and ornamental tree, the value of the Japanese chestnut as a forest tree is doubtful. It can be recommended only experimentally at present for forest planting. It certainly will not take the place of the American chestnut. The tree is said to attain a height of 50 or 60 feet in Japan. As seen in this country, it is a handsome tree, dwarfish and compact in habit, and rather slow growing. It has hardly had time to show how large it can grow.

The immunity of the Japanese chestnut, together with the fact that it was first introduced and cultivated on Long Island and in the very locality from which the disease appears to have spread, suggests the interesting hypothesis that the disease was introduced from Japan. So far, however, no facts have been adduced to substantiate this view.

[Reprint of Forest Service unnumbered circular, issued Oct. 21, 1908.]

EXTENT AND IMPORTANCE OF THE CHESTNUT BARK DISEASE.

By E. R. Hodson.

Introduction.

Three years ago a destructive fungous disease of the chestnut first attracted attention and almost immediately assumed the character of an epidemic. It seems to be one of the most serious diseases which has ever attacked an American forest tree, and has done great damage locally in and around New York City, and is now spreading rapidly in all directions to forest tracts in Connecticut, New York, New Jersey, and even into Pennsylvania.

The disease was first studied by Dr. W. A. Murrill, of New York, and during the past 18 months it has been under investigation by Dr. Haven Metcalf, of the Bureau of Plant Industry. The technical details given in this circular have been derived chiefly from the publications of the former and information supplied by the latter.

Manner of Infection.

The disease is caused by a fungus known as *Diaporthe parasitica* or *Valsonectria parasitica*, the spores of which enter the tree through wounds on branches or trunk. Dead twigs also offer a means of entrance, and there are probably other ways, not yet known, by which the trees become infected.

From the point of entrance the fungus spreads in all directions throughout the cambium and inner bark until it completely girdles the branch or trunk it has attacked. It has been found that a few of the outer annual rings of the wood are also attacked, and it is very likely that the fungus penetrates some of the medullary rays in search of the food material which they contain; but the real seat of the injury is the inner bark and the growing layer of the wood.

Symptoms.

When a tree is first attacked the disease is not noticeable, and is likely to be overlooked. In many instances the trees are attacked first on the smaller branches. These are soon girdled, and the foliage turns yellow and then wilts. By these wilted branches the disease can be detected from a distance. The girdled branches or trees do not usually die until the second year, except when they are attacked very early in the season, or when the infected limbs are small.

On limbs with smooth bark the diseased patches are sunken and discolored, with small brownish or yellow knobs scattered over the surface. On the edge of the affected area in the growing season there is a ring of greenish, yellowish, or bright yellow excrescences which resemble horns and are very conspicuous, so that in young trees the disease is easily detected even before the branches wilt. In very dry weather, however, these horns may be nearly or entirely suppressed. Where the bark is thick, as on large trees, it is not changed in appearance, but the brownish knobs of the fruiting bodies show in the cracks, and the bark sounds hollow when struck.

On account of its rapid action in killing or wilting small branches, the disease can not remain long undetected if the trees are under inspection. At the end of a single year the disease has usually made its presence conspicuous by a large number of dead and dying trees.

Localities Affected.

In 1905 the disease had already spread over a considerable area around New York City, where it apparently originated. In the present year it is spreading rapidly in a westerly direction over northern New Jersey, where in Morris County large tracts have recently been attacked. New York City is about the center of the infected area. Last year the chestnut tracts in Westchester and Nassau Counties in New York, Fairfield County in Connecticut, and Bergen County in New Jersey were severely attacked, and now Morris Essex, and Monmouth Counties, N. J., can be added.

In Connecticut the disease is very severe at Stamford. It has been found near Danbury and Waterbury, and is known to extend along the coast to New London. It is also reported in southeastern Massachusetts and as far north as Wellesley.

On Long Island it is common in the western part and along the northern shore to Huntington. It is likely that it occurs on the island wherever there is chestnut, although it has not yet been reported from the eastern end. It extends up the Hudson to Poughkeepsie, and across the river to the west; it has been found, though not in great abundance, at Turner and Warwick, and has been reported at Marlborough. Near the Connecticut line it occurs as far north as Pawling and is very destructive from Katonah all the way southward to New York City.

In New Jersey the disease is very abundant in the northern and eastern parts, particularly near the coast in Bergen, Essex, and Monmouth Counties. Southward it is found along the Delaware River to Trenton, and abundantly along the coast near Chapel Hill and Eatontown in the northern part of Monmouth County. Recently a belt around Morristown and German Valley has become badly infected, and the disease has been discovered in wild trees at Newark and Fenton, Del., and at various points near Philadelphia, Pa. In Pennsylvania it is nowhere abundant yet, although it exists at Easton, South Bethlehem, and Morrisville, and is reported as far north as the Pocono Mountains and as far south now as Philadelphia. It has also been found near Baltimore, Md., and in Bedford County, Va.

The range at present, then, includes eight States: Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and Massachusetts. Pennsylvania, so far as known, is not infected to any great extent, except in the eastern border, while Massachusetts, Maryland, and Virginia are touched only at one or two points.

How the Disease Spreads.

The yellow fruiting bodies so common on the diseased trees are constantly giving off millions of summer spores all through the growing season. These are transported by various agencies to healthy trees, where they gain entrance through wounds in the bark. Wind is probably the principal agency, but the spores are no doubt carried by animals, birds, insects, and by shipment of infected material.

The disease spreads locally through the gradual distribution of the spores from tree to tree, and at a distance chiefly through the shipment of infected material, such as nursery stock, bark, nuts, and other products. There is a possibility that long-distance infection is also effected by means of migratory birds.

There are a number of facts which support the view that the wind has been the principal agency in spreading the disease over the present area. For instance, trees in open spaces exposed to winds, such as those along roads, at the edges of woods, or near streams or ponds, are apt to be infected sooner than the trees in more sheltered situations; trees on slopes or in depressions with diseased trees on higher ground near them usually become infected, evidently because they have been exposed to the wind-scattered spores from above; and in thinned stands, if the disease is present in the neighborhood, almost every chestnut becomes affected. In this instance the frequency of wounds is probably a large contributory cause. Dense woods, as a rule, act as a bar to the progress of the infection, except where the disease is very prevalent in the vicinity, in which case nothing seems to check its spread.

Amount of Damage.

The amount of loss caused by this disease is especially great, because it has developed in a region where the chestnut trees are extensively used for ornamental and park purposes. For this reason the losses have been acutely felt. There is, of course, no satisfactory basis for estimating the value of trees which are useful chiefly for æsthetic purposes, but the loss is certainly several million dollars.

In Prospect Park, Brooklyn, there are but 6 chestnut trees left alive out of 1,400. In Forest Park, at Jamaica, Long Island, practically all the chestnut trees are diseased and many are dead. The same applies to Bronx Park in New York City. In Nassau County, in western Long Island, few chestnut tracts have escaped serious damage. In Westchester County, N. Y., it is apparently only a question of a short time when nearly all the chestnuts will be destroyed. Many estates have sustained losses in scenic beauty which it is impossible to estimate. In the part of New Jersey adjacent to New York City the damage has been of the same character; parks and country estates have lost large number of fine chestnut trees which would not have been sold at any price.

Although so far the injury to ornamental trees has attracted the most attention, the damage is not confined to these alone. Indeed, a far more serious phase of the epidemic is the menace to commercial forest tracts. Already many large tracts in at least five States have been attacked, and though great damage has been done in certain localities, it is very small compared with what it will be if the disease continues to spread.

A favorable feature in the situation is that so far the disease has done most damage in the vicinity of the sea, and there are some indications that back from the sea, where there is less atmospheric moisture, it may be less virulent and may spread less rapidly.

The damage which would result from the destruction or extensive depreciation of the commercial chestnut forests would be many times that from the loss of ornamental trees. Chestnut is one of the most rapidly growing and most useful of American forest trees, and it plays a very important part in the forests of the eastern United States. The wood is exceedingly durable and has, therefore, been extensively used for posts, poles, and railroad ties, while its grain, color, and ease of working give it a place among furniture and finishing woods. It is, moreover, a very vigorous sprouter and lends itself admirably to forest management. With the exception of white pine, chestnut probably makes the most profitable timber crop that can be grown in the northeastern part of the United States.

UTILIZATION OF DEAD AND DISEASED TREES.

Since the fungus does not work in the wood to any extent and ceases its activities when the tree is dead, the wood is not damaged as a result of the disease. In many cases only a part of the tree is affected, while the rest is healthy and can be utilized without difficulty.

Dead trees are looked upon with suspicion, especially if they are killed by a disease, and the wood is popularly thought to be weaker than seasoned live timber. In the case of this fungus there is no ground for such a prejudice; as a matter of fact, the dead material is fully as strong as any other timber if it is utilized within a few years, before the ordinary agencies of decay cause it to deteriorate.

In most of the places where the disease prevails the problem of cutting and marketing small amounts is a difficult one. The damage from the disease is sudden, and it is often hard to find a market on short notice, especially for small quantities.

In order to market the material, owners should encourage the contractors and pole buyers, who as a class are also vitally interested in the perpetuation of the chestnut, to go into sections where the disease is doing damage. Where the tracts are large enough or several are located close together, a portable sawmill might be put in. Where the quantity of chestnut is small, the best disposal is for ties, cordwood, and fence posts. Owners of small tracts where the disease has appeared can often cooperate to great advantage in order to find a market or make a lumbering operation possible.

MEASURES OF PREVENTION.

The chestnut-bark disease is not like ordinary fungous diseases, which destroy a tree here and there after a number of years; it is even more virulent than the well-known pear blight, which it resembles in many particulars. It destroys quickly and spreads rapidly, and it is of the utmost importance to those who are interested in chestnut forests to secure a means of checking or stamping it out and of preventing its spread to localities which are as yet unaffected.

Seedlings and sprouts are attacked with equal virulence and old and young trees are killed alike. There is therefore no system of forestry which can be used to control the disease. Two methods of checking its spread and lessening the source of the infection are available:

1. To cut out the diseased trees.
2. To institute a quarantine against the shipment of infected material.

In a forest tract the diseased trees should be cut outright—all trees which show the least sign of infection should be removed. In other situations, where the trees have a peculiar value, it may be possible to save them by cutting off the diseased parts only; but if the trunk of a tree is attacked, the whole tree, no matter how valuable it is, should be cut at once, for it is practically useless to try to save it.

Since the disease generally spreads less rapidly in dense stands than in thin ones, it will often be possible, by close inspection and the prompt removal of infected trees, to stamp out the disease altogether from a forest tract. For the same reason, however, if many diseased trees are to be removed and their removal would make the stand very open, it will often be better to make a clean cut of all the chestnut.

All diseased bark should be removed and burned. After that is done the wood is practically free from infection and can be used or stored with safety.

Even greater effort should be directed toward preventing the spread of the disease to localities which are as yet unaffected than to stamping it out in places where it already has a firm hold.

For this reason definite legislation seems necessary, and it is very desirable that each State concerned should enact a law providing for a quarantine against infected chestnut products, chiefly nursery stock. The law should also provide for systematic and thorough inspection of the disease and require the cutting out of infected trees wherever they are a menace to healthy stands of chestnut.

The nature of the disease and the necessity of fighting it should be made known to the people throughout the region affected by means of the press and by enlisting the aid of the granges and other organizations interested.

It is to be hoped that some natural limitation to the destructiveness of the disease may be found and that it may be checked by natural causes. But its rapid spread and its great virulence make waiting dangerous. Prompt and energetic measures should be taken to stamp it out wherever it appears.

[Reprint of Bureau of Plant Industry Bulletin No. 141, Pt. V, issued Aug. 30, 1909.]

THE PRESENT STATUS OF THE CHESTNUT BARK DISEASE.

By HAVEN METCALF, *Pathologist in Charge*, and J. FRANKLIN COLLINS, *Special Agent, Investigations in Forest Pathology.*

HISTORY OF THE CHESTNUT BARK DISEASE.

In 1904 Mr. H. W. Merkel, of the New York Zoological Park, observed a disease which was destroying large numbers of chestnut trees in the city of New York. This disease is what is now known as the chestnut bark disease. Even at that time it is certain that it had spread over Nassau County and Greater New York, and had found lodgment in the adjacent counties of Connecticut and New Jersey. No earlier observation than this is recorded, but it is evident that the disease, which would of necessity have made slow advance at first, must have been in this general locality for a number of years in order to have gained such a foothold by 1904. Conspicuous as it is, it is strange that the fungus causing this disease was not observed or collected by any mycologist until May, 1905, when specimens were received from New Jersey by Mrs. F. W. Patterson, the Mycologist of the Bureau of Plant Industry. In the same year Dr. W. A. Murrill began his studies of the disease, publishing the results in the summer of 1906. By August, 1907, specimens received by this bureau showed that the disease had reached at least as far south as Trenton, N. J., and as far north as Poughkeepsie, N. Y., and was spread generally over Westchester and Nassau Counties, N. Y., Bergen County, N. J., and Fairfield County, Conn.

PRESENT DISTRIBUTION.

The present distribution of the chestnut bark disease is shown on the accompanying map (fig. 1). By this it will be seen that infection is now complete in the general vicinity of the city of New York. Outside of this area the disease already occurs at scattering points in a number of States. In every case its occurrence has been definitely authenticated by specimens which have been examined microscopically. Reports have been received indicating that the disease is found at many other places, but not being substantiated by specimens these localities have not been shown on the accompanying map. It is only fair to state, however, that such reports have been received from points as remote as Cape Cod, Wellesley, and Pittsfield, Mass.; Rochester and Shelter Island, N. Y., and Akron, Ohio.

The bark disease is entirely different from a disease which during the past 20 years has caused the death of many chestnut trees on the Atlantic slope, particularly south of the Potomac River. The latter disease, which is now being studied by the Department of

Agriculture, is associated with insects, is much slower in action than the bark disease, and produces a stag-headed condition of the tree. It can be quite confidently stated that the bark disease does not yet occur south of Virginia and at only a few points in that State.

Investigations are in progress to determine the origin of the bark disease in America and the details regarding its spread. The theory advanced in a previous publication of this bureau,[1] that the Japanese chestnuts were the original source of infection, has been strengthened by many facts. It yet lacks much of demonstration, however, and is still advanced only tentatively.

While the disease has spread principally from the vicinity of New York there is much to indicate that it occurred at other points at an early date. Chester's Cytospora on a Japanese chestnut, noted at Newark, Del., in 1902, may have been the bark disease. Observations by the junior writer indicate that this disease may have been present in an orchard in Bedford County, Va., as early as 1903, and that in Lancaster County, Pa., it probably was present as early as 1905. All other points shown on the map outside of the area of general infection appear to have been infected only within one or two years.

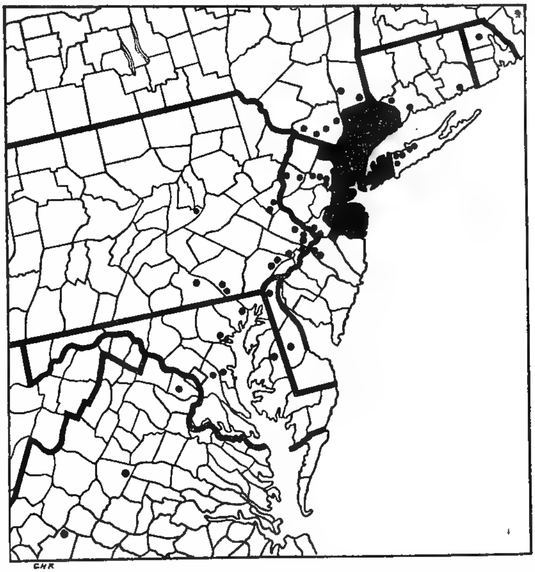

FIG. 1.—Map of the eastern portion of the United States, showing the distribution of the chestnut bark disease. The heavily shaded part shows the counties wherein infection is already complete. The round dots show other points where the disease is positively known to occur.

The bark disease appears practically to exterminate the trees in any locality which it infests. A survey of Forest Park, Brooklyn, showed "that 16,695 chestnut trees were killed in the 350 acres of woodland in this park alone. Of this number about 9,000 were between 8 and 12 inches in diameter, and the remaining 7,000 or more were of larger size."

In a recent publication Dr. W. A. Murrill estimates the financial loss from this disease "in and about New York City" at "between five and ten million dollars." The aggregate loss throughout the whole area of country affected must be much greater.

The bark disease occurs on both chestnut and chinquapin, regardless of age, origin, or condition. It does not occur on any other tree so far as known. All reports of its occurrence on the chestnut oak (*Quercus prinus*) have proved to be unfounded. It is not yet known whether the goldenleaf chinquapin of the Pacific coast (*Castanopsis chrysophylla*) is subject to this disease.

[1] Bureau of Plant Industry, U. S. Department of Agriculture, Bulletin 121, Pt. VI. 1908.

According to Sudworth, the range of the native chestnut is "from southern Maine to northwestern Vermont (Winooski River), southern Ontario, and southern shores of Lake Ontario to southeastern Michigan; southward to Delaware and southeastern Indiana, and on the Allegheny Mountains to central Kentucky and Tennessee, central Alabama, and Mississippi." The range of the chinquapin is "from southern Pennsylvania (Adams, York, Franklin, and Cumberland counties) to northern Florida and eastern Texas (Neches River)." The bark disease may, therefore, be expected to occur at any point within these limits, as well as in any other localities where the chestnut is grown as an ornamental or orchard tree.

Cause and Symptoms.

The disease is caused by the fungus *Diaporthe parasitica* Murrill (also known as *Valsonectria parasitica* (Murrill) Rehm). The spores of this fungus, brought by some means from a previously diseased tree, enter the bark through wounds; possibly also in other ways. The leaves and green twigs are not directly affected. From the point of infection the fungus grows in all directions through the inner bark until the growth meets on the opposite side of the trunk or limb, which in this way is girdled. The wood is but little affected. Limbs with smooth bark attacked by the fungus soon show dead, discolored, sunken patches of bark covered more or less thickly with the yellow, orange, or reddish-brown pustules of the fruiting fungus. In damp weather or in damp situations the spores are extruded in the form of long irregular "horns," or strings, at first greenish to bright yellow in color, becoming darker with age. Plate XVII, figure 3, shows a part of a branch of a diseased chestnut tree magnified 3½ diameters. In this illustration the typical appearance of the pustules in damp weather and the projection of the spores of the fungus in the form of "horns," or threads, are shown. These threads may be especially conspicuous near the edges of diseased areas. If the spot is on the trunk or a large limb with very thick bark there is no obvious change in the appearance of the bark itself, but the pustules of the fungus show in the cracks of the bark and, on account of the destruction of the layers beneath, the bark often sounds hollow when tapped. A patch usually grows fast enough to girdle the branch or trunk that it is on during the first summer.

The damage may not be immediately apparent, since the water supply from the roots continues to pass up through the comparatively uninjured wood to the leaves, but when in the following spring the new leaves are put out they are usually stunted and soon wither. The appearance of such trees is very characteristic. Plate XVII, figure 1, shows large chestnut trees killed by the bark disease. In this illustration the trees to the left show the characteristic stunted foliage, which indicates that they were girdled during the previous year, while the tree on the right having no foliage was presumably girdled by the fungus at least two summers before the photograph reproduced was taken. Plate XVII, figure 2, shows an orchard tree with recently girdled branches. Nothing else except an actual mechanical injury—breaking off of trunk or limb—produces such an effect as is shown in these illustrations. The imperfectly developed leaves often persist on the dead branches throughout the summer.

The great damage which the disease has done thus becomes most apparent in the last week of May or the first week in June, giving rise to the false but common idea that the fungus does its work at this time of the year, when in reality the harm is done during the previous summer. If the first attack is on the trunk, of course the entire tree dies. If, on the other hand, the small branches are first involved, the tree may live for several years.

It is very easy for a person not familiar with fungi to confuse this parasite with various other fungi which occur commonly on the dead wood of chestnut and other trees, such as species belonging to the genera Calocera, Cytospora, and Cytosporina. The superficial resemblance is sometimes very strong, but a microscopical examination instantly reveals the true nature of the organism in question. On account of this common confusion no dependable diagnosis of the bark disease can be made in a new locality without a microscopical examination of specimens by an expert.

Restriction of Spread.

HOW THE FURTHER SPREAD OF THE BARK DISEASE MAY BE LIMITED.

By the Inspection of Diseased Nursery Stock.

It becomes more and more evident as this disease is studied that diseased nursery stock is the most important factor in its spread to distant points. In that part of the country where it is already well established in the native chestnuts its progress is rapid and sure, but there is no evidence at present that it is able to pass to remote districts, tens or hundreds of miles away, except on diseased nursery stock. Of course it is conceivable that the spores are carried by birds. Such distribution would, however, follow in general the great lines of bird migration north and south and hence would not be an important factor in the western spread, except locally. During the summer of 1908 nearly every chestnut nursery and orchard of importance in the Atlantic States north of North Carolina was visited, and very few were found free from the bark disease. Several cases were observed where the disease had obviously spread from the nursery to adjacent wild trees. This is the only way in which the disease is likely to spread beyond the Alleghenies.

It is therefore obvious that every State in which the chestnut or chinquapin grows should as speedily as possible pass a law putting the chestnut-bark disease on the same footing as other pernicious diseases and insect pests, such as the San Jose scale, against which quarantine measures are taken. The Department of Agriculture will be glad to give detailed suggestions or advice regarding the framing of such laws. Inspectors who already have legal power to quarantine against this disease should now take special care that no shipment of chestnut stock escapes their rigid inspection.

A campaign of education should also be undertaken by pathologists and inspectors in every State in order to acquaint the public with the nature and appearance of the bark disease, so that it may be quickly recognized and stamped out in any particular locality in which it appears. The Department of Agriculture will cooperate in the following ways: Specimens from suspected trees sent in by any person will be promptly examined and the presence or absence of the disease reported. Typical specimens showing the disease (with the fungus previously killed by soaking in formalin to insure against any infection from this source) will be sent upon application to any inspector, forester, pathologist, or other State or experiment station officer, to any nurseryman or orchardist growing chestnuts, or to any botanist or teacher of botany. So far as the supply permits lantern slides and photographs will, upon application, be loaned for special lectures, exhibits, etc., to the officers of States, experiment stations, or colleges. By these means the inspectors first, and then the general public, may become familiar with the appearance and work of the disease in localities that it has not yet reached, and when it does appear may be able to recognize it before it is too late to take efficient measures against it.

Although its present distribution is that shown by the map (fig. 1), the bark disease may be confidently looked for in any orchard or nursery in the United States that contains chestnut trees. All such places should therefore be rigidly inspected at the earliest possible date.

By the Prompt Destruction of Diseased Trees.

When the bark disease is first noticed in any locality all the affected trees should be immediately cut down unless, as in the case of orchard and some few ornamental trees, they are of sufficient individual value to warrant special treatment. Diseased trees if untreated are doomed to death in any case. If permitted to stand, every such tree becomes a center of infection, certain to spread the disease to all neighboring trees, and so long as it will soon die if left to itself the sooner it is cut down the better.

When cut, the brush should be immediately gathered and burned in order to destroy the fungus in the bark. Whenever the bark is removed from the trunk—as, for example, when the trees are to be used for poles—it should be immediately burned with the brush. Even when the tree is to be used for firewood an effort should be made to cut off at least all the diseased patches of bark on the trunk and large limbs when the tree is cut and to burn this bark along with the brush; otherwise the brush and the piled wood will continue to spread infection, since it has been found that the fungus continues alive on dead bark for at least six months after cutting.

Sprouts arising from the stumps of cut trees will be free from the disease for the first year at least, but must then be carefully inspected to be sure that no infection has persisted.

By the Treatment of Diseased Trees.

During the past two years the Office of Investigations in Forest Pathology has been conducting certain experiments and collecting information in regard to the best methods of treating diseased trees.

At present it is impossible definitely to record general beneficial results from any of the sprayings which have been undertaken or have been under observation. This may in part be due to the fact that it is yet too early to judge satisfactorily all the results and in part, perhaps, to the infrequency of sprayings.

Observations and experiments seem to bear out the statement that it is very improbable that any method of spraying can interfere with the growth of the fungus if it has once established itself in the inner bark, but it may be of considerable importance in preventing the development of spores which come from other trees or from other parts of the same tree.

It has already been demonstrated that the crotches of branches and enlarged bases of sprouts are very susceptible to infection because they are favorable places for the lodgment of water, dust, spores, etc. In a large majority of cases infections are definitely known to have originated at a point where the outer bark had been injured in some way, leaving the inner living bark exposed, or where the entire bark over a more or less limited area had been stripped from the tree or cracked and split away from the wood. Certain injuries which are known to have afforded entrance for the disease have been of such a nature that they might easily be overlooked, while others have been quite obvious, even to the careless observer. Among the latter may be mentioned broken limbs, split limbs, branches which have been carefully cut but not properly treated with tar or paint, bruises from hames, plows, and cultivators; also poor grafts and diseased grafting scions. Among the former may be included bruises from boot heels, climbing spurs, holes made by borers and other insects, knife and saw cuts, and frost cracks.

Almost the only treatment that can at present be safely recommended as surely retarding the spread of the disease to a greater or less extent is one which will never be of practical use except in the case of orchard trees or certain valuable ornamental trees. It consists essentially in cutting out the infected branches or areas of bark and carefully protecting the cut surfaces from outside infection by means of a coat of paint or tar. This cutting must be thoroughly done and the bark of every infected place entirely removed for a distance of at least an inch (where the size of the branch permits) beyond the characteristic, often fan-shaped, discolored areas produced by the growing fungus in the inner bark. All small infected twigs or branches should be cut from the tree, the cut being made well back of the diseased area. A pruning knife with an incurved tip, a hollow gouge, or any other clean-cutting instrument will serve for cutting out diseased spots. So far as the exigencies of the case will permit, all borers' holes should be cut out. It has been repeatedly observed in the field that infection often starts where borers are at work, or even at the old holes made by them. The paint or tar may be applied by means of a good-sized brush, care being taken to cover every part of the cutting. Treatment should begin, or observations at least, at the base of the tree and the fact ascertained whether the disease has already girdled the trunk. If such is the case it will be a waste of time to attempt any treatment; instead, cut the tree down at once. A rigid watch must be kept, especially during the growing season, for new infections or infections which were overlooked in the earlier examinations, and if any are observed they must be treated promptly as above mentioned. Constant vigilance is necessary to keep the disease in check. It is suggested that examinations be made about June 1, July 15, and September 1. During a very rainy or foggy season, when conditions are particularly favorable for the growth of fungi, it may be advisable to inspect as often as once a month.

In regions in which the disease is so widespread that almost every tree is infected, as, for instance, within 25 miles of the city of New York, it is extremely doubtful whether any individual treatment will pay. Under such conditions immediate reinfection is almost sure to occur at one or more of the small unnoticed abrasions or injuries which are quite certain to exist on most trees. In a region, however, where only isolated cases have yet appeared it is quite possible to stamp out the disease, or at least to prevent its rapid spread, by promptly cutting out and carefully burning all diseased bark and limbs, thus destroying these new sources of infection. If a tree is too badly infected to be worth treating it should not be left standing, for it will then become a continual menace to all surrounding chestnuts.

The Office of Investigations in Forest Pathology asks the cooperation of all persons who have observed the disease or experimented with it in any way. If such people will send in an early report of the kind of treatment used, time of treatment, methods employed, and results obtained (even if adverse), it may be possible to arrive at an earlier and more definite conclusion in regard to the possibilities or impossibilities of control than would otherwise be the case.

Conclusions.

It is to be hoped that in the economy of nature some limiting factor will arise to check the spread of the bark disease before it has wrought the same destruction throughout the country that it already has in the vicinity of New York. But at present there is nothing in sight that promises even remotely to check its spread into new territory except the general adoption of the measures advocated in these pages. It can not be argued that because of its apparently recent origin and rapid spread it will soon disappear of itself. Such diseases as pear blight and peach yellows have been in the country for more than a century and yet show no sign of abating except when actively combated by modern quarantine methods. Nor can any conclusions be drawn from the fact that chestnuts in the Southern States have suffered from a disease during the past twenty years, since, as already stated, that is a totally different thing from the bark disease.

Where the bark disease is already firmly established and has attacked 50 per cent or more of the chestnut trees, as in the vicinity of the city of New York, it is probably too late to try to do anything, but where the disease is just appearing there is no reason to doubt that strict quarantine methods will apply as well to this as to any other disease, whether of plants or animals. The question to settle is simply which is more costly—to use the methods recommended or to lose the trees. The people concerned must decide.

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THE CONTROL OF THE CHESTNUT BARK DISEASE.

By Haven Metcalf and J. Franklin Collins.

The Disease.

HISTORY AND DISTRIBUTION.

The chestnut bark disease was first recognized as a serious disease in the vicinity of New York City in 1904, and the first publication regarding it appeared in 1906. There is reliable evidence, however, that it was present on Long Island at least as early as 1893. Its origin is unknown, but there is some evidence that it was imported from the Orient with the Japanese chestnut. This view is not, however, held by all investigators. But whatever may have been its time or place of origin, it is certain that it has now spread into at least 10 States, as is shown by the accompanying map (fig. 2). In the vicinity of New York City and through adjacent counties it has killed practically all chestnut trees. Throughout a much larger neighboring area, as shown in figure 2, practically all chestnut trees are infected. Outside of this area, throughout the country from the northern border of Massachusetts and from Saratoga County, N. Y., to the western border of Pennsylvania and the southern border of Virginia, scattering areas of infection are known to occur and may be expected at any point.

So far as is now known, the bark disease is limited to the true chestnuts—that is, to the members of the genus Castanea. The American chestnut, the chinquapin, and the cultivated varieties of the European chestnut are all readily subject to the disease. Only the Japanese and perhaps other east Asian varieties appear to have resistance. In spite of popular reports to the contrary, it can be quite positively stated that the bark disease is not now known to occur on living oaks, horse-chestnuts, beeches, hickories, or the golden-leaf chinquapin (*Castanopsis chrysophylla*) of the Pacific coast.

FINANCIAL LOSSES.

The bark disease appears ultimately to exterminate the chestnut trees in any locality which it infests. A survey of Forest Park (Brooklyn) showed "that 16,695 chestnut trees were killed in the 350 acres of woodland in this park alone. Of this number, about 9,000 were between 8 and 12 inches in diameter, and the remaining 7,000 or more were of larger size." Three years ago the financial loss from this disease "in and about New York City" was estimated at "between five and ten million dollars."

The writers regard $25,000,000 as a conservative estimate of the financial loss from this disease up to 1911. In many localities the greatest damage has been among chestnuts grown for ornamental purposes, which have a value greatly in excess of their value as lumber. Depression in the value of real estate, especially suburban or near-suburban, owing to the death of the chestnut trees, must be taken into account in an estimate of this kind, as well as the loss of the trees themselves.

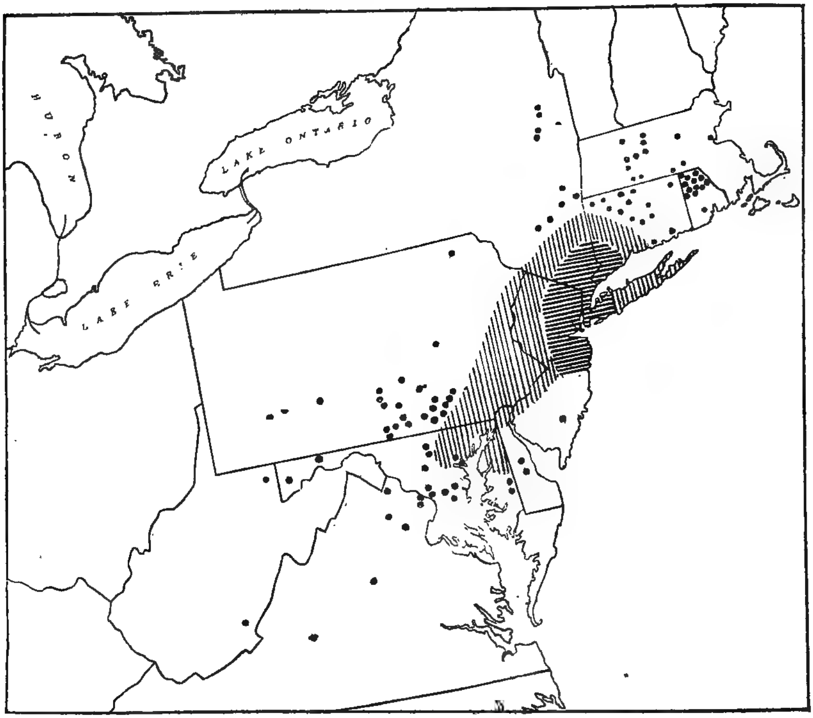


FIG. 2.—Map of the northeastern part of the United States, showing the distribution of the chestnut bark disease. The horizontally lined part shows the approximate area wherein the majority of chestnut trees are already dead from the bark disease. The part marked by vertical lines shows the approximate area wherein infection is already complete. The round dots show the location of advance infections of the disease. Many of these have already been eradicated. The map has been compiled from both observations and correspondence. The writers are under especial obligations to Dr. Perley Spaulding, Prof. A. H. Graves, Mr. I. C. Williams, Mr. W. H. Rankin, Mr. J. F. O'Byrne, Mr. F. W. Besley, Dr. Ernest S. Reynolds, and Mr. H. G. MacMillan, for data along this line. According to Dr. G. P. Clinton (Connecticut Agricultural Experiment Station, Report of the Botanist, 1909 and 1910) there are many more points of infection in Connecticut than are shown on this map.

CAUSE AND SYMPTOMS.

The chestnut bark disease is caused by a fungus parasite known under the technical name of *Diaporthe parasitica* Murrill. When any of the microscopic spores (reproductive cells) of this fungus gain entrance into any part of the trunk or limbs of a chestnut tree they give rise to a spreading "sore" or lesion, which soon girdles the tree. If the part attacked happens to be the trunk, the whole tree in consequence is killed, perhaps in a single season. If the smaller branches are attacked, only those branches are killed, or only those portions of branches beyond the point of attack, and the remainder of the tree may survive for several years (fig. 3).

Some of the symptoms are quite prominent. Limbs with smooth bark attacked by the fungus soon show dead, somewhat discolored, sunken areas (occasionally with a raised margin), which continue to enlarge and soon become covered more or less thickly with yellow, orange, or reddish-brown spots about the size of a pinhead. These spots are the pustules of the fruiting fungus. In damp weather or in damp situations, masses of summer spores are extruded in the form of long, irregularly twisted strings or "horns," which are at first bright yellow to greenish yellow or even buff, becoming darker with age (Pl. XVII, fig. 3). If the lesion is on the trunk or a large limb with very thick bark, there is no obvious change in the appearance of the bark itself, but the pustules show in the cracks and the bark often sounds hollow when tapped. After smooth-barked limbs or trunks are girdled the fungus continues to grow extensively through the bark, sometimes covering the entire surface with reddish-brown

FIG. 3.—Large chestnut tree partly killed by the bark disease. Note the sprouts with leaves near the top, the dwarfed leaves on the lower right-hand limb, and the healthy lower branches with leaves.

pustules (fig. 4). These pustules produce mostly winter spores (ascospores), although occasionally the long strings of summer spores (Pl. XVII, fig. 3) are also produced, even on bark that has been dead at least a year.

After a branch or trunk is girdled, the leaves change color and sooner or later wither. Such branches have a very characteristic appearance and can hardly be mistaken for anything else, except in certain localities where the work of twig-girdling insects may produce a similar appearance in the spring. In case the girdling by the fungus is completed late in the season, the leaves of the following spring assume a yellowish or pale appearance and do not develop to their full size (fig. 3). If the girdling is completed between spring and midsummer the leaves may attain their full size and then turn a somewhat characteristic reddish-brown color, which can easily be detected at a long distance. Later this leaf coloration changes to a more brownish tinge and the leaves are commonly persistent for a considerable time. The chestnut fruits (burs) on a spring-girdled branch may or may not attain full size, according to whether the girdling by the disease was completed late or early in the spring. These burs commonly persist on the tree during the following winter, thus producing the only symptom which is at all conspicuous during the leafless season. The great damage which the disease has done in the late summer thus becomes most evident at the beginning of the next season, and that done in the spring becomes evident later in the same season, giving rise to the false but common idea that the fungus does its work at the time of year that the leaves change color, when in reality the harm was done much earlier.

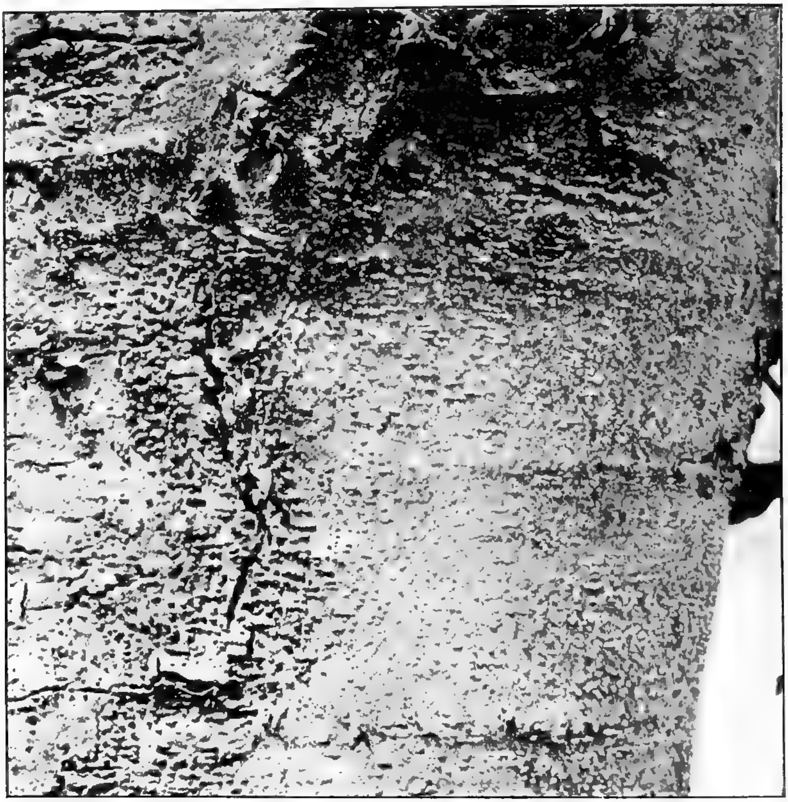


FIG. 4.—Dead chestnut bark showing pustules of the parasitic fungus bearing winter spores.

Perhaps the most easily seen as well as the longest persistent symptom of the bark disease is the prompt development of sprouts, or "suckers," on the trunk of the tree (fig. 3) and at its base, or somewhat less frequently on the smaller branches. Sprouts may appear below every girdling lesion on a tree, and there are usually many such lesions. These sprouts are usually very luxuriant and quick growing, but rarely survive the second or third year, as they in turn are killed by the fungus. The age of the oldest living sprout, as determined by the number of its annual rings, is an indication of the minimum age of that portion of the infection immediately above it. Sprouts are sometimes produced as a result of other injuries; for instance, trees girdled by borers may develop sprouts, but these are generally less rapid in growth and are distributed with greater uniformity over the trunk.

MEANS OF SPREAD AND ENTRANCE.

The disease is spread by the spores of the fungus, of which there are two kinds. As both kinds of spores appear to be sticky, there is no evidence that they are transmitted by wind except where they may be washed down into the dust and so blown about with the dust. The spores are spread easily through short distances by rain; particularly they are washed down from twig infections to the lower parts of the tree. There is strong evidence that the spores are spread extensively by birds, especially woodpeckers, and there is also excellent evidence that they are spread by insects and by various rodents, such as squirrels. The disease is carried bodily for considerable distances in tan bark and unbarked timber derived from diseased trees. One of the most prolific sources of general infection has been the transportation of diseased chestnut nursery stock from infected to uninfected localities.

When the spores have once been carried to a healthy tree, they may develop in any sort of hole in the bark which is reasonably moist. These may be wounds or mechanical injuries, but by far the most common place of infection is a tunnel made by a borer. Borers' tunnels are moist, even in dry weather, and in them the spore finds surroundings favorable to its development. In many parts of the country where the disease is prevalent there is very direct evidence that bark borers, and particularly the two-lined chestnut borer (*Agrilus bilineatus*), are directly associated in this way with 90 per cent or more of all cases of this disease. We are informed that the Bureau of Entomology will issue a circular on the insects associated with the chestnut bark disease.

The writers have no definite evidence, experimental or otherwise, to show that a tree with reduced vitality is more susceptible to infection, or that the disease spreads more rapidly in such a tree, than in a perfectly healthy and well-nourished tree of either seedling or coppice growth, provided that such reduced vitality does not result in or is not accompanied by bark injuries through which spores can gain entrance.

The Control of the Disease.

ELIMINATION AND QUARANTINE.

Fundamental Observations and Experiments.

No method of immunizing individual trees against the bark disease is yet known, and no method of treating or curing them when once attacked is certain in its results. While this is unfortunate from the standpoint of the owner of orchard trees and large ornamental trees of great individual value, no method of dealing with single trees—surgery, medication, spraying, etc.—however successful in itself, would meet the demands of the present situation. It is not practicable at present to apply any individual method of treatment to forest trees; the individual tree is not worth it, and will not be for many years. Therefore, so far as the chestnut forests are concerned, we do not need to regret particularly that no individual treatment has yet been discovered that is entirely effective.

Fortunately, however, there is a method of dealing with the situation which is applicable to the country as a whole and which, so far as tested, is practicable. Early in the course of the writers' investigations it became evident that the disease advances but slowly in a solid line, but instead spreads from isolated centers of infection, often many miles in advance of the main line of disease. That such is the case is evident from a glance at figure 2. It therefore seemed probable that if these advance infections could be located at a reasonably early stage they could be eliminated at relatively little expense, thus preventing further spread from these points at least. Accordingly, the country within approximately 35 miles of Washington, D. C., was chosen in the fall of 1908 as preliminary territory in which to test this method of control. This section has since been gone over fairly thoroughly once a year. As will be seen by figure 2, 14 points of infection were located, and the infected trees destroyed. Most of this work was done by the senior writer. The largest infection was a group of nursery trees that had been imported from New Jersey; the smallest, a single lesion on a small branch of a large forest tree. In one case 11 forest trees in a group were infected, the original infection having been two trees, dating apparently from as early as 1907. Up to the present time (June, 1911) the disease has not reappeared at any point where eliminated and the country within a radius of approximately 35 miles from Washington is apparently free from the bark disease, although new infections must be looked for as long as the disease remains elsewhere unchecked. It is therefore believed that this method of attack will prove equally practicable in other localities, and if carried out on a large scale will result ultimately in the control of the bark disease.

Legal Considerations.

In carrying such a scheme of control into effect on a large scale, however, legal difficulties are at once encountered. The bark disease threatens the extinction of the chestnut throughout its range. As it has already been found in at least 10 States and the District of Columbia, it is essentially a national issue, but there is no law whereby the Federal Government can attempt to cope with the emergency. Each State must act on its own initiative and control the disease or let it go as its officers and legislative bodies see fit. Herein lies one of the most serious aspects of the matter; for if one State elects to undertake control of the disease it will be seriously handicapped if neighboring States do not. Any method of elimination, isolation, or quarantine in dealing with any disease of plants, domestic animals, or human beings necessitates general cooperation. It is not practicable to try to control the bark disease solely by the cooperation of individual owners of chestnut woodland, since a single indifferent or obstinate person can nullify the efforts of an entire community. The control of the chestnut bark disease must therefore be undertaken by the separate States under special legislation.

Possibly in certain States the crop and woodland pest laws, which ordinarily apply only to nursery stock, may be broad enough to include this disease, but in most States the first thing to be done is to obtain the necessary legal authority and an appropriation for action along the following lines, as has already been done in Pennsylvania.

The Method in Detail.

Locating advance infections ("scouting").—The first thing to be done in each State is to determine the exact range of the disease in that State, and particularly to locate the advance points of infection. This is by far the most difficult feature of the entire program, because the work must be directed and in large measure carried out by experts; otherwise diseased trees will be left, and the results can not be depended upon. It is best intrusted to professional plant pathologists, or at least to botanists familiar with fungi and the collecting of fungi, and even these must have some preliminary knowledge of this particular disease. The symptoms of the disease are too obscure and the means of locating it too intricate to make it possible for a person without a professional knowledge of plant diseases to deal successfully with the situation, no matter how well informed in agriculture or forestry or how experienced in the care of trees. It is suggested that in most States this part of the work would be best handled by the pathologists of the State agricultural experiment stations.

For assistants the pathologists having this work in charge should choose the best scientific observers obtainable, regardless of other considerations, but persons with some knowledge of plant pathology are to be preferred. College students trained in these lines are usually available, for the summer vacation at least, and make in many respects the most desirable "scouts" for this work. But all "scouts" must be carefully and individually trained by the expert in charge.

Attention should first be directed to the advance spots of infection already known to exist, and when found the diseased trees should be destroyed or marked for destruction. No difficulty will be experienced in locating infections 2 years old or more, but the greatest difficulty will be met in locating infections of the current year. Every tree in the immediate vicinity of older infected trees must be carefully gone over. Many dubious cases will be found, and from such trees samples of the suspected bark must be taken and sent to some laboratory for expert judgment. It is absolutely necessary to have arrangements with some laboratory whereby such work can be done and the results promptly reported.

After the spots already known to exist have been delimited and the trees destroyed or marked for destruction, the search should be continued. It is best next to clearly define the location of the main line of advance of the disease, back of which infection is general. Working away from this line as a base, a complete survey of the remainder of the State must be made, until it is reasonably certain that all spots have been located.

Scouting is best discontinued as soon as the leaves change color in the fall, since from October to April, inclusive, the symptoms are very obscure. Practically no sign of the disease is visible from a distance, except in those cases where the burs persist on the older trees.

Even the pustules of the fungus become weathered, so that even a close examination of a tree may not yield visible results. But the destruction of trees already marked can continue through the winter.

Destroying advance infections.—Many of the advance infections will be found to consist of single trees or of less than half a dozen trees. These may perhaps be destroyed by the person who finds them, especially if remote from other infections; but the greater part of the work of elimination is best handled by other persons under separate direction. Undoubtedly this work can be best directed in each State by the State forestry officials.

The work of elimination should be done as soon as possible after the diseased trees are located, but may be done at whatever time of year is most convenient, since new infections will be detected by the scouting of the following year. The marked trees should be cut down. So far as is now known, the timber may be safely utilized in various ways, provided it is barked. The bark and brush should be piled over the stumps and, as soon as practicable, burned. If it is not practicable to have the fire over the stumps, the stumps should be barked to the ground; but in any case the bark and brush must be burned.

It will be readily seen that the task of locating the disease, and the subsequent one of eliminating it, call for very different talents. The "scouting" calls for carefully trained and absolutely accurate scientific observers working under the most highly specialized direction that can be obtained. The work of elimination calls not for scientific knowledge, but for executive ability, tact in dealing with owners and in otherwise administering the law, and a knowledge of forestry and of lumbering, market, and transportation conditions. In a word, the first is a task for pathologists, the second for foresters. Another advantage of thus dividing the work is that a certain rivalry will usually develop, resulting in more thorough work on both sides. It is, moreover, of the utmost importance to have as many different forces and interests as possible in any given State working toward the common end of controlling this disease.

Establishing the "immune zone."—After all advance spots of infection are eliminated, attention must be turned to the main line of advance—the edge of the area of general infection. Here the problem will present local differences. It may prove necessary in some States to destroy all chestnut trees, diseased or healthy, in a belt 10 to 20 miles wide, or possibly less. Advantage must be taken of natural barriers to infection, such as unforested areas or wooded areas without chestnuts. In this way an "immune zone" will be established, across which the disease can not easily be transmitted by merely local agents. Back of this line the chestnut trees may be abandoned to the disease. Every effort should be made, however, to have them cut down and the timber utilized as soon as possible, since they remain sources of distant infection as long as any spore-laden bark or diseased sprouts remain on them.

Quarantine.—Whether any restrictions are placed upon the movement of chestnut products from the area of complete infection to the protected territory will depend largely on local conditions and must be left to the judgment of State authorities. Barked timber can probably be moved with comparative safety. It will always be desirable to limit the movement of unbarked chestnut timber and firewood and of chestnut tan bark. An inspection of local conditions will readily determine whether the danger from these sources is sufficiently great to warrant the business inconvenience which would be caused by the quarantine of any or all chestnut products.

Program for the second year.—The work for the second year will consist mostly of reinspection of the advance spots where the bark disease has been eradicated the previous year and of general scouting to locate new spots. If the work of the first year has been thoroughly done and there has been time to complete the elimination of all spots located, only scattering infections may be expected. From this time on the persons in charge of scouting will have the bulk of work and responsibility.

THE EXAMPLE OF PENNSYLVANIA.

Pennsylvania enjoys the distinction of being the first and so far the only State to undertake in any way the control of the chestnut-bark disease. In the summer of 1910 the Main Line Citizens' Association—an organization of citizens residing along the main line of the Pennsylvania Railroad near Philadelphia—appointed a committee of seven, under the chairmanship of Mr. Harold Peirce, to determine the status of the disease in that locality and to see what could be done toward controlling it. An extensive local survey of the disease was made under the direction of Mr. I. C. Williams, deputy State forest commissioner. The committee soon became convinced that the problem was of State and even national importance, and could only be solved by legislation and by the broadest cooperation. Accordingly they devoted their energies to securing the passage by the Pennsylvania Legislature of the following bill, which has now become a law. This law is almost unique in conservational legislation, and on account of its important bearing as precedent for similar laws in other States it is here reproduced in full.

AN ACT To provide efficient and practical means for the prevention, control, and eradication of a disease affecting chestnut trees, commonly called the chestnut-tree blight; providing for the destruction of trees so affected; creating a commission to carry out the purpose of this act; fixing penalties for violation of the provisions hereof; and making an appropriation therefor.

SECTION 1. *Be it enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania in General Assembly met; and it is hereby enacted by the authority of the same:* That a commission to consist of five members, to be appointed by the governor for a period of three years from the date of the approval of this act, and to be called "The Commission for the Investigation and Control of the Chestnut-Tree Blight Disease in Pennsylvania," is hereby created, with power to ascertain, determine upon, and adopt the most efficient and practical means for the prevention, control, and eradication of a disease of the chestnut tree commonly known as the chestnut-tree blight disease; and for this purpose, in collaboration with the department of forestry, or otherwise, to conduct scientific investigations into the nature and causes of such disease and the means of preventing its introduction, continuance, and spread; to establish, regulate, maintain, and enforce quarantine against the introduction and spread of such disease; and, from time to time, to adopt and prescribe such regulations and methods of procedure as to it may seem necessary and proper for carrying into effect the purpose of this act, and exercising the powers and authority hereby conferred: *Provided*, That in the work of collaboration by the commission with the department of forestry said department may employ such means, and make detail of such men, and do such other things, as may seem to be necessary or expedient to accomplish the purpose of this act.

SEC. 2. Any member of the commission, or any of its duly authorized agents or employees, shall have the right, at any time, to enter upon any premises, wild lands, farms, fields, private grounds, and inclosures for the purpose of examining into the condition of any chestnut tree or trees thereon, and determining whether or not such trees, or any of them, have been attacked or infected by the chestnut-tree blight; and whenever this disease is found to exist, such commissioners, their duly authorized agents and employees, shall, in all practicable ways, cooperate with the owners of such trees in and for the removal, cure, control, and eradication of such disease, and the prevention of its spread to other chestnut trees upon adjoining and other properties; shall specifically advise and direct such owner how he shall proceed for the accomplishment of these ends; and shall leave with such owner, his agent, tenant, or other representative having charge of such trees, a notice, in writing, containing a description or plan specifically designating the trees so found to be diseased, and full and specific instructions for the treatment of such trees, or for the removal and destruction of designated parts thereof, or of an entire tree or trees, as the case may require.

Sec. 3. If any owner of such trees, so found to be diseased by the said commission, its duly authorized agents or employees, shall neglect or refuse to cooperate in applying the necessary remedies for the removal, cure, control, and eradication of such disease, and the prevention of its spread to other chestnut trees upon adjoining and other properties; or shall neglect or refuse to comply with the requirements of the notice aforesaid, prescribing the treatment which shall be applied to such trees, so found to be diseased, within 20 days from the time such notice shall have been served, the said commission may at once proceed, through its duly authorized agents and employees, to do whatever may be found by it to be necessary and proper to accomplish the cure, control, or eradication of such disease and the prevention of its spread to other chestnut trees; and for this purpose, whenever it may be found necessary may remove, cut down, and destroy, or cause to be removed, cut down, or destroyed, any trees or parts of trees so found to be infected with such disease; and shall immediately thereafter duly certify to the owner of such trees, so treated or destroyed, or to his tenant, agent, or other representative in charge of such trees, the amount of the cost or expenses actually incurred by the commission in the treatment, removal, or destruction of such trees; and if the amount of such expense, so certified, shall not be paid by such owner of said trees, so treated, removed, or destroyed, within 60 days after it shall have been so certified, the same may be recovered by the said commission, from such owner, by an action in the name of the Commonwealth, in the same manner as debts of like amount are now recoverable, and when recovered may be used by said commission in carrying out the purposes of this act.

Provided, however, That any owner or owners of trees, his or their tenants, agents, or representatives, who may be dissatisfied with any decision, order, or notice of any member of the commission, or any of its agents or employees, directing or prescribing the treatment, removal, or destruction of trees belonging to or controlled by them, shall have the right within 10 days from the time of the service upon them of such order or notice to appeal therefrom, in writing, to the commission, which shall thereupon, without avoidable delay, direct a reexamination of the premises or trees in question, by competent experts, who shall make report of their findings to the commission; which shall then fix a time and a place for a hearing before it, upon such appeal, and notify the person making appeal thereof. All further proceedings under such order or notice shall be suspended until the decision of the commission shall have been formally rendered.

Sec. 4. Whenever, in the judgment of the commission, it may be necessary to destroy chestnut trees not affected by the chestnut-tree blight, for the purpose of establishing a quarantine to prevent and control the spread of the disease, the owner of such trees shall be reimbursed for the loss of all the good and unaffected trees so destroyed; the amount to be paid therefor to be not greater than the stumpage prices of such trees, prevailing at the time in the locality where such trees grew; such value to be determined by the commission, by such method or procedure as it may adopt, and payment therefor to be made from the fund hereinafter specifically appropriated for the use of the said commission in performing the duties required by this act. Should any owner of trees be dissatisfied with the amount awarded to pay for the destruction of such good and unaffected trees, said owner shall have all the remedies now existing, or which may hereafter be provided by law, for the protection of his interests.

Sec. 5. Any person who shall willfully violate any of the provisions of this act, or any of the regulations of the commission intended to assist in carrying this act into effect, or shall willfully resist or interfere with any agent or employee of the said commission in the performance of his duties in accordance with the regulations and orders of the commission, under the provisions hereof, shall be deemed guilty of misdemeanor, and shall upon conviction thereof be punished by a fine not exceeding $100, or by imprisonment not exceeding one month, either or both, at the discretion of the court. The word "person," as used in this act, shall include not only individuals or natural persons, but as well artificial persons, existing only in contemplation of law, and shall be construed to mean partnerships, limited partnerships, joint-stock companies, and corporations, and the officers, agents, and employees of the same.

SEC. 6. The members of the commission shall serve without pay, but shall be reimbursed for all actual expense incurred by them in exercising the powers conferred upon them and performing the duties required by this act. The employees of the commission shall receive such compensation for their services as the commission shall determine will fairly compensate them for the work to be done. The commission shall be furnished with suitable rooms in the Capitol building at Harrisburg, or elsewhere, by the Superintendent of Public Grounds and Buildings. The sum of $25,000 is hereby specifically appropriated, to be immediately available upon the approval of this act, for the payment of such expense as may be incurred by the commission, for such scientific research and for office expenses, as in their judgment may be necessary to comply with the provisions hereof, said appropriation to be available until the 1st day of June, A. D. 1913; and the further sum of $250,000, or so much thereof as shall be necessary, is hereby specifically appropriated, to be available only upon the approval of the governor, for the performance of all other duties herein required to be done; as, for quarantine, removal of diseased trees or other trees, conducting outside investigations and operations, and every other means of eradication and control, as to it may seem necessary in complying with the provisions hereof.

SEC. 7. All acts or parts of acts inconsistent herewith are hereby repealed.

The commission authorized by the bill has been appointed by the governor of Pennsylvania and consists of the following persons: Mr. Winthrop Sargent, chairman; Mr. Harold Peirce, secretary; Messrs. Samuel T. Bodine, George F. Craig, and Theodore N. Ely. Persons desiring information regarding the work on this disease in Pennsylvania should address the executive officer of the commission, Mr. Samuel B. Detweiler, 1112 Morris Building, Philadelphia, Pa.

INSPECTION OF DISEASED NURSERY STOCK.

As has been indicated, diseased chestnut nursery stock has in the past been a most important factor in the spread of the bark disease. On account of a well-grounded fear of this disease much less nursery stock is being moved now than formerly, but there is still enough to constitute a serious source of danger. It is therefore obvious that every State in which the chestnut grows, either naturally or under cultivation, should as speedily as possible pass a law putting the chestnut bark disease on the same footing as other pernicious diseases and insect pests, such as peach yellows and the San Jose scale, against which quarantine measures are taken. Many inspectors already have legal power to quarantine against the bark disease on chestnut nursery stock, and they should now take special care that no shipment, however small, escapes their rigid inspection.

The most serious practical difficulty in inspecting nursery stock for this as for other fungous diseases lies in the fact that practically all State inspectors are necessarily entomologists, and are not trained in recognizing the more obscure symptoms of fungous diseases. Nursery trees affected by the bark disease rarely show it prominently at the time when shipped; the threads of summer spores or the yellow or orange pustules are rarely present, and usually all the inspector can find is a small, slightly depressed, dark-colored area of dead bark, usually near the ground, which is easily overlooked or mistaken for some insignificant injury. Upon cutting into such a spot, the inner bark shows a most characteristic disorganized "punky" appearance, quite different from that of any other bark injury; but it is impossible to adequately describe this appearance without recourse to colored illustrations. Occasionally a yellowish-brown band, either girdling or partly girdling the young tree, may be seen; this is very characteristic, but is so prominent a symptom that it may be noticed at the nursery, and presumably trees so affected will not be shipped.

If infected trees are set out they develop the disease with its characteristic symptoms the following spring. But on account of their small size such trees are girdled and die before the end of the summer, often in two or three weeks. Meanwhile they are spreading the disease to neighboring orchard and forest trees. Orchardists and nurserymen purchasing chestnut trees are therefore warned to watch them closely during the first season, no matter how rigidly they may have been inspected.

INDIVIDUAL TREATMENT OF DISEASED TREES.

Where valuable ornamental, shade, or orchard chestnut trees become infected in one or more spots, the life and usefulness of such trees can be prolonged for several or for many years, depending largely upon the thoroughness with which the recommendations herein given for cutting out the diseased areas (lesions) are carried out. These recommendations are based upon the results of extensive experiments with hundreds of lesions during the past four years. These experiments were performed for the most part by the junior writer.

The essentials for the work are a gouge, a mallet, a pruning knife, a pot of coal tar, and a paint brush. In the case of a tall tree a ladder or rope, or both, may be necessary, but under no circumstances should tree climbers be used, as they cause wounds which are very favorable places for infection. Sometimes an ax, a saw, and a long-handled tree pruner are convenient auxiliary instruments, though practically all the cutting recommended can be done with a gouge with a cutting edge of 1 or 1½ inches. All cutting instruments should be kept very sharp, so that a clean and smooth cut may be made at all times.

By cutting with the gouge into a diseased area a characteristically discolored and mottled middle and inner bark is revealed. All of this diseased bark should be carefully cut out for at least an inch beyond the discolored area if the size of the branch will allow it. This bark should be collected in a bag or basket and burned. If the cutting is likely to result in the removal of the bark for much more than half the circumference of the branch or trunk, it will probably be better to cut off the entire limb or to cut down the tree, as the case may be, unless there is some special reason for attempting to save the limb or tree. The fungus usually, though not always, develops most vigorously in the inner bark next to the wood. When this is the case, not only all the diseased bark and an inch of healthy bark around it must be removed, but at least two or three annual layers of wood beneath the diseased bark must also be gouged out. Special care should be taken to avoid loosening the healthy bark at the edges of the cut-out areas. Except in the early spring this is not difficult after a little experience in manipulating the gouge and mallet, provided the gouge is kept sharp.

Small branches which have become infected should be cut off, the cut being made wel' back of the disease—at least 2 or 3 inches, if possible.

All cut-out areas and all the cut ends of stubs should be carefully and completely painted with coal tar. A good grade of paint has been recommended by some authorities as superior to tar, but it is more expensive. If the tar is very thick, the addition of a little creosote will improve it for antiseptic purposes as well as for ease in applying. If the first coat is thin, a second one of fairly thick tar should be applied within a few weeks or months. Other coats should be applied later whenever it becomes necessary.

The entire tree should be carefully examined for diseased spots and every one thoroughly cut out and treated in the way already described. In case of suspicious-looking spots a portion of the outer bark can be cut out with the sharp gouge as a test. If this cut shows the characteristically discolored bark the spot can be considered as diseased and cut out accordingly; if the cut shows healthy bark, it need merely be treated with tar or paint, as other cuts are treated. In examining a tree for diseased spots it is always best to begin at the base of the trunk and work up, for if the trunk is girdled at the base it is useless to work anywhere on the tree.

When the spores of the fungus are present, especially in the form of threads, or "horns," they are readily washed down the branches and trunk by every rain, and are thus carried down to or toward the base of the tree. As a result the base of a tree, the crotches, and other places which afford easy lodgment for the spores are particularly subject to infection.

Although spraying with any of the standard fungicides appears to have no effect whatever in stopping the progress of the disease after it has once started in the inner or middle bark, there is little doubt that it is of use in preventing infection from spores washed down by rain from the upper part of a tree or from spores which have been transported from other trees. For this reason the spraying, after each rain, of the parts of a tree below a spore-bearing lesion is recommended, but only on an experimental basis. If no spore-bearing lesions occur on the tree, there is less apparent reason for spraying. The scattering of slaked lime about the base of a tree and the whitewashing of the trunk and larger limbs have shown apparently beneficial results in preventing infections and perhaps also depredations of borers.

A tree which is being treated for individual infections must be carefully watched and the diseased spots promptly cut out as they appear. For this purpose each tree should be examined very carefully two or three times at least during the growing season.

The Department of Agriculture asks the cooperation of all persons who have experimented with the disease in any way, and in return is ready to give specific advice, based upon extensive experience with the disease, as to the best methods of attempting its control or as to what are likely to be the most profitable systematic observations or experiments.

ADVICE TO CHESTNUT ORCHARDISTS.

In view of the uncertain future of the chestnut tree, the Department of Agriculture advises against planting chestnuts anywhere east of Ohio, at least until it is settled what efforts will be made by the individual States to control the bark disease. The only exception is that Japanese chestnuts may be grown if raised from imported seeds and not grafted on American stocks. If the seed is raised in America, the trees are more than likely to be hybrids with the American chestnut and to vary greatly in resistance to the bark disease. If grafted on American stocks, the stocks readily succumb to the disease, and so the whole tree is killed, no matter how resistant the scion may be. However, the nut of the true Japanese chestnut is of poor quality at best, and it is an open question whether it can ever be made a commercial success.

West of the natural range of the American chestnut, however, the situation is quite different. Obviously the western chestnut orchardist has before him a great opportunity. No matter how successful efforts to limit the bark disease in the East may be, the nut crop will be reduced for some years, and the business of growing fine orchard chestnuts in the East will be depressed for the same length of time. There is no apparent reason why, with rigid inspection, both of any purchased stock and of the orchards themselves, all chestnut orchards and nurseries from Ohio to the Pacific coast can not be kept permanently free from the bark disease; therefore all persons interested in growing the chestnut in the West as an orchard tree are earnestly advised not to secure any chestnut nursery stock from eastern nurseries; to be sure that stock from any source is rigidly inspected; to watch with the utmost care their own nurseries and orchards; and to destroy immediately by fire any trees that may be found diseased.

There is presumptive evidence that the bark disease was introduced into America on the Japanese chestnut, but until this point is definitely settled orchardists west of Ohio are advised not to import nursery stock of this variety. Seed can probably be imported with a reasonable degree of safety, however.

ADVICE TO OWNERS OF CHESTNUT WOODLAND.

Owners of chestnut woodland anywhere within the area of complete infection are earnestly advised to convert their trees into lumber as quickly as possible. The trees that are not already killed will soon die in any case and the timber will quickly deteriorate in quality. Such trees are a continual source of further infection, and, moreover, large areas of dead chestnut trees, by harboring bark and wood inhabiting insects, are likely to start some insect epidemic. Indeed, with the quantity of dead chestnut timber now standing it will be remarkable if some serious infestation of insects extending to sound trees does not follow.

Owners of chestnut woodland outside the area of general infection are counseled to watch for the first appearance of the disease, and when it appears to cut down immediately all affected trees, bark them, and burn the bark and brush, over the stump if practicable. Such procedure will distinctly retard the spread of the disease in that particular woodland, even if no concerted efforts at elimination are made by neighboring owners. It is to be expected, however, that in all cases of this kind the owner will have the cooperation of the State authorities in a general quarantine movement.

It is almost needless to add that until we know what action is to be taken in all the chestnut-growing States and what the results are likely to be, chestnut woodland is a poor investment. Furthermore, in forest management, as in improvement cuttings, etc., there should be discrimination against the chestnut.

ADVICE TO OWNERS OF ORNAMENTAL CHESTNUT TREES.

Until the future of the chestnut tree is better known, or at least until we know what legalized action is going to be taken in the States concerned, the owners of chestnut-timbered land available for building should pursue a very conservative policy. Houses should not be located with sole reference to chestnut groves or to isolated ornamental chestnut trees. Houses so located should be discriminated against in purchasing homes in so far as the death of the chestnut trees would injure the appearance of the place.

When ornamental trees become diseased they had better be cut down at once and, if practicable, large trees of other species moved in to take their places. In expert hands the moving of large trees is a perfectly practicable and successful procedure and, although more expensive, is much more satisfactory than waiting for nursery trees to grow.[1]

All owners of diseased ornamental chestnut trees are specifically warned against "fake" tree doctors. Large sums of money have been paid out in many cases for treatment that has been worse than useless. Reliable tree specialists will have nothing to do with trees affected with the chestnut bark disease, or, if they do anything, do it with the distinct understanding in advance that it is entirely at the owner's risk. Of course, if an owner desires to employ tree surgeons to experiment, that is another matter.

ADVANCING POPULAR KNOWLEDGE OF THE DISEASE.

In the localities where infection is general or complete (fig. 2) everyone knows what the chestnut bark disease is and what its symptoms are and everyone appreciates its seriousness; but in these localities it is too late even to attempt its control. On the other hand, in Delaware, Virginia, West Virginia, western and southern Maryland, western Pennsylvania, central and northern New York, Massachusetts, and Rhode Island very few people know the symptoms of the disease. On this account no one notices it until it is thoroughly established, and by the time public sentiment is sufficiently aroused to authorize the necessary legislation and bring about united action for public protection it is too late for such action to be of service. Obviously, then, every effort should be made by all State and other officials having such matters in charge to acquaint every citizen with the prominent symptoms of the bark disease and to familiarize him with the fact that unless prompt and united action is taken there is every indication that the chestnut tree in the States above mentioned will become practically extinct within 10 years.

COOPERATION OF THE DEPARTMENT OF AGRICULTURE.

In this campaign of education the Department of Agriculture will cooperate in the following ways: Copies of this bulletin or of other publications of this department relating to the bark disease, and also

[1] In case such action is not immediately desirable or possible, a very good, though temporary, scenic effect can be obtained by lopping off the ends of the larger branches of the dead and dying chestnut trees, removing the bark, and planting some rapid-growing vine at their foot, which soon covers them. One of the best for this purpose is the Japanese kudzu vine (*Pueraria thumbergiana* (S. and Z.) (Benth.), on account of its extraordinarily rapid growth. Such vine-covered stumps must be carefully watched, however, for in a very few years they decay and are liable to be blown over.

typical specimens of the disease, will be sent to any person applying for them. Two specimens will be sent to each person—one showing the appearance of the disease on smooth bark, and the other the later development of the fungus on thick bark. In both these specimens the fungus will have been killed by soaking in formalin to insure against any infection from this source.

So far as the supply permits, lantern slides and photographs will, upon application, be loaned for special lectures, exhibits, etc., to the officers of States, experiment stations, colleges, and schools where agriculture is taught, as well as to tree wardens and other officials whose work may bear directly upon local campaigns of publicity.

This department will always examine any suspected specimens of this disease sent to Washington by mail, and will report the findings as promptly as possible. Before sending specimens, however, all persons are urged to read the paragraphs on symptoms on pages 6 to 9 in order to select the specimens intelligently. For example, if the end of a girdled and withered branch is sent, it is not possible to make a dependable diagnosis unless a portion of the girdling area happens to be included. This is the only part where the fungus is surely present, and the fungus iteslf must be seen in order to be absolutely sure of the disease. Portions of the bark that show the small orange or reddish-brown pustules, about the size of the head of a pin, should always be sent, if these can be found. These commonly occur near the lower edge of the girdling area.

PUBLIC COOPERATION.

With many people familiarized with the appearance of the chestnut-bark disease and its possibilities of harm, the disease will be noticed and stamped out by private effort in many places when it first appears and the public will understand and be ready to cooperate in any official measures of control as soon as these become necessary in any locality.

All possible forces must be enlisted in a campaign of publicity. The cooperation of all newspapers, particularly local papers, can be easily secured in all the States where the chestnut is an important tree. A portion of the program for Arbor Day, 1912, should be devoted to a consideration of this disease. Teachers of nature study, botany, or agriculture in the public schools can do great service by teaching their pupils how to recognize the disease and by training them to be on the lookout for its first appearance in the home community. Such a body as the "Boy Scouts" can, if properly trained, become in every community a most efficient force for locating the disease. The boys will readily appreciate that such work is real "scouting" against a most insidious and destructive public enemy. And, finally, many private owners of chestnut trees will be eager to cooperate with the State authorities in the early elimination of advance infections if only they are able to recognize such infections.

THE PROTECTION OF THE SOUTHERN STATES.

It must be remembered that the bark disease has as yet done only a small fraction of the damage that it is undoubtedly capable of doing. The best chestnut timber of America is south of the Potomac River and there the bark disease is present in only a few spots. For this reason it is of extraordinary importance that these few spots be eradicated and that the disease be soon controlled immediately north of the Potomac. If the bark disease once becomes well established in the chestnut forests of the South, it will be well-nigh impossible to control it, on account of the sparsely settled and mountainous condition of much of that country and for other reasons which do not obtain farther north.

SUMMARY.

(1) The chestnut-bark disease was first noted near New York City in 1904 and is now present in at least 10 States. It attacks the American chestnut, the European chestnut, the chinquapin, and, rarely, the Japanese chestnut.

(2) The total financial loss from this disease is now estimated at $25,000,000.

(3) The disease is caused by a fungus, and the entrance of a spore at any point where the bark is broken may cause infection. The disease spreads primarily in the inner bark and produces characteristic lesions which girdle the tree at the point attacked.

(4) Conspicuous symptoms are the development of bunches of sprouts below the girdling lesions; the half-formed yellowish leaves in the spring on the previously girdled branches, the reddish-brown leaves on branches girdled in summer, and the yellow, orange, or reddish-brown pustules of the fruiting fungus on the bark. It is practically useless to attempt systematic location of the disease from October to April, inclusive.

(5) The spores may be carried considerable distances on chestnut nursery stock, tan bark, and unbarked timber; also by birds, insects, squirrels, etc., which have come in contact with the sticky spore masses. Water quickly dissolves these spore masses and the minute spores are in this way carried along with water, as, for instance, with rain water running down a tree. Borers' tunnels form the most common places of entrance for spores.

(6) The only known practical way of controlling the disease in a forest is to locate and destroy the advance infections as soon as possible after they appear and, if the disease is well established near by, to separate the area of complete infection from the comparatively uninfected area by an immune zone. Advance infections should be located by trained observers and destroyed by cutting and burning. As the disease develops almost entirely in the bark, this must be completely destroyed (burned).

(7) In order to carry out the above methods it is essential that the several States concerned secure necessary legislation and appropriations, following the example of Pennsylvania, as no law exists whereby the Federal Government can undertake such work and cooperation among private owners without State supervision is impracticable.

(8) Chestnut nursery stock should be rigidly inspected for the disease and only perfectly healthy plants passed.

(9) The life of valuable ornamental trees may be greatly prolonged by promptly cutting out all diseased areas and removing all disease-girdled branches and then covering the cuts with tar. Spraying is

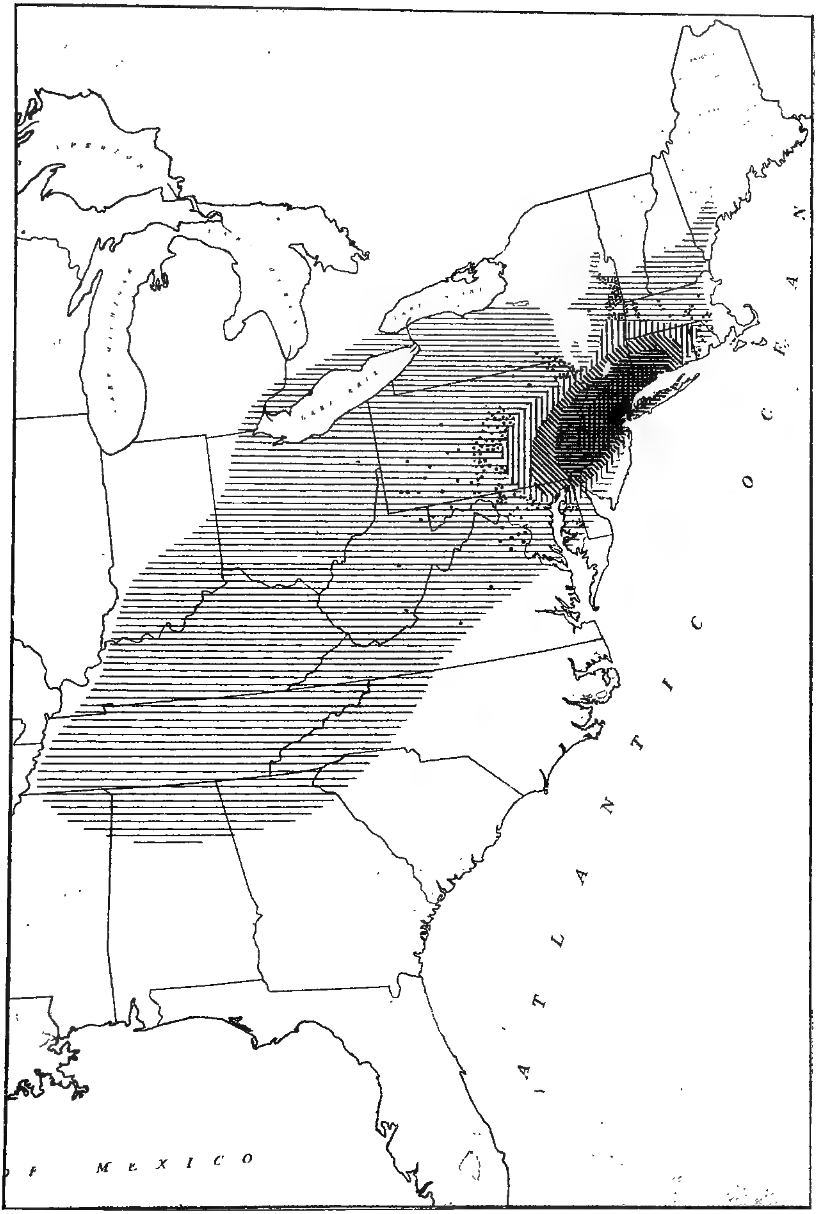
of no use in stopping the fungus after it has once started growth in the bark.

(10) It is recommended that owners of infected woodland cut down and utilize the diseased chestnut timber as soon as possible.

(11) For the present the planting of chestnuts anywhere east of Ohio is not advised, but there is no apparent reason why chestnut orchards west of Ohio may not be kept free from the disease.

O

PLATE I.



KNOWN DISTRIBUTION OF THE CHESTNUT BARK DISEASE FEBRUARY 1, 1912.

[Horizontal lines show the botanical distribution of the American chestnut tree. Dots represent advance infections. Thicker lines, arranged concentrically about New York City, show various degrees of general infection and death.]

FIG. 1.—TYPICAL GROUP OF LARGE CHESTNUT TREES DYING WITH THE BARK DISEASE. NEAR BROOKVILLE, N. Y.

[Note appearance of foliage.]

FIG. 2.—DEAD CHESTNUT TREES ALONG A BOULEVARD, NEAR RICHMOND HILL, N. Y.

[Note healthy condition of trees of other species.]

Fig. 1.—The most Southern Point of Infection—A Group of Diseased Chestnut Trees at Fontella, Bedford County, Va.

Fig. 2.—Forest Tree Nearly Dead. Parkton, Md.

[Note characteristic sprouts and dwarfed leaves of the only surviving branches.]

FIG. 1.—TREE WITH SOME LARGE BRANCHES GIRDLED, WESTBURY, N. Y.

[Note appearance of foliage.]

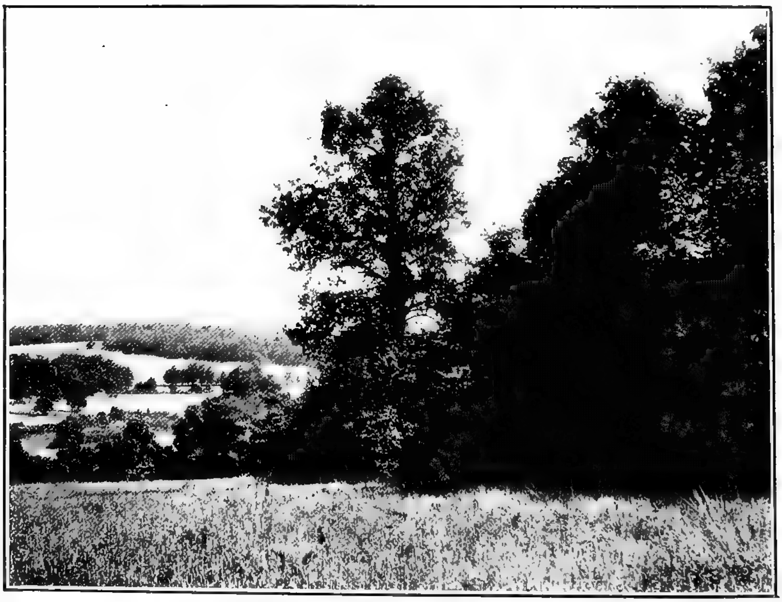


FIG. 2.—TREE WITH SMALL BRANCHES GIRDLED, BUCK, PA.

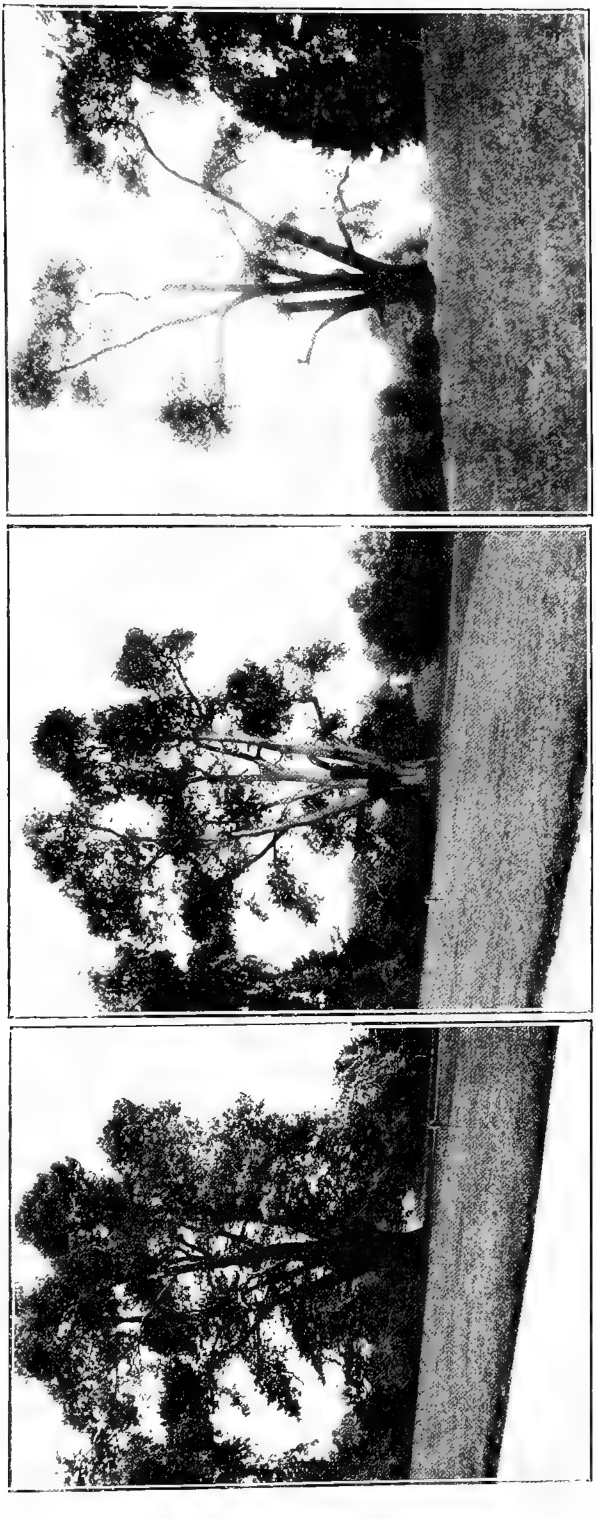
[Note appearance of foliage.]

COMPLETE DESTRUCTION OF CHESTNUT TREES IN MIXED STAND.

[Note healthy condition of trees of other species. Views along the Long Island Railroad.]

FIG. 1.—COMPLETE DESTRUCTION OF CHESTNUT TREES IN NEARLY PURE STAND.
[Many of the trunks have been dead long enough to shed their bark. Near Brooklyn, N. Y.]

FIG. 2.—COMPLETE DESTRUCTION OF CHESTNUT TREES IN A NEARLY PURE STAND.
[Note healthy condition of other species. Forest Park, near Brooklyn, N. Y.]



VIEWS OF THE SAME TREE, TAKEN ON THREE SUCCESSIVE YEARS, 1909, 1910, AND 1911 RESPECTIVELY. WYNCOTE, PA.

[The branches have been cut off as fast as they were killed. The tree will die this summer (1912).]

GRAFTED VARIETIES OF ORCHARD CHESTNUTS, NEARLY DEAD. MARTIC FORGE, PA.

[Note the suckers on the trunk and the appearance of the foliage.]

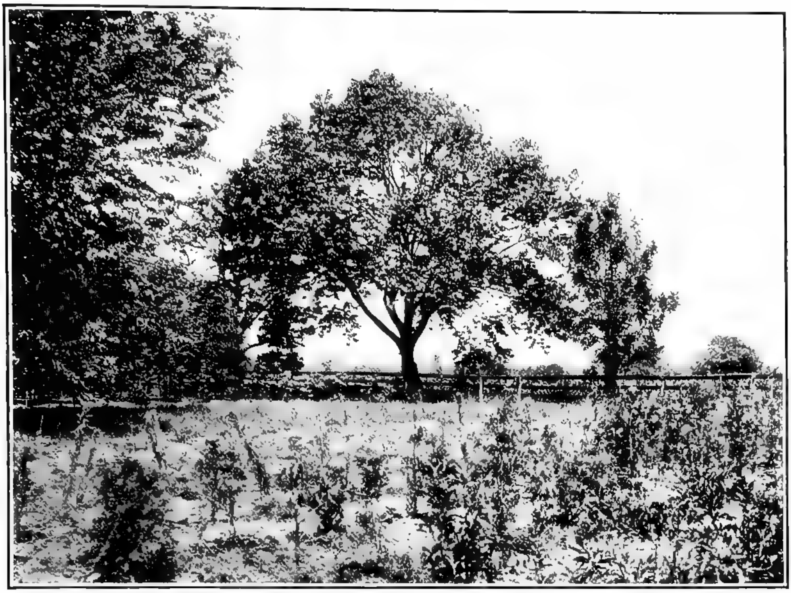


FIG. 1.—EARLY STAGE OF DISEASE. INFECTION OF A SMALL BRANCH IN THE TOP OF THE TREE. WESTBURY, N. Y.

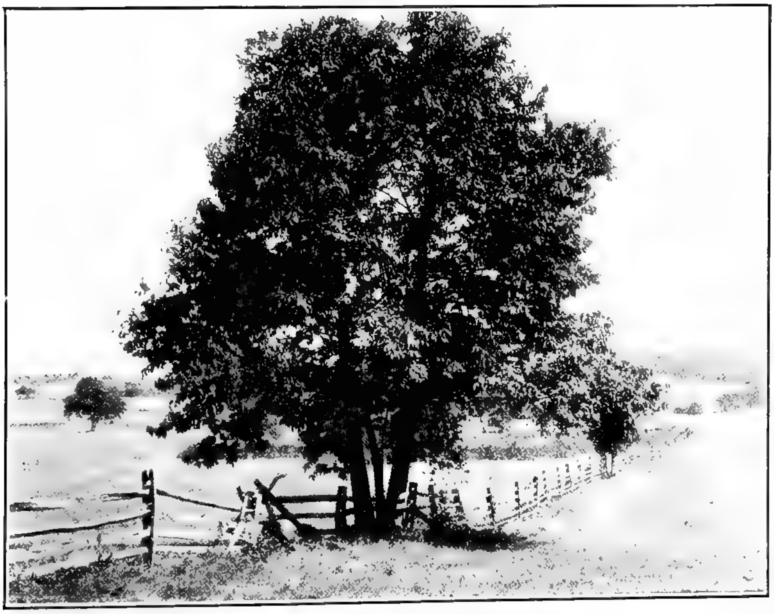


FIG. 2.—EARLY STAGE OF DISEASE. END OF BRANCH GIRDLED AT UPPER RIGHT-HAND OF PICTURE. LANCASTER COUNTY, PA.

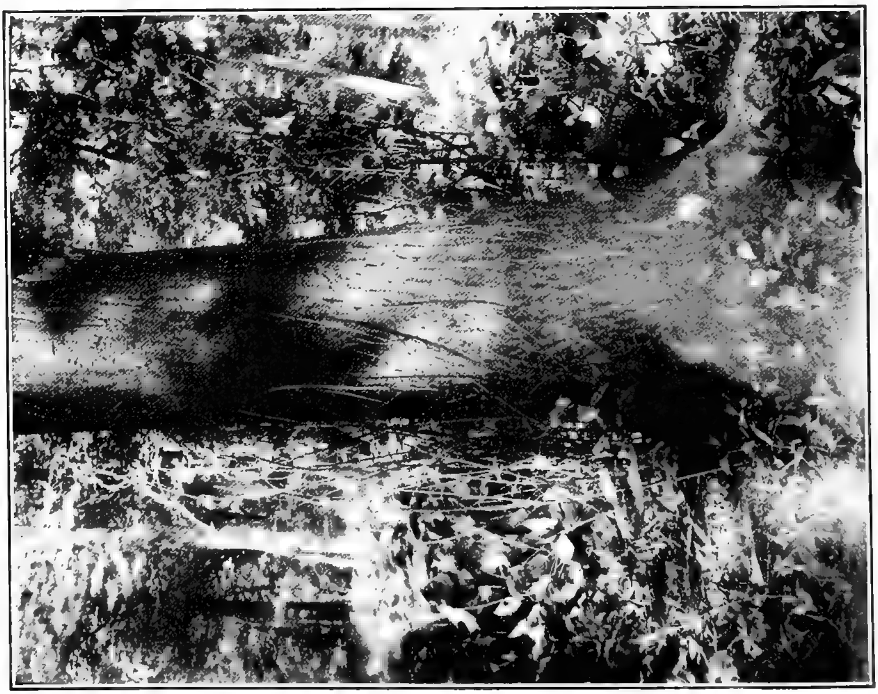


FIG. 1.—LARGE FOREST CHESTNUT TREE GIRDLED AT BASE, SHOWING CHARACTERISTIC GROWTH OF SPROUTS. MOST OF THESE SPROUTS ARE ALREADY GIRDLED BY THE DISEASE.

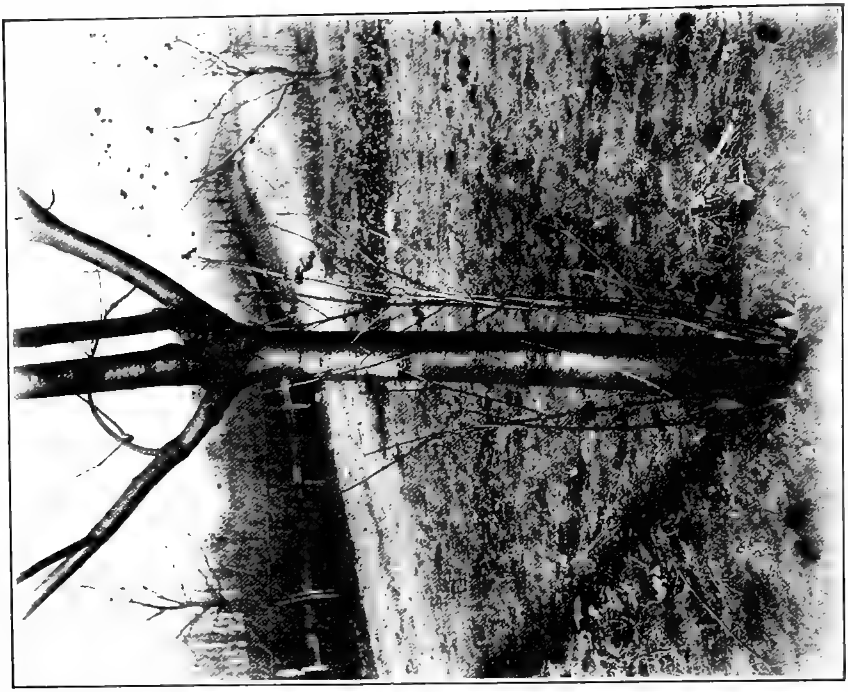
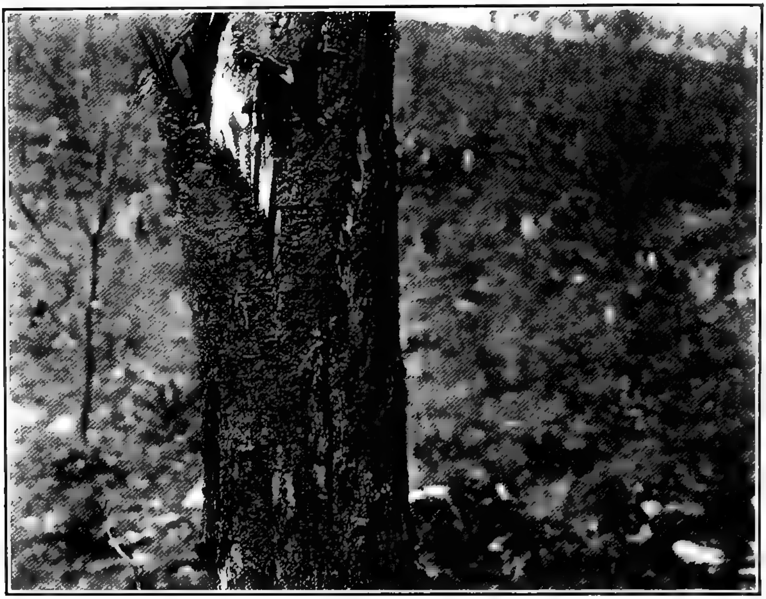
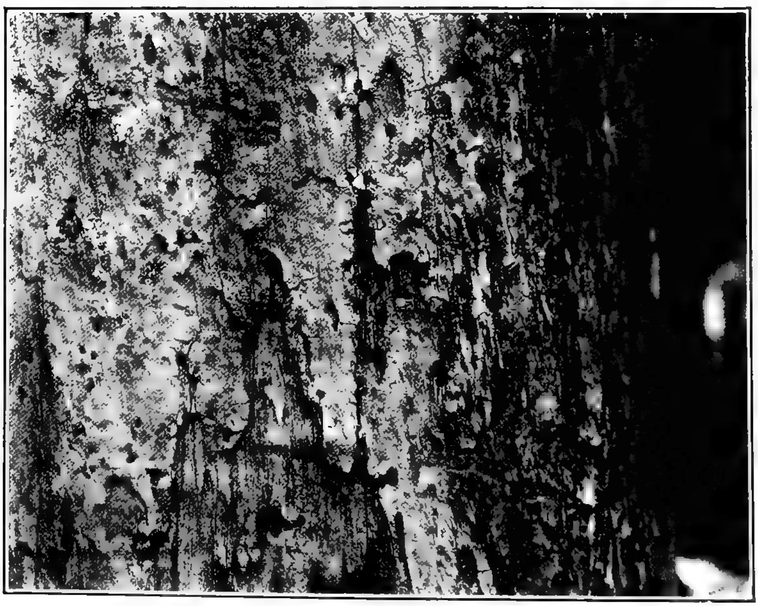


FIG. 2.—ORCHARD CHESTNUT, GIRDLED AT BASE, WITH CHARACTERISTIC GROWTH OF SPROUTS WHICH HAVE BEEN IN TURN GIRDLED AND KILLED BY THE DISEASE.

DEAD CHESTNUT TREES, WITH BARK IN SUCCESSIVE STAGES OF DECAY, SHOWING PUSTULES OF THE FUNGUS IN WHICH THE WINTER SPORES ARE BORNE.





LATE STAGES OF DECAY OF BARK AND OUTER LAYERS OF WOOD.

FIG. 1.—DEAD AND DYING SPROUT GROWTH, PORT JEFFERSON N. Y.

[Note healthy condition of trees of other species.]

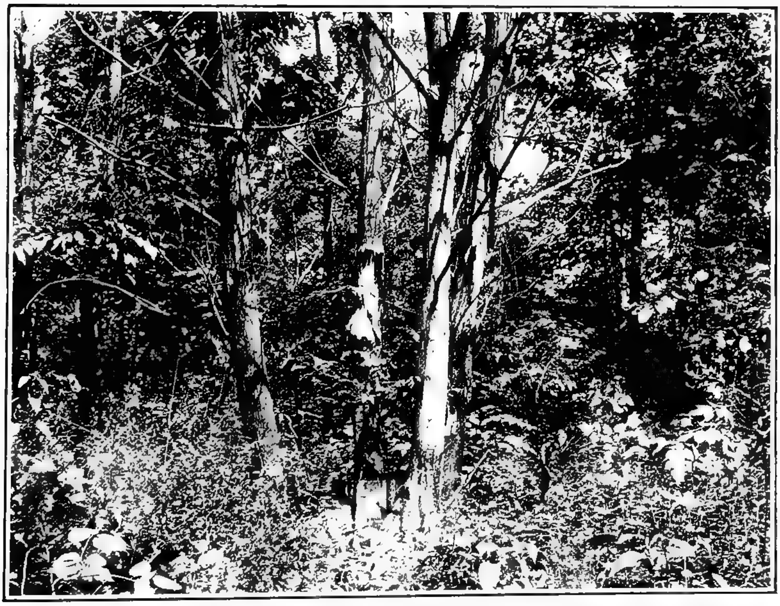


FIG. 2.—TYPICAL GROUP OF DEAD CHESTNUT TREES. NEAR BROOKLYN, N. Y.

[Note dead suckers on the trunks. From left to right: The first trunk shows the disease less than 1 year old; the second from 2 to 3 years old; the third 4 or more years old; and the fourth about 3 years old.]

FIG. 1.—EXTERNAL APPEARANCE OF A YOUNG LESION OF THE CHESTNUT BARK DISEASE, SHOWING THE SPREAD OF THE DISEASE FROM AN INSECT PUNCTURE.

FIG. 2.—THE SAME AS FIG. 1, WITH THE OUTER BARK REMOVED TO SHOW THE CENTRIFUGAL SPREAD OF THE MYCELIUM OF THE PARASITIC FUNGUS.

SMALL CHESTNUT TREE IN POT ABOUT 3 MONTHS AFTER ARTIFICIAL INOCULATION WITH SUMMER SPORES FROM A PURE CULTURE OF THE FUNGOUS PARASITE. TREE GIRDLED AT BASE, LEAVES ABOVE WITHERED; VIGOROUS SUCKERS GROWING UP FROM BELOW GIRDLED POINT.

EXAMPLES OF TREE SURGERY, SHOWING HEALING PROCESSES AFTER CUTTING OUT LESIONS, IN TREATMENT OF ORCHARD TREES.

FIG. 1.—LARGE CHESTNUT TREE KILLED BY THE BARK DISEASE.

FIG. 2.—AN ORCHARD TREE, SHOWING RECENTLY GIRDLED BRANCHES.

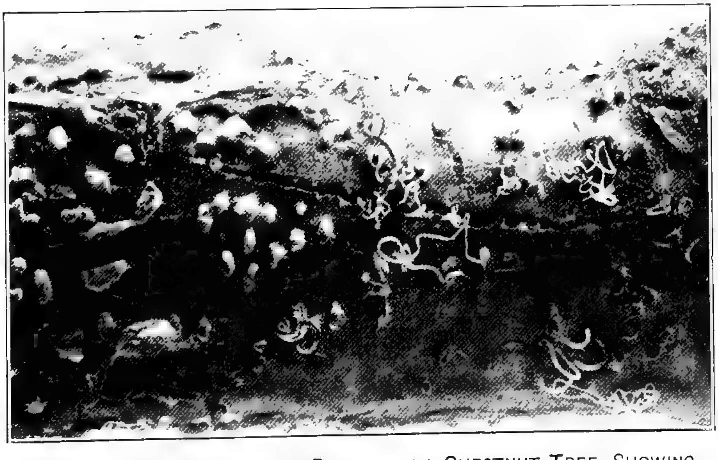


FIG. 3.—PART OF A DISEASED BRANCH OF A CHESTNUT TREE, SHOWING TYPICAL PUSTULES AND FORM OF SPORE DISCHARGE IN DAMP WEATHER.

[Magnified 3 diameters.]

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BIRDS AS CARRIERS OF THE CHESTNUT-BLIGHT FUNGUS[1]

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INTRODUCTION

Various writers have expressed the opinion that birds play a part in the dissemination of the chestnut-blight fungus, *Endothia parasitica* (Murr.) And. Since most of these statements were not based on any published investigations, the work described in this paper (6)[2] was undertaken in order to furnish positive evidence as to whether birds actually do carry spores of this fungus.

Birds do not seem to have been extensively accused of spreading plant diseases. Evidence has been presented by Waite (15) that pear-blight is disseminated by humming birds. The same writer (16) also gives a brief statement of the part played by sapsuckers and brings out the probability of long-distance distribution of blight germs by birds. It has been stated (7) that the organism causing the olive-knot disease is carried by birds. Johnston (8) has expressed the belief, based upon some experiments which he conducted, that turkey buzzards are instrumental in spreading the bud-rot of the coconut. In all of these instances the causal organisms are bacteria. Only a single reference has come to our attention in which birds have been charged with spreading fungous diseases, except in the case of the chestnut blight, as will be stated later. In a consideration of the die-back (Naemospora) of peaches, Massee (10, p. 449) says that "probably the conidia are conveyed on the feet of birds from diseased to healthy shoots."

HISTORICAL REVIEW

The first article published by Murrill (13) on chestnut blight refers to the possible relation of birds to the dissemination of the disease, as follows: "And from these numerous yellowish brown pustules millions of

[1] Investigations conducted in cooperation with the Pennsylvania Chestnut Tree Blight Commission.
[2] Bibliographic citations in parentheses refer to "Literature cited," pp. 421-422.

minute summer spores emerge from day to day in elongated reddish brown masses to be disseminated by the wind and other agencies, such as insects, birds, squirrels, etc." The same author also says (13) "every bird and insect that rests upon an infected spot is liable to carry the spores upon its feet or body to other trees." A few years later Mickleborough (12) mentions birds as carriers of spores of the blight fungus. He says "the minute spores are carried by wind, on the feathers of birds, and the fur of squirrels." Still later Metcalf and Collins (11) say that "there is strong evidence that the spores are spread extensively by birds, especially woodpeckers." Various writers have mentioned the fact that woodpeckers frequent chestnut trees in search of insects. Fulton (2) states in a report on field work done at Orbisonia, Pa., by Mr. R. C. Walton that "woodpecker work was noted in about one-tenth of the oldest lesions," but he offers no conjecture as to the part played by birds in the dissemination of the disease.

Stewart (14) says that "undoubtedly the spores are carried long distances by birds, especially woodpeckers, which visit the diseased trees, seeking borers, in the tunnels of which most of the infections occur." This statement is based on the report of Metcalf and Collins previously referred to and is discredited by Fisher (1), who brings out the point that this and similar statements are not based on positive evidence.

Kittredge (9) reports that field observations at Petersham, Mass., indicate "that birds may be a very important, if not the primary agent," in the distribution of the blight fungus. He is led to this conclusion from the greater number of infections near the borders of coniferous woods, where, he says, birds are more abundant, and from the much larger number of lesions in the middle third of the trunk, which he attributes to the work of creepers, nuthatches, and woodpeckers.

There are numerous popular articles which also accuse birds of being instrumental in the spread of the blight, but these, as well as the statements already quoted, are based entirely on circumstantial evidence.

The first serious attempt to determine whether birds actually do carry the spores of the chestnut-blight fungus was made by the field pathologists of the Pennsylvania Chestnut Tree Blight Commission during the summer of 1912. Since only negative results were obtained, it may be well to quote their statement giving the method employed:

> Birds found on the infected parts of trees were shot during the summer, and their feet, bills, and tail feathers washed separately in sterile water. This water was then centrifuged to bring down the spores that might have been washed from the birds. Part of the sediment was then examined under the microscope and the other part plated out in dilution plates. When colonies of fungi appeared, they were isolated to determine whether they were Diaporthe.

The above description is not sufficiently detailed to make possible an accurate judgment as to whether the negative results obtained were due to imperfect technique, but our experience leads us to believe that such may have been the case. Plates heavily seeded with bacteria and various fungi give no accurate or reliable results, since the colonies of the chestnut-blight fungus are very slow growing and would be overrun before they had reached sufficient size to be visible to the naked eye. Pycnospore colonies of this fungus at ordinary laboratory temperatures are barely large enough to mark at the end of four days and so would be entirely overlooked in plates crowded with bacteria and other fungi (3).

The negative results reported were based upon analyses of the following: Downy woodpeckers, 8; creepers (kind not specified), 3; hairy woodpeckers, 2; flickers, 4; bluejays, 3; total, 20.

METHOD USED IN EXPERIMENTS

Nearly all the birds tested by the writers were shot[1] either at Martic Forge or at West Chester, Pa., or in the vicinity of these places, in order that use could be made of the rainfall and temperature records which were kept at these stations. The birds from Martic Forge were shot in or near a 300-acre orchard of badly diseased Paragon trees grafted on native stock. Those from West Chester were taken in the main from a young coppice growth which is practically 100 per cent diseased.

Most of the birds were shot from diseased trees, and in many cases they were working on cankers at the time of shooting or had been seen on chestnut-blight lesions a few minutes before they were killed. They were immediately placed in sterile paper sacks for transport to the laboratory at the University of Pennsylvania.

In the laboratory the procedure was, first, to sterilize a moist chamber in a Lautenschläger sterilizer for 35 minutes at 150° C. A stiff bristle brush was also sterilized in boiling water for half an hour or more. Before beginning work in the culture room the hands and arms of the operator were washed with soap and water and then in mercuric-chlorid solution (1 to 1,000).

When the moist chamber had cooled to room temperature, a flask containing 100 c. c. of sterile tap water was emptied into it. The bird to be tested was held in one hand and the feet, wing, and tail feathers and the head and the bill scrubbed vigorously with the brush, the operation being carried out so that only the parts scrubbed were permitted to come in contact with the wash water. The moist chamber was then well shaken, so as to secure a uniform suspension, and 1 c. c. of the wash water was transferred with a sterile pipette to a second flask containing 99 c. c. of sterile tap water. With a second sterile pipette 1 c. c. or fractions were transferred from the second flask, which had also been well shaken, to each of a series of Petri dishes. The dilutions used varied

[1] The birds used in this work were shot by Mr. C. E. Taylor, formerly in the employ of the Pennsylvania Chestnut Tree Blight Commission, who also centrifuged the wash water for its sediment.

somewhat, but the following were found to give the most satisfactory results:

1 c. c. from second flask to each of 2 Petri dishes.
10 drops from second flask to each of 4 Petri dishes.
5 drops from second flask to each of 4 or 6 Petri dishes.
1 drop from second flask to each of 4 Petri dishes.

In this way the number of plates per bird ranged from 12 to 20 in all cases, except bird No. 1. The number of drops delivered per cubic centimeter by the pipette were counted each time and were found to be fairly constant for any single pipette, although they varied from 24 to 53 drops for the different ones used. A tube of melted 3 per cent dextrose agar plus 10, which had been previously cooled to from 42 to 45° C., was added to each Petri dish and the plates rotated, so as to secure a uniform distribution of the spores. The entire operation of scrubbing and plating was carried out in a culture room, with every precaution against contamination from any source.

The plates were incubated in an inverted position in the laboratory and an attempt was made to keep the temperature of the room as nearly as possible at 25° C. At the end of four days those colonies suspected of being the chestnut-blight fungus were marked with india ink (3). Two or three days later this diagnosis was verified, and all doubtful colonies were transferred to other agar plates, to make certain of their identity. A count was also made of the number of bacterial and yeast colonies, of the number of fungous colonies other than those of *Endothia parasitica*, and of the number of species of fungi represented, as nearly as could be determined from cultural characteristics. With this information and knowing the calibration of the pipette used, it was an easy matter to compute the total number of viable spores or bacteria carried by each bird.

The original wash water was poured back into the flask and several cubic centimeters of formalin added to inhibit the growth of the spores. At a later time the wash water of those birds yielding positive results was centrifuged in 10 c. c. quantities, the sediments thus obtained thrown together and centrifuged again, so that the entire sediment was concentrated in about 2 c. c. of water. This final sediment was given a thorough microscopic examination, primarily for its pycnospore or ascospore content of *Endothia parasitica* and secondarily for the number and kinds of other fungous spores which it might contain.

LIST OF BIRDS TESTED

A detailed record of the place and time of shooting of each bird is given below.

The birds tested belonged to nine different species. (See Table I.) One of these, the flicker, gets most of its food from the ground, although, as a rule, it flies into a tree when the person approaching is still a good distance away. Another species, the junco, gets practically all of its food from the ground; both juncos tested were, however, shot out of infected trees. The golden-crowned kinglet is found mostly among foliage. The six other species, the black-and-white creeper, the brown creeper, downy woodpecker, hairy woodpecker, sapsucker, and white-breasted nuthatch, are birds which are in the habit of creeping or climbing over the bark of the trunk and larger branches. As these were considered the most likely carriers of the spores of the chestnut-blight fungus, nearly all of the birds tested, 32 out of 36, belonged to these species. Particular attention was paid to the movements of the birds at the time of shooting, noting especially whether they were working on cankers or, at least, in blighted trees.

It is not uncommon, as stated before, to find evidence that woodpeckers have been at work in older lesions. An example of this is shown in Plate XXXVIII.

Bird No. 1.—Hairy woodpecker (*Dryobates villosus*). (0.)[1]

Shot at Tyrone, Pa., on December 11, 1912. Received and cultures made on December 12, 1912.

Bird No. 2.—Downy woodpecker (*Dryobates pubescens medianus*). (0.)

Shot at Martic Forge, Pa., at 1.10 p. m., on February 21, 1913, while at work on a canker about 12 feet from the ground. Bird was not killed at once, but fluttered along ground for 8 or 10 feet. Canker on which bird was working showed light-orange stromata, with abundant papillæ that were fairly prominent. Cultures made on February 22, 1913.

Bird No. 3.—Junco (*Junco hyemalis*). (0.)

Shot at Martic Forge, Pa., at 10.30 a. m., on February 28, 1913, from blight-infected chestnut tree. Rain of previous night was 0.36 inch, and the air was still very humid at the time the bird was taken. Plates made on March 1, 1913.

Bird No. 4.—Junco. (10,000.)

Same as Bird No. 3.

Bird No. 5.—Downy woodpecker. (30,000.)

Shot at Martic Forge, Pa., on March 10, 1913, out of a small tulip tree. Had been picking about some large, badly diseased, and dead chestnut trees. Cultures made on March 11, 1913.

Bird No. 6.—Downy woodpecker. (73,333.)

Shot near diseased coppice growth at West Chester, Pa., at 10.30 a. m., on March 19, 1913. Had been working on a small canker. Cultures made on March 19, 1913.

Bird No. 7.—Downy woodpecker. (109,022.)

Shot in diseased coppice growth, West Chester, Pa., at 12.30 p. m., on March 19, 1913. Had been working on a canker. Cultures made on March 19, 1913.

Bird No. 8.—Downy woodpecker. (92,000.)

Shot in diseased coppice growth at West Chester, Pa., at 12.40 p. m., on March 19, 1913. Was on a canker when shot. Received and cultures made on March 19, 1913.

Bird No. 9.—Flicker (*Colaptes auratus luteus*). (0.)

Shot at Martic Forge, Pa., on March 24, 1913. Came from the badly infected wood lot to the west of the orchard and was killed in the orchard. Received and cultures made on March 25, 1913.

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[1] The numbers in parentheses, following the names of the birds, represent the number of spores of the chestnut-blight fungus carried, as determined by cultures. See Table I.

Bird No. 10.—Downy woodpecker. (757,074.)

Shot from a chestnut tree at Martic Forge, Pa., at 2 p. m., on March 28, 1913. Had been working on a canker, but was not on a canker when killed. Received and cultures made on March 29, 1913.

Bird No. 11.—Downy woodpecker. (15,625.)

Shot at Martic Forge, Pa., at 11 a. m., on March 31, 1913. Was on a canker on an old chestnut tree (22 inches D. B. H.) when killed. Received and cultures made on April 1, 1913.

Bird No. 12.—Downy woodpecker. (31,111.)

Shot at York Furnace, Pa. (near Martic Forge), at 11 a. m., on April 2, 1913. Had been working around a canker on a large chestnut tree. Received and cultures made on April 3, 1913.

Bird No. 13.—Downy woodpecker. (25,000.)

Shot at York Furnace, Pa., at 11.30 a. m., on April 2, 1913. Was on a canker on a large chestnut tree when killed. Received and cultures made on April 3, 1913.

Bird No. 14.—White-breasted nuthatch (*Sitta carolinensis*). (0).

Shot at York Furnace, Pa., at 1 p. m., on April 2, 1913. Shot out of a chestnut-oak tree; had not been seen on any chestnut trees. Received and cultures made on April 3, 1913.

Bird No. 15.—Downy woodpecker. (0.)

Shot at Martic Forge, Pa., at 10 a. m., on April 3, 1913. Was on chestnut tree when killed; had been drumming on an old tree. Not seen on cankers. Received and cultures made on April 4, 1913.

Bird No. 16.—Brown creeper (*Certhia familiaris americana*). (0.)

Shot at Martic Forge, Pa., at 12.30 p. m., on April 7, 1913, from chestnut tree to the side of which it was clinging. Trunk was apparently sound, and no cankers were visible from the ground. Received and cultures made on April 8, 1913.

Bird No. 17.—Golden-crowned kinglet (*Regulus satrapa*). (6,566.)

Shot at Martic Forge, Pa., at 12.30 p. m., on April 7, 1913, from a hemlock tree. Had been climbing up and down trees; was seen on oaks, but not on chestnut. Received and cultures made on April 8, 1913.

Bird No. 18.—Sapsucker (*Sphyrapicus varius*). (5,000.)

Shot from a hickory tree beyond Broomall, Pa., 9 miles west of Philadelphia, at 4 p. m., on April 10, 1913. Had been visiting cankers on chestnut trees. Received and plated out at 8.30 p. m. on April 10, 1913.

Bird No. 19.—White-breasted nuthatch. (5,655.)

Shot out of a chestnut tree beyond Broomall, Pa., at 4 p. m., on April 10, 1913. Had been running up and down trunk of chestnut tree and about cankers. Received and plated out at 8.30 p. m. on April 10, 1913.

Bird No. 20.—Downy woodpecker. (0.)

Shot out of a small dogwood tree about 5 miles west of Philadelphia, Pa., at 4 p. m., on April 10, 1913. Had been working around cankers. Received and plated out at 8.30 p. m. on April 10, 1913.

Bird No. 21.—Downy woodpecker. (5,780.)

Shot out of a soft-maple tree, 2 rods west of orchard at Martic Forge, Pa., on April 15, 1913. Had not been seen on or about any chestnut trees. Received and plated out on April 16, 1913.

Bird No. 22.—Sapsucker. (7,502.)

Shot out of a chestnut tree in a small grove immediately west of blighted orchard at Martic Forge, Pa., at 3.05 p. m., on April 17, 1913. Received and cultures made on April 18, 1913.

Bird No. 23.—Brown creeper. (254,019.)

Shot out of a black oak tree in woods north of coppice growth at West Chester, Pa., on April 18, 1913. Had not been seen on or about chestnut trees. Received and plated out on April 19, 1913.

Bird No. 24.—Black-and-white creeper (*Mniotilta varia*). (o.)

Shot out of a dogwood tree at Martic Forge, Pa., at 10.40 a. m., on April 21, 1913. Had been running up and down a chestnut tree, but was not seen on any cankers. Received and plated out on April 22, 1913.

Bird No. 25.—Downy woodpecker. (27,108.)

Shot while on a canker on a chestnut tree at West Chester, Pa., at 10.30 a. m., on April 25, 1913. Received and plated out on April 26, 1913.

Bird No. 26—Downy woodpecker. (59,742.)

Shot just east of chestnut orchard in a sprout growth of chestnut and oak at Martic Forge, Pa., at 12 m., on April 30, 1913. Had not been seen on or about cankers. Received and plated out on May 1, 1913.

Bird No. 27.—Downy woodpecker. (624,341.)

Shot just east of chestnut orchard from a canker in sprout growth at Martic Forge, Pa., at 12 m., on April 30, 1913. Received and plated out on May 1, 1913.

Bird No. 28.—Black-and-white creeper. (o.)

Shot out of a chestnut oak tree in woods north of sprout growth at West Chester, Pa., at 2.20 p. m., on May 2, 1913. Was not seen on or about any chestnut trees. Received and plated out on May 3, 1913.

Bird No. 29.—Hairy woodpecker. (o.)

Shot out of chestnut tree west of badly infected coppice at West Chester, Pa., on May 2, 1913. Was not positively seen on or about cankers. Received and plated out on May 3, 1913.

Bird No. 30.—Black-and-white creeper. (o.)

Shot in sprout growth of chestnut and oak east of the chestnut orchard at Martic Forge, Pa., at 10.15 a. m., on May 5, 1913. Was not seen on or about cankers. Received and plated out on May 6, 1913.

Bird No. 31.—Black-and-white creeper. (o.)

Shot from a badly diseased chestnut tree in sprout growth east of orchard at Martic Forge, Pa., at 11 a. m., on May 5, 1913. Was not seen on or about cankers. Received and plated out on May 6, 1913.

Bird No. 32.—Black-and-white creeper. (o.)

Shot in timber just west of orchard at Martic Forge, Pa., at 12.30 p. m., on May 5, 1913. Had been seen on chestnut trees, but not about cankers. Received and plated out on May 6, 1913.

Bird No. 33.—Downy woodpecker. (36, 312.)

Shot in wood lot east of coppice at West Chester, Pa., at 10 a. m., on May 9, 1913. Probably was on a canker when shot, but was too high up for this to be positively determined. Received and plated out on May 9, 1913.

Bird No. 34.—Black-and-white creeper. (o.)

Shot out of a diseased chestnut tree about which it had been creeping, north of diseased coppice at West Chester, Pa., at 10.30 a. m., on May 9, 1913. Received and plated out on May 9, 1913.

Bird No. 35.—Hairy woodpecker. (o.)

Shot from a dead chestnut stub west of diseased coppice at West Chester, Pa., at 12.55 p. m., on May 9, 1913. Was not seen on or about any cankers. Received and plated out on May 9, 1913.

Bird No. 36.—Black-and-white creeper. (o.)

Shot in orchard at Martic Forge at 10.30 a. m., on May 12, 1913. Had been creeping over a small canker. Received and plated out on May 13, 1913.

RESULTS OF TESTS AS SHOWN BY CULTURES

The results obtained from the cultures are given in Table I.

Of the 36 birds tested 19 were found to be carrying spores of the chestnut-blight fungus. The highest positive results were obtained from two downy woodpeckers, which were found to be carrying 757,074 and 624,341 viable spores of *Endothia parasitica*. The next highest was a brown creeper, with 254,019 spores. In each case where the number of colonies of *Endothia parasitica* was very large, there was only a relatively small number of other fungous colonies present. This is best shown in bird No. 10, which yielded almost 14 times as many colonies of the chestnut-blight fungus as of all other fungi. Another good example, although not quite as striking, is bird No. 23, where the proportion was 5 to 1. Part of the plate cultures from bird No. 23 were photographed at the end of nine days (Pl. XXXIX). These show the characteristic development of *Endothia parasitica* colonies on dextrose agar and also the relatively small number of other fungous colonies present.

Positive results were obtained from one of the two juncos tested. Although this species is primarily ground-frequenting in habit, both juncos were shot from blight-infected trees. There are, therefore, two possible sources for the 10,000 spores of the chestnut-blight fungus carried by bird No. 4. First, the blighted tree from which it was shot; second, the pycnospores which had been washed into the soil around the bases of infected trees and which have been found to remain viable for a period of 2 to 13 days of dry weather (5).

In those cases in which the birds were shot directly from a chestnut-blight canker it might be suggested that the spores carried were scattered by the impact of the shot and lodged upon the feathers, and so were not obtained during the normal movements. A brief consideration of the tests of birds giving positive results will throw definite light on this subject.

Of the 19 birds yielding positive results only 6 were on cankers when killed, and positive results were also obtained from 6 of the 8 birds which had been working on cankers just previous to shooting, but which were not on cankers when killed. Again, 7 birds of the 20 which were not seen on cankers at all yielded positive results.

Of the 4 birds yielding the highest numbers of spores of the chestnut blight fungus, only 1, No. 27, was on a canker when shot; 2, Nos. 7 and 10, were not on cankers when shot but had been working on some previous to being killed; while 1, No. 23, had never been seen on a canker.

These results point clearly to the fact that the impact of the shot was not responsible for the presence or any increase in number of blight spores upon the bodies of the birds.

It will be noted that the number of bacterial and yeast colonies was quite large in most instances. The plates from five birds were so heavily seeded with bacteria that it was impossible to get a reliable count of the number of fungous colonies, or even a test of the presence of colonies of *Endothia parasitica*. In most instances, however, the bacteria caused little or no trouble.

TABLE I.—*Results of tests of birds Nos. 1 to 36 as fungus carriers as shown by cultures*

No.	Date.	Locality where shot (Pennsylvania).	Kind of bird.	Number of cultures.	Number of bacteria and yeasts.	Total number of fungous colonies.	Number of Endothia parasitica colonies.	Number of fungous species not Endothia parasitica.
1	1912. Dec. 11	Tyrone	Hairy woodpecker.	6	....	....	....	....
2	1913. Feb. 21	Martic Forge	Downy woodpecker.	18	7,600,000	156,600	0	12
3	Feb. 28	...do...	Junco	12	1,800,000	80,000	0	9
4	...do...	...do...	...do...	12	56,500	125,000	10,000	14
5	Mar. 10	...do...	Downy woodpecker.	18	62,500	642,500	30,000	10
6	Mar. 19	West Chester	...do...	12	950,000	173,333	73,333	6
7	...do...	...do...	...do...	12	127,819	173,648	109,022	7
8	...do...	...do...	...do...	12	76,000	328,000	92,000	10
9	Mar. 24	Martic Forge	Flicker	12	12,910,000	60,000	0	10
10	Mar. 28	...do...	Downy woodpecker.	18	69,827	812,164	757,074	6
11	Mar. 31	...do...	Downy woodpecker.	18	190,625	262,500	15,625	11
12	Apr. 2	York Furnace	...do...	12	2,964,444	444,444	31,111	6
13	...do...	...do...	...do...	12	18,300,000	285,000	25,000	7
14	...do...	...do...	White-breasted nuthatch.	12	225,000	90,000	0	6
15	Apr. 4	Martic Forge	Downy woodpecker.	12	(a)	(a)	(a)	(a)
16	Apr. 7	...do...	Brown creeper.	12	40,000	80,000	0	5
17	...do...	...do...	Golden-crowned kinglet.	12	32,849	85,357	6,566	5
18	Apr. 10	9 miles west of Philadelphia.	Sapsucker	12	170,000	145,000	5,000	9
19	...do...	...do...	White-breasted nuthatch.	12	96,045	33,900	5,655	4
20	...do...	5 miles west of Philadelphia.	Downy woodpecker.	12	130,000	130,000	0	8
21	Apr. 15	Martic Forge	...do...	12	3,740,000	121,387	5,780	6
22	Apr. 17	...do...	Sapsucker	12	344,936	337,584	7,502	9
23	Apr. 18	West Chester	Brown creeper.	14	102,309	304,004	254,019	6
24	Apr. 21	Martic Forge	Black-and-white creeper.	14	14,925,000	90,000	0	4
25	Apr. 25	...do...	Downy woodpecker.	16	358,437	159,638	27,108	9
26	Apr. 30	Martic Forge	...do...	14	64,338	657,169	59,742	8
27	...do...	...do...	...do...	14	6,121,951	970,731	624,341	4
28	May 2	West Chester	Black-and-white creeper.	14	478,571	28,581	0	1
29	...do...	...do...	Hairy woodpecker.	14	(a)	(a)	(a)	(a)
30	May 5	Martic Forge	Black-and-white creeper.	16	(a)	(a)	(a)	(a)
31	...do...	...do...	...do...	16	(a)	(a)	(a)	(a)
32	...do...	...do...	...do...	16	(a)	(a)	(a)	(a)
33	May 9	West Chester	Downy woodpecker.	16	1,893,854	64,245	36,312	5
34	...do...	...do...	Black-and-white creeper.	16	18,181	28,571	0	5
35	...do...	...do...	Hairy woodpecker.	20	172,413	51,724	0	5
36	May 12	Martic Forge	Black-and-white creeper.	16	24,000	16,000	0	4

a Discarded; too heavily seeded with bacteria for a reliable test.

Table I.—*Results of tests of birds Nos. 1 to 36 as fungus carriers as shown by cultures*—Continued

SUMMARY

No.	Kind of bird.	Number tested.	Number carrying Endothia parasitica spores.	Maximum number of spores of Endothia parasitica carried by single bird.
1	Black-and-white creeper	7	0	0
2	Brown creeper	2	1	254,019
3	Downy woodpecker	16	13	757,074
4	Flicker	1	0	0
5	Golden-crowned kinglet	1	1	6,566
6	Hairy woodpecker	3	0	0
7	Junco	2	1	10,000
8	White-breasted nuthatch	2	1	5,655
9	Sapsucker	2	2	7,502
	Total	36	19	....

RELATION OF RAINFALL TO BIRDS AS CARRIERS OF THE CHESTNUT-BLIGHT FUNGUS

The highest positive results were invariably obtained soon after a period of heavy rainfall, generally one extending over several days. (See Table II.) During the time covered by our tests there were four such rains. (See Table III.) Birds shot from two to four days after each period were found to be carrying the highest numbers of spores of *Endothia parasitica*. Some of the birds shot at other times were also found to be carrying spores of the chestnut-blight fungus, but in much smaller numbers. This relation between the high number of spores and the periods of rainfall is explained by the fact that the pycnospores of the chestnut-blight fungus are produced in large numbers during and after rains and are washed down the trunks of the trees (4). This is explained more in detail later.

Table II.—*Rainfall related to birds as carriers of the chestnut-blight fungus*

Rainfall in inches.				No. of bird.	Locality where shot (Pennsylvania).	Date killed.	Number of Endothia parasitica spores.	Number of fungous spores not Endothia parasitica.
Date.	West Chester, Pa.	Date.	Martic Forge, Pa.					
1913.		1913.				1913.		
Feb. 21 Feb. 22	0.19 .07	Feb. 22	0.09	2	Martic Forge	Feb. 21	0	156,600
Feb. 27	.78	Feb. 27	.36	3	....do	Feb. 28	0	80,000
....	....	Mar. 5	.02	4	....do	Feb. 28	10,000	115,000
Mar. 9	.03	....	....	5	....do	Mar. 10	30,000	612,500
Mar. 10	.53	Mar. 10 Mar. 13	.55 1.29	6	West Chester	Mar. 19	73,333	100,000
Mar. 13 to Mar. 15	1.38	Mar. 15	.92	7	....do	Mar. 19	109,022	64,626
....	....	....	....	8	....do	Mar. 19	92,000	236,000
Mar. 21 Mar. 26 Mar. 27	1.64 1.18	Mar. 21 Mar. 26	.62 3.47	9	Martic Forge	Mar. 24	0	60,000
....	....	....	....	10	....do	Mar. 29	757,074	55,090
Mar. 30 Mar. 31	.30 .20	Mar. 31	.04	11	....do	Mar. 31	15,625	246,875

TABLE II.—*Rainfall related to birds as carriers of the chestnut-blight fungus*—Continued

Rainfall in inches.				No. of bird.	Locality where shot (Pennsylvania).	Date killed.	Number of Endothia parasitica spores.	Number of fungus spores not Endothia parasitica.
Date.	West Chester, Pa.	Date.	Martic Forge, Pa.					
1913.		1913.				1913.		
		Apr. 2	0.10	12	York Furnace	Apr. 2	31,111	413,333
				13	do	Apr. 2	25,000	260,000
				14	do	Apr. 2	0	90,000
Apr. 4	.56	Apr. 4	.23	15	Martic Forge	Apr. 4	0	0
				16	do	Apr. 7	0	80,000
				17	do	Apr. 7	6,566	78,691
				18	West of Philadelphia	Apr. 10	5,000	140,000
Apr. 10 to Apr. 13	2.49	Apr. 11	.55	19	do	Apr. 10	5,655	28,245
		Apr. 15	1.23	20	do	Apr. 10	0	130,000
Apr. 13 to Apr. 16	1.57	Apr. 16	1.15	21	Martic Forge	Apr. 15	5,780	115,607
				22	do	Apr. 17	7,502	330,082
				23	West Chester	Apr. 18	254,019	49,985
				24	Martic Forge	Apr. 21	0	90,000
				25	West Chester	Apr. 25	27,108	132,530
Apr. 28 Apr. 29	2.43	Apr. 28	2.33	26	Martic Forge	Apr. 30	59,742	597,427
Apr. 29	.11	Apr. 29	.07	27	do	Apr. 30	624,341	346,390
				28	West Chester	May 2	0	28,581
				29	do	May 2		
				30	Martic Forge	May 5		
				31	do	May 5		
				32	do	May 5		
				33	West Chester	May 9	36,312	27,933
				34	do	May 9	0	28,571
				35	do	May 9	0	51,724
				36	Martic Forge	May 12	0	16,000

TABLE III.—*Relation of maximum number of spores of the chestnut-blight fungus carried to periods of maximum rainfall*

Rainfall in inches.				Date bird was shot.	Locality where bird was shot (Pennsylvania).	Number of spores of Endothia parasitica carried.
Date.	West Chester, Pa.	Date.	Martic Forge, Pa.			
1913.		1913.		1913.		
Mar. 10	0.53	Mar. 10	0.55			
Mar. 13 to Mar. 15	1.38	Mar. 13	1.29			
		Mar. 15	.92			
				Mar. 19	West Chester	73,333
				Mar. 19	do	109,022
				Mar. 19	do	92,000
Mar. 26 to Mar. 27	1.18	Mar. 26	3.47			
				Mar. 29	Martic Forge	757,074
Apr. 10 to Apr. 13	2.49	Apr. 11	.55			
Apr. 13 to Apr. 16	1.57	Apr. 15	1.23			
		Apr. 16	1.15			
				Apr. 18	West Chester	254,019
Apr. 27 to Apr. 28	2.43	Apr. 28	2.33			
				Apr. 30	Martic Forge	59,742
				Apr. 3	do	624,341

MICROSCOPIC EXAMINATION OF CENTRIFUGED SEDIMENTS

The sediments from those birds yielding positive results were given a thorough microscopic examination, primarily to ascertain whether the birds were carrying pycnospores or ascospores. (See Table IV.) Ascospores were not found to be present in a single instance. However, in sediments from birds yielding high positive results pycnospores could be found very easily. Where the positive results were not so high, pycnospores were located with more difficulty, but could be found in all sediments except those from birds showing by cultures the smallest number of spores of the blight fungus. The results from cultures substantiate the microscopic examinations, since the rate of development of colonies of the chestnut-blight fungus always indicated their origin from pycnospores (3).

TABLE IV.—*Results of microscopic examination of centrifuged sediments of birds Nos. 1 to 36*

Bird No.	Number of spores of Endothia parasitica carried, as shown by cultures.	Kind of spores shown by microscopic examination.	Bird No.	Number of spores of Endothia parasitica carried, as shown by cultures.	Kind of spores shown by microscopic examination.
1....	0	Examination not necessary.	20....	0	Examination not necessary.
2....	0	Do.	21....	5,780	No ascospores.
3....	0	Do.	22....	7,502	Do.
4....	10,000	No ascospores.	23....	254,019	No ascospores; pycnospores fairly abundant.
5....	30,000	No ascospores; pycnospores present.	24....	0	Examination not necessary.
6....	73,333	Do.	25....	27,108	No ascospores; pycnospores present.
7....	109,022	Do.	26....	59,742	Do.
8....	92,000	Do.	27....	624,341	No ascospores; pycnospores fairly abundant.
9....	0	Examination not necessary.	28....	0	Examination not necessary.
10....	757,074	No ascospores; pycnospores abundant.	29....	0	Do.
11....	15,625	No ascospores; pycnospores present.	30....	0	Do.
12....	31,111	Do.	31....	0	Do.
13....	25,000	Do.	32....	0	Do.
14....	0	Examination not necessary.	33....	36,312	No ascospores; pycnospores present.
15....	0	Do.	34....	0	Examination not necessary.
16....	0	Do.	35....	0	Do.
17....	6,566	No ascospores.	36....	0	Do.
18....	5,000	Do.			
19....	5,655	Do.			

During the time covered by our analyses there were five periods during which ascospores were expelled in the field—i. e., on March 20 and 21, 26 and 27, April 4 and 5, 13 to 16, 27 to 29. On these days ascospores were ejected at both Martic Forge and West Chester, but only a very few spores were expelled on March 20 and 21 and on April 4 and 5. If the remaining dates are compared with Table III, it will be noticed that the birds yielding the highest positive results were shot just after the rains which produced copious expulsion of ascospores. It might therefore be expected that birds would be carrying these spores as well as pycnospores, but such does not appear to have been the case. Studies on wind dissemination show that ascospores are carried away by the wind upon being shot out of the perithecia. Other work (4) has shown that ascospores are not washed down the trunks of trees by the rains. The birds, therefore, have little, if any, opportunity of collecting ascospores, unless they happen to be working on a canker at the time when expulsion is taking place.

That the pycnospores were not obtained directly from spore horns is indicated by the fact that these were very rare during the earlier part of the period covered by the tests. Furthermore, the number of spores carried by a single bird was much smaller than would be expected if individual spore horns had been brushed off, since a medium-sized tendril is known to contain millions of pycnospores. We know that pycnospores are washed down the trunks of trees in large numbers even by the winter and spring rains (4). Work done in this laboratory shows that viable pycnospores can be obtained in abundance from the healthy bark below lesions. From the facts cited we are led to the conclusion that the pycnospores carried by the birds are brushed off from either normal or diseased bark, or from both, in the movements of the birds over these surfaces.

BIRDS AS CARRIERS OF OTHER FUNGI

Results from cultures show that a few of the birds (Nos. 7, 10, 23, 27, and 33) were carrying a greater number of viable spores of the chestnut-blight fungus than of all other species of fungi combined. The reverse, however, was true of all other birds, most of which were found to be carrying fungous spores in large numbers. (See Table II.) The number of species of fungi other than *Endothia parasitica* represented in the cultures varied from 4 to 14 per bird, with an average of 7. (See Table I.) Those met with most frequently were various species of Penicillium, Cladosporium, and Alternaria. Many of the other fungi, which appeared in smaller numbers, were not identified, on account of their failure to fruit in culture.

The microscopic examination of the centrifuged sediments revealed the fact that more species of fungi were carried than was indicated by the cultures. Spores of different species were distinguished by form, size, septation, and coloration. For example, the cultures from bird No. 7 indicated the presence of only 7 species other than *Endothia parasitica*, while the sediment showed at least 12 different kinds of spores. Again, bird No. 23 gave 6 species in cultures and at least 19 by microscopic examination of the sediment. The types of spores found in the sediments of these two birds are illustrated by figures 1 and 2. The actual number of fungous spores carried was beyond doubt greater in every case than is indicated in Table I. The smaller number of species obtained from the cultures was due to the fact that the medium used was not suitable to the growth of some of the spores, or that they grew so slowly that they were overrun by other more rapid-growing forms before they had become visible.

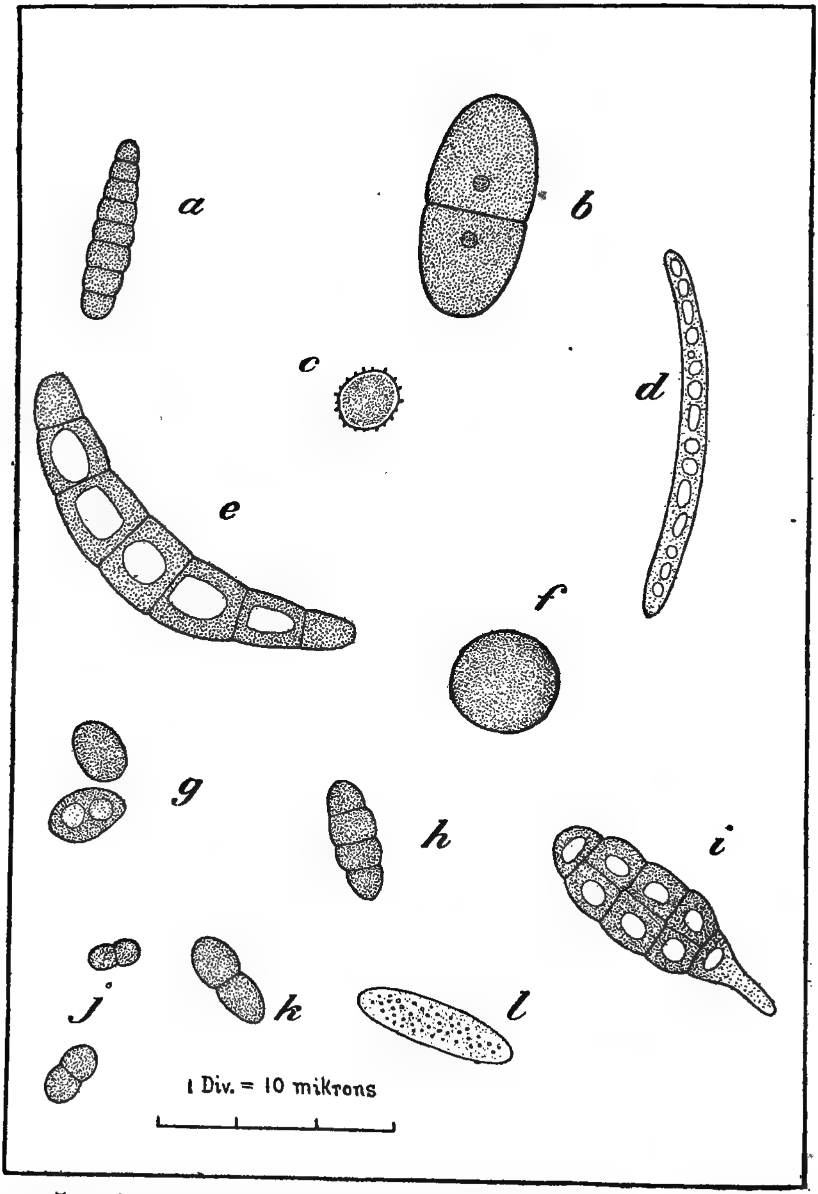

FIG. 1.—Types of spores other than those of *Endothia parasitica* obtained by the microscopic examination of the centrifuged sediment from the test of bird No. 7, a downy woodpecker: *a*, Brown; *b*, dark brown; *c*, brown; *d*, cyanophyceous; *e*, brown; *f*, nearly black; *g*, smoky; *h*, brown; *i*, brown; *j*, brown; *k*, brown; *l*, cyanophyceous.

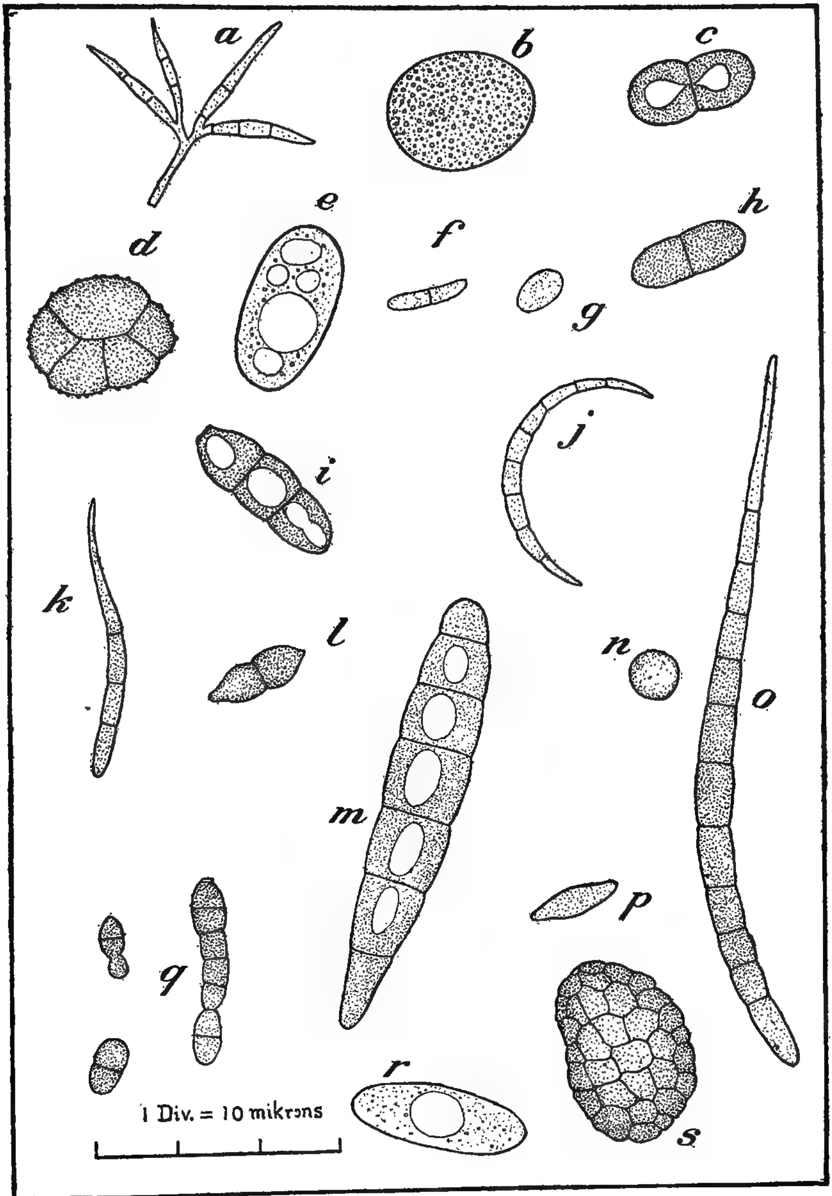

FIG. 2.—Types of spores other than those of *Endothia parasitica* obtained by the microscopic examination of the centrifuged sediment from the test of bird No. 23, a brown creeper. Brown-spored forms appear to predominate: *a*, Hyaline; *b*, hyaline; *c*, dark brown; *d*, nearly black; *e*, hyaline; *f*, light brown; *g*, smoky; *h*, pale smoky; *i*, dark smoky; *j*, hyaline; *k*, pale smoky; *l*, dark smoky; *m*, smoky; *n*, hyaline; *o*, brown; *p*, hyaline; *q*, dark smoky; *r*, hyaline; *s*, very dark, almost black.

No attempt was made to determine whether any of the spores other than those of the chestnut-blight fungus belonged to parasitic species. Judging, however, from the large numbers and kinds of fungous spores carried and from the very high numbers of spores of *Endothia parasitica* obtained at certain times, it is reasonable to suspect that these birds or birds of other species may be important agents in the spread of some other plant diseases, at least under certain favorable conditions. In the light of facts revealed by this investigation it is suggested that birds may play a part in the dissemination of such troubles as the brown-rot of stone fruits, die-back of peaches, plums, and apricots, or of any other diseases where birds may be attracted to the host.

SUMMARY AND CONCLUSIONS

(1) The 36 birds tested belonged to 9 different species.

(2) Of the 36 birds 32 were those which are in the habit of climbing over the trunk and larger branches of trees.

(3) Most of the birds were shot from blighted chestnut trees; some directly from blight cankers.

(4) The bill, head, feet, tail, and wings of each bird were scrubbed with a brush and poured plates were made from the wash water, which was retained and centrifuged for its sediment.

(5) Of the 36 birds tested, 19 were found to be carrying spores of the chestnut-blight fungus, *Endothia parasitica.*

(6) The viable spores of the chestnut-blight fungus carried by two downy woodpeckers numbered 757,074 and 624,341, respectively, while a brown creeper carried 254,019.

(7) The cultures from some of the birds showed from 2 to 14 times as many viable spores of the chestnut-blight fungus as of all other fungi combined.

(8) The highest positive results were invariably obtained from birds shot from two to four days after a period of considerable rainfall.

(9) The rate of development in cultures always indicated that the colonies of the chestnut-blight fungus originated from pycnospores; pycnospores were generally found in the centrifuged sediments, while ascospores were never detected. The birds were therefore carrying pycnospores only.

(10) The pycnospores carried were probably brushed off from either normal or diseased bark, or from both, in the movements of the birds over these surfaces.

(11) Both the cultures and an examination of the centrifuged sediments showed that the birds were carrying a large number of spores of many species of fungi other than *Endothia parasitica.*

(12) From the above facts the writers are led to the conclusion that birds in general are important carriers of fungous spores, some of which may belong to parasitic species.

(13) Furthermore, many birds which climb or creep over the bark of chestnut trees are important agents in carrying viable pycnospores of the chestnut-blight fungus, especially after a period of considerable rainfall.

(14) Birds are probably not very important agents in spreading the chestnut blight locally, on account of the predominance of other and more important factors of dissemination, as, for example, the wind.

(15) The writers believe, however, that many of the so-called "spot infections" (local centers of infection isolated from the area of general infection) have had their origin from pycnospores carried by migratory birds. Some of the birds tested were not permanent residents of eastern Pennsylvania, but were shot during their migration northward. These, no doubt, carry spores great distances. Each time the bird climbs or creeps over the trunk or limbs of a tree some of the spores may be brushed off and may lodge in crevices or on the rough bark. From this position they may be washed down into wounds by the rain and may thus cause infections.

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PLATE XXXVIII

Old blight canker on chestnut, showing the work of woodpeckers.

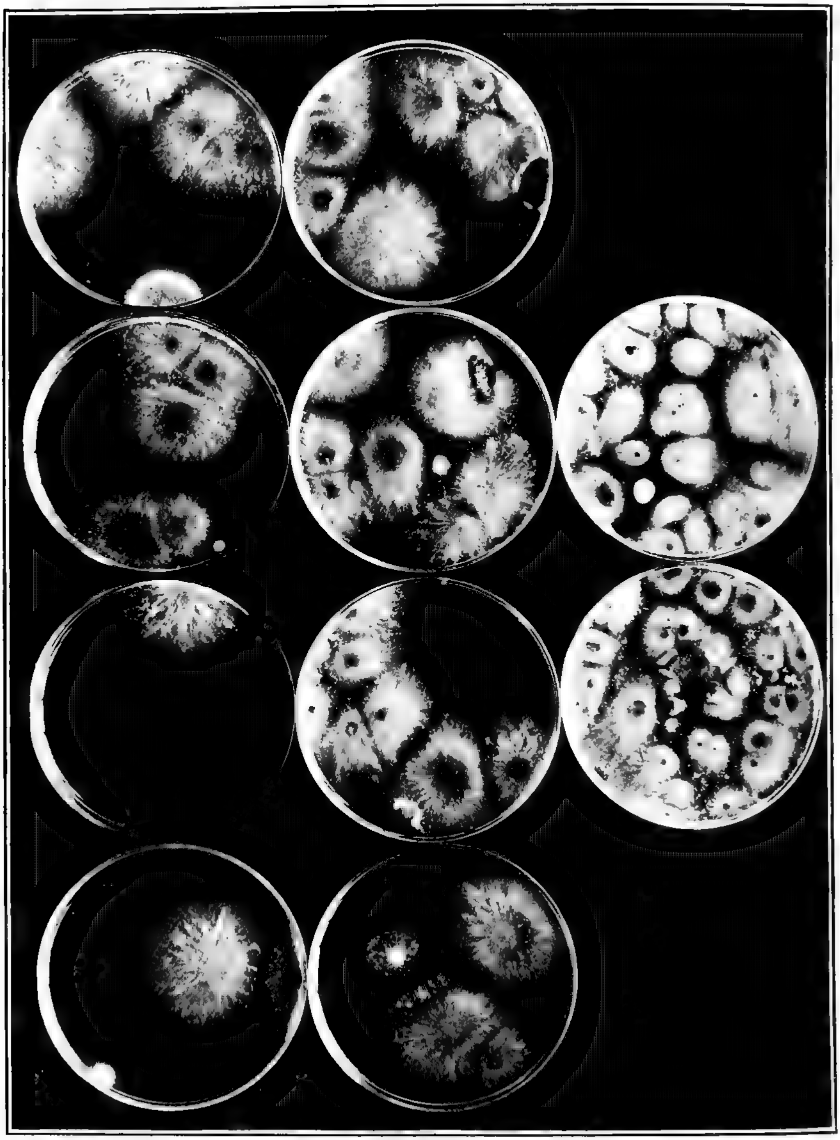

PLATE XXXIX

Series of cultures 9 days old obtained in the test of bird No. 23, a brown creeper. Each Petri dish of the first series (first row) contained 1/10,000 of the water in which the bird was washed; each of the second series (middle row), 1/45,000; and each of the third series (third row), only 1/90,000.

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AIR AND WIND DISSEMINATION OF ASCOSPORES OF THE CHESTNUT-BLIGHT FUNGUS

By F. D. HEALD, M. W. GARDNER, and R. A. STUDHALTER

AIR AND WIND DISSEMINATION OF ASCOPORES OF THE CHESTNUT-BLIGHT FUNGUS

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HISTORICAL INTRODUCTION

Wind dissemination of the chestnut-blight fungus (*Endothia parasitica* (Murr.) And.) was first suggested by Murrill (13)[2] in 1906, although he apparently had only the pycnospores in mind, as is shown by the following quotation:

> Later the fruiting pustules push up through the lenticels and give the bark a rough, warty appearance; and from these numerous yellowish-brown pustules millions of minute summer spores emerge from day to day in elongated reddish-brown masses to be disseminated by the wind and other agencies, such as insects, birds, squirrels, etc.

A few years later, in a discussion of the means of spreading the disease, Hodson (9) says:

> Wind is probably the principal agency, but the spores are no doubt carried by animals, birds, insects, and by shipment of infected material.

He also cited some observations to substantiate the wind-dissemination theory, but it was not brought out clearly whether he had in mind the ascopores or the pycnospores only. A similar opinion is expressed by Mickleborough (12) a little later. After speaking of both the ascopores and the conidal, or summer, spores, he states:

> The minute spores are carried by the wind, on the feathers of birds, and the fur of squirrels.

Referring to the spore horns, Mickleborough writes:

> These threads are dissolved and washed away by the rain and the spores are blown about by the wind.

There are two possible ways in which pycnospores might be disseminated by the wind: First, by the direct transport of spore horns or small fragments of these structures; second, by the transport of dust particles bearing spores previously washed down by rains.

Fulton (4) reports experiments which indicate that the former method of transport of pycnospores is of little importance in the spread of the disease. He concludes his discussion of this topic with the following statement:

> It seems likely the detachment was largely of small bits of the tendrils made up of large numbers of spores, and that these are too heavy to be carried great distances;

[1] The writers received valuable assistance in this work from Mr. R. C. Walton, also an agent, Investigations in Forest Pathology.

[2] Reference is made by number to "Literature cited," p. 525–526.

and suggests that under natural conditions infection may be spread short distances by the wind.

The second possibility is brought out by Metcalf and Collins (11), as may be noted in the following quotation:

> As both kinds of spores appear to be sticky, there is no evidence that they are transmitted by wind except where they may be washed down into the dust and so blown about with the dust.

While it has not yet been demonstrated that pycnospores are carried in this way, the tests of Heald and Gardner (7) on the longevity of pycnospores in soil give added plausibility to the theory, since these spores were found to persist in the soil between periods of rain and were able to withstand complete desiccation in the laboratory for months.

Attention was first directed to the strong probability of wind dissemination of ascopores by Rankin (14), who reported their forcible expulsion. In a later report the same writer (15) makes the following statement:

> Under moist conditions the ascospores are shot forcibly out in the air where they can be caught up by the wind and carried for a considerable distance. The speaker found ascopores being shot from mature pustules during every rainy period last summer. * * * The question at once arises, Why could not these ascospores once shot into the air be carried long distances and, owing to their abundance, cause a large majority of the infection?

After carrying out field experiments during the summer of 1912, Rankin (16), referring to ascospores, says:

> They are shot out in vast numbers with every rain during the summer and are carried by the wind.

Detailed field work on dissemination was carried out by Anderson (1) and his assistants for the Pennsylvania Chestnut Tree Blight Commission (2). These publications confirm the statement of Rankin that expulsion of spores takes place only when the pustules are moist. The seasonal duration of shooting under natural conditions was not determined, as the field tests were confined to the month of August. Under artificial conditions in the laboratory, the time required for moistened bark bearing perithecia to begin the expulsion of spores was determined, the shortest time recorded being three minutes.

The duration of the shooting period following a rain was determined by artificial tests in either the field or laboratory, performed by soaking the specimens or drenching cankers with water. The maximum duration recorded was five hours and two miniutes. While these tests under artificial conditions gave suggestive results, they were not necessarily a reliable indication of what would happen under natural conditions.

It was also determined that bark kept constantly moistened continued to expel spores for a maximum period of 25 days, and the point was emphasized that no continuous rainy weather would be longer. The fact that ascospores expelled during a rain would be washed down to the ground without being carried any appreciable distance is not mentioned. Since they germinate at once in rain water, the great bulk of such spores would be lost for anything but very local infections. The really important point would appear to be the length of time shooting continues after a rain ceases, for at that time the conditions of the atmosphere would be such as to favor a wider dissemination. This question does not seem to have been satisfactorily answered. The data given on height and horizontal distance of projection, as well as the rate of expulsion, certainly indicate the importance of wind transport of spores following rainy periods.

The spore content of the air was studied by means of aspirator tests and exposure plates. In this work, carried out during dry weather, Anderson and his assistants failed to get positive results under natural conditions in the field. They report the use of over 100 exposure plates and tests of 500 liters of air without finding a single spore of the chestnut-blight fungus. Tests made of aspirated air and by exposure plates gave positive results, however, when the cankers were artificially drenched with water. For the aspirator tests the horizontal distances of the aspirator opening from the canker varied from 2 inches to 5 feet (?) and the maximum vertical distance was 22 feet.

The tests made by exposing agar plates under artificial conditions in the field again pointed to the probability of wind dissemination, but one is forced to admit that they were not conclusive, since the conditions were so different from the natural in that the cankers were drenched with water artificially instead of waiting for a rain. The results with exposure plates may be summed up as follows: No spores of the chestnut-blight fungus were obtained under natural conditions in the field during dry weather; by the use of artificially drenched cankers spores were obtained at distances varying from 1 inch to 51 feet, with very few at the maximum distance.

The final and most conclusive argument in favor of wind dissemination in the minds of the authors cited was afforded by inoculations made by offering an opportunity for wind-borne spores to be introduced into wounds. There is little doubt in the minds of the writers of this paper that infection did take place in the way claimed, but it should be pointed out that a covering of cotton would not prevent spores from being washed into the wounds by rains (6). A fairly compact mass of cotton has been shown to retain but few of the pycnospores present in water passing through it. It must therefore be admitted that, under the conditions of the experiments reported, infection by spores washed down by rains was one of the possibilities.

It is interesting to note in this connection that Kittredge (10), as a result of field observations on the spread of the disease around a center of infection, arrives at the following conclusion:

> The location of infected trees in partially infected groups of sprouts shows that wind is not the prime factor in the distribution of the spores.

The author admitted, however, that the observations reported were rather meager in support of this conclusion.

PURPOSE AND SCOPE OF PRESENT WORK

Since most of the previous work on wind dissemination of the chestnut-blight fungus which yielded positive results was done under artificial conditions, it was the aim of the present writers to study the problem under absolutely natural conditions. Briefly stated, the purpose of these tests was to determine whether or not, and if so, to what extent, wind [1] acts as an agent in dissemination of the spores of this fungus. It was also the object of the work herein recorded to ascertain at what particular times under natural conditions spores of *Endothia parasitica* are prevalent in the air, the possible distances transported by the wind, and the kind of spores (whether ascospores or pycnospores).

The locality chosen in which to conduct our tests was a 4-acre plot of native chestnut (*Castanea dentata*) coppice near West Chester, Pa. The trees in this plot ranged from 4 to 8 inches in diameter and all were badly infected with the chestnut blight, many having already succumbed.

In these tests, which covered a period of 36 consecutive days during August and September, 1913, four methods were employed in studying the points in question. To determine the prevalence of spores of *Endothia parasitica* in the air at particular times and places a series of 756 exposure plates was made. The occurrence of ascospore expulsion was detected and its exact period of duration ascertained by the examination of ascospore traps in the shape of object slides supported over perithecial pustules on the trees. The number of spores present in the air was determined quantitatively by the aspirator method. Rather prolonged exposures of water spore traps, consisting of sterile water in dishes, were made to secure additional information as to the kind of spores in the air, the periods of occurrence, and the distance transported.

EXPOSURE-PLATE TESTS

In testing the spore content of the air among diseased trees in the field for the presence of spores of *Endothia parasitica* the exposure of sterile poured plates of chestnut-bark agar proved to be the most satisfactory method. The use of chestnut-bark agar [2] was found advantageous, since this medium inhibits the development of bacterial colonies and retards the growth of rapid-growing fungi, spores of which are

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[1] Falck has pointed out the importance of convection currents in the dissemination of ascospores. (Falck, Richard. Über die Luftinfektion des Mutterkornes (Claviceps purpurea Tul.) und die Verbreitung pflanzlicher Infektionskrankheiten durch Temperaturströmungen. *In* Ztschr. Forst- u. Jagdw., Jahrg. 43, No. 3, p. 202–227, 4 fig., 1911.) For this reason we have used the word "air" in the title of the present paper.

[2] Chestnut-bark agar was made according to the following formula: Add 50 gm. of finely chopped or ground air-dry chestnut bark to 1,000 c. c. of distilled water and boil for 15 minutes. Filter through cheesecloth or absorbent cotton and add water to make up to 1,000 c. c. Add 15 gm. of agar and boil until the agar has melted; then cool to 60° C. or under, clear with the whites of two eggs, filter, and sterilize in the autoclave.

present in the air. At the same time the growth of *E. parasitica* on this medium is vigorous and characteristic.

As supports or stations on which to expose the plates, it was found convenient and satisfactory to make use of the numerous large flat-topped stumps scattered throughout the coppice stand of diseased trees. To facilitate the recording of data, all of the stumps used were numbered with crayon and carefully described and located with regard to surrounding trees (fig. 1). Here it may be mentioned, however, that other supports, such as the top rail of a fence or the top of a stake driven into the ground, were used in case of emergency attendant upon certain weather conditions.

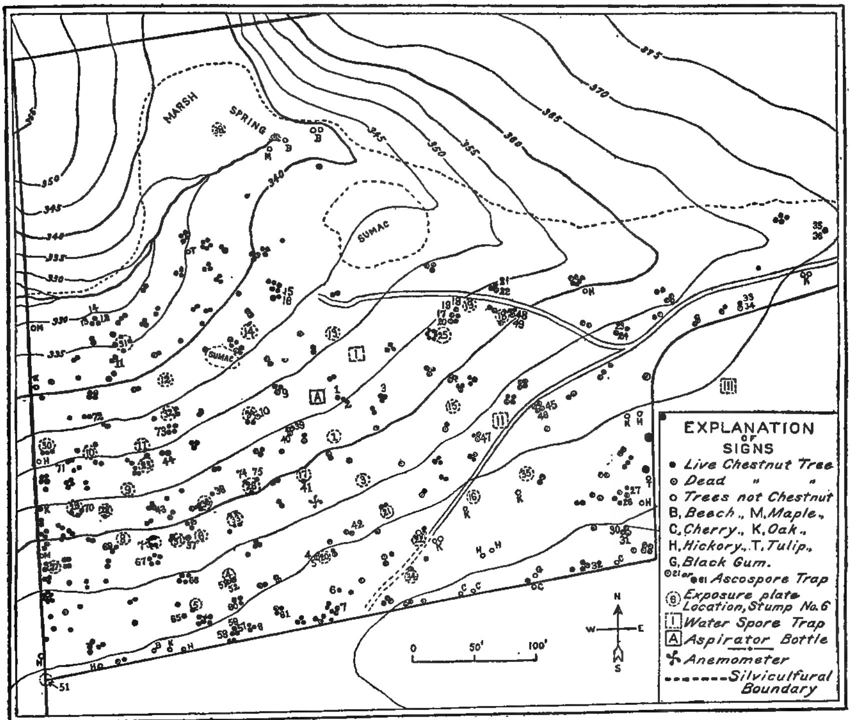

FIG. 1.—Map of chestnut coppice growth at West Chester, Pa., in and near which the experiments on wind dissemination of the chestnut-blight fungus were carried out.

The stumps, rails, and stakes used for this purpose were all of such an age or nature that they were entirely free from lesions of the chestnut blight.

Under conditions of ordinary fair weather the routine followed in making the exposures was similar throughout the tests. Plates were exposed at the rate of one about every half hour during the day, and the average length of exposure was about 5 minutes for each plate during the first 18 days. Then it was found advisable to lengthen the time of exposure, and thereafter 10 minutes, more or less, was the usual time allowed. Wind direction determined what stations were utilized each day, since an effort was usually made to expose plates at stations where there were many diseased trees to the windward.

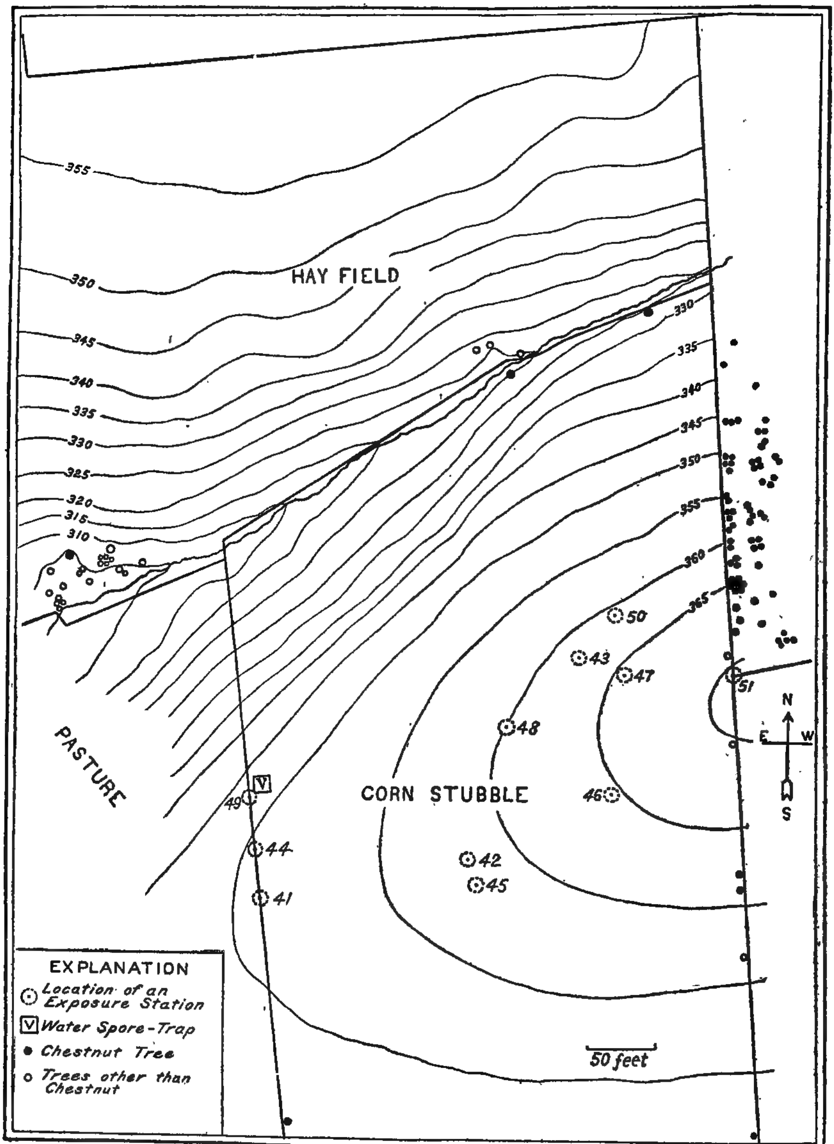

FIG. 2.—Map showing the location of some of the important outlying exposure-plate stations. Station 51 is at the corner of tne plot represented in figure 1.

During wet weather the routine was often varied considerably, especially just after the cessation of a rain. At such times plates were often exposed in more rapid succession, even to the extent of exposing several in different locations at about the same time.

An anemometer was erected in the experimental plot, and from the successive readings of this instrument the wind velocities were computed. Continuous records of temperature were secured by means of a thermograph located in a standard instrument shelter near the plot, and by use of a rain gauge the exact rainfall in inches was determined. As complete data as possible were also secured relative to the exact duration of all rains.

In describing and locating the stations used for exposure plates, measurements were made to the nearest diseased trees and to the nearest lesions, the horizontal distance being recorded. To supplement the description, detailed topographic maps were made, showing the location of each station (figs. 1 and 2).

The exposed plates were incubated at room temperature, and two records were usually taken. First, at the end of three days after exposure all fungous and bacterial colonies visible were marked and counted, and those suspected of being *Endothia parasitica* were especially noted. After six or seven days of incubation the final record on each plate was taken. This included the total number of fungi, the number of bacterial and yeast colonies, and the number of colonies of *E. parasitica*, if any were present. In case of doubt as to the identity of the latter, owing to crowding by other colonies, transfers were made to 3 per cent dextrose agar, on which medium the growth of this fungus is even more characteristic than on chestnut-bark agar.

The results obtained in the exposure-plate tests are presented in a somewhat summarized form in Tables I and II.

TABLE I.—*Summary of exposure-plate tests at West Chester, Pa., in 1913, giving number of fungous colonies caught*

Date of cultures.	Number of plates exposed.	Length of exposure for each plate.	Total time represented.	Rainfall.	Number of fungous colonies in any plate.		Total number of fungous colonies.	Total number of colonies of Endothia parasitica.
					Maximum.	Minimum.		
		Minutes.	*H. m.*	*Inches.*				
Aug. 19	18	5 to 6	1 39	0.40	81	3	332	1
20	22	6 to 10	2 19¼	0	24	1	227	0
21	19	5 to 7	1 48½	0	26	0	168	0
22	20	1½ to 7½	1 44	} 0.25	{ 35	2	340	0
23	25	4 to 8	2 19		28	1	256	0
24	17	4½ to 6	1 28¼	0	47	1	206	0
25	19	4 to 6	1 34	0	75	5	419	0
26	20	4 to 7	1 48½	0	95	8	574	0
27	28	4 to 9⅓	2 44½	0.175	70	4	446	94
28	18	4 to 6½	1 32	0	20	2	196	0
29	19	4 to 5½	1 30½	} 1.10	{ 51	1	309	0
30	22	5 to 6½	1 57¼		146	0	363	0
31	20	4 to 7	1 48	0	32	1	261	1
Sept. 1	19	5 to 6½	1 44	0	12	1	122	0
2	19	4 to 6	1 37	0	39	3	213	0
3	19	5 to 6½	1 37½	0	10	1	68	2
4	18	5	1 30	0	48	5	245	1
5	18	5 to 6	1 31	0	40	0	179	1

TABLE I.—*Summary of exposure-plate tests at West Chester, Pa., in 1913, giving number of fungous colonies caught*—Continued

Date of cultures.	Number of plates exposed.	Length of exposure for each plate.	Total time represented.	Rainfall.	Number of fungous colonies in any plate. Maximum.	Number of fungous colonies in any plate. Minimum.	Total number of fungous colonies.	Total number of colonies of Endothia parasitica.
		Minutes.	*H. m.*	*Inches.*				
Sept. 6..	18	5 to 10½	2 14¾	0	6	0	39	0
7..	19	7 to 11¾	3 4¾	0.37	22	1	186	0
8..	27	7¼ to 12	4 16		15	1	195	9
9..	18	6 to 11½	2 23	0	31	2	194	2
10..	18	8 to 11¾	2 50¼	0	31	0	138	0
11..	18	9½ to 14¼	3 19¼	0	25	0	118	0
12..	18	5 to 14	3 12⅓	0.095	41	1	121	0
13..	19	7 to 13	3 5¼		73	2	332	0
14..	18	9 to 11¼	3 9½	0	20	2	126	0
15..	18	9½ to 11	3 6	0	20	6	202	0
16..	19	9½ to 27	3 34½	0	28	0	251	0
17..	17	9½ to 15½	3 13¾		36			
				0.26		2	221	[a] 2
18..	28	9¾ to 13½	5 15¼		67			
				0.68		1	539	55
19..	26	10¼ to 17	5 24½		400			
				0.09		1	814	7
20..	28	9¼ to 18	6 13¾		23			
				0.43		1	194	90
21..	25	3½ to 20	5 52½	0.10	160			
				0.73		5	1,187	160
22..	36	6½ to 30	9 50		60	0	494	2
23..	24	12¼ to 23	6 36	0	30	0	261	0

[a] From wind-blown bark fragments.

TABLE II.—*Detailed record of all exposure plates in which spores of Endothia parasitica were caught at West Chester, Pa., in 1913*

Plate No.	Date of exposure.	Rainfall.	Time elapsed since cessation of rain.	Length of exposure.	Horizontal distance to nearest blight lesion.	Number of spores of Endothia parasitica caught.
		Inches.	*D. h. m.*	*Minutes.*	*Feet.*	
4008	Aug. 19	0.4	6+ 0	5	[a] 1½	1
4376	Aug. 27	.12	42	9⅓	4½	1
4382	.....do	.12	1 44	6	15½	3
4383	.....do	.055	18	6½	15½	16
4384	.....do	.055	20	6	11	21
4385	.....do	.055	22	8	25	33
4386	.....do	.055	33	5	4½	20
4460	Aug. 31	1.10	1 10+ 0	5	[a] 2	1
4509	Sept. 3	1.10	5 0 0	5	[a] 2	1
4529	Sept. 4	1.10	5 0 0	5	[a] 2	2
4553	Sept. 5	1.10	6 0 0	5	[a] 2	1
4599	Sept. 8	.37	5+ 0	10½	11	2
4600	.....do	.37	5 1	11½	14	1
4602	.....do	.37	5 21	12	[a] 1	1
4606	.....do	.37	7 0	9¼	[a] 2	1
4609	.....do	.37	8 30	12	[a] 1½	1
4610	.....do	.37	9 0	10	[a] 2½	1
4617	.....do	.37	13 0	8	[a] 2	1
4619	.....do	.37	14 0	9	[a] 2	1
4626	Sept. 9	.37	1 8 0	6	[a] 2	1
4627	.....do	.37	1 8 30	8½	[a] 4½	1

[a] Stumps more or less overhung by diseased sprouts.

TABLE II.—*Detailed record of all exposure plates in which spores of Endothia parasitica were caught at West Chester, Pa., in 1913*—Continued

Plate No.	Date of exposure.	Rainfall.	Time elapsed since cessation of rain.			Length of exposure.	Horizontal distance to nearest blight lesion.	Number of spores of Endothia parasitica caught.
		Inches.	*D.*	*h.*	*m.*	*Minutes.*	*Feet.*	
4772	Sept. 17	0.095	4	0	0	10	[a] 2½	1
4784	.....do	.095	4	0	0	10½	[a] 2	[b] 1
4787	Sept. 18	.26		1	51	9¾	15½	11
4788	.....do	.26		1	54	10	16	16
4789	.....do	.26		2	0	10	4½	9
4790	.....do	.26		2	19	13	11	4
4791	.....do	.26		2	35	11	7	5
4792	.....do	.26		2	48	11	15½	2
4793	.....do	.26		2	54	12	[a] 4½	2
4795	.....do	.26		3	25	11	15½	2
4796	.....do	.26		3	34	11	17½	1
4797	.....do	.26		3	58	10¼	16	1
5006	.....do	.26		9	14	13½	[a] 1	1
5010	.....do	.26		11	19	11	[a] 2	1
5018	Sept. 19	.68		1	23	11¼	4½	2
5020	.....do	.68		2	7	12½	27	1
5027	.....do	.68		6	4	11½	[a] 2	1
5029	.....do	.68		7	8	12¾	[a] 5	1
5033	.....do	.68		10	5	10¼	[a] 5	1
5037	.....do	.68		12	7	13½	27	1
5041	Sept. 20	.09		1	55	16	217	10
5042	.....do	.09		2	0	13	195	7
5043	.....do	.09		2	1	14	110	4
5044	.....do	.09		2	8	12¾	27	22
5045	.....do	.09		2	19	12¼	85	11
5046	.....do	.09		2	23	15	180	7
5047	.....do	.09		2	25	15	237	10
5048	.....do	.09		2	45	13½	7	6
5049	.....do	.09		3	12	11½	11	7
5050	.....do	.09		3	37	13	11	3
5051	.....do	.09		3	45	16¾	86	1
5052	.....do	.09		4	29	10	4½	1
5053	.....do	.09		5	14	13½	5	1
5069	Sept. 21	[c] .35			0	14½	19	12
5070	.....do	.35			5	10½	17½	20
5071	.....do	.08			15	20	17½	62
5072	.....do	.08			17	19	19	24
5073	.....do	.08			44	13½	17½	19
5074	.....do	.08			56	15¼	14	1
5075	.....do	.08		1	1	12	7	2
5087	.....do	[c] .07			20	14½	19	20
5098	Sept. 22	.73		6	0	16	77	1
5102	.....do	.73		6	30	15	1½	1

[a] Stumps more or less overhung by diseased sprouts. [b] From fragments of bark. [c] Approximately.

To supplement the tables, it may be well to give in chronological order a more detailed record of the actual routine pursued.

A rain occurred the night previous to August 19, and examination of the ascospore traps (see "Ascospore-trap tests") showed that abundant expulsion of ascospores had occurred. But when the first plates were exposed too long a time had evidently intervened since the rain, as no positive results were obtained, except that one colony of *Endothia parasitica* developed in a plate exposed in the early afternoon.

The next two days were fair, and as was expected for these weather conditions, no spores of this Endothia were caught. In the evening of August 22 there was a rain of 0.25 inch; 6 plates, therefore, were exposed early the next morning before the sun had dried the vegetation. Although the ascospore traps gave evidence that expulsion had occurred, no positive results were obtained, which is explained by the fact that again too long a time had elapsed after the rain ceased.

Dry, hot weather now continued until the afternoon of August 27, and the exposure plates yielded no evidence of the presence of spores of *Endothia parasitica* in the air. In the afternoon of August 27, however, two thunder storms occurred, in consequence of which the regular routine was departed from. Tables II and III show the outcome of the tests of this date. After the first storm two sets of plates were exposed in the course of an hour and a half. Two out of the second set yielded colonies of *E. parasitica*. Since the ascospore-trap tests (Tables X and XVII) did not give evidences of expulsion occurring when the first five plates were exposed, negative results were to be expected in those plates, and it is not surprising that only two out of the second set of seven plates yielded colonies of *E. parasitica* when the 19 ascospore traps examined for this particular period showed evidence of expulsion from only one perithecium. The meagerness of these results is partially accounted for by the small amount of rain, rapid drying, and the fact that the perithecia had hardly been wet a sufficient length of time.

TABLE III.—*Record of exposure plates made on August 27, 1913, at West Chester, Pa.*

BEFORE RAIN.

Plate No.	Time.	Length of exposure.	Station No.	Wind.		Number of bacteria and yeasts.	Total number of fungi.	Number of colonies of Endothia parasitica.
				Direction.	Miles per hour.			
		Minutes.						
4359	8.35 a. m.	4	1	SW.	1.6	2	7	0
4360	9.09 a. m.	5	3	SW.	1.6	1	8	0
4361	9.32 a. m.	5	1	SW.	1.6	1	6	0
4362	10.03 a. m.	5	13	SW.	1.6	0	6	0
4363	10.29 a. m.	6	14	SW.	1.6	1	7	0
4364	10.57 a. m.	5	3	W.	1.6	3	9	0
4365	11.34 a. m.	5½	1	W.	1.7	2	19	0
4366	11.57 a. m.	5	1	W.	1.7	0	15	0
4367	1.16 p. m.	5	1	W.	1.7	0	22	0
4368	1.39 p. m.	5	13	W.	1.7	0	33	0
4369	2.09 p. m.	5½	13	W.	1.7	1	13	0
4370	2.45 p. m.	5	3	W.	1.7	1	7	0
RAIN NO. 1 (0.12 INCH, 3.15 TO 3.28 P. M.)								
4371	3.48 p. m.	7	3	W.	2.4	1	12	0
4372	3.50 p. m.	6½	15	W.	2.4	0	10	0
4373	3.49 p. m.	6⅝	13	W.	2.4	0	17	0
4374	3.48 p. m.	6¾	1	W.	2.4	0	32	0
4375	3.51 p. m.	7	8	W.	2.4	0	9	0
4376	4.10 p. m.	9⅓	6	W.	Trace.	0	7	1
4377	4.12 p. m.	8⅔	11	W.	Trace.	0	8	0
4378	4.14 p. m.	8⅛	3	W.	Trace.	2	15	0
4379	4.15 p. m.	8	16	W.	Trace.	0	11	0
4380	4.17 p. m.	5⅝	15	W.	Trace.	1	9	0
4381	4.40 p. m.	4	3	W.	Trace.	0	4	0
4382	5.12 p. m.	6	3	W.	Trace.	1	13	3

TABLE III.—*Record of exposure plates made on August 27, 1913, at West Chester, Pa.*—Continued

RAIN NO. 2 (0.055 INCH, 5.35 TO 5.50 P. M.)

Plate No.	Time.	Length of exposure.	Station No.	Wind.		Number of bacteria and yeasts.	Total number of fungi.	Number of colonies of Endothia parasitica.
				Direction.	Miles per hour.			
		Minutes.						
4383	6.08 p. m.	6½	3	NW.	1.2	0	30	16
4384	6.10 p. m.	6	1	NW.	1.2	0	25	21
4385	6.12 p. m.	8	16	NW.	1.2	2	70	33
4386	6.23 p. m.	5	6	N.	.7	0	25	20

The second shower on August 27 took place late in the afternoon, and though the precipitation was light, the cumulative effect of this rain upon that of the preceding one caused abundant expulsion of ascospores. The four plates exposed within about half an hour after this shower yielded colonies of *E. parasitica* in such numbers as to prove beyond doubt that the ascospores were at that time very prevalent in the air. The ascospore-trap tests for this period (Tables X and XVII) showed that, although out of the 14 examined only 1 bore any evidence of spore expulsion during the first 15 minutes after the cessation of the rain, 12 out of 14 showed expulsion of ascospores during the time in which the plate exposures were made. The sun had gone down, and the weather conditions following this storm were not conducive to the rapid drying of the bark. The results of this date were the first evidence secured which indicated beyond doubt that ascospores of *Endothia parasitica* are disseminated by wind under natural conditions.

During the dry, hot weather of August 28 evidently no spores of *Endothia parasitica* were present in the air, nor were any detected on August 29. On this date the humidity was high and cloudiness prevailed, accompanied by traces of rain insufficient to cause ascospore expulsion. As there was a rainfall of 1.10 inches in the evening of August 29, several plates were exposed in rapid succession the next morning, but no spores were caught. This failure is attributed to the fact that once more too long a time had passed since the rain ceased, and spore expulsion, though probably abundant in the night, had no doubt ceased long before the first exposures were made. Throughout the following week there was no rain, and no ascopore expulsion occurred at any time.

For the night previous to September 8 a rainfall of 0.37 inch was recorded, the time of cessation being prior to 1.30 a. m. The ascopore traps gave evidence of plentiful spore expulsion. Between 6.27 and 8 a. m. eight exposures were made before the sun had dried the vegetation and while the bark was still wet in places. Three of these plates yielded colonies of *Endothia parasitica*, and as two of them were exposed at stations more or less in the open, it would seem that ascospores were at that time prevalent in the air to some extent. The third plate and also five others exposed at later intervals during the day each yielded one colony of *E. parasitica*.

Of the plates exposed on September 9, a dry, hot day, two in the morning also yielded one colony each of *Endothia parasitica*. During the dry weather of September 10 and 11 negative results were obtained.

Cloudiness prevailed on September 12, with traces of rain insufficient to cause spore expulsion. In the night less than one-tenth of an inch of rain fell, and subsequent examination of the ascospore traps showed that very light ascospore expulsion had occurred. Five plates were exposed before 8 o'clock the next morning, but the bark was dry at the time and no spores were obtained in any of the plates exposed that day. Three days of clear, hot weather followed, and no spores were caught. Of the plates exposed on September 17, two yielded one colony each of the fungus.

In the evening of September 17 a series of rains began, occurring usually in the night. Our most important positive results were obtained from tests made following these rains. Tables II and IV give the results of the plates exposed on September 18. Although the rain ceased before 4 a. m., a heavy fog prevailed in the early morning, there was only a trace of wind, and it was more or less cloudy all day. Because of these conditions the bark of the trees was slow in drying, and examination of the ascospore traps (Tables XI and XVII) showed that abundant spore expulsion had occurred in the night and was still in progress while the first four exposure plates were made. A few of the traps gave evidences of the continuation of expulsion during the time in which the next 11 plates were exposed. Six of these yielded colonies of *Endothia parasitica* in varying numbers, and two exposed much later in the day also showed one colony each.

TABLE IV.—*Record of exposure plates made on September 18, 1913, at West Chester, Pa.*[a]

Plate No.	Time.	Length of exposure.	Station No.	Wind.		Number of bacteria and yeasts.	Total number of fungi.	Number of colonies of Endothia parasitica.
				Direction.	Miles per hour.			
		Minutes.						
4787	5.51 a. m.	9¾	3	NW.	Trace.	4	20	11
4788	5.54 a. m.	10	15	NW.	Trace.	6	58	16
4789	6.00 a. m.	10	6	NW.	Trace.	6	39	9
4790	6.19 a. m.	13	1	NW.	Trace.	(b)	59	4
4791	6.35 a. m.	11	11	NW.	Trace.	(b)	67	5
4792	6.48 a. m.	11	3	NW.	Trace.	1	16	2
4793	6.54 a. m.	12	4	NW.	Trace.	(b)	32	2
4794	7.02 a. m.	10½	16	NW.	Trace.	(b)	23	5
4795	7.25 a. m.	11	3	NW.	Trace.	(b)	30	2
4796	7.34 a. m.	11	13	NW.	0.4	3	8	1
4797	7.58 a. m.	10¼	15	W.	.7	8	11	1
4798	8.04 a. m.	10¾	9	W.	.7	0	2	0
4799	8.29 a. m.	10	17	W.	.7	0	1	0
5000	9.20 a. m.	12¼	1	W.	1.1	0	8	0
5001	9.49 a. m.	11	3	W.	1.8	0	25	0
5002	10.21 a. m.	10¼	6	W.	2.8	5	10	0
5003	10.54 a. m.	12	15	W.	2.8	1	19	0
5004	11.25 a. m.	11	33	W.	3.7	0	12	0
5005	11.51 a. m.	11½	3	W.	3.7	3	13	1
5006	1.14 p. m.	13½	26	W.	2.2	1	17	0
5007	1.44 p. m.	10¼	21	W.	2.8	0	7	0
5008	2.15 p. m.	10½	22	W.	1.8	1	10	0
5009	2.46 p. m.	15	6	W.	1.2	1	12	1
5010	3.19 p. m.	11	33	W.	1.2	0	12	0
5011	3.45 p. m.	11	21	W.	.9	1	16	0
5012	4.16 p. m.	13½	25	W.	.9	0	1	0
5013	4.44 p. m.	11½	23	W.	.2	4	21	0
5014	5.23 p. m.	10¾	1	W.	.1	0	3	0

[a] Rainfall, night previous, 0.26 inch. Time of cessation, prior to 4 a. m. [b] Numerous.

In the night of September 18 a rain of 0.68 inch was recorded, the time of cessation being the next morning before 3.45. Fog again prevailed all day September 19 and a noticeable spray fell until 5.38 a. m. and began again after 2.41 p. m. Ascospore-trap tests (Tables XII and XVII) showed that in 10 out of the 17 traps examined there was spore expulsion after 7.35 a. m. Of the eight plates exposed prior to this time but two yielded colonies of this Endothia. The first three plates were exposed in an open field at considerable distances from the trees (fig. 2, stations 41, 42, and 43) in the same direction toward which the wind was blowing, but no spores of *E. parasitica* were caught. These negative results may be accounted for by the action of the falling mist. Later in the day four exposures at various intervals yielded one colony each of the chestnut-blight fungus.

TABLE V.—*Record of exposure plates made on September 20, 1913, at West Chester, Pa.*[a]

Plate No.	Time.	Length of exposure.	Station No.	Wind.		Number of bacteria and yeasts.	Total number of fungi.	Number of colonies of Endothia parasitica.
				Direction.	Miles per hour.			
		Minutes.						
5041	5.50 a. m.	16	44	NE.	2.6	0	12	10
5042	5.55 a. m.	13	45	NE.	2.6	0	9	7
5043	5.56 a. m.	14	46	NE.	2.6	0	10	4
5044	6.03 a. m.	12¾	51	NE.	2.6	0	23	22
5045	6.14 a. m.	12¼	47	NE.	2.6	0	14	11
5046	6.18 a. m.	15	48	NE.	2.6	0	9	7
5047	6.20 a. m.	15	49	NE.	2.6	0	11	10
5048	6.40 a. m.	13½	11	ENE.	2.6	0	6	6
5049	7.07 a. m.	11½	1	ENE.	2.6	0	9	7
5050	7.32 a. m.	13	9	ENE.	2.6	0	6	3
5051	7.40 a. m.	16¾	50	ENE.	2.6	0	6	1
5052	8.24 a. m.	10	6	ENE.	2.5	0	1	1
5053	9.09 a. m.	13½	8	ENE.	2.5	0	1	1
5054	9.37 a. m.	14½	27	ENE.	3.0	5	11	0
5055	10.01 a. m.	14¾	6	ENE.	2.4	0	2	0
5056	10.32 a. m.	9¼	10	E.	2.4	0	3	0
5057	11.09 a. m.	10	29	E.	2.6	0	12	0
5058	11.44 a. m.	11¼	26	E.	2.6	0	6	0
5059	12.08 p. m.	10	10	E.	2.7	0	2	0
5060	1.05 p. m.	14½	30	E.	2.7	0	2	0
5061	1.35 p. m.	13½	11	E.	2.5	0	1	0
5062	2.08 p. m.	14¾	10	E.	2.5	0	19	0
5063	2.36 p. m.	15½	8	E.	2.7	2	4	0
5064	3.09 p. m.	13¼	9	E.	2.7	0	1	0
5065	3.42 p. m.	14	29	E.	2.7	0	2	0
5066	4.06 p. m.	18	23	E.	2.3	0	4	0
5067	4.41 p. m.	12¼	12	ESE.	2.7	0	4	0
5068	5.25 p. m.	12	12	SE.	2.7	3	4	0

[a] Rainfall, night previous, 0.09 inch. Time of cessation, 3.25 to 3.55 a. m.

While there was but 0.09 inch of rain in the night of September 19, very important results were obtained on September 20. Tables II and V give the results secured. Fog prevailed during the entire day, and the bark on the trees dried very slowly. Examination of the ascospore traps to determine the duration of spore expulsion (Tables XIII and XVII) showed that in 8 out of 19 the perithecia were active after 9.18 a. m.

All of the 13 plates exposed previous to this time yielded colonies of *Endothia parasitica*. Eight of these exposures were made in the open field at varying distances south and west of the plot of diseased trees (fig. 2), the wind being from the northeast. The distance relations brought out by these tests are discussed later. Although five ascospore traps showed evidences of the occurrence of spore expulsion after 10.07 a. m., no colonies of this fungus appeared in any of the plates exposed after 9.23 a. m. This indicates that spores were evidently not sufficiently numerous in the air after that time to be detected by the exposure-plate method.

The results obtained on September 21, as shown in Tables II and VI, bring out again the direct relation of rain to wind dissemination. Two plates exposed during a 16-minute interval between showers in the early morning yielded colonies of *Endothia parasitica* in such numbers as to prove without doubt that ascospores were very prevalent in the air at that time. After the second rain, ending at 8.20 a. m., only the five plates exposed within an hour after its cessation yielded colonies of *E. parasitica*, even though 14 out of the 21 ascospore traps examined showed that considerable spore expulsion had taken place after 10 a. m. (Table XI). However, a south wind of increasing velocity prevailed, and at 9.21 the sun appeared, causing a marked rise in temperature, so that the bark dried very rapidly after that time. Furthermore, the higher wind may also have dispersed and scattered the fewer spores expelled thereafter to such an extent that none happened to fall into the exposed plates.

TABLE VI.—*Record of exposure plates made on September 21, 1913, at West Chester, Pa.*

Plate No.	Time.	Length of exposure.	Station No.	Wind. Direction.	Wind. Miles per hour.	Number of bacteria and yeasts.	Total number of fungi.	Number of colonies of Endothia parasitica.
RAIN NO. 1 (ABOUT 0.35 INCH, CEASED 6.24 A. M.)								
		Minutes.						
5069	6.23 a. m.	14¼	12	SSE.	2.6	(a)	30	12
5070	6.30 a. m.	10½	13	SSE.	2.6	(a)	50	20
RAIN NO. 2 (ABOUT 0.08 INCH, 6.40 TO 8.20 A. M.)								
5071	8.35 a. m.	20	13	SSE.	2.6	(b)	70	62
5072	8.37 a. m.	19	12	SSE.	2.6	2	28	24
5073	9.04 a. m.	13½	13	SSE.	3.1	1	21	19
5074	9.16 a. m.	15¼	19	S.	3.1	1	5	1
5075	9.21 a. m.	12	11	S.	3.1	0	9	2
5076	9.40 a. m.	15	13	S.	3.1	3	37	0
5077	9.43 a. m.	13½	37	S.	3.1	1	18	0
5078	10.25 a. m.	15	13	SSW.	5.8	3	30	0
5079	10.28 a. m.	16	19	SSW.	5.8	12	80	0
5080	10.46 a. m.	10	37	SSW.	5.8	0	21	0
5081	11.00 a. m.	12	14	SSW.	5.8	6	44	0
5082	11.07 a. m.	13½	37	SSW.	5.8	1	28	0
5083	11.48 a. m.	16½	12	SSW.	5.8	5	98	0
5084	1.19 p. m.	15½	13	S.	5.6	0	26	0

[a] Numerous. [b] Few.

TABLE VI.—*Record of exposure plates made on September 21, 1913, at West Chester, Pa.*—Continued

Plate No.	Time.	Length of exposure.	Station No.	Wind.		Number of bacteria and yeasts.	Total number of fungi.	Number of colonies of Endothia parasitica.
				Direction.	Miles per hour.			
RAIN NO. 3 (ABOUT 0.03 INCH, 1.43 TO 2.11 P. M.)								
		Minutes.						
5085	2.20 p. m.....	3½	13	S.	6. 2	8	160	0
RAIN NO. 4 (ABOUT 0.04 INCH, 2.20 TO 2.50 P. M.)								
5086	2.53 p. m.....	15¾	13	S.	6. 2	0	144	0
5087	3.10 p. m.....	14½	12	S.	6. 2	0	35	20
RAIN NO. 5 (ABOUT 0.03 INCH, 3.26 TO 4.07 P. M.)								
5086A	4.08 p. m.....	19¾	13	S.	8. 0	10	58	0
5087A	4.17 p. m.....	14	37	S.	8. 0	3	50	0
5088	4.35 p. m.....	10	11	S.	8. 0	4	45	0
5089	4.55 p. m.....	15	12	S.	8. 0	6	42	0
5090	5.16 p. m.....	17½	11	S.	8. 0	3	38	0
5091	5.33 p. m.....	11	10	S.	8. 0	5	20	0

In the afternoon of the same day three light showers occurred, and one plate exposed in the interval after the second of these caught 20 ascospores. After the first of these showers the exposure was cut too short by the recurrence of rain to give a reliable test. It will be seen that none of the six plates exposed during the 1 hour and 36 minutes after the last shower yielded colonies of *Endothia parasitica*, despite the fact that 6 out of 11 ascospore traps examined (Tables XIV and XVII) gave evidence that expulsion had occurred during that period. In explanation it may be stated that the wind had attained a higher velocity at this time and was blowing quite briskly in the open. It is readily conceivable that with such a wind the spores as they were expelled might have been transported with such speed and their numbers dissipated so rapidly that none chanced to fall on the rather small area represented by the exposure plates.

A rather heavy rainfall was recorded on the night of September 21, but it ceased before 12.45 a. m. Examination of the ascospore traps showed that there was abundant spore expulsion during the night, and 5 out of 21 traps gave evidences of the occurrence of expulsion after 7.30 a. m., on September 22 (Tables XV and XVII). Of the 13 plates exposed between 5.56 a. m. and 7.35 a. m. but 2 yielded positive results (Table II). No spores were caught in any of the plates exposed thereafter, even though two ascospore traps bore evidences of the occurrence of light expulsion after 11.24 a. m. The meager results obtained on this date are no doubt due to the long period of time intervening since the cessation of rain the night before.

Clear, hot weather prevailed during September 22 and 23, and no spores were caught.

The relation of the time elapsed since the cessation of rain to the prevalence of ascospores in the air among diseased trees is shown in Table VII.

TABLE VII.—*Relation of the time elapsed since the cessation of rain to the number of spores falling on an area of 1 square foot per minute in 1913 at West Chester, Pa.*

PLATES EXPOSED ON SEPTEMBER 18, 1913

No. of plate.	Time elapsed since cessation of rain.	Number of colonies of Endothia parasitica.	Number of spores of Endothia parasitica falling on an area of 1 square foot per minute.
	H. m.		
4787	1 51	11	15.74
4788	1 54	16	22.32
4789	2 ..	9	12.55
4790	2 19	4	4.29
4791	2 35	5	6.34
4792	2 48	2	2.53
4793	2 54	2	2.32
4795	3 25	2	2.53
4796	3 34	1	1.27
4797	3 58	1	1.36
4798	4 4	0	0
4799	4 29	0	0

PLATES EXPOSED ON SEPTEMBER 21, 1913

No. of plate.	Time elapsed since cessation of rain.	Number of colonies of Endothia parasitica.	Number of spores of Endothia parasitica falling on an area of 1 square foot per minute.
5071	15	62	43.24
5072	17	24	17.62
5073	44	19	19.64
5074	56	1	0.91
5075	1 1	2	2.32
5076	1 20	0	0
5077	1 23	0	0
5078	2 5	0	0

An examination of these tables shows that on September 18 the spore content of the air decreased more or less gradually during the third and fourth hours after the rain, while on September 21 the spore content decreased very abruptly and no spores were obtained after the first hour following the cessation of the rain. The duration and the abundance of the ascospore expulsion on these dates (Table XI) are seen to have differed likewise, and a comparison of the weather conditions gives the probable explanation, since it was calm and foggy on the 18th and hot and sunny with a brisk wind just following the rain of the 21st. Conditions following the rain on the 18th were such as to prevent rapid drying of the bark, so that spore expulsion continued during a much longer time than on the 21st, when the bark dried rapidly. Furthermore, the brisk wind of September 21 would tend to disperse the spores very rapidly, whereas the comparative calm of September 18 would be favorable to a more prolonged prevalence in the air near their source. In this regard it should also be noted that on September 20 (Table II), when foggy weather followed the rain, spores were prevalent in the air during at least five hours after the rain had ceased.

A glance at the figures representing the number of spores falling each minute on a surface equal to 1 square foot shows that during periods of one to four or more hours after a rain—in other words, during such time as expulsion continues—healthy trees among diseased ones would be subject to infection, since some of the ascospores would find lodgment upon exposed parts of trunks and branches.

The results obtained in the early morning of September 20 by making exposures in an open field at varying distances from the principal source of spores (figs. 2 and 3) are presented in Table VIII.

TABLE VIII.—*Relation of distance from source of spores to number of spores falling on an area of 1 square foot per minute in 1913 at West Chester, Pa.*[a]

Plate No.	Time.	Distance from source of spores.	Number of spores falling on an area of 1 square foot per minute.
		Feet.	
5044	6.03 a. m.	27	24.07
5045	6.14 a. m.	85	12.52
5046	6.18 a. m.	180	6.51
5042	5.55 a. m.	266	7.51
5047	6.20 a. m.	409	9.30
5041	5.50 a. m.	414	8.71

[a] Plates exposed on Sept. 20, 1913.

These exposures, all made within about half an hour and in the same general direction from the plot of diseased trees—i. e., the direction toward which the wind was blowing—show that in a general way the number of spores falling upon equal surfaces in equal intervals of time decreases as the distance from the source of spores is increased. The fact alone that in an open field at rather long distances from diseased trees ascospores were prevalent in the air to such an extent that every minute from 6 to 24 spores were settling upon a surface equal to 1 square foot (Pl. LXIII, figs. 1 and 2) indicates that at such a time many opportunities would be offered for exposed parts of undiseased trees at considerable distances from diseased ones to become infected by wind-borne ascospores.

Furthermore, these results show that the maximum distance over which ascospores might be transported by the wind was by no means obtained, and the large numbers found at the longest distances in this experiment, given in Table VIII, when a light wind prevailed, indicate that even with a relatively light wind ascospores are probably conveyed distances far greater than these.

In a consideration of the exposure plates yielding the high numbers of colonies of *Endothia parasitica* it is interesting to note the relatively large proportion of the spore content of the air formed by ascospores of this fungus at certain times (Table IX).

TABLE IX.—*Percentage of the number of spores of Endothia parasitica to the total spore content of the air, as shown by exposure-plate tests on chestnut-bark agar in 1913 at West Chester, Pa.*

Plate No.	Date.	Total number of fungous colonies.	Number of colonies of Endothia parasitica.	Percentage of colonies of Endothia parasitica to total spore content of air.	Plate No.	Date.	Total number of fungous colonies.	Number of colonies of Endothia parasitica.	Percentage of colonies of Endothia parasitica to total spore content of air.
4383	Aug. 27....	30	16	53	5046	Sept. 20....	9	7	77
4384	...do.......	25	21	84	5047	...do.......	11	10	91
4385	...do.......	70	33	47	5048	...do.......	6	6	100
4386	...do.......	25	20	80	5049	...do.......	9	7	77
4787	Sept. 18....	20	11	55	5050	...do.......	6	3	50
5041	Sept. 20....	12	10	83	5069	Sept. 21....	30	12	40
5042	...do.......	9	7	77	5070	...do.......	50	20	40
5043	...do.......	10	4	40	5071	...do.......	70	62	88
5044	...do.......	23	22	95	5072	...do.......	28	24	85
5045	...do.......	14	11	78	5073	...do.......	21	19	90

In connection with these figures it should be borne in mind that the fungi represented are such as will grow only on chestnut-bark agar. Taking into consideration, however, the relatively large numbers of other fungi ordinarily developing in the exposure plates (Table I), it is a noteworthy fact that at certain periods when ascospore expulsion was in progress the spores of this one species should constitute from 40 to 100 per cent of the total spore content of the air.

Since these plates were exposed not long after a rain, a possible explanation suggested is that spores of other fungi were washed from the air by the rain and the supply had not yet been replenished, whereas conditions were very favorable to the abundant expulsion of ascospores of *Endothia parasitica.* It has also been suspected that certain types other than this fungus which were often found in plates exposed at such times represented other ascomycetous fungi the spores of which had just been expelled.

SUMMARY OF EXPOSURE-PLATE TESTS

In all of the exposure plates yielding colonies of *Endothia parasitica* it was determined from the time of appearance of these colonies that all originated from ascospores. Therefore we may safely state at the outset that under the conditions of the tests little or no wind dissemination of pycnospores occurred.

By comparison with ascospore-trap tests it is evident that ascospores of *Endothia parasitica* were caught in the exposure plates in numbers and at some distances from trees only during certain periods following rains when ascospore expulsion was in progress. The possible exception occurred on the morning of September 8, when no series of observations was made on the ascopore traps.

As the occurrence of ascospores in the air in considerable numbers is the prime requisite for wind dissemination and as ascospore expulsion occurs only when the perithecia-bearing bark has been wet by rains, the following facts are presented to show that wind dissemination is directly dependent upon weather conditions causing spore expulsion.

Of the total number of 756 plates exposed during these tests 95 were exposed while ascospore expulsion was known to have been in progress, and of these, 41 yielded colonies of *Endothia parasitica*. Of the remaining 661 plates exposed at other times than those noted above, but 23 yielded colonies of *E. parasitica*, and 14 of these were exposed within 12 hours after expulsion was known to have occurred.

To bring out in a more striking manner the relation of rain to wind dissemination, it is worthy of note that out of a total of 427 ascospores of *Endothia parasitica* caught in the exposed plates 402, or 94 per cent, were caught in plates exposed while spore expulsion was known to have been in progress, and of the remaining 25 spores 3 were caught within 5 hours after the cessation of a rain (Sept. 8) and 12 more were caught within 12 hours after ascospore expulsion was known to have occurred. This leaves but 10 out of 427 spores, or 2.3 per cent, seeming to be stray ascospores bearing no relation to a rain.

As to the origin of the 22 colonies of *Endothia parasitica* appearing in plates exposed when spore expulsion was known not to be in progress (see Table II), the following points are cited to prove that they originated from stray ascospores which, after expulsion, lodged on near-by or, perhaps, distant trunks, limbs, or leaves and were subsequently loosened by the mechanical action of some agency.

1. All but one of the 21 plates containing these colonies yielded only a single colony of *Endothia parasitica* each.

2. In one colony a fragment of bark was visible at its center.

3. All except one of these spores were caught at stations more or less overhung by branches of diseased trees, and all except three were caught on stumps surrounded by sprouts.

4. Only 1 out of 192 plates exposed at unsheltered stations when expulsion was not in progress yielded a colony of *Endothia parasitica*.

If these had been stray spores that were still floating in the air since expulsion, they would have fallen just as frequently into plates exposed out in the open at unsheltered stations. During a period of ascospore expulsion following a rain it seems probable that the spores would not all be swept away by air currents but that some few would find lodgment upon near-by leaves and branches. Such lodgment is especially likely to take place if there is no noticeable wind when expulsion is in progress. Thus, it seems quite probable that the colonies obtained when perithecia were not active originated from spores dislodged from either healthy or diseased parts of trees more or less overhanging the plates.

Unless attached to a bark fragment, the path of these spores in falling would not necessarily approach the vertical, and such spores might be transported by the wind just as readily as though they were freshly expelled. This explains, perhaps, why one spore was caught in plate No. 5037, exposed 27 feet from the nearest chestnut tree. The probable reason, then, why, with this exception, such stray spores were caught only under trees is that the rareness of their occurrence in the air prevented their detection elsewhere than in very close proximity to their place of temporary lodgment, since with the exposure-plate method the chance of detecting these spores decreases very rapidly as the distance from their source is increased.

Obviously no exposures could be made during a rain, but ascospore-trap examinations have shown that abundant spore expulsion may occur during the actual fall of the rain. It is evident, however, that at such a time wind dissemination would be reduced to a minimum, because the spores upon expulsion would soon be washed to the ground or to near-by bark or foliage.

Therefore, under the conditions of our tests it can be said that, with the exception of the few stray ascospores loosened from temporary lodgment, wind dissemination of *Endothia parasitica* occurs only during certain periods after rains, when ascospore expulsion is in progress.

ASCOSPORE-TRAP TESTS

In order to detect ascospore expulsion whenever it occurred, use was made of what we have termed "ascospore traps." An ascospore trap consisted of a glass object slide held in place over perithecial pustules on the bark of a diseased tree by means of a wooden bracket either above or below the slide (Pl. LXIV, figs. 1 and 2). The slide was wedged firmly into a slot in the bracket so as to be suspended about one-eighth of an inch or less from the papillæ underneath. These traps were placed on lesions of various ages on trees more or less scattered throughout the experimental plot (fig. 1).

As the ascospores of *Endothia parasitica* are expelled they adhere to the glass, and the spores expelled from each ostiole usually form a definite "spot," so that the number of spots on the slide represents the number of perithecia in the area underneath which have expelled spores.

During the progress of the work on wind dissemination, it was found possible by means of these traps not only to detect the occurrence of ascospore expulsion but to determine even with some degree of accuracy the exact duration of perithecial activity.

As has been brought out in the discussion of the exposure-plate tests, the occurrence of ascospores in the air in numbers is directly dependent upon the continuation of their expulsion after a rain has ceased. The duration of expulsion becomes, therefore, an essential factor in determining the period during which wind dissemination may occur.

In making this determination the method of procedure was as follows: Out of the total number of 69 ascospore traps usually about 20 were selected, representing areas of vigorous perithecia where previous experience indicated that abundant expulsion was most likely to occur. The slides from these traps were collected as soon as possible after the rain and were replaced with clean slides. Then, after a convenient interval, this second set of slides was collected and replaced with clean ones. This operation was repeated at intervals of several minutes to several hours until none of the slides bore spots of expelled ascospores.

Several series of trap collections were usually made after each rain, and a subsequent examination of each slide revealed whether or not any expulsion had occurred under that trap in the period during which that particular slide had been in place on the tree. Although usually visible to the unaided eye, an examination with a hand lens was often necessary to detect very faint or very diffuse spots of ascospores on the slides.

The detailed results for September 20 are given to show the behavior of individual traps (Table X). The results given in the summary for the other dates were obtained in a similar manner and the individual records will therefore be omitted.

Table X.—*Record of ascospore-trap collections on September 20, 1913, at West Chester, Pa.*[a]

Time from cessation of rain to—		Number of perithecia expelling ascospores between times stated.																		
Replacing of slides.	Collection of slides.	Trap No. 59.	Trap No. 58.	Trap No. 60.	Trap No. 62.	Trap No. 63.	Trap No. 64.	Trap No. 65.	Trap No. 68.	Trap No. 69.	Trap No. 74.	Trap No. 75.	Trap No. 72.	Trap No. 14.	Trap No. 15.	Trap No. 39.	Trap No. 40.	Trap No. 45.	Trap No. 4.	Trap No. 50.
...	2^h48^m to 3^h10^m	44	22	118	73	79	53	40+	14	238+	82	77	2	7	13	8	5	0	0	0
2^h48^m to 3^h10^m	4^h5^m to 4^h27^m	23	7	67	66	43	5	23	0	101	53	34	1	3	2	1	4	0	0	0
4^h5^m to 4^h27^m	5^h23^m to 5^h41^m	6	4	19	17	15	1	9	0	22	30	4	0	2	0	1	0	0	0	0
5^h23^m to 5^h41^m	6^h12^m to 6^h33^m	0	1	0	8	1	1	1	0	11	4	0	0	1	0	0	0	0	0	0
6^h12^m to 6^h33^m	6^h53^m to 7^h11^m	0	0	0	5	0	0	0	..	4	0	..	..	1	0	..	..	0	0	0
6^h53^m to 7^h11^m	7^h35^m to 7^h47^m	..	..	..	3	0	..	..	..	2	..	..	..	0	0	..	..	0	0	..
7^h35^m to 7^h47^m	10^h34^m to 11^h31^m	0	11	0	0	0	0	0	0	0	0	0	..	0	0	1	0	0	0	0
10^h34^m to 11^h31^m	13^h14^m to 13^h38^m	..	9	..	..	..	..	..	..	0	..	..	..	0	0	..	..	0	0	..
13^h14^m	13^h49^m	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
13^h49^m	14^h40^m	..	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

[a] Rainfall, night previous, 0.09 inch. Time of cessation, between 3.25 and 3.55 a. m.

Table XI.—*Summary of records of ascospore-trap collections in 1913 at West Chester, Pa.*

Date.	Rainfall.	Number of traps examined.	Time from cessation of rain to— Replacing of slides.	Collection of slides.	Number of perithecia expelling ascospores between times stated.
	Inches.				
		19	...	0^m to 18^m	0
Aug. 27	0.12	19	0^m to 18^m	1^h22^m to 1^h27^m	1
		14	...	0^m to 15^m	1
Do.	.055	14	0^m to 15^m	45^m to 1^h	360
		14	45^m to 1^h	14^h (Aug. 28)	227
		19	...	2^h6^m to 2^h37^m	1,047+
		19	2^h6^m to 2^h37^m	3^h19^m to 3^h54^m	53
Sept. 18	.26	19	3^h19^m to 3^h54^m	4^h20^m to 4^h38^m	9
		19	4^h20^m to 4^h38^m	5^h47^m to 7^h19^m	35
		9	5^h47^m to 6^h37^m	12^h25^m to 13^h10^m	1
		8	...	1^h48^m to 2^h4^m	236
Sept. 19	.68	10	...	3^h35^m to 5^h30^m	219
		8	1^h48^m to 2^h4^m	3^h35^m to 5^h30^m	15
		17	3^h35^m to 5^h30^m	12^h10^m to 13^h	46
		19	...	2^h48^m to 3^h10^m	875+
		19	2^h48^m to 3^h10^m	4^h5^m to 4^h27^m	433
		19	4^h5^m to 4^h27^m	5^h23^m to 5^h41^m	130
		19	5^h23^m to 5^h41^m	6^h12^m to 6^h33^m	28
Sept. 20	.09	14	6^h12^m to 6^h33^m	6^h53^m to 7^h11^m	10
		7	6^h53^m to 7^h11^m	7^h35^m to 7^h47^m	5
		18	7^h35^m to 7^h47^m	10^h34^m to 11^h31^m	12
		6	10^h34^m to 11^h31^m	13^h14^m to 13^h38^m	9
		1	13^h14^m	13^h49^m	2
		21	...	1^h40^m to 2^h	2,494+
Sept. 21	.43	21	1^h40^m to 2^h	3^h6^m to 3^h22^m	211
		19	3^h6^m to 3^h22^m	5^h28^m to 5^h36^m	0
		11	...	33^m to 41^m	1,199+
Do.	.10	11	33^m to 41^m	53^m to 1^h1^m	14
		6	53^m to 1^h	1^h31^m	0
		21	...	5^h10^m to 5^h30^m	577+
		21	5^h10^m to 5^h30^m	6^h31^m to 6^h51^m	27
Sept. 22	.73	21	6^h31^m to 6^h51^m	8^h6^m to 8^h25^m	12
		21	8^h6^m to 8^h25^m	9^h35^m to 11^h11^m	3
		2	10^h39^m to 11^h2^m	14^h12^m to 14^h16^m	6
		10	...	1^h3^m to 1^h11^m	618
Oct. 20	.85	3	1^h3^m to 1^h11^m	1^h16^m to 1^h21^m	82
		[a] 4	...	12^m to 27^m	245
		3	12^m to 27^m	22^m to 31^m	303
		4	20^m to 31^m	37^m to 43^m	387
		4	37^m to 43^m	45^m to 54^m	379
Do.	.01	4	45^m to 54^m	57^m to 1^h9^m	390
		4	57^m to 1^h9^m	1^h12^m to 1^h26^m	262
		4	1^h12^m to 1^h26^m	1^h28^m to 1^h46^m	152
		4	1^h28^m to 1^h46^m	1^h55^m to 2^h9^m	37
		4	1^h50^m to 2^h9^m	5^h21^m to 5^h54^m	2

[a] This summary includes the records of traps Nos. 58, 59, 72, and 74 only.

The data secured relative to the duration of ascospore expulsion after certain rains are given in a summarized form in Table XI. As will be seen, all of these, except the results obtained on October 20, bear reference to rains occurring during the progress of exposure-plate tests. Although the exact time of cessation of rain is a very important point, in the cases of September 18, 19, 20, and 22 it could not be more accurately determined, because the rains all ceased in the night. A comparison of the figures presented in these tables with the results obtained in the exposure-plate tests will show a close interrelation.

On October 20 another opportunity was offered to obtain data relative to duration of spore expulsion. By selecting only a few traps and changing the slides at much shorter intervals more in detail was learned in regard to the activity of the perithecia (Table XI).

Since the point had been often suggested that these ascospore-trap tests might not yield results typical of natural conditions because of the protection from drying afforded by the glass suspended over the bark and that because of this spore expulsion was greatly prolonged, occasion was taken on October 20 to determine the validity of this contention.

About two hours after the cessation of rain, when expulsion had apparently ceased under most of the ascospore traps that were being tested (Table XI), a number of clean slides were placed at random over other areas of perithecia-bearing bark which appeared still to be damp, to determine whether or not perithecia on bark unprotected by glass slides were expelling spores at this time. Owing to the high south wind and occasional sunshine, such promising areas of bark were found only on the north side of trunks, either where loosened bark about a bad lesion had become soaked or in locations more or less protected by sprouts or by stumps from the drying action of the wind. The slides were held in place by a cord tied around the trunk, and care was taken to prevent contact with the papillæ. The results obtained from these 22 test traps are given in Table XII.

TABLE XII.—*Record of test traps on October 20, 1913, at West Chester, Pa.*[a]

Trap No.	Time of placing slide.	Time of collection.	Results of examination.
1	11.20 a. m.	1.30 to 2.00 p. m.	0.
2	11.25 a. m.	1.30 to 2.00 p. m.	1 faint spot.
3	11.27 a. m.	1.30 to 2.00 p. m.	0.
4	11.27 a. m.	1.30 to 2.00 p. m.	0.
5	11.32 a. m.	1.30 to 2.00 p. m.	0.
6	11.35 a. m.	1.30 to 2.00 p. m.	0.
7	11.35 a. m.	1.30 to 2.00 p. m.	1 light spot.
8	11.39 a. m.	1.30 to 2.00 p. m.	0.
10	11.34 a. m.	1.30 to 2.00 p. m.	0.
11	11.47 a. m.	1.30 to 2.00 p. m.	0.
12	11.47 a. m.	1.30 to 2.00 p. m.	0.
14	11.55 a. m.	1.30 to 2.00 p. m.	0.
15	12.00 to 12.04 p. m.	1.30 to 2.00 p. m.	1 faint spot.
16	12.00 to 12.04 p. m.	1.30 to 2.00 p. m.	0.
17	12.00 to 12.04 p. m.	1.30 to 2.00 p. m.	0.
18	12.00 to 12.04 p. m.	1.30 to 2.00 p. m.	0.
19	12.00 to 12.04 p. m.	1.30 to 2.00 p. m.	0.
20	12.00 to 12.04 p. m.	1.30 to 2.00 p. m.	3 spots; 1 rather heavy.
21	12.00 to 12.04 p. m.	1.30 to 2.00 p. m.	0.
22	12.17 p. m.	1.30 to 2.00 p. m.	1 light spot.

[a] Rainfall, 0.86 inch. Time of cessation, 9.09 a. m. Wind, high SSW.

SUMMARY OF ASCOSPORE-TRAP TESTS

From the standpoint of wind dissemination, the all-important feature proved beyond doubt by these tests is that in every case where ascospore expulsion occurred at all it continued for a time after the cessation of the rain, thus insuring a supply of spores in the air.

A glance over these results shows that in a general way the volume of ascospore expulsion, as measured by the character and number of spots on the slides, is greatest during or shortly after the rain and decreases more or less uniformly as the bark dries. On August 27 the rains were of the thunderstorm type, being of very short duration, and consequently the perithecia had hardly been wet for a sufficient length of time when the rain ceased. The greatest volume of expulsion occurred, therefore, a little later, evidently between 15 minutes and 1 hour after the rain had ceased.

With the exception of the rain in the afternoon of September 21, the tests of September 18, 19, 20, 21, and 22 are rather unsatisfactory, since no records could be obtained until some time after the rain had ceased. The summary for these dates (Table XI) shows that the maximum volume of spore expulsion had occurred before the first collections were made, and whether the climax occurred during the rain or shortly afterwards can not be stated. In the case of the afternoon rain of September 21 very evidently the maximum volume of spore expulsion took place before 33 minutes had elapsed after the cessation of the rain.

On October 20, after the bark had been thoroughly saturated by a rain in the night, the greatest volume of expulsion occurred within one hour after the rain. Two hours and nine minutes later a light rain of 58 minutes' duration began, and the results secured after this shower (Table XI) show that in three traps tested the greatest volume of expulsion occurred, not during the rain, but after 22 to 43 minutes had elapsed since its cessation.

As to the rate of subsidence of ascospore expulsion after the rains, Table XI shows a marked contrast between the results obtained on different dates. This has been mentioned in the discussion of the exposure plates and the relation of the subsidence of ascospore expulsion to weather conditions. In the cases of September 18, 19, 20, and 22 the duration of expulsion is seen to have been prolonged after the rains, and in all cases except September 19 the data show that the rate of subsidence was very gradual. Except for the last three hours of the duration of expulsion on September 22, fog or cloudiness and low wind prevailed, and the weather conditions were not favorable to rapid drying of the bark.

After the rains of September 21 and October 20 the rate of subsidence of ascospore expulsion was relatively abrupt and rapid, and its duration was comparatively short, especially after the second rain on September 21. Here, again, the relation of duration of expulsion to rapidity of drying of the bark is shown, since the rains on these dates were followed by brisk winds, and, except for the second rain of September 21, by rapid clearing and sunshine. Such weather conditions were, of course, very conducive to the rapid drying of the bark.

The maximum duration of ascospore expulsion as determined by these tests after each of these rains is shown in Table XIII. In considering these data the weather conditions just described should be borne in mind.

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TABLE XIII.—*Maximum duration of ascospore expulsion after the cessation of rain, as determined by the examination of slides in ascospore traps at West Chester, Pa., in 1913*

Date.	Rainfall.	Maximum duration of spore expulsion after rain.	Date.	Rainfall.	Maximum duration of spore expulsion after rain.
	Inches.	*H. m.*		*Inches.*	*H. m.*
Aug. 27	0.175	45	Sept. 21	0.43	1 58
Sept. 18	.26	6 15	21	.10	40
19	.68	5 27	22	.73	11 2
20	.09	13 14	Oct. 20	.86	3 8

It should be mentioned in this connection that the figures given in the Table XIII were secured in all cases, except that of October 20, from bark that had been protected continuously by the trap slide from the drying action of the wind, and it is possible that under such conditions the duration of expulsion may be slightly prolonged. But the data relative to the maximum duration of expulsion on October 20 were secured from bark previously unprotected by slides, since seven perithecia in five exposed areas were found to be expelling spores after expulsion had ceased in all but one area protected by the ascospore traps (Table XII). These tests prove beyond doubt that under natural conditions certain exposed areas of diseased bark do remain wet enough to cause spore expulsion fully as long as the particular areas protected by the ascospore traps. Of course, such areas would usually be in locations more or less protected from the wind or sun; but, nevertheless, they would continue to act as a source of spores for wind dissemination as long as any expulsion was in progress.

The direct bearing of the results of these ascospore-trap tests upon the results obtained in the exposure plates has been brought out in the discussion of the latter topic.

ASPIRATOR TESTS

It has already been brought out in the historical introduction that previous analyses of air by the aspirator method under natural conditions in the field during dry weather failed to show the presence of spores of the chestnut-blight fungus (2). Positive results were obtained, however, under artificial conditions in the field, and it seems probable that failure to detect spores under natural conditions was due to the fact that most of the analyses were made during dry weather. If positive results were obtained following periods of rain, that fact was not brought out in the discussion (2). In order to obtain definite information on this point, the aspirator tests reported in the following pages were made so as to include the filtration of air immediately following periods of rain, as well as during the intervening dry weather.

METHOD OF MAKING THE ANALYSIS

The apparatus used in this series of tests consisted of a 4-liter aspirator bottle set on a level stump near the center of the field (fig. 1). The nearest trees were 15 feet north, 19 feet east, and 33 feet west, and the nearest lesion was on a branch 13 feet to the north. The standard sugar-tube method of making a quantitative bacteriological analysis of air was employed. The bottle was refilled with 4 liters of water at intervals of 20 or 30 minutes, thus making the aspiration practically continuous. One sugar tube was generally used each day, and the quantity of air drawn through each tube averaged 58 liters, with a maximum of 96 liters. The medium employed was a 3 per cent dextrose agar, with a reaction of +10. Ten plates were poured for each test and were incubated and the colonies counted in the same way as those in the experiments with the water spore traps (p. 520).

TABLE XIV.—*Summary of results of aspirator tests in 1913 at West Chester, Pa.*

Sugar tube No.	Date of aspiration.	Rainfall.[a]	Quantity of air represented.	Number of bacteria and yeasts per liter.	Total number of fungi per liter.	Number of spores of Endothia parasitica per liter.	Number of species of fungi.
		Inches.	*Liters.*				
1	Aug. 19	0.40	12	26.42	4.16	0	4
2	Aug. 20	0	28	3.21	4.28	0	9
3	Aug. 21	0	36	.83	3.05	0	9
4	Aug. 22	0	48	2.29	5.21	0	7
5	Aug. 23	.25	68	1.47	17.65	0	3
6	Aug. 24	0	56	2.86	11.07	0	5
7	Aug. 25	0	56	3.96	3.96	.35	7
8	Aug. 26	0	56	4.64	8.93	0	10
9	Aug. 27	.175	47	2.12	8.3	0	11
10	.....do	....	12	3.75	5.0	.42	9
11	Aug. 28	0	68	1.35	4.04	0	12
12	Aug. 29	....	40	2.5	5.875	0	9
13	Aug. 30	1.10	60	1.25	3.91	0	7
14	Aug. 31	0	56	1.16	7.67	0	10
15	Sept. 1	0	92	1.25	38.37	0	11
16	Sept. 2	0	72	1.18	1.87	0	8
17	Sept. 3	0	72	1.32	7.91	0	12
18	Sept. 4	0	56	1.78	36.60	0	11
19	Sept. 5	0	68	1.69	20.00	0	11
20	.....do	0	4	16.78	6.25	0	7
21	Sept. 6	0	76	1.12	8.09	0	12
22	Sept. 7	....	64	4.61	3.90	0	13
23	Sept. 7 and 8	.37	12	6.25	8.33	0	10
24	Sept. 8	....	76	.39	4.86	0	10
25	Sept. 9	0	60	.16	1.41	0	5
26	Sept. 10	0	76	2.17	6.90	0	10
27	Sept. 11	0	72	....	1.94	0	7
28	Sept. 12	....	80	1.50	2.58	0	....
29	Sept. 13	.095	68	.59	1.91	0	9
30	Sept. 14	0	72	.14	1.11	0	6
31	Sept. 15	0	72	.62	1.18	0	10
32	Sept. 16	0	72	.41	1.25	0	6
33	Sept. 17	....	80	1.00	1.12	0	8
34	Sept. 18	.26	52	7.59	14.23	.192	8
35	.....do	....	64	.15	5.94	0	14
36	Sept. 19	.68	96	1.04	4.27	0	10
37	Sept. 20	.09	76	.59	1.31	0	9
38	Sept. 21	.43	40	1.50	4.50	.125	8
39	.....do	.10	28	1.52	6.25	.089	10
40	Sept. 22	.73	52	2.30	1.82	0	6
41	Sept. 23	0	80	.875	1.31	0	....
	Average	....	57.9	2.91	7.03	....	8.8

[a] [illegible] date of aspiration, except on Aug. 27.

DISCUSSION OF RESULTS OF ASPIRATOR TESTS

The results obtained from these tests are presented in Table XIV. The average number of bacteria per liter of air was 2.91, while the number of fungi per liter averaged 7.03. The number of fungus species represented in the cultures ranged from 3 to 14.

In only five instances did any colonies of the chestnut-blight fungus appear in culture, and the number of spores per liter was never large. It is not impossible that the small numbers of spores of *Endothia parasitica* obtained may be due to the effect of sunlight, for in those instances where the rains were followed by fair weather the aspirator was exposed to the direct rays of the sun for a part of the day. This may also be the explanation of the fact that no spores of *E. parasitica* were obtained after some of the rains when ascospore-trap collections made it certain that expulsion was taking place, notably those of September 7 and 8 and September 21 and 22 (Table XV). Unfortunately there are no published investigations which give any information on the effect of sunlight on ascospores of the chestnut-blight fungus.

TABLE XV.—*Relation of aspiration tests to rainfall in 1913 at West Chester, Pa.*

Date of rain.	Rainfall.	Date of aspiration.	Quantity of air tested.	Number of spores of Endothia parasitica to 10 liters of air.	Results with exposure plates.
	Inches.		*Liters.*		
Aug. 27	0.175	Aug. 27	12	4.2	+
29–30	1.10	30	60	0	−
Sept. 7–8	.37	Sept. 7–8	12	0	+
12–13	.095	13	68	0	−
17–18	.26	18	52	1.92	+
18–19	.68	19	96	0	+
19–20	.09	20	76	0	+
20–21	.43	21	40	1.25	+
21	.10	21	28	.89	+
21–22	.73	22	52	0	+

The chief explanation of the small number of spores of *Endothia parasitica* to the liter is to be found in the small amount of air drawn through each tube. While this averaged 38 liters for those tubes yielding positive results, only a few liters were drawn through the tube in the several hours during which copious expulsion of ascospores took place. The figures given in the tables are therefore smaller than the actual number of spores per liter during the period of copious expulsion. In view of these facts, Tables XIV and XV do not represent the true number of ascospores present in the air during the time of their actual prevalence, since the period of aspiration included many hours when they were not prevalent, as shown by the exposure-plate tests.

The rate of development of the colonies of the chestnut-blight fungus showed that they all originated from ascospores and none from pycnospores (5).

The spores obtained from sugar tube No. 7 two days after a rain may have been stray spores similar to those obtained in several exposure plates.

The aspirator tests do not appear to have given as reliable results as the exposure-plate method, since it may be noted from Table XV that negative results were obtained on certain days when the exposure plates showed that ascospores were prevalent. The importance, however, of the aspirator tests lies in the fact that ascospores were obtained under perfectly natural conditions in the field at a distance of 13 feet from the nearest lesion and that they were obtained at times when ascospore expulsion was taking place.

WATER SPORE-TRAP TESTS

The use of water spore traps for testing the transport of spores of the chestnut-blight fungus by the wind was the outcome of our attempts to use the method of Burrill and Barrett (3) in their study of the wind dissemination of *Diplodia zeae*. First, substituting a funnel for the glass plates employed by the writers just cited, an attempt was made to find some mixture which could be applied to the inner surface of the funnel and which would fulfill the necessary requirements, as follows:

1. The mixture must contain no substances toxic to spores of the chestnut-blight fungus.
2. It must spread readily and adhere to a glass surface.
3. It must be sticky, so as to retain the spores which lodge upon the surface, which is coated with it.
4. It must retain its sticky character at least 24 hours under field conditions.
5. It must be readily soluble in water.

Glycerin of various percentages was tried alone, as well as in combination with various quantities of gum arabic or gelatin, but in all cases the mixtures either dried too soon or did not spread well on a glass surface.

The fact that pycnospores do not germinate in water (4) suggested the substitution of dishes of sterile water for the funnels. The first idea was that analyses of the water from these dishes exposed in the field under natural conditions could be made at intervals of some days and would reveal the presence of pycnospores if they had been carried by the wind. Experience in the field, however, proved that the method was also well adapted to the study of ascospore dissemination.

DESCRIPTION OF THE WATER SPORE TRAPS

A water spore trap consisted of a crystallizing dish 5 cm. deep and 10 to 12 cm. in diameter, into which sterile water was introduced. The dishes were wrapped in paper and sterilized in the laboratory for transport to the field. Each dish was supported about 2 feet above the ground by a tripod of three small stakes driven into the ground. Ten-penny nails were driven into the ends of the stakes, whose ends were converged to make a support for the dish. The nails were held in proper position by a heavy cord attached to them and encircling the dish. By this means they were so firmly secured that they were never in danger of being blown out by the wind (Pl. LXIV, fig. 3). After placing a dish in its proper field location, 100 to 150 c. c. of sterile water were introduced. Water for this purpose was kept in stock in small Erlenmeyer flasks.

The dishes of water were exposed in the field in various selected locations and analyses made at certain intervals (fig. 3; also Pl. LXV, figs. 1 and 2).

METHOD OF MAKING A TEST

At the end of an exposure period the contents of each dish were emptied into sterile flasks provided for the purpose and transported to the laboratory at the University of Pennsylvania, where the work of making an analysis was completed. They were then replaced with other sterile dishes and sterile water introduced as before.

For each water spore trap 15 to 20 plate cultures were employed, and these were made by introducing 0.1 to 0.5 c. c. of the water by means of a graduated 1 c. c. pipette into each Petri dish. In this way only 4 to 5 c. c. of the total water returned to the laboratory were used in each

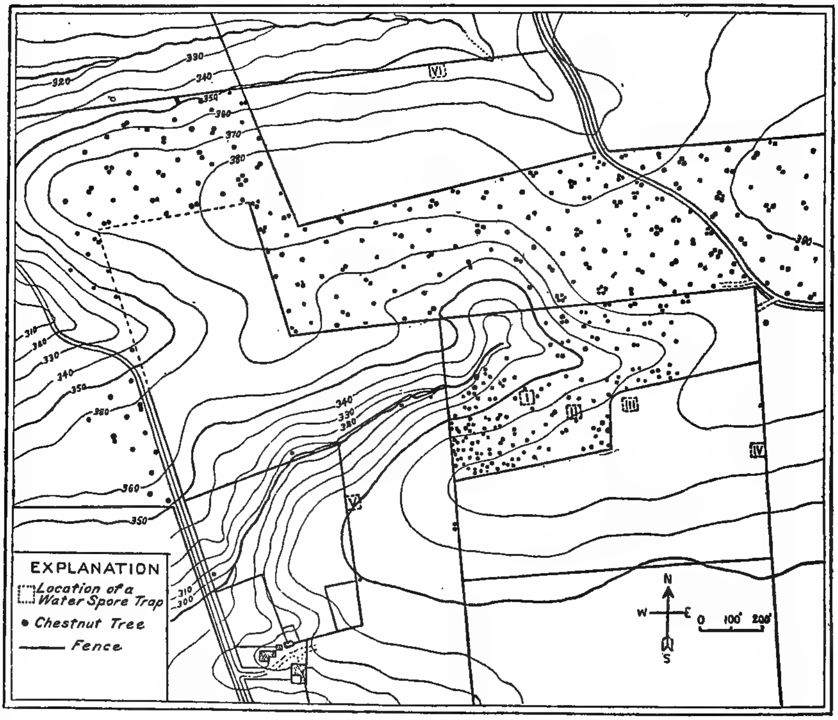

FIG. 3.—Map showing the location of water spore-trap stations Nos. I to VI. Stations I and II are in the chestnut coppice, the detailed composition of which is shown in figure 1; Stations III to V are at various distances from the same coppice; Station VI is to the north of a mixed chestnut and oak woodland.

test, but special pains were taken to secure a uniform suspension before the removal of the quantities used. Chestnut-bark agar was used for all of these analyses (see p. 496 for formula) since experience had proved that it was a poor medium for the growth of bacteria, which were always present in some quantity. In fact, the medium is so unfavorable for the development of ordinary bacteria that in most cases the colonies remained as minute specks during the period the plates were under observation and with proper dilution offered no hindrance to the development of colonies of *Endothia parasitica* and other fungi. All cultures were incubated as nearly as possible at 25° C., and the colonies of fungi suspected of being the chestnut-blight fungus were marked at the end of three days. The count was completed on the fifth day, and any uncertain colonies were transferred to 3 per cent dextrose agar for further study. In general, it may be said that transfers were not necessary, for the colonies of *E. parasitica* are very characteristic on chestnut-bark agar at the end of five days, if they have had sufficient room in which to develop. It was only in the case of plates badly crowded with other fungi that such transfers were necessary.

RESULTS AND DISCUSSION OF TESTS

The water spore traps were exposed in or near the same plot of badly diseased chestnut trees at West Chester, Pa., which was employed for the exposure plates previously reported. Six different stations were selected for the location of water spore traps at distances varying from 15 to 389 feet from the nearest blight lesions, although Station V was 404 feet from the nearest probable source of spores. More detailed information in regard to these stations is given in Table XVI.

TABLE XVI.—*Relation of water spore-trap stations to diseased chestnut trees in 1913 at West Chester, Pa.*

Trap station No.	Distance and direction from station to nearest lesions.	Position of station with reference to diseased chestnut trees.
I	25 feet west and east	Surrounded by 15- to 18-year-old coppice.
II	15 feet southwest; 19 feet north.	Do.
III	50 feet north; 50 feet west	In cornfield 50 feet from coppice.
IV	383 feet northwest	Across cornfield from coppice.
	398 feet north	Across open field from a single tall tree.
V	237 feet northwest	Across pasture from a single tall tree.
	265 feet south	Do.
	317 feet northeast	Across cornfield from a single tall tree.
	404 feet east	Across cornfield from coppice.
VI	389 feet south	Across hayfield from older forest.

TABLE XVII.—*Summary of the tests with water spore traps in 1913, at West Chester, Pa.*

Test No.	Trap station No.	Culture Nos.	Period of exposure.	Date of cultures.	Total number of fungous spores.	Number of spores of Endothia parasitica.
1	I	4227–4234	Aug. 30 to Sept. 4	Sept. 5	11,215	0
2	II	4235–4242	....do	...do	13,868	0
3	III	4243–4250	Aug. 31 to Sept. 4	...do	23,239	0
4	III	4821–4835	Sept. 4 to Sept. 8	Sept. 10	1,236	0
5	I	4906–4920	Sept. 4 to Sept. 13	Sept. 16	6,375 (?)	0
6	I	4951–4960	Sept. 13 to Sept. 18	...do	10,666	1,749
7	II	4967–4976	....do	...do	10,583	3,507
8	III	4983–4992	....do	...do	7,886	2,113
9	I	5303–5312	Oct. 13 to Oct. 20	Oct. 21	....	0
10	VI	5313–5322	Oct. 20, a. m.–p. m.	...do	1,666	30
11	IV	5345–5354	Oct. 19 to Oct. 22	Oct. 23	....	0
12	V	5355–5364	....do	...do	....	0
13	I	5371–5380	Oct. 22 to Oct. 27	Oct. 28	22,139	378
14	IV	5381–5390	....do	...do	13,148	380
15	V	5391–5400	....do	...do	4,591	820
16	VI	5401–5410	....do	...do	113,203	431
17	I	5411–5420	Oct. 27 to Nov. 10	Nov. 11	Numerous.	0
18	V	5421–5430	....do	...do	Numerous.	0
19	VI	5431–5440	....do	...do	Numerous.	0

The map (fig. 3) shows the location of the coppice growth and other chestnut trees than those used in the test, with the position of the exposure stations. The character of the diseased coppice growth is shown in Plate LXV, fig. 1, which shows a view taken from Station V. The older forest, which was the source of the ascospores for the traps exposed at Station VI, is shown in Plate LXV, fig. 2. The period from August 30 to November 11, 1913, was covered by the tests presented in Table XVII.

The time and amount of rainfall, and in some cases the wind direction, are necessary in interpreting the results. Table XVIII gives the rainfall for the time covered by the water spore-trap tests.

TABLE XVIII.—*Rainfall record for period covered by the water spore-trap tests in 1913 at West Chester, Pa.*

Date of rain.	Rainfall.	Date of rain.	Rainfall.	Date of rain.	Rainfall.
	Inches.		*Inches.*		*Inches.*
Aug. 29 and 30	1.10	Sept. 21 and 22	0.83	Oct. 20	0.08
Sept. 7 and 8	.37	30	.02	24	
12 and 13	.095	Oct. 1	1.12	25	1.44
17 and 18	.26	2	.12	26	
18 and 19	.68	3	.06	Nov. 8 and 9	1.00
19 and 20	.09	11	.73		
20 and 21	.43	19	.86		

Tests Nos. 1, 2, and 3 were started in the field after the rain of August 29 and 30, late in the day, and the traps were taken to the laboratory for analysis before the next rain. Judging from the results obtained from our exposure plates, no ascospores should have been present, and our failure to get any colonies of the chestnut-blight fungus in the test cultures suggests that during that period there was no wind dissemination of either pycnospores or ascospores. There was a small amount of rain during the period that traps 4 and 5 were exposed, but the analyses were not made until two and three days later. Considering the fact that ascospores germinate at once in water, the failure to get any colonies of the *Endothia parasitica* in these tests is not surprising and again points to the absence of pycnospores. Traps 6, 7, and 8 were removed from the field a few hours after the heavy rain of September 18 and 19, and the analyses gave a large number of colonies of the chestnut-blight fungus. It appears probable that the spores were caught during the few hours following the rain, since the cultures indicated the origin of the colonies from ascopores only (5). It should be noted from Tables XVII and XVIII that traps 9 to 12 were removed from the field just following periods of rain. The wind was blowing from the infected trees toward trap 10 only, and this was the only one in the series which yielded the blight fungus. Traps 13 to 16 were removed from the field shortly after the rainy period of October 24 to 26, and all yielded positive results, trap 16, located 389 feet from the nearest chestnut tree, giving 431 spores. The length of time after the rain when the tests were made and the direction of the wind are the possible explanation for the negative results for traps 17 to 19. Unfortunately no traps were exposed during the rainy periods of October 1 to 3 and October 11.

It is probable that the figures recorded for tests Nos. 6 to 8 and 13 to 16 represent the number of spores blown into the traps during the few hours following the rain. This appears to be substantiated by negative results obtained during dry periods and by positive results obtained with exposure plates and slide traps just following a period of rain. The results are briefly summarized in Table XIX. It is interesting to note the number of viable ascospores of the chestnut-blight fungus that must have fallen on each square inch of water surface for the time represented. This information is presented in Table XX.

TABLE XIX.—*Summary of positive results obtained from water spore traps in 1913 at West Chester, Pa.*

Station.	Number of tests represented.	Distance of station from nearest lesion.	Total number of spores of Endothia parasitica caught, as determined by cultures.
		Feet.	
I	2	25	2,136
II	1	15	3,507
III	1	50	2,113
IV	1	383	380
V	1	237	820
VI	2	389	461

TABLE XX.—*Number of ascospores of Endothia parasitica falling on each square inch of water surface at various distances in 1913 at West Chester, Pa.*

Test No.	Surface area of water trap.	Number of spores of Endothia parasitica falling on each square inch of water surface.	Distance to nearest lesion.	Test No.	Surface area of water trap.	Number of spores of Endothia parasitica falling on each square inch of water surface.	Distance to nearest lesion.
	Sq. inches.		*Feet.*		*Sq. inches.*		*Feet.*
6	12.5	139	25	14	16.5	23	383
7	12.5	280	15	15	16.5	50	237
8	12.5	169	50	16	16.5	26	389
13	16.5	23	25				

The large number of spores of *Endothia parasitica* falling on each square inch of surface for a single rainy period certainly emphasizes the fact that healthy trees in the vicinity of badly diseased ones have innumerable opportunities to become infected by wind-borne spores.

It should be mentioned in this discussion of the results obtained by the water spore traps that there are some possibilities of error. It might be claimed that the spores found in the water traps were carried by birds or insects. This, however, appears exceedingly improbable. The cultures always indicated ascospores and tests have shown that birds are carriers of pycnospores only (8). The position of the traps was such as to reduce the insect visitors to a minimum. Insects tested as carriers of the chestnut-blight fungus yielded both pycnospores and ascospores, but the former were very much more abundant (17). Besides, it was rare that any insects were found in the exposure dishes. Furthermore, spores were present in the traps only at periods following rains when other tests had indicated their prevalence.

CONCLUSIONS

(1) As a result of 756 exposure plates made in or near the badly diseased chestnut coppice at West Chester, Pa., it can be definitely stated that ascospores of *Endothia parasitica* (Murr.) And. are prevalent in the air and after expulsion are carried for varying distances from their source.

(2) As shown by the same exposure plates, the period of prevalence of ascospores varies with the conditions following the cessation of rains; when there is a rapid drying of the bark, this period is short, but when drying is retarded, this period is correspondingly extended. The tests indicate a general prevalence of ascospores within the first 5 hours following the cessation of rains, with less abundance during later hours. The longest period for our entire series was 14 hours.

(3) During periods of dry weather ascospores, although not generally prevalent, may occasionally be detected by the exposure-plate method. These are apparently stray ascospores expelled during some previous period of rain and now loosened from lodgment on some near-by objects.

(4) In and near badly diseased chestnut groves or forests the number of ascospores falling on each square foot of exposed surface following a period of rain, as indicated by exposure plates, is very large and is sufficient to offer abundant opportunity for new infections.

(5) Ascospores are forcibly expelled in large numbers from the perithecia during and after each warm rain in case the amount is sufficient to soak up the pustules. Following a dry period a rain of 0.18 to 0.25 inch has been observed to cause copious expulsion of ascospores, while rains of 0.01 to 0.10 inch, if immediately preceded by a copious rainfall, have been sufficient to cause the resumption of spore expulsion.

(6) As determined by the ascospore traps, the duration of expulsion depends on the rapidity with which the bark dries and only continues when the stromata are moist. Under natural conditions in the field the period of expulsion for eight rains varied from 45 minutes to 13 hours and 14 minutes.

(7) In some cases at least the maximum of ascospore expulsion occurs after the cessation of rain.

(8) The fact that the period of ascospore expulsion as determined by the ascospore traps coincides in general with the period during which spores were obtained by exposure plates points to these forcibly expelled spores as the ones prevalent following periods of rain. This is definitely substantiated by the development of colonies in the exposure plates from ascospores only.

(9) It is possible to determine the presence of ascospores of the chestnut-blight fungus in the air under natural conditions in the field by the standard aspirator method of bacteriological analysis. By this method positive results were obtained following four different rainy periods, but only when the period of aspiration included a period of copious ascospore expulsion.

(10) By the use of water spore traps stationed at varying distances from diseased trees it was possible to determine that ascospores are prevalent in the air and fall upon exposed surfaces in considerable numbers, the number diminishing with the distance from the source of supply.

(11) By making possible long exposures the water spore traps offered some advantages over the exposure-plate and aspirator methods. The presence of spores of the chestnut-blight fungus, however, was never shown by this method unless the period of exposure included a period of ascospore expulsion.

(12) The failure to obtain colonies of the *Endothia parasitica* from the water spore traps exposed during dry periods, as well as the fact that only ascospore colonies were indicated in the aspirator and exposure-plate tests, points to the conclusion that pycnospores are not generally prevalent in the air at any time. If present they certainly would be detected by the prolonged exposure of water spore traps.

(13) The time immediately following a rain, when the bark is still moist, would appear to be a favorable one for new infections, since the supply of moisture would offer opportunity for germination of spores. It is a noteworthy fact that it is only during this favorable period for germination that the dissemination of ascospores takes place.

(14) All of these experiments point to air and wind transport of the ascospores of the chestnut-blight fungus as one of the very important methods of dissemination and substantiate the conclusions of Rankin (15, 16) and Anderson (1, 2). It can now be said with absolute certainty that following each warm rain of any amount ascospores are carried away from diseased trees in large numbers. Since they have been obtained in large numbers at distances of 300 to 400 feet from the source of supply, the conclusion of the authors that they may be carried much greater distances is justified. During dry periods wind dissemination of ascospores does not occur at all or sinks to a very insignificant minimum.

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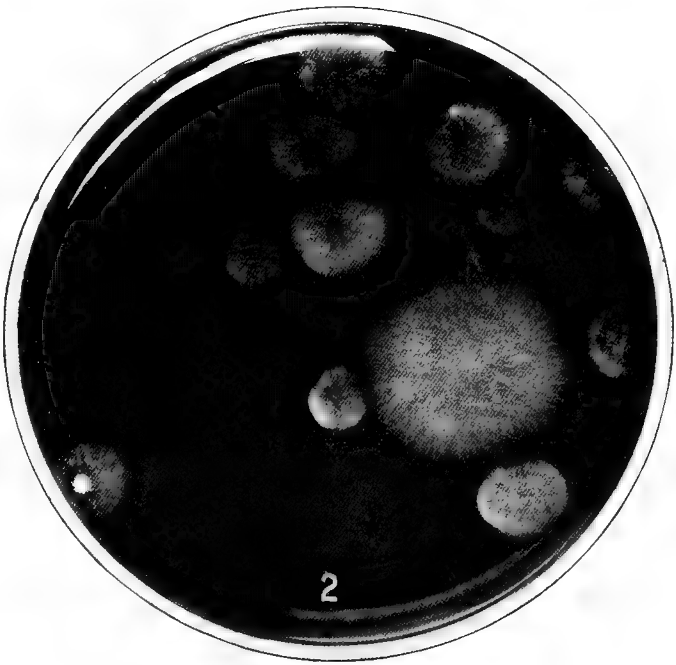
PLATE LXIII

Fig. 1.—Petri-dish culture 5044 from 12 minutes' exposure of chestnut-bark agar, made on September 20, 1913, 2 hours and 8 minutes after the cessation of a rain, at station 51, located 27 feet from the nearest lesion.

Fig. 2.—Petri-dish culture 5041 from 16 minutes' exposure of chestnut-bark agar, made on September 20, 1913, 1 hour and 55 minutes after the cessation of a rain, at station 49, located 414 feet from the source of the spores. Ten of the twelve colonies are those of *Endothia parasitica*.


1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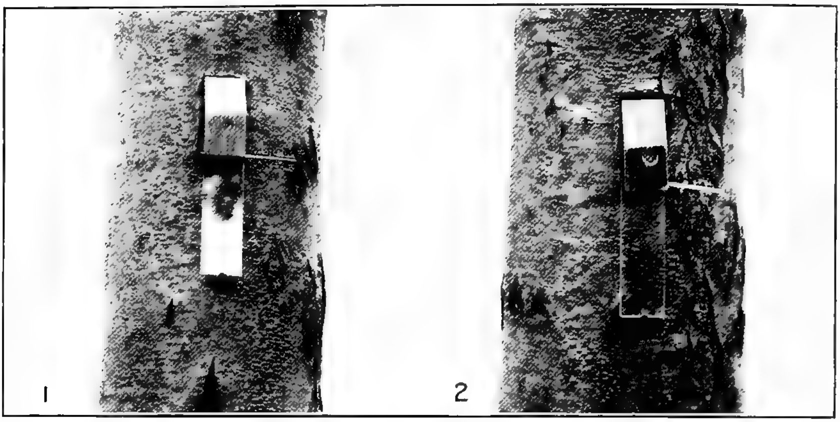
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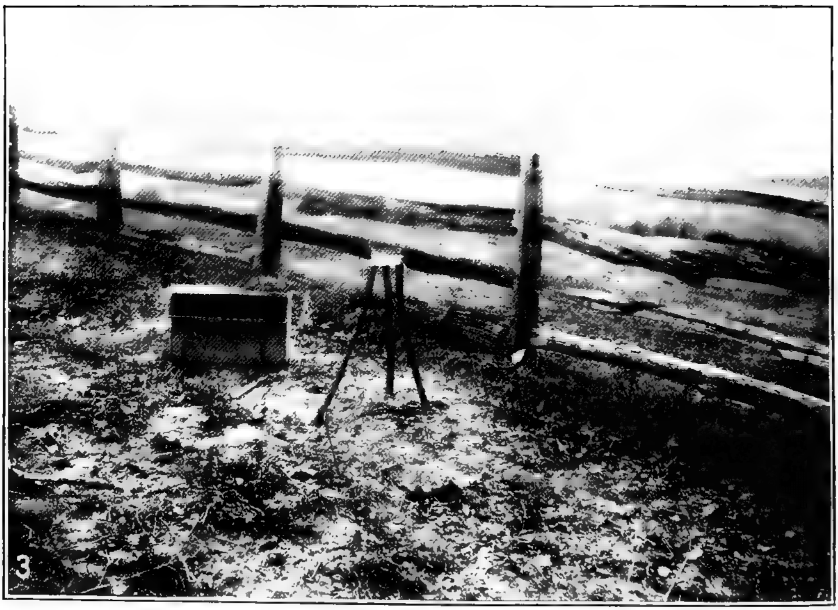
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PLATE LXIV

Fig. 1.—Ascospore trap 51. This consists of a wooden bracket which supports an object slide over perithecial pustules.

Fig. 2.—Ascospore trap 52.

Fig. 3.—Water spore trap located at Station V. The trap consists of a crystallizing dish containing sterile water and is supported on a tripod.

PLATE LXV

Fig. 1.—View looking towards the coppice growth from water spore-trap Station V. The trees in the background at the right are at the end of the plot shown in text figure 1.

Fig. 2.—View of a mixed chestnut and oak grove taken from water spore-trap Station VI. This grove was the source of the spores of the blight fungus caught at Station VI.

the undesirables, as a rule, are descended from normal parents.

Prohibition of marriage would not, therefore, have much effect upon the continued production of an undesirable class. We would have just about as many undesirable people appear in the next generation, *born from the normal population*.

Then again, the tendency to reversion to the normal type of the race is so strong that the children of undesirables are mainly of the normal type; so that prohibition of marriage would prevent the production of very many more normal children than undesirable children.

Whatever processes may be employed to improve the race, we shall always have the undesirable with us, because they are sprung mainly from the normal class; and *it is more practicable to improve the undesirable strains than to eradicate them*.

If undesirables marry normal or desirable partners they will not only have fewer undesirable children than if they married one another, but the potency of the offspring to produce undesirable grandchildren will be reduced. The undesirable blood is diluted, so to speak, by admixture with normal blood; and most of the offspring will be of the normal type.

CONCLUSION.

A public sentiment already exists that persons possessing inherited characteristics of a desirable kind should marry and have large families. This sentiment undoubtedly is favorable to the improvement of the race; but it does not go far enough.

We should impress upon the public the point that one certain means of increasing the prevalence of any hereditary characteristic in a community is to induce the individuals who possess it *to marry one another;* and thus produce a more potent stock in the next generation.

It is neither practicable nor advisable that the individuals referred to should marry exclusively among themselves, but only to a much greater extent than now prevails; and the public policy should be: Promote the marriages of the desirable with one another.

Selection by Birth-Rate

The eugenist recognizes that selection is essential to the progressive improvement of the human race, but he seeks to substitute a selective birth-rate for the selective death-rate which has been the cruel instrument used by nature.—W. C. Marshall, in the Eugenics Review.

Need of Eugenic Education

Recent investigations point with no uncertain hand to degeneracy rather than racial progress as the probable result of our existing social system. How then is this danger to be averted? The social reformer has long been busy in his attempts to improve the environment of the people; and his efforts merit our warmest approval. Progress in the evolutionary sense is, however, not certainly thus promoted, and may not be promoted at all. What we also need is an intellectual campaign, which will make the path of eugenic reform stand out more clearly in front of us by increasing our knowledge of the laws of heredity; and a moral campaign to make our fellow countrymen now ready to accept the sacrifices necessary to insure the racial progress of their country in the future.—Extract from presidential address (1913) of Major Leonard Darwin before The Eugenic Education Society, London.

THE CHESTNUT BARK DISEASE

An Undesirable Immigrant Which Has Secured Firm Foothold in Eastern United States—Breeding Resistant Species Probably the Only Solution of Problem—Opportunity for Orchardists On Pacific Coast to Build Up Industry.

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IN A remote part of northeastern China, in the province of Chili, east of the Great Chinese Wall, and four or five days' journey by bullock cart from Peking, there is a little-known section of mountainous country. Here a species of chestnut, the exact identity of which is not yet known, but which may possibly be *Castanea mollissima*, grows wild on the mountain slopes and valleys and is also cultivated by the Chinese for its nuts (fig.1). These chestnut trees have a disease which in appearance is somewhat like the European apple canker, as it occurs in America on apple trees. So far as we know it does relatively little harm to the chestnut trees of China, simply producing permanent cankers on some of them, killing a few limbs, and probably occasionally killing young trees. There is no reason to suppose that the Chinese ever had any clear cognizance of it as an especially harmful agent, and it does not appear to be conspicuous enough to have attracted the attention of even the observing traveler, until it was discovered this summer by Frank N. Meyer, of the United States Department of Agriculture. Probably it is not more conspicuous than certain canker diseases of junipers in America, which have only recently been recognized and described.

It would seem at first thought that such a condition, occurring in an unknown corner of the Orient, was about as remotely connected with any practical interest in this country as the complexion of the Grand Lama. But the world is rapidly becoming a small place, and obscure facts of natural history in one remote section may become of profound significance on the other side of the globe, affecting property, health, and even life. The disease above referred to is what we now know as the Chestnut Bark Disease, and is caused by the fungus *Endothia parasitica*. This parasitic fungus appears to have been unwittingly introduced into this country, probably in the 90's or late 80's, and to have been distributed to various points in chestnut nursery stock. The parasite found the American sweet chestnut a wonderfully susceptible host, and has spread and assumed characters on this tree which, so far as we know, are wholly unparalleled in its native habitat. There were possibly many importations of this disease. Its early history in this country is obscure, and will probably always remain so. By 1903 or 1904 it was in full blast in the vicinity of New York City, and its subsequent spread is authentic history. There were other old centers, but the vicinity of New York City appears to be the oldest.

ITS DISTRIBUTION

The disease is now generally distributed in native chestnuts from Merrimack County, N. H., and Warren County, N. Y., on the north, to Albemarle County, Va., on the south. In New York the western border of distribution is sharply delimited by an area without chestnut trees—a natural "immune zone"—which extends southward along the eastern borders of Fulton, Montgomery, and Schoharie Counties nearly to the Pennsylvania line in Delaware County. Consequently, in New York the range of the disease is at present practically limited to the valley of the Hudson. In Pennsylvania the western limit of general infection is roughly along a curved line extending

A CHESTNUT GROVE IN CHINA.

The Chinese chestnut (*Castanea mollissima*) has been cultivated for centuries by the Chinese horticulturists. This photograph, sent in by Frank N. Meyer, agricultural explorer of the United States Department of Agriculture, shows the low-branching, open-headed habit of the species. Scars on the trunks caused by attacks of the bark disease can be seen plainly. Near San tun ying, province of Chili, June 1, 1913. (Figure 1.)

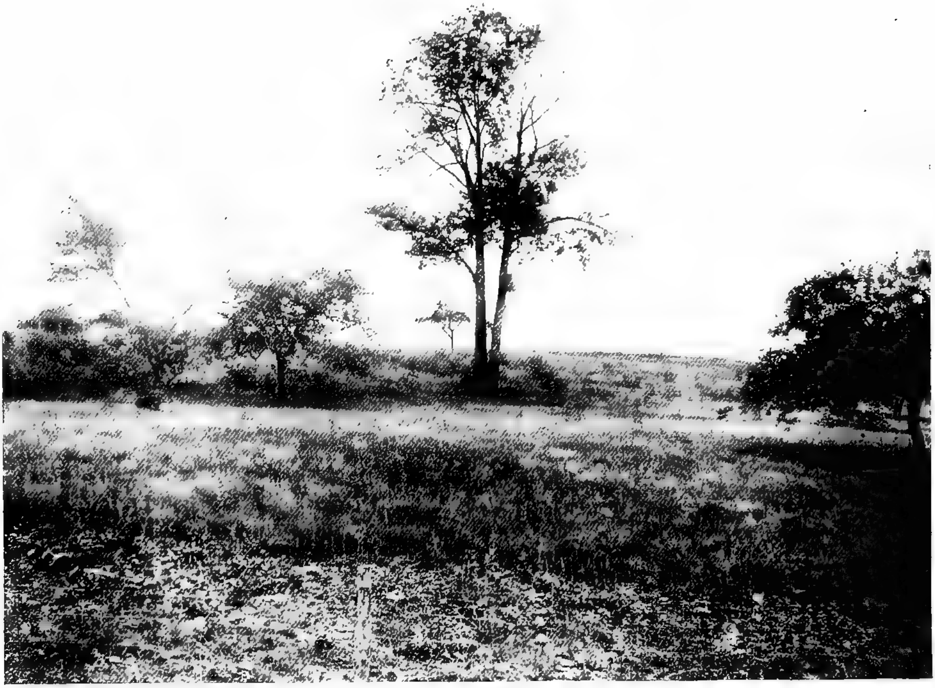
from the northwest corner of Susquehanna County to the eastern border of Clearfield County and on to the southwest corner of Fulton County. West of this line the advance infections were cut out by the Pennsylvania Chestnut Tree Blight Commission. The disease has not yet been found in Ohio or Indiana. In general it appears to spread northeastward and southwestward, following the direction of the ridges of the Appalachians, much more rapidly than westward, across the ridges and valleys.

Scattering infections occur outside of this area. Of these, the outposts are two infections on planted chestnuts in Franklin and Androscoggin Counties, Maine, and one infection in a nursery in North Carolina. There is reason to suppose that the North Carolina infection, and an orchard infection in British Columbia, owe their origin to trees in

The disease has not yet been reported from Europe, but its appearance there must be only a question of time.

It is difficult to estimate the financial loss which the above distribution represents, as we have no exact statistics on the value of standing chestnut timber. The estimate of $25,000,000 made in 1911 as representing the loss up to that time was probably much too conservative. But the total loss to date is insignificant compared with the loss which will ensue when the disease attacks the virgin chestnut timber of the South Appalachians. The bark disease has killed all the chestnut trees in those localities where it has been present long enough, and there is not now the slightest indication that it is decreasing in virulence or that the climate of any region to which it has spread is having any appreciable retarding effect upon

Insects which eat the pustules of the



AMERICAN CHESTNUT ATTACKED.

This and the four following figures, showing stages in the progress of the bark disease, were taken by Professor J. F. Collins at various points on Long Island. This photograph shows where the disease has secured a foothold on some of the smaller limbs, which are quickly killed. When the infection is on the smaller limbs, however, the rest of the tree may survive for several years. (Figure 2.)

parasite have been considered as possible retarding agents, but as these same insects appear to also distribute the spores, their controlling influence is not likely to prove important.

MANNER OF INFECTION

When, in the Chinese chestnut, any spores of the parasitic fungus gain entrance into a wound on any part of the trunk or limbs, they give rise to a canker which persists on the tree, becoming deeper year by year as healthy wood is formed around it. In the American chestnut, however, the canker rapidly enlarges until it girdles the tree. If the part attacked happens to be the trunk, the whole tree is killed, sometimes in as short a time as a single season. If the smaller branches are attacked, only those portions beyond the point of attack are killed, and the remainder of the tree may survive for several years. Ultimately, however, all American chestnut trees that are attacked, die completely (fig. 5). Figures 2, 3, and 4 show the typically ragged appearance of such trees, due to the fact that some branches are not yet girdled and still have normal foliage, while others are dead.

Limbs and trunks with smooth bark soon show cankers in the form of dead, discolored, sunken areas, which continue to enlarge and become covered more or less thickly with the yellow, orange, or reddish brown pustules of the fruiting fungus (figs. 6 and 7). From these pustules masses of minute spores (conidia) are commonly extruded

SECOND STAGE OF THE DISEASE.

One after another, the limbs are invaded by the parasitic spores, and quickly succumb. A peculiar ragged appearance in the tree is produced, due to the fact that many branches have not yet been girdled by the fungus, and therefore retain their normal foliage. When the canker begins in the trunk, it rapidly extends until it girdles the whole tree, and death quickly results. (Figure 3.)

in the form of long, irregularly twisted strings or horns (fig. 6), which are at first bright yellow to greenish yellow, or even buff, becoming darker with age. If the canker is on the trunk or a large limb with very thick bark there is no obvious change in the external appearance of the bark itself, but the pustules show in the cracks (fig. 7), and the bark often sounds hollow when tapped. After the limbs or trunks are girdled the fungus continues to grow extensively through the dead bark, sometimes, if conditions of moisture are favorable, covering the entire surface with the reddish brown pustules (fig. 7). These pustules produce mostly the type of spores called ascospores. If the proper conditions of moisture are present the fungus may grow on the bark of chestnut logs and even upon bare wood.

When a branch or trunk is girdled the leaves beyond change color and sooner or later wither (figs. 2, 3, 4, and 8). These prematurely killed leaves often remain on the branches, forming, together with the persistent burs, the most conspicuous winter symptom of the disease (fig. 8). Suspicion has been recently aroused in some quarters that the dwarfed and abortive nuts in these burs may under some circumstances be unwholesome, or even poisonous, when eaten. So far, however, the evidence on this point is wholly inconclusive.

CONSPICUOUS SYMPTOMS.

The most conspicuous symptom at all times of the year is the occurrence of sprouts at the base of the tree, on the

THIRD STAGE OF THE DISEASE.

Most of the limbs have been killed, although the withered leaves may remain on them for some time afterward, and the bark may show few external symptoms of the disease. Sprouts are put out thickly at the base of the tree and in various parts of the top where there is still vitality. Any burs produced are dwarfed, but there is no evidence to prove that nuts from them are poisonous. (Figure 4.)

trunk, or on the branches (figs. 2, 3, and 4). Sprouts may appear below every canker on a tree, and there are often many such cankers. These sprouts are usually very luxuriant and quick growing, but rarely survive their third year, as they in turn are killed by the fungus. The age of the oldest sprout, as determined by the number of its annual rings, is an indication of the minimum age of the canker immediately above. The annual development of sprouts from the base of a tree has been observed to continue for at least seven years after the death of the tree. If infection of these basal sprouts could be prevented, they would develop into a much better type of coppice than is usually seen, since they are well rooted in the ground. After the tree is dead the dead sprouts on the trunk, together with the scars left by cankers on the outer layers of wood, serve to show what killed the tree long after the bark has completely decayed and fallen away.

The wood is not materially injured, and may be used for all timber purposes for which healthy trees might be used, provided the diseased trees do not stand so long after they are dead that they become sap-rotted and checked. This fact greatly facilitates the prompt destruction of diseased trees, which will do much to check the rapid spread of the disease, and in localities where such work is organized under State control, as in Virginia and West Virginia, may limit it entirely. If the course of the disease is not thus checked by human effort, the complete destruction of the present stand of chestnut is a practical certainty. This will be

FINAL STAGE OF THE DISEASE.

The entire tree finally succumbs, often within two or three years after the first infection. The wood is not materially injured for timber purposes, but great care must be used in disposing of it, that the spores are not carried into new regions and set free on trees which have not previously been attacked. (Figure. 5)

followed by a struggle between the fungus and the sprouts from the roots of the killed trees. In this struggle the marvelous regenerative power of the chestnut may enable it finally to overcome its subtle antagonist, but so far little hope of this can be held out from observation. Hundreds of chestnut trees have been under the writer's close observation since 1907, and although some have produced a new crop of sprouts each year since that time, the sprouts have rarely passed their second year without becoming diseased, or their third year without being girdled. North of the Potomac River the main problem now is how to dispose most profitably of the timber of the dead and dying trees. In Southern New England the proposition has already been made on distinguished authority, to replace the disappearing chestnut stand as rapidly as possible with white pine.

As has been indicated, diseased chestnut nursery stock has been the most important factor in the spread of the bark disease. On account of the well-grounded fear of this disease much less chestnut nursery stock is being moved now than formerly, but there is still enough to constitute a serious source of danger. It is therefore obvious that every State in which the chestnut grows, either naturally or under cultivation, should as speedily as possible pass a law putting the chestnut bark disease on the same footing as other pernicious diseases and insect pests, such as peach yellows and the San Jose scale, against which quarantine measures are now taken. Many inspectors already have the legal power

"SUMMER SPORES" OF THE FUNGUS.

These strings or "horns" of conidia are extruded from the pustules of the fruiting fungus on all the cankered limbs. At first the conidia are bright yellow or greenish yellow, but they gradually turn darker with age. These conidia are by no means always present, however, and in some cases, as in young nursery stock, it is exceedingly difficult for anyone except an expert to detect the presence of the fungus. (Figure 6.)

PUSTULES IN CRACKS OF BARK.

When the pustule attacks a large limb or the trunk, there is little obvious change in the external appearance of the bark itself, but the pustules show in the cracks of the bark, as can be clearly seen in this photograph. The bark often sounds hollow when tapped. The fungus continues to grow after the trunk is girdled, sometimes covering the entire surface with reddish-brown pustules, which produce the type of spores called ascospores. (Figure 7.)

to quarantine against the bark disease on chestnut nursery stock, and they should now take special care that no shipment, however small, escapes their rigid inspection.

A PRACTICAL DIFFICULTY.

The most serious practical difficulty in inspecting nursery stock for this, as for other fungous diseases, lies in the fact that virtually all State inspectors are entomologists and are usually not trained in recognizing the more obscure symptoms of fungous disease. Nursery trees affected by the bark disease rarely show it prominently at the time when they are shipped; the threads of conidia or the yellow or orange pustules are rarely present, and usually all the inspector can find is a small, slightly depressed, dark-colored area of dead bark, usually near the ground, which is easily overlooked or mistaken for some insignificant injury. Upon cutting into such a spot the inner bark shows a most characteristic, disorganized, "punky" appearance and characteristic "fans" of the yellow mycelium of the fungus. Occasionally a very characteristic yellowish brown or reddish band or blotch, either girdling or partly girdling the young tree, may be seen.

If infected trees are set out they develop the disease with its characteristic symptoms the following spring. On account of their small size such trees are girdled and die before the end of the summer. Meanwhile they become a source of danger to neighboring orchard and forest trees. Orchardists and nurserymen purchasing chestnut trees are therefore urged to watch them closely during the first season, no matter how rigidly they may have been inspected.

In view of the uncertain future of the chestnut tree the planting of chestnuts anywhere east of Indiana, at least for the present, can hardly be advised. West of the natural range of the American chestnut, however, the situation is quite different. Obviously the western chestnut orchardist has before him a great opportunity. No matter how successful efforts to limit the bark disease may be, the nut crop will be reduced for some years, and the business of growing fine orchard chestnuts in the East will be depressed for the same length of time. There is no apparent reason why, with rigid inspection of purchased stock and of the orchards themselves, all chestnut orchards and nurseries from Indiana to the Pacific coast can not be kept permanently free from the bark disease; therefore, all persons interested in growing the chestnut in the West are earnestly advised to be sure that stock from any source is rigidly inspected, to watch continually and with the utmost care their own nurseries and orchards, and to destroy immediately by fire any trees that may be found diseased. The discovery of an infected orchard in British Columbia indicates that other chestnut orchards will probably be found on the Pacific coast which have become infected by direct importation from the Orient.

BREEDING NECESSARY.

Probably the most practical control results in the long run will be obtained by the breeding and propagation of varieties of chestnut that are immune or highly resistant to the bark disease. Elsewhere in this magazine Dr. W. Van Fleet has described his work in this line. It appears that so far no immune or even resistant individuals of the American chestnut have been found, in spite of strenuous search; so that we must largely depend on the Asiatic varieties. The slight resistance of the chinquapin, as observed in the field, may be due only to its comparative freedom from bark insects. The species of Chinese chestnut upon which the disease occurs in China (fig. 1) is apparently resistant to the disease in that climate, but it remains to be seen to what extent this resistance will persist when the trees are grown in America. The Japanese chestnut is highly resistant, and certain strains apparently immune; these strains form at present the most hopeful basis for breeding. At present we do not know exactly what the Japanese chestnut is; most of the trees that pass under this name in the American market appear to be hybrids with the American or other varieties.

DWARFED LEAVES AND BUR.

These are borne on a branch girdled by the bark disease. It has been widely reported that eating nuts from such burs produced symptoms of poisoning in human beings, and also that cases of poisoning had occured when squirrels which had fed on such nuts were eaten. There is not evidence, however, to prove either of these suppositions. These persistent, dwarfed burs with their abortive nuts are the most conspicuous winter symptom of the disease. (Figure 8.)

All of the Asiatic varieties of chestnut so far known are small trees and probably slow growing. The Chinese chestnut, or at least the variety shown in figure 1, bears nuts that are about the size of the American chestnut, or a trifle larger, and of a delicate, sweet flavor and fine texture. The Japanese varieties are also small trees and in general have large, coarse nuts, with a bitter adherent inner skin; but there appear to be some strains that are sweet. No European varieties have yet been found that are appreciably resistant. Perhaps the greatest desideratum at this time is a resistant tree of the forest type. But this may yet be found, as the world-species of Castanea are not yet assembled.

How much easier it would have been, and how much loss could have been avoided if importation of nursery stock had been safeguarded in time to have excluded this latest addition to our collection of foreign diseases and pests. Prevention is cheaper than cure; this is the first great lesson to be learned from the invasion of the chestnut bark disease. It is too late to exclude this undesirable citizen; but we can at least redouble our efforts to see that no others get a foothold on this continent.

Inheritance of Milk Yield

Inheritance of the property of milk production in a registered herd of cows in East Prussia is discussed by J. Peters in Nos. 11, 12 and 13 of the Deutsche Landwirtschaftliche Tierzucht, Hannover, Germany, 1913. His data show great variations in the inheritance of milk yield. The offspring of the best mothers yielded, on the average, the most milk and those of the inferior mothers least. The range of variation was not, however, so great among daughters as among mothers. First class cows produced both good and inferior offspring, and *vice versa*. The inheritance varied around a center, which was somewhat higher in the daughters of superior mothers than in those of inferior cows. The magnitude of the variation was the same for all classes.

Peters then determined the milk production of the grandparents and of the separate families of the herd. With regard to the families, he found that some produced relatively many good animals, while the descendants of others were usually inferior cows; in other families, again, he observed unusually large variations in the performance of the offspring. As a rule, however, the offspring of good families were good milkers and those of inferior families unsatisfactory. Inheritance varied in the case of mediocre families.

The writer comes to the conclusion that it is not sufficient to estimate the absolute and relative yield of cows, and upon these data to select the offspring of the best *individual* performers for further breeding, but it is necessary to select the *best families*, for among the descendants of these will be found the largest number of good milch cows. His data are summarized in the Bulletin of the International Agricultural Institute, Rome.

The Improvement of the Human Race

The improvement of the breed of mankind is no insuperable difficulty. If everybody were to agree on the improvement of the race of man being a matter of the very utmost importance, and if the theory of the hereditary transmission of qualities in man was as thoroughly understood as it is in the case of our domestic animals, I see no absurdity in supposing that, in some way or other, the improvement would be carried into effect.—Francis Galton, in Macmillan's Magazine (1865).

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 380

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER January 15, 1917

ENDOTHIA PARASITICA AND RELATED SPECIES

By

C. L. SHEAR, Pathologist, and NEIL E. STEVENS, Pathologist, Fruit-Disease Investigations, and RUBY J. TILLER, Scientific Assistant, Office of Investigations in Forest Pathology

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OFFICE OF INVESTIGATIONS IN FOREST PATHOLOGY.

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CONTENTS.

TAXONOMY.

INTRODUCTION.

The discovery of a serious canker of the chestnut in the New York Zoological Park in 1904, by Merkel (49),[2] first attracted the attention of pathologists and foresters to what has proved to be one of the most serious epidemics of a plant disease ever known in this country.

The fungus which was found associated with these cankers (Pl. I and Pl. II, fig. 1) and soon demonstrated experimentally to be their cause was described by Murrill (57) in 1906 as a new species of Diaporthe (*D. parasitica*). Search for the fungus in other places in New York and vicinity soon showed that it was already established and apparently rapidly spreading. Investigations which have been continued and extended from year to year have shown

[1] Formerly Pathologist, Office of Investigations in Forest Pathology.
[2] Serial numbers in parentheses refer to "Literature cited," at the end of the bulletin.

NOTE.—This bulletin is of value to botanists, especially plant pathologists and mycologists, and to all persons who are interested in the study of chestnut blight.

conclusively that the disease is spreading very rapidly, especially west and south from New York and also north and east.

The exact identity and relationships of the fungus causing the disease and the origin of the epidemic soon became the subject of study by various mycologists and pathologists. Different explanations were offered for the sudden appearance and behavior of the disease, one view being that the fungus was probably a foreign parasite which had been introduced; another, that the organism was probably a native species which had recently attracted attention, chiefly by reason of the weakened condition of the chestnut trees due to abnormal climatic or other conditions.

In attacking the problem of the origin of the parasite and its possible control, it was evidently necessary to secure all the information possible in regard to its life history, identity, distribution, and relationships. The senior writer in an unpublished paper prepared in 1908 pointed out the close relationship and possible identity of *Diaporthe parasitica* with certain species of Endothia. Clinton (16) and Farlow (28) soon after also made the same suggestion. Two species of Endothia had already been described from this country by Schweinitz (74) under the old generic name, Sphaeria. These, however, had in recent years been regarded as a single species and referred to *Endothia gyrosa* (Schw.). Owing to a lack of knowledge of the types of these two species and for want of good specimens showing ascospores, it was difficult to determine what species of Endothia were indigenous in the eastern United States. Since it had been suggested that *Diaporthe parasitica* was either identical with one of Schweinitz's species or a mere variety of it, the present writers undertook a thorough study of the genus Endothia in its taxonomic, ecological, and pathological relations. It was first necessary to determine the identity of the two species already described by Schweinitz from America and also to learn their distribution and host relations. As one or both of Schweinitz's species were reported to occur in southern Europe on chestnut, it was important to obtain exact knowledge in regard to the identity and relationships of the European species. The senior writer spent several months in Europe collecting material of Endothia in the field and studying herbarium specimens of types and authentic collections of Schweinitz and other authors. Material was also acquired by collection and exchange with pathologists and mycologists in nearly every region of the world in which Endothia was known to occur. Comparative cultural studies were made of all the living material secured, as well as inoculation experiments on various hosts. The recent discovery of the typical chestnut-blight parasite, *Endothia parasitica*, by Meyer (27, 76, 78), in China and Japan and the failure to find in Europe or America any native form which would produce the disease appear to settle beyond question its foreign origin.

The present paper presents the results of several years' field and laboratory study of the species of Endothia. This includes the study of practically all the herbarium material of this genus preserved in the principal herbaria of Europe and America; also field and laboratory studies of over 600 new collections from various localities and hosts in America, Europe, and Asia. Over 4,000 cultures have been studied and about the same number of inoculations made. These studies include the systematic relations of the species of Endothia and their physiological behavior on various culture media and under various conditions of light, moisture, and temperature; also inoculation experiments with the various species on various hosts.

The writers wish to record here their grateful acknowledgment and thanks for opportunities to examine specimens and for assistance rendered by various mycologists and pathologists and directors and curators of botanical gardens and museums, especially the following: Prof. O. Comes, Naples; Prof. Romualdo Pirotta, Prof. Giuseppi Cuboni, and Drs. E. Pantanelli and L. Petri, Rome; Prof. P. Baccarini, Florence; Prof. P. A. Saccardo, Padua; Dr. G. Briosi, Pavia; Dr. J. Briquet, Delessert Herbarium, Geneva; M. G. Beauverd, Boissier Herbarium, Geneva; Prof. L. Jost, Strasburg; Prof. W. Pfeffer, Leipzig; Dr. G. Lindau, Berlin; Dr. J. W. C. Goethart, Leiden; Prof. H. O. Juel, Upsala; Dr. P. Hariot, Paris; Sir David Prain, Kew; Dr. A. B. Rendle, British Museum; Prof. I. B. Balfour, Edinburgh; Prof. T. Petch, Peredeniya, Ceylon; Dr. C. Spegazzini, La Plata, Argentina; Dr. W. G. Farlow, Harvard University; Dr. W. A. Murrill, New York Botanical Garden; Mr. Stewardson Brown, Philadelphia Academy of Science; Dr. G. T. Moore, St. Louis Botanical Garden; Prof. E. Bethel, Denver, and Drs. G. P. Clinton, P. J. Anderson, and F. D. Heald. The writers have also received specimens and cultures from numerous other colleagues which have been of great assistance and are duly appreciated.

THE GENUS ENDOTHIA.

The genus Endothia was established by Elias Fries in 1849 (33, pp. 385–386), as follows:

(X. Endothia. Fr.*)

* Colore rubro fulvove, habitu Tuberculariae, peritheciis cellulosis difformibus pallidis, ascis diffluentibus, facile distinctum genus, nobis exoticum, sed jam in Europa australi obvium v. c. *Sph. gyrosa* Schw.—et subgenus, tuberculo uniloculari, sistit *S. Tubercularia* Dec. Omnium horum generum characteres proxime plenius exhibeamus, examinatis multis speciebus exoticis.

The description of the genus transcribed here was published as a footnote in the work cited and was evidently based on the specimens contained in Fries's herbarium at the time the book was written.

Fries (31, p. 73) had at that time, according to his own statement, authentic specimens of *Sphaeria gyrosa* sent him by Schweinitz and also the specimens collected by Guepin and Levieux in France, which he identified as this species. In Fries's herbarium at Upsala at present are found specimens of true *S. gyrosa* Schw. with Schweinitz's autograph label, but no specimens of *S. gyrosa* could be found attributed to Guepin or Levieux. There is a small packet marked "*Sph. gyrosa*," apparently in Fries's handwriting, but there seems to have been some confusion in the labeling or mounting of this specimen, as a small stroma of *Hypoxylon annulatum* which does not look at all like Endothia is included. The other piece consists of an irregular pycnidial stroma which may be the southern European specimens referred to in the description quoted. Fries's identification of this European material as *E. gyrosa* was apparently based chiefly upon its superficial resemblance to the pycnidial stromata of Schweinitz's American specimens. The senior writer has seen and made a careful microscopic examination of a specimen collected by Guepin in France and preserved in De Notaris's herbarium at Rome. It is labeled "*Sphaeria gyrosa* Fries, Guepin, Angers." The specific name "gyrosa" has been crossed out by De Notaris and "radicalis Schw." written above it and the date "April, 1845," added. This appears to be a part of the same collection that Guepin sent to Fries, as the specimen agrees well with Fries's description and consists chiefly of pycnidial stromata which are rather larger than is usual for *Sphaeria radicalis* and show considerable superficial resemblance to the stromata of *Sphaeria gyrosa* Schw. A thorough examination of this specimen, however, reveals a few perithecia and ascospores, which leave no doubt that it is *S. radicalis* of Schweinitz, as indicated by De Notaris on the label. What the plant sent Fries by Levieux was is unknown, as no specimen so labeled could be found in Fries's herbarium. It appears from all the evidence at hand that Fries was mistaken in his identification of the material from Levieux and Guepin, as no specimens of the true *Sphaeria gyrosa* Schw. have yet been seen from Europe.

There seems to be no doubt, however, that Fries intended the true *Sphaeria gyrosa* Schw. to represent the type of his genus Endothia, as he had a part of Schweinitz's original collection at the time and never definitely placed any other species in the genus; hence, *Sphaeria gyrosa* Schw. should be adopted as the nomenclatorial type of the genus. It is clear from Fries's writings and specimens that he knew *Sphaeria radicalis* Schw., as he had American specimens from Schweinitz as well as European collections at the time he founded this genus. He did not, however, apparently regard it as congeneric with *S. gyrosa*. His specimens of *S. radicalis* show the typical perithecia with necks, whereas no perithecia have been found in any of Schweinitz's specimens of *S. gyrosa* examined by the writers. Fries, in common with Schweinitz, regarded the pycnidial cavities of *S. gyrosa* as perithecia. When the pycnidia of *S. gyrosa* are mistaken for perithecia and compared with the real perithecia of *S. radicalis* the differences appear marked. It was therefore quite as natural for Fries to place the two species in different genera as it had been for Schweinitz to place them in different tribes of the genus Sphaeria. Fries's mistake in describing as perithecia the pycnidial cavities in the stroma of *S. gyrosa* explains his reference to the asci as "ascis diffluentibus." Believing that he had perithecia but finding no asci, he interpreted this as indicating that they had disappeared.

According to the plan of accepting only names originally applied to the ascospore stage, this name would be invalid, as proposed by Fries, and would be attributed to De Notaris, who placed the perithecial form of *Sphaeria radicalis* Schw. in the genus and described the ascospores. There is not the slightest question, however, in regard to the identity of the different stages of this fungus and their genetic connection, and the name Endothia has been almost invariably applied to these two species in both stages.

SYNONYMY.

There are only two true generic synonyms of Endothia: Endothiella Saccardo, 1906 (71, p. 278) and Calopactis H. and P. Sydow, 1913 (81, p. 82). Endothiella was based on *Endothiella gyrosa* Sacc., which, according to authentic specimens from Saccardo, is undoubtedly the pycnidial form of *Endothia fluens* as found in Italy. Calopactis was based on *C. singularis*, the pycnidial condition of *Endothia singularis* (H. and P. Syd.) S. and S. Ascospore cultures of this have not yet produced any pycnidia, but the proof of the genetic connection of the two stages appears rather conclusive from the occurrence of pycnidia and perithecia in the same stroma, as shown in Plate XII. Perithecial stromata and ascospores were also found in the specimen of the Sydow exsiccati in the Pathological and Mycological Collections of the Bureau of Plant Industry.

Von Höhnel (43, p. 1479–1481) considers Cryphonectria Sacc. as a synonym of Endothia, taking *C. gyrosa* (B. and Br.) as the type of that genus because it is the first species listed by Saccardo in connection with his description of the genus. Saccardo, however, had previously established Cryphonectria as a subgenus, with *C. abscondita* as the type, which is not an Endothia. Valsonectria is also considered by Von Höhnel a synonym of Endothia, but apparently he had not compared specimens of Spegazzini's fungus, which is found upon examination of the type species to be separate from Endothia. The

Tulasnes (83, p. 87–89) do not appear to have regarded Endothia as distinct from Melogramma, to which they referred *E. gyrosa.* The type of Melogramma, however, is *M. melogramma* (Bull.), which has a somewhat similar stroma, but the ascospores are 3-septate and dark colored and the perithecia not separable from the stroma, while the pycnospores are long, slender, and curved.

STUDY OF EARLY COLLECTIONS AND TYPES.

There has always been more or less uncertainty in regard to the identity of the older species of this genus of fungi. In order to get more light on this subject, a thorough study of all the available material in the way of literature, type specimens, and manuscripts was made. The first species to be described in this country was *Sphaeria gyrosa* Schw. This was collected by Schweinitz at Salem, N. C., and published in 1822 (72, p. 3).[1] Two hosts were given in the original description, Fagus and Juglans.

As Schweinitz's description was prepared before the advent of careful microscopical studies and spore measurements, it is impossible to identify the organism satisfactorily from the original description. It was, therefore, important, if possible, to locate the type specimens upon which the description was based. Schweinitz's herbarium was left at his death, in 1834, to the Philadelphia Academy of Science. His specimens of fungi at the time they were transferred to the academy were contained in small, folded paper packets, as shown in Plates V and VI. These packets were then inclosed in other heavy paper wrappers, folded to small quarto size, and three or four of these large packets, each bearing a manuscript list of the species contained, were then inclosed in quarto pasteboard covers, tied with tape. The individual species packets were labeled in Schweinitz's handwriting, with the name of the species and the locality of the collection, as shown in Plate V, figure 2.

These species packets frequently bore the names of several localities, but usually two, Salem [N. C.] and Bethlehem [Pa.], as most of his collecting was done at these places. This fact, in addition to the evidence afforded by the specimens in the packets, clearly indicates Schweinitz's method of handling his specimens.

Frequently some of the specimens in a packet show the remains of a gummed strip. This will be noticed in Plate III, which indicates

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[1] 24. *Sphaeria gyrosa* Sz.

S. subperipherica minor gregaria subconfluens aurantio miniata, sphaerulis gyrosis farctis demum prominulis pulverulentis, stromate lutescenta.

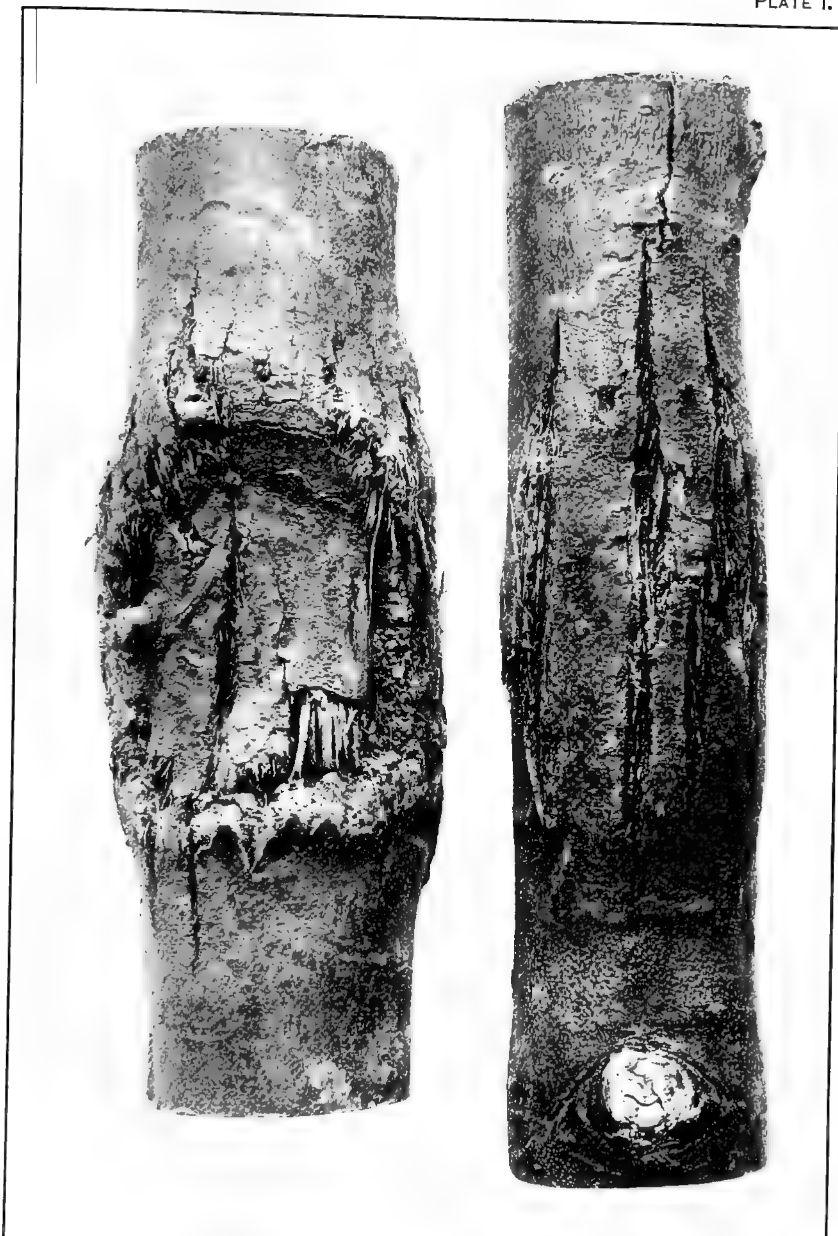
In cortice nondum corrupto etiam vivo Fagorum et Iuglandum. Junior planiuscula, ubi adolevit sistit corpus subrotundum, tuberculis minimis et magoribus asperum et gyrosum. Sphaerulae farctae, teretes, supra gyrosae, paucae, radiatim divergentes a superficie ad centrum fere stromatis continuantur, primum sublantes, demum prominulae, cortice pulverulento; ipsum tamen centrum farinacea carne componitur. Gelatina asciphora albet. Ostiola indistincta.—Transitum facit ad Sphaerias septimae divisionis.

that at one time the specimen was apparently attached to a sheet by a gummed paper strip. This seems to have been the way in which Schweinitz originally mounted his specimens, but later, apparently, he changed to the plan of putting them in paper packets and removed those which had been attached to sheets. It is clear from an examination of the specimens still found in some of the original packets that two or more different hosts were sometimes included. In some cases as many as four or five different collections appear to have been placed in the same packet and each new locality added on the outside. This method of keeping specimens makes it rather difficult in some cases to determine which belongs to the first collection. In the case of *Sphaeria gyrosa* but two localities are indicated on the packet, Salem and New England. (See Pl. VI, fig. 2.)

The difficulties in determining the true type specimen of any species would have been sufficiently great if the collection had been preserved as it was left by Schweinitz. The matter is, however, further complicated by the later handling and rearrangement of the collection. Some time after Schweinitz's death (the exact date the writers have been unable to determine) his collection of fungi was more or less completely rearranged and mounted. The greater part of this work was evidently done by Dr. Ezra Michener. Dr. Michener was a lifelong resident of Chester County, Pa. He early became interested in botany, and in 1840 was elected a correspondent of the Philadelphia Academy of Natural Science. He paid special attention to the collection and study of fungi and corresponded and exchanged with various mycologists, especially Curtis and Ravenel. He left a large collection of fungi, which the writers have recently had the privilege of examining. Among his specimens are found many labeled "Ex. Herb. Schw.", which are undoubtedly part of Schweinitz's original collections at the Philadelphia Academy. These specimens, as well as all of Michener's fungi, are mounted in exactly the same manner as the mounted portion of Schweinitz's collection at the Philadelphia Academy. The mounting paper, the specimen slips, the arrangement, manner of attachment, and the handwriting on the labels are identical, as will be readily perceived by comparing the illustrations from photographs of sheets from both herbaria. It is, therefore, clear that the mounted collection of Schweinitz's herbarium was prepared by Dr. Michener. He evidently took from Schweinitz's original paper packets what appeared to him to be the best or most typical specimen of the species in the packet and attached it with glue to a square slip of paper, as shown in Plate III. Where there was but little material in the original packet it was all mounted in this manner. In case there were several pieces in the original packet he used his own discretion in making the selection of the part to be mounted and the part to be left.

When there were included in the original packet specimens from different hosts or different localities, in some cases representing different species, it would have been difficult, if not impossible, to determine which was the original material from which Schweinitz's description was made. At the same time, Dr. Michener, in case the specimen was not too scanty, evidently took a small portion of it for his own herbarium. Michener's catalogue of his herbarium lists *Sphaeria gyrosa* Schw. Consulting his collection it is found that No. 1431, the number of Schweinitz's specimen, is missing. Pin holes in the mounting sheet, however, show that the specimen which was once there has been removed. As perhaps throwing some light on the possible location of this specimen, it may be said that a specimen apparently typical *S. gyrosa*, pycnidial form on beech, labeled by Dr. William Trelease as *Sphaeria gyrosa* from Pennsylvania, was seen in the Boissier Herbarium, Geneva. Dr. Trelease tells the writers that this specimen probably came from Dr. Michener, and as there is no evidence that Dr. Michener or any one else has collected *E. gyrosa* in Pennsylvania there is considerable probability that this specimen represents a portion of Schweinitz's original collection.

In most cases all of the material in Schweinitz's original species packets was removed and either mounted or distributed. This was the case with *Sphaeria gyrosa*. The original packet of Schweinitz, which was fortunately preserved with all the others, is empty and apparently a part at least of the specimen which it contained is found in the mounted collection as prepared by Michener. This consists of a single piece of bark shown in Plate VI, figure 1. From the evidence the writers have been able to gather from Schweinitz's manuscripts and correspondence, as well as from studies of his writings and specimens in other herbaria, it appears that this specimen is the one indicated on the original packet and also by Schweinitz (74, p. 206) as having been collected in New England and sent to him by Torrey. This, as shown by his correspondence, was after he had left North Carolina. The bark upon which the fungus grew is clearly not Fagus, Juglans, or Quercus, the hosts originally given for *S. gyrosa*, but apparently Acer. It is therefore not a part of the original specimens from Salem, N. C., upon which his description was based, and in reality is not *Sphaeria gyrosa*, but a species of Nectria, which Schweinitz incorrectly identified as *S. gyrosa*. Portions of this same specimen are found in Berkeley's herbarium at Kew and in the Curtis herbarium at Harvard. They are clearly the Nectria referred to above from Torrey. In this connection, it may be noted that E. Hitchcock in 1829 (42, p. 63) reports *Sphaeria gyrosa* Schw. from Amherst, Mass., and states in the preface to his list that Dr. Torrey assisted in the determination of the cryptogams.



"CANKERS" CAUSED BY ENDOTHIA PARASITICA ON CASTANEA DENTATA. × ½.

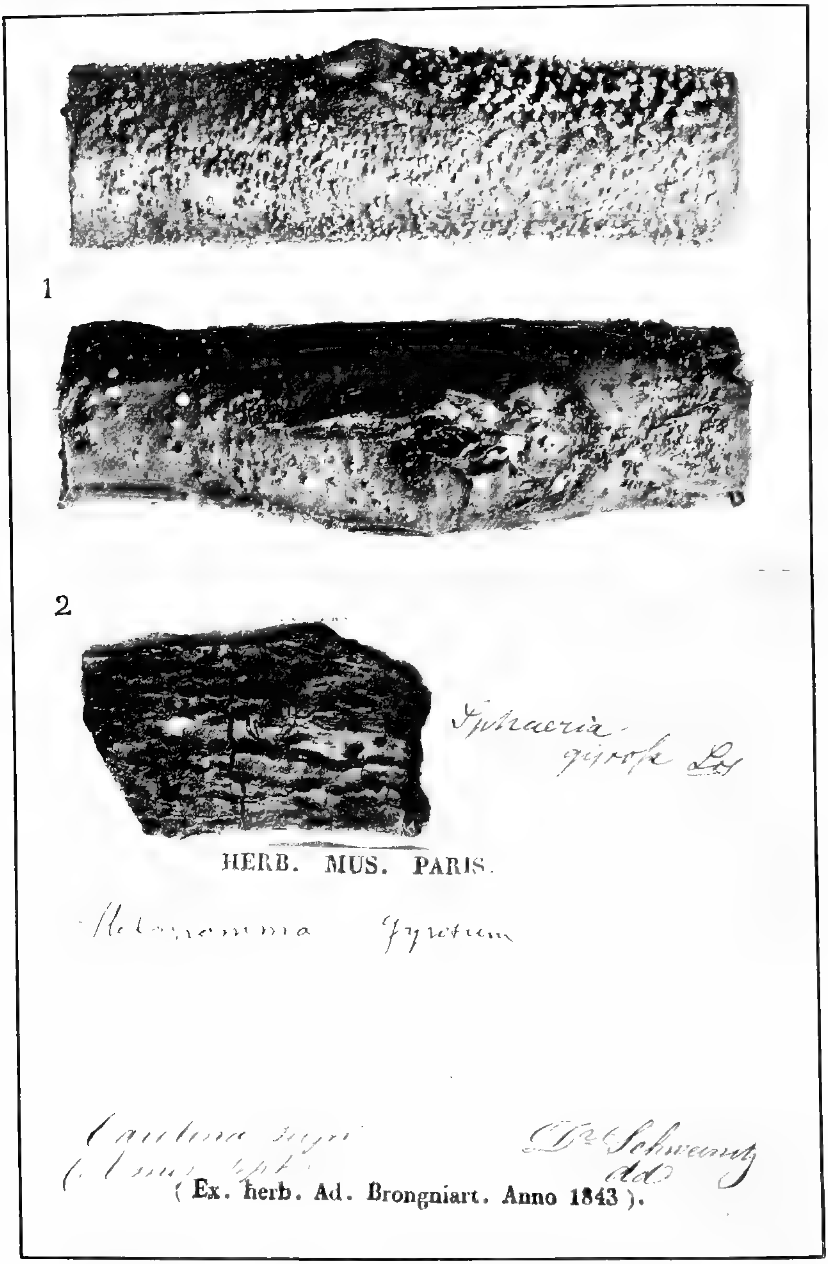
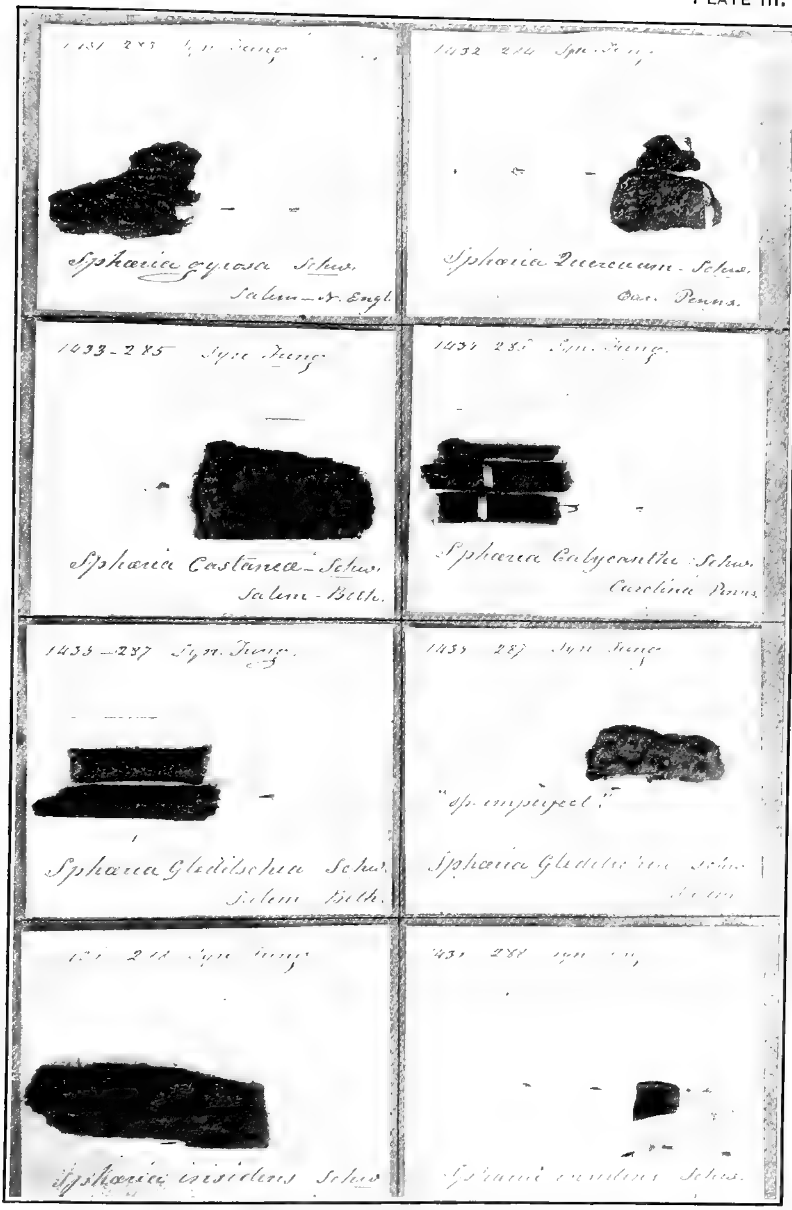
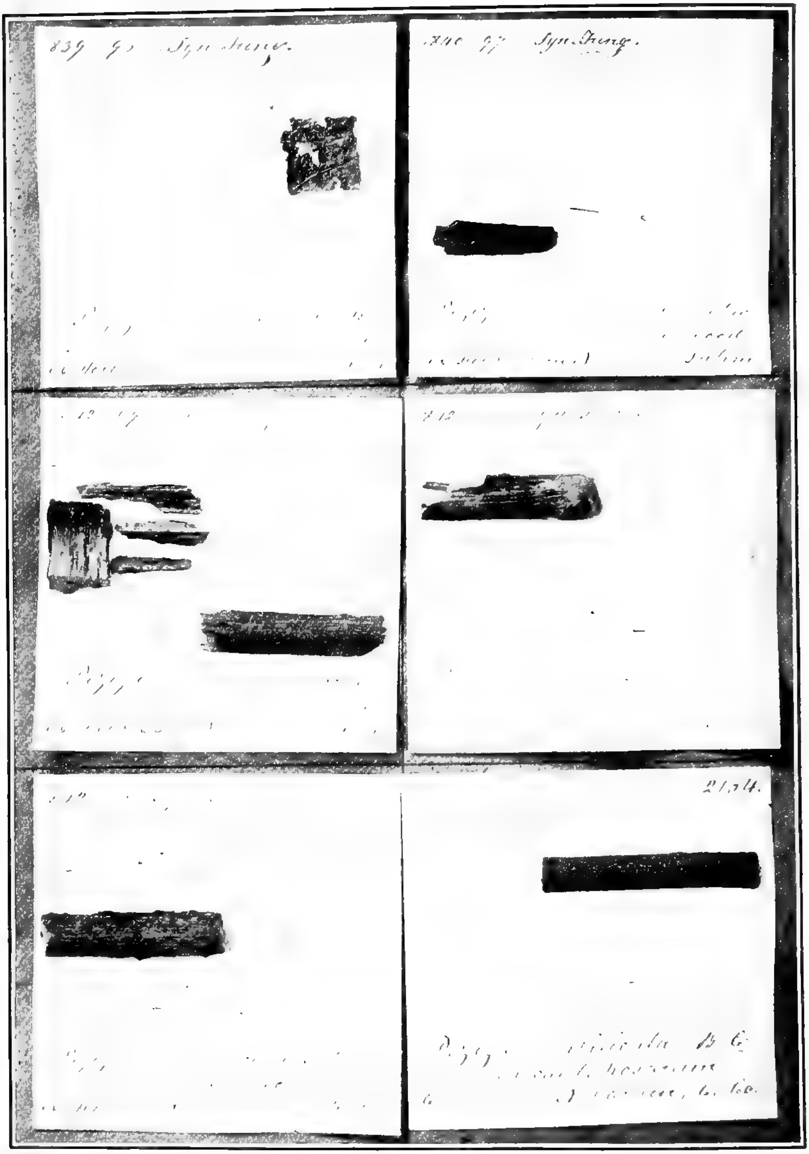


FIG. 1.—PERITHECIA AND PYCNIDIAL STROMATA OF ENDOTHIA PARASITICA WITH CANKERS ON CASTANEA DENTATA. FIG. 2.—COTYPE OF SPHAERIA GYROSA SCHW. ON FAGUS.

Specimen now in the Paris Museum sent to Brongniart by Schweinitz, showing Tulasne's label "*Melogramma gyrosum*" and Schweinitz's autograph label.



A SHEET FROM THE MOUNTED PORTION OF SCHWEINITZ'S HERBARIUM AT THE PHILADELPHIA ACADEMY OF SCIENCES, SHOWING SPECIMENS AS PREPARED AND LABELED BY MICHENER.



A SHEET FROM MICHENER'S HERBARIUM, SHOWING A PART OF SCHWEINITZ'S TYPE OF PEZIZA CINNABARINA (UPPER RIGHT HAND CORNER); ALSO SHOWING CLEARLY THAT THE MOUNTING AND LABELING OF THIS AND SCHWEINITZ'S COLLECTION WERE DONE BY THE SAME PERSON.

This seems to explain the origin of the specimen which Schweinitz received from Dr. Torrey. The writers have searched in vain for *Endothia gyrosa* in Amherst and vicinity and they know of no collections of the fungus from Massachusetts. No specimens upon which Hitchcock's list was based have been located.

Since it can be clearly shown that little or none of the original type collection of this species is in the Philadelphia Academy collection it must be looked for elsewhere. It is found by reference to Schweinitz's correspondence and manuscripts, which have been carefully examined by the writers through the courtesy of the Philadelphia Academy and the descendants of Schweinitz, and also by studies in foreign herbaria that he divided his specimens with many of his European and American correspondents. As he does not appear to have kept any duplicates separate from his regular collection it seems probable that the specimens he distributed were taken from the original packets. Thus in some cases, apparently all of a type specimen was removed from the original packet. In fact, in one instance (73, p. 5) he states that he sent his only specimen of a species of Hypoxylon to Dr. Schwaegrichen, of Leipzig.

It seems rather certain from statements made by Schwaegrichen in his introduction to Schweinitz's paper on the fungi of North Carolina (72) that specimens of a large number, if not all, of the species represented in that work were sent to him. The types or parts of the types should therefore be found in Schwaegrichen's herbarium. In spite of all their efforts, however, through correspondence and personal search in Europe, the writers have been unable to locate Schwaegrichen's collection of fungi. They found, however, in the herbarium of the University of Leipzig a small bit of a specimen labeled "*Sphaeria gyrosa* Schwein. Juglans Fagus Carolina D. Schwaegrich. dd 5–21 K. Z." This specimen is evidently a part of the original collection of Schweinitz which was sent to Schwaegrichen and given by him to Dr. Kunze. The host is apparently neither Juglans nor Fagus, but seems to be Quercus. It may be noted in this connection that in spite of diligent search by the writers and various other collectors no specimen of Endothia has yet been found on Juglans in this country. Neither have the writers been able to find any specimen in the various herbaria examined. They have concluded, as a result of their studies, that the mention of Juglans by Schweinitz was an error in the identification of the host, which it is believed was really Quercus, the host upon which *E. gyrosa* is most frequently found in the South, and especially in the vicinity of Salem. According to the American Code,[1] however, the specimen which should be taken as the type in this case is the one on

[1] American Code of Botanical Nomenclature. Canon 14, b. Bulletin, Torrey Botanical Club, vol. 34, p. 172. 1907.

Fagus, as this is the first-mentioned host in the original description. No specimen of this species on Fagus from Schweinitz was found in Kunze's collection. However, authentic specimens from Schweinitz on Fagus have been found in Fries's herbarium at Upsala, in Hooker's herbarium at Kew, and in Brongniart's herbarium in the Paris Museum. The last, which is the largest and best specimen, is shown in Plate II, figure 2. Microscopic studies of the specimens at Paris and Kew show only pycnidia with pycnospores. The writers were unable to examine microscopically the specimen in Fries's herbarium, but it agreed in all macroscopic respects and also, so far as could be determined with a hand lens, with the Paris and Kew specimens. These specimens agree with all the material collected on Fagus from various localities in the South. Studies of numerous collections of *E. gyrosa* have shown that the pycnidial form can be distinguished with certainty from any of the other species of Endothia at present known. The connection between this pycnidial form and the perithecial form as described has been demonstrated by pure cultures from ascospores and also by the association of typical pycnidia and pycnospores with perithecia and ascospores in the same stroma. There appears to be no reasonable doubt, therefore, that the specimens collected by Schweinitz on Fagus were the pycnidial form of *Endothia gyrosa*, and the specimen in the Paris Museum which was sent by Schweinitz to Brongniart about 1825 may properly be considered a cotype of Schweinitz's species. The specimen from Schweinitz in Kunze's herbarium at Leipzig also proves on microscopic examination to be the pycnidial form of the same fungus. It is probable from the evidence at hand that Schweinitz did not collect any specimen showing ascospores of this fungus. However, the specimen in Kunze's herbarium shows some perithecia evidently immature and without spores. A part of the specimen from Schweinitz in Fries's herbarium shows stromata on a piece of bark, evidently not Fagus, but probably Quercus. This also appears to be pycnidia only.

The specimen referred to by Clinton (18), which was found in the original packet of Schweinitz at Philadelphia with *Sphaeria enteromela*, is also undoubtedly the pycnidial form of *E. gyrosa*, which closely resembles some early stages in the development of species of Hypoxylon, especially *H. enteromela*. These species may be easily confused with each other, and this would seem to be a probable explanation of the accidental presence of this specimen in this packet. Another point of interest in this connection is the fact that in spite of diligent search on the part of the writers and many other collectors and an examination of numerous specimens of Endothia on Fagus in all stages of development and from different localities only *Endothia gyrosa* has been found on this host. Of course, it can not be positively stated that *E. fluens* does not occur on Fagus in this country, but if it does it must be rare. In this connection, it is also perhaps worthy of note that, notwithstanding the mention of Fagus as a host in Europe, the writers have never seen any European specimens of Endothia on this host. The specimens so named by Roumeguere and distributed as No. 989 Fun. Gal. on beech are, according to several specimens examined, evidently a young condition of some Hypoxylon, probably *H. coccineum*, which in this state bears a superficial resemblance in form and color to the stromata of Endothia, but can be easily distinguished by the dark-brown or blackish color of the interior of the stroma. The identity of Schweinitz's *Sphaeria gyrosa* with the long ascospore form of Endothia shown on Plate VII is based on careful microscopic study of the stromata and measurement of the pycnospores from four specimens of the original collections of Schweinitz in North Carolina, three on Fagus and one labeled Juglans. The three on Fagus show the typical pycnidial stromata and pycnospores of the species, either of which is sufficient for positive identification when thoroughly known. The specimen referred to by Schweinitz as on Juglans also shows typical pycnospores of *E. gyrosa*. The evidence, as stated above, leaves no reasonable doubt as to the identity of the fungus which Schweinitz described as *Sphaeria gyrosa*.

According to a specimen which is probably a portion of Schweinitz's type found in Michener's herbarium, *Peziza cinnabarina* Schw. is the pycnidial form of *E. gyrosa* (Schw.) (See Pl. IV.) It is the form with small pycnidia on bare wood of Liquidambar. This was first reported by Schweinitz as "Peziza flammea A. and S." and later changed as above. Later Saccardo (69, vol. 8, p. 399), thinking that this was a Discomycete, transferred it to the genus Lachnella.

The other American species of Endothia which was described by Schweinitz as *Sphaeria radicalis* and first published by Fries in 1828 (31, p. 73) has also until recently been more or less misunderstood. The only specimens of this species found at present in Schweinitz's mounted collection at the Philadelphia Academy of Science is a small piece of bark of an oak root bearing a few pycnidial stromata. No host was given in Fries, but Schweinitz in 1832 (74 p. 197) gives Fagus as the host. That this was an error and that the host was really Quercus and not Fagus is clearly indicated by all of Schweinitz's specimens examined, not only those in the Philadelphia Academy but those found in several herbaria in Europe and one in Curtis's herbarium at Harvard, and also in Schweinitz's autograph label on the original packet in his herbarium. A photograph of this packet is shown in Plate VI.

The description of this species was first published by Fries in 1828 (31, p. 73). Schweinitz's specimen at the Philadelphia Academy shows only pycnidia. (See Pl. V, fig. 2.) His description, however, as well as his unpublished illustrations preserved in the library of the Academy, show clearly that perithecia were present in the material from which the description was made. This is also conclusively shown by authentic specimens from Schweinitz in at least two European collections, those of Fries at Upsala and Hooker at Kew. A microscopic examination of these specimens shows good perithecia and mature ascospores having the characters and measurements given elsewhere in this paper for *Endothia fluens* (Sow.). (See Pl. XVII, fig. 9.) As there is no indication in Schweinitz's writings or in his manuscript notes and records that he made more than one collection of this species, there is no reason to doubt that the material at Upsala and Kew is a part of that upon which he based his description of *Sphaeria radicalis* Schw. The true type specimen of the species is that in Fries's herbarium upon which he based his description, which was added to the diagnosis sent by Schweinitz.

One year after the description of this species from America it was reported from Italy by Rudolph, in 1829 (66, p. 393), and in 1830 Fries (32, p. 541) himself reports the fungus from France. This species had, however, been collected and described before in its pycnidial condition in 1814 by Sowerby (79, pl. 438) under the name of *Sphaeria fluens*. This was reported in 1836 by Berkeley (8, p. 254) as *Sphaeria gyrosa* Schw. A microscopic study of the original material of this species, which was collected by Charles Lyell on chestnut in the New Forest in southern England and is now preserved in the Kew Herbarium, leaves no doubt that it is the pycnidial form of *Endothia radicalis* (Schw.). Plate XVII, figure 3, shows pycnospores from Sowerby's specimen at Kew. This specimen agrees with Sowerby's illustration and is apparently the one from which this figure was made. The pycnospore masses are somewhat larger than usual; otherwise it is typical of *E. radicalis* Schw.

At first it did not seem possible to distinguish the species of Endothia in their pycnidial condition, but thorough microscopic studies of large quantities of material in the field and laboratory in both America and Europe have shown that the two sections of the genus and some of the species can usually be separated with certainty in this stage of their development, as indicated by the tables of measurements and in the photographs of pycnospores, and especially by the stromata of the different species.

The first description of the ascospores of *E. radicalis* was given in 1858 by Currey (21, p. 272), who examined the specimens from Schweinitz in Hooker's herbarium at Kew. Currey figured what he believed to be four ascospores. Two are apparently typical *E.*

fluens; the other two are more than 1-septate and belong to some other organism. Cesati and De Notaris, in 1863 (11), first definitely referred *Sphaeria radicalis* Schw. to Endothia. Up to this time *Sphaeria gyrosa* and *Sphaeria radicalis* were generally regarded by mycologists as separate species and were placed by Schweinitz and Fries in different groups of the genus Sphaeria, though they both mention a similarity in external appearances.

In 1863 the Tulasnes, in their epoch-making work on the fungi (83, pp. 87–89), made a careful microscopic study of the specimens from Schweinitz preserved in the Paris Museum and also specimens received from De Notaris, Berkeley, and other collectors. At that time no ascospores of *Sphaeria gyrosa* had apparently been described by mycologists. The material of *S. gyrosa* from Schweinitz which the Tulasnes found in the Paris Museum included the specimen on Fagus which had been sent by Schweinitz to Brongniart. There seems to be no evidence that the Tulasnes examined other specimens from Schweinitz or that they examined any specimens showing ascospores of the true *Sphaeria gyrosa.* This is indicated by their description and measurements of the ascospores. From their studies of Schweinitz's specimens and from other Carolina specimens sent them by Berkeley they concluded that *Sphaeria gyrosa* and *Sphaeria radicalis* are the same species and called it *Melogramma gyrosum.*

Fries (33, pp. 385–386) had earlier (1849) reported *Sphaeria gyrosa* as occurring in southern Europe. This report was apparently based upon specimens of pycnidial stromata of *E. fluens*, somewhat larger and more irregular in shape than usual, collected in western France by Guepin and Levieux and already referred to.

The statement of the Tulasnes (83, pp. 84–89) in regard to the identity of these species was accepted by practically all mycologists down to 1912, when the discussion in regard to the origin and relationships of *Endothia parasitica* commenced. Ellis and Everhart in 1892 (26, p. 552) apparently figured the true *E. gyrosa* Schw. but cited exsiccati of both *E. gyrosa* and *E. fluens* and gave the ascospore characters and measurements of *E. fluens*, apparently copied from Winter (85, p. 803), as the spores figured do not agree with the description.

THE SPECIES OF ENDOTHIA.

ENDOTHIA Fries, 1849, Sum. Veg. Scand., p. 385.[1]

SYNONYMS:

Endothiella Sacc., 1906, in Ann. Mycol., v. 4, no. 3, p. 273. Type species, *E. gyrosa* Sacc., l. c.

Calopactis H. and P. Syd., 1912, in Ann. Mycol., v. 10, no. 1, p. 82. Type species, *C. singularis*, l. c.

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[1] All references to literature in synonymy are given in full in "Literature cited," p. 77.

Stromata subcorticular in origin, variable in size and shape, pustular to subspherical, subcoriaceous to friable, sometimes confluent, surface light auburn[1] or chestnut to mahogany red, capucine yellow or cadmium orange to scarlet within; pycnidial and perithecial stromata the same or similar; pycnidia few to numerous, consisting of simple cavities or complex and irregular chambers; pycnospores minute, simple, bacilliform to oblong, yellowish to reddish in mass; perithecia deeply immersed, in one or more irregular layers, usually black when mature, with long necks, black within, colored like the stroma without; asci clavate to oblong fusoid, 8-spored, usually without paraphyses; ascospores oblong fusoid or subellipsoid to cylindric or allantoid cylindric, uniseptate or nonseptate, hyaline to pale yellowish.

Section 1.—Ascospores short cylindric to allantoid, continuous or pseudoseptate.

ENDOTHIA GYROSA (Schw.) Fries, 1849, Sum. Veg. Scand., p. 385. p. p.

SYNONYMS:

Pycnidia: *Sphaeria gyrosa* Schw., 1822, Syn. Fung. Car. Sup., p. 29, no. 24.
- *Peziza flammea* Schw. (not. Alb. and Schw.), 1822, Syn. Fung. Car. Sup., p. 93, no. 41, p. p. ad Liquidambar.
- *Sphaeria gyrosa* Fries, 1822, Syst. Mycol., v. 2, p. 419.
- *Peziza gyrosa* Spreng., 1827, Syst. Veg., v. 4, pars. 1, p. 515.
- *Peziza cinnabarina* Schw., 1832, Syn. Fung. Am. Bor., p. 173.
- *Melogramma gyrosum*, L. R. and C. Tul., 1863, Selecta Fung. Carpol., t. 2, p. 87. p. p. min.
- *Melogramma gyrosum* M. A. Curtis, 1867, Cat. Indig. Nat. Plants, p. 143.
- *Endothia gyrosum* (Tul.) Fckl., 1869, Symb. Mycol., p. 226.
- *Melogramma gyrosum* Tul., Rav., 1879, Fung. Amer. Exs., no. 352.
- *Lachnella cinnabarina* Sacc., 1889, Syll. Fung., v. 8, p. 399.

Perithecia: *Sphaeria gyrosa* Schw., Rav., 1852, Fung. Car. Exs., no. 49.
- *Melogramma gyrosum* Tul., Cooke, 1878, *in* Ann. N. Y. Acad. Sci., v. 1, no. 5/6, p. 185.
- *Endothia gyrosa* Fckl., Sacc., 1882, Syll. Fung., v. 1, p. 601. p. p. min.
- *Endothia gyrosa* Schw., Ell. and Ev., 1887, No. Amer. Fung. Exs., no. 1956.
- *Endothia gyrosa* (Schw.) Ell. and Ev., 1892, No. Amer. Pyren., p. 552, p. p.
- *Endothia radicalis* (Schw.) Farl., Clint., 1912, *in* Science, n. s., v. 36, no. 939, p. 908.
- *Endothia radicalis* (Schw.) Shear, 1912, *in* Phytopathology, v. 2, no. 5, p. 211.
- *Endothia radicalis* (Schw.) Fries, P. J. and H. W. And., 1912, *in* Phytopathology, v. 2, no. 5, p. 210.

TYPE SPECIMEN.—The type in Herb. Schw. is wanting. A cotype is in Herb. Museum of Paris.

PYCNIDIA.—Stromata corticular or subcorticular, pulvinate to tubercular, rugulose, scattered or gregarious, occasionally confluent, 1.5 to 3 mm. in diameter by 1.5 to 2 mm. high, orange chrome when young to chestnut when mature,

[1] In the following descriptions of cultures and elsewhere throughout this paper, the names of colors are taken from Ridgway's recent work on color nomenclature (64).

becoming almost black when old and weathered, cadmium orange within; pycnidia consisting of numerous irregular labyrinthiform chambers in the stroma, separated by walls of varying thickness and opening by irregular pores in the surface of the stroma; sporophores cylindric or slightly tapering toward the apex, 6 to 9 μ long; pycnospores oblong, straight or sometimes slightly curved, appearing hyaline when separate, warm buff to ochraceous buff or darker, according to mass and moisture content, 3 to 4 by 1.5 to 2 μ.

PERITHECIA.—Stromata the same or similar to those producing pycnidia; perithecia dark, membranous, few to many, mostly 25 to 50, usually arising in the lower portion of the stroma, 150 to 300 μ in diameter, very irregularly arranged in one to several layers, prolonged into slender necks which penetrate the stroma above and sometimes protrude somewhat, terminating in a short conical ostiole; asci oblong fusoid or subclavate, very short stipitate, 25 to 30 by 6 to 7 μ; ascospores irregularly biseriate, cylindric to allantoid, 7 to 11 by 2 to 3 μ, mostly 7.5 to 10 by 2 to 2.5 μ, hyaline when separate, slightly yellowish in mass, with a very thin gelantinous envelope when mature.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show an abundant thick growth of mycelium producing irregular tubercular masses resembling pycnidial stromata, but without spores. The surface color is capucine buff. The medium usually changes to perilla purple. It is distinguished from *E. singularis*, its nearest relative, by its more rapid growth and the formation of the large tubercular masses.

HOSTS.—Exposed roots and branches: *Quercus alba, Q. coccinea, Q. falcata, Q. georgiana, Q. ilicifolia, Q. imbricaria, Q. marylandica, Q. nigra, Q. phellos, Q. prinus, Q. rubra, Q. velutina, Q. virginiana, Liquidambar styraciflua, Fagus americana* and *F. sylvatica* cult. vars., *Castanea dentata* and cult. vars., and *Vitis* sp. (25).

A specimen of this species collected by Ravenel has the host given as maple (Acer), but microscopic examination shows it to be Liquidambar.

TYPE LOCALITY.—Salem, N. C.

GEOGRAPHICAL DISTRIBUTION.—Southwestern Connecticut to central Michigan, southward to Florida and Texas; also Kansas and California.

ILLUSTRATIONS.—Ell. and Ev., 1892, No. Amer. Pyren., pl. 36, fig. 68; Clint. 1913, *in* Conn. Agr. Exp. Sta. Rpt., 1911, 1912, pl. 28, fig. a, d, and g.

EXSICCATI.—Pycnidia: Baker, Pl. Pac. slope, 722, on *Quercus agrifolia;* Rav. Fung. Amer., 352, on Quercus. Perithecia: Ell. and Ev. No. Amer. Fung., 1956, on Quercus; Rav. Fung. Car., 49, on Quercus and Liquidambar.

ENDOTHIA SINGULARIS (H. and P. Syd.) S. and S. nov. comb.

SYNONYMS:

Pycnidia: *Calopactis singularis* H. and P. Syd., 1912, *in* Ann. Mycol., vol. 10, no. 1, p. 82.

Endothia gyrosa Ell. and Ev., in Herb. N. Y. Bot. Gard.

Endothia gyrosa (Schw.) Fckl. Höhnel, 1913, *in* Sitzber, K. Akad. Wiss. [Vienna], Math. Naturw. Kl., Abt. 1, Bd. 122, Heft 2, p. 298.

TYPE SPECIMEN.—H. and P. Syd., Fung. Exot, no. 88, on *Q. gambellii.*

PYCNIDIA.—Stromata corticular, erumpent, depressed globose, sometimes irregular, scattered, or gregarious, 3 to 5 mm. wide by 2 to 4 mm. high, outer wall thick, coriaceous, becoming brittle, mahogany red without, scarlet within; pycnidia consisting of innumerable nearly spherical cavities throughout the stroma, 25 to 35 μ in diameter, the walls disintegrating into a powdery mass and the whole set free by the irregular rupture of the stroma wall, usually leaving a cup-like basal portion attached to the bark; sporophores, according to the Sydows, short, hyaline, subulate, 6 to 8 by 1 μ; pycnospores ovoid oblong, hyaline, the contents of each pycnidial cavity adhering in a globular mass, when set free, 3 to 4 by 1 to 1.5 μ.

PERITHECIA.—Stromata the same or similar to those producing pycnidia; perithecia membranous, few to many, usually 100 or more, 200 to 350 μ in diameter, irregularly arranged in several series, prolonged into slender necks which sometimes protrude from the stroma; ostioles depressed conical; asci, oblong cylindric or subclavate to fusoid, substipitate, 25 to 35 by 4.5 to 5.5 μ; ascospores irregularly biseriate, cylindric to allantoid, with a thin gelatinous envelope, hyaline when separate, slightly yellowish in mass, 7 to 11 by 1.5 to 3 μ; mostly 7.5 to 10 by 2 to 2.5 μ.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal have a cadmium and orange to capucine buff mycelium. It is distinguished from *E. gyrosa* by its slower growth and brighter color and the want of tubercular, stromalike masses. No spores of this species have been produced in any of the writers' cultures.

HOSTS.—*Quercus gambellii, Q. leptophylla, Q. nitescens, Q. utahensis.* Bethel also reports it on *Q. pungens.*

TYPE LOCALITY.—Palmer Lake, Colo.

GEOGRAPHICAL DISTRIBUTION.—Colorado and New Mexico.

ILLUSTRATIONS.—Pycnidia: H. and P. Syd., 1912, *in* Ann. Mycol., vol. 10, no. 1, p. 82, figs. 1–5.

EXSICCATI.—Pycnidia and perithecia: H. and P. Syd., Fung. Exot., 88, on Quercus. Pycnidia: Bart. Fung. Col., 4002, on *Quercus utahensis.*

In shape and size of pycnospores and ascospores this species closely resembles *E. gyrosa*, but is easily separated by the much greater size of its stromata, its brighter color and very numerous, small, regular pycnidial cavities and more numerous perithecia, as well as its geographical distribution.

The specimens of the Sydow exsiccati, No. 88, in the Pathological and Mycological Collections of the Bureau of Plant Industry show both pycnidia and perithecia.

Section 2.—Ascospores oblong fusiform to oblong ellipsoid, uniseptate when mature.

ENDOTHIA FLUENS (Sow.) S. and S. nov. comb.

SYNONYMS:

Pycnidia: *Sphaeria fluens* Sow., 1814, Col. Fig. Engl. Fungi, Sup. pl. 438, figs. 1, 2.

Sphaeria gyrosa Berk., 1836, Brit. Fungi, p. 254. Not Schw.

Endothia gyrosa Fries, 1849, Sum. Veg. Scand., p. 385. p. p. Europ.

Sphaeria radicalis Fckl., 1861, Enum. Fung. Nass., p. 76, no. 640.

Endothia gyrosum Fckl., 1869, Symb. Mycol., p. 226. p. p. spec. cit.

Endothia gyrosa (Schw.) Fckl., forma *castaneae vescae* Sacc., 1876, Mycol. Ven. Exs., no. 929.

Endothiella gyrosa Sacc., 1906, *in* Ann. Mycol., v. 4, no. 3, p. 273.

Perithecia: *Sphaeria radicalis* Schw., Fries, 1828, Elenchus Fung., v. 2, p. 73.

Sphaeria radicalis Schw., Rudolphi, 1829, *in* Linnaea, Bd. 4, Heft 3, p. 393.

Sphaeria radicalis Schw., Fries, 1830, *in* Linnaea, Bd. 5, Heft 4, p. 541.

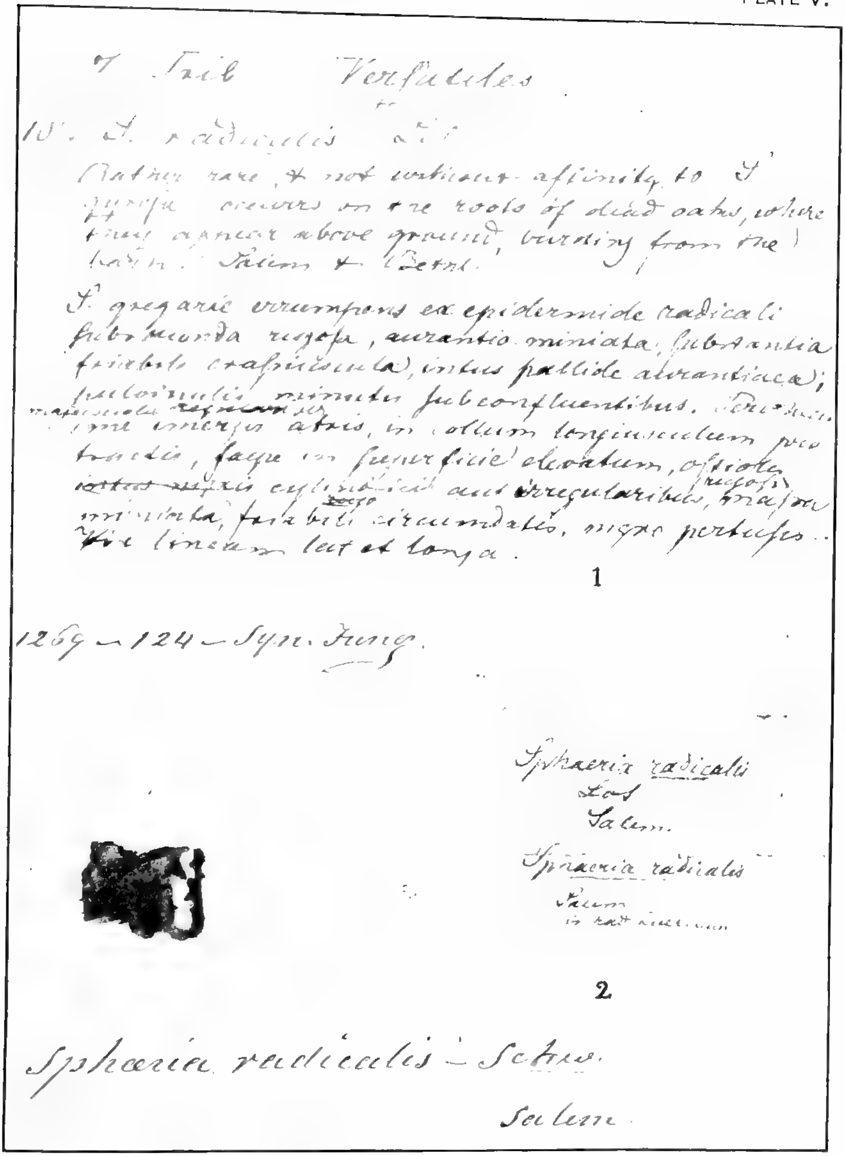


FIG. 1.—PHOTOGRAPH OF SCHWEINITZ'S MANUSCRIPT NOTES, WITH HIS DESCRIPTION OF SPHAERIA RADICALIS.' FIG. 2.—SPECIMEN OF S. RADICALIS IN THE MOUNTED COLLECTION OF SCHWEINITZ, AS PREPARED BY MICHENER; ALSO ORIGINAL PACKET WITH SCHWEINITZ'S AUTOGRAPH LABEL.

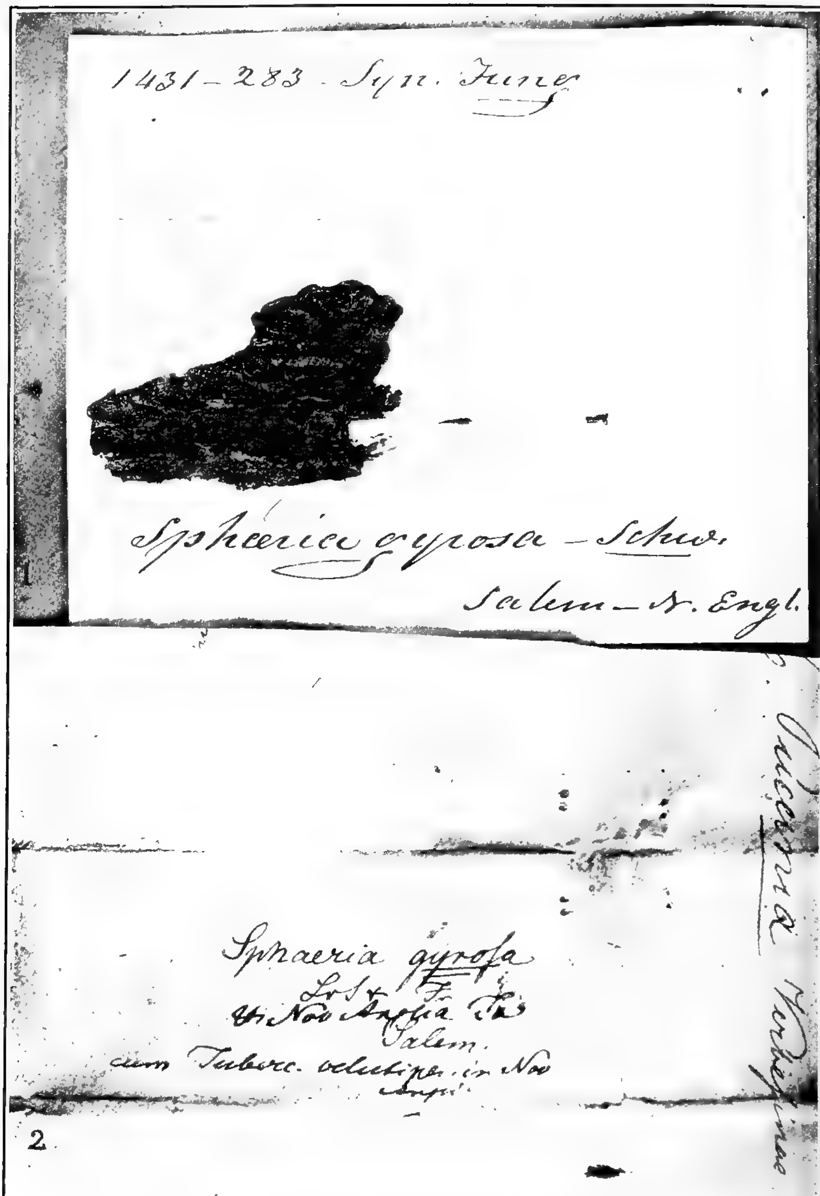


FIG. 1.—PHOTOGRAPH OF THE SPECIMEN IN SCHWEINITZ'S HERBARIUM MOUNTED BY MICHENER. NOT TRUE ENDOTHIA GYROSA BUT A NECTRIA. FIG. 2.—ORIGINAL PAPER PACKET IN WHICH SCHWEINITZ'S TYPE MATERIAL OF E. GYROSA WAS PRESERVED, WITH HIS AUTOGRAPH LABEL.

ENDOTHIA GYROSA GROWING ON THE RECENTLY CUT END OF A LIVING BRANCH OF FAGUS SP. NATURAL SIZE.

MYCELIAL FANS OF ENDOTHIA PARASITICA UNDER THE BARK OF CASTANEA DENTATA.

Illustration from Heald (39), by courtesy of I. C. Williams, Pennsylvania State Forestry Department.

SYNONYMS—Continued.

Perithecia—Continued.

Sphaeria radicalis Schw., 1832, Fun. Am. Bor., p. 197.

Sphaeria radicalis Schw., Mont., 1834, *in* Ann. Sci. Nat. Bot., s. 2, t. 1, p. 295.

Sphaeria (Diatrype) *radicalis* Fries, Currey, 1858, *in* Trans. Linn. Soc. London, v. 22, pt. 3, p. 272, pl. 47, fig. 89. p. p.

Valsa radicalis Ces. and De Not., 1863, *in* Comm. Soc. Crittog. Ital., v. 1, p. 207.

Endothia radicalis (Schw.) Ces. and De Not., 1863, *in* Comm. Soc. Crittog. Ital., v. 1, opp. p. 240.

Melogramma gyrosum L. R. and C. Tul., 1863, Selecta Fung. Carpol., t. 2, p. 87. p. p. max.

Sphaeria (Diatrype) *radicalis* Schw., Currey, 1865, *in* Trans. Linn. Soc. London, v. 25, pt. 2, p. 244.

Endothia gyrosa (Schw.) Fckl., Sacc., 1882, Syll. Fung., v. 1, p. 601. p. p.

Endothia gyrosa var. *rostellata* Sacc., 1882, Syll. Fung., v. 1, p. 602.

Endothia radicalis (Schw.) Wint., 1887, Pilze, p. 803.

Endothia gyrosa Schw., Ell. and Ev., 1892, No. Amer. Pyren., p. 552. p. p.

Endothia virginiana P. J. and H. W. And., 1912, *in* Phytopathology, v. 2, no. 6, p. 261.

Endothia gyrosa (Schw.) Fries, Clint., 1913, *in* Conn. Agr. Exp. Sta. Rpt., 1911–12, p. 425.

Endothia pseudoradicalis Petri, 1913, *in* Atti R. Accad. Lincei Rend. Cl. Sci. Fis., Mat. e Nat., s. 5, v. 22, sem. 1, fasc. 9, p. 654.

Endothia gyrosa (Schw.) Fckl., Höhnel, 1913, *in* Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., Abt. 1, Bd. 122, Heft 2, p. 298.

TYPE SPECIMEN.—Sowerby in Herb. Kew. on *Castanea sativa,* New Forest, England. Coll. C. Lyell, Apr. 15, 1809.

PYCNIDIA.—Stromata corticular or subcorticular, truncate conical to pulvinate, usually separate and gregarious, but frequently confluent, 0.75 to 3 mm. in diameter by 0.5 to 2.5 mm. high, compact, varying from light auburn to chestnut on the surface and capucine yellow to cadmium orange within; pycnidia consisting of simple or more or less complex and irregular chambers in the stroma, opening by an irregular pore or slit at the apex of the stroma; sporophores usually simple, sometimes branched near the base, cylindric to subclavate, 10 to 13 μ long, sometimes 24 to 30; pycnospores oblong to rod-like, pale yellowish in mass, 3 to 5 by 1.5 to 2 μ, mostly 3.5 to 4 by 2 μ.

PERITHECIA.—Stromata the same or similar to those producing pycnidia; perithecia membranous, few to many, mostly 15 to 25, 300 to 400 μ in diameter, usually arising in the lower portion of the stroma, irregularly arranged in one to three layers, prolonged into slender necks which penetrate the stroma above and protrude usually from 300 to 600 μ, terminating in conical ostioles; asci oblong fusoid or subclavate, very short stipitate, 30 to 40 by 6 to 8 μ, mostly 30 to 35 by 7 μ, ascospores irregularly biseriate, oblong fusoid or subellipsoid, not constricted at the septum, hyaline with a thin gelatinous envelope, 6 to 10 by 3 to 4.5 μ, mostly 6.5 to 9 by 3 to 4 μ.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show a compact growth with a nearly smooth surface. The color ranges from light cadmium to empire yellow, and the medium becomes perilla purple. Pycnidia and spores usually appear a little later, forming large erumpent stromata which extrude thick masses of pycnospores. The light mycelium with large pycnidial stromata and spore masses are distinguishing characters on this medium.

HOSTS.—America: Exposed roots and branches of *Q. alba, Q. coccinea, Q. marylandica, Q. prinus, Q. rubra, Q. velutina,* and *Castanea dentata.* Europe: Specimens examined, *Quercus pedunculata, Castanea sativa, Alnus glutinosa, Ulmus campestris, Carpinus betula,* and *Corylus* sp. Japan: *Castanea* sp. and *Pasania* sp. It is also reported on *Aesculus, Fagus,* and *Juglans* by Traverso.

TYPE LOCALITY.—New Forest, England.

GEOGRAPHICAL DISTRIBUTION.—America: Southern Pennsylvania and Ohio to South Carolina and northern Mississippi. Europe: Southern England, France, South Germany, and Switzerland to southern Italy and Transcaucasia. Asia: Japan.

ILLUSTRATIONS.—Sowerby, 1814, Col. Fig. Engl. Fungi, Sup., pl. 438; Currey, 1858, *in* Trans. Linn. Soc. London, v. 22, pt. 3, pl. 47, fig. 89 (2 upper spores); Ces. and De Not., 1863, *in* Comm. Soc. Crittog. Ital., pl. 3; Sacc., 1873, *in* Atti Soc. Veneto-Trentina Sci. Nat. Padova, v. 2, fasc. 1, pl. 14, fig. 63–65; Sacc., 1883, Gen. Pyren., pl. 6, fig. 6; Ruhl., 1900, *in* Hedwigia, Bd. 39, pl. 2, fig. 10; Trav., 1906, *in* Soc. Bot. Ital. Fl. Ital. Cript., pars 1, v. 2, fasc. 1, p. 180, fig. 34; P. J. and H. W. And., 1913, *in* Penn. Chestnut Tree Blight Com. Bul. 4, p. 22, fig. 2, A and C; Clint., 1913, *in* Conn. Agr. Exp. Sta. Rpt., 1911–12, pl. 28, fig. b, e, h, and j; Petri, 1913, *in* Atti R. Accad. Lincei Rend. Cl. Sci. Fis., Mat. e Nat., v. 22, sem. 1, fasc. 9, p. 656, fig. 1–3.

EXSICCATI.—Pycnidia: Thüm. Myc. Univ., 769, on Castanea; Sacc. Myc. Ven., 670, on *Carpinus betula;* Sacc. Myc. Ven., 929, on Castanea. Perithecia: Fckl. Fun. Nass., 640, on *Ulmus campestris;* Erb. Critt. Ital., 986, on Castanea; Rab. Herb. Viv. Myc., 254, on Castanea.

Roum. Fun. Sel. Gal., 989, labeled *Endothia gyrosa* Schw. on beech is apparently young *Hypoxylon coccineum.*

The most important synonyms given here have already been discussed. Of the others the writers have examined the types or collections upon which the identifications were based. All the material of Endothia in the herbaria of Cesati, De Notaris, Fuckel, and Berkeley, as well as other smaller collections, has been carefully studied. *E. virginiana* And. and And. has been studied in cultures, as well as typical specimens from the authors of the species, and agrees in every particular with *E. fluens.*

Through the kindness of Dr. Petri a part of the type of his *E. pseudoradicalis* has been examined, but unfortunately no cultures could be obtained from the specimen. The writers have been unable to distinguish his specimen from forms of *E. fluens* which appear to show all the intermediate conditions of variation connecting it with typical *E. fluens.* The ascospores of *E. fluens* are more variable in size and shape than those of any other species of Endothia studied. After examining many specimens of this species from Europe, it does not seem possible at present to separate any of them. The case of *E. pseudoradicalis* can not perhaps be regarded as closed until more material of it has been collected and compared in culture. In fact, the slide from the type of *Sphaeria radicalis* Schw. shows ascospores of both the narrow and broad form. The photomicrograph, Plate XVII, fig. 9, shows an ascospore which agrees with Petri's description and figures.

ENDOTHIA FLUENS MISSISSIPPIENSIS S. and S. nov. comb.

SYNONYM:

Endothia radicalis mississippiensis Shear and Stevens *in* U. S. Dept. Agr., Bur. Plant Indus. Cir. 131, p. 4. 1913.

TYPE SPECIMEN.—No. 1782, on *Castanea dentata*, Blue Mountain, Miss., N. E. Stevens, Feb. 13, 1913. Deposited in Pathological and Mycological Collections, Bureau of Plant Industry.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show a compact, rather uniform surface, the color of the mycelium varying from cadmium orange to xanthine orange. This variety is distinguished from the species by the color of its mycelium, by the numerous small pycnidia thickly scattered over the surface of the culture, and by the lack of any purple color in the medium.

HOSTS.—*Castanea dentata*, *Quercus alba*, and *Q. velutina*.

GEOGRAPHICAL DISTRIBUTION.—Northern Mississippi, Kentucky, Tennessee.

COLLECTIONS EXAMINED.—On *Castanea dentata:* No. 1706 A. pycnidia, Corinth, Miss., T. E. Snyder; no. 708, pycnidia, Dumas, Miss., T. E. S.; no. 1782, ascospores, Blue Mountain, Miss., N. E. S.; no. 1806, ascospores, Blue Mountain, Miss., N. E. S. On Quercus: No. 1989, pycnidia, Danville, Ky., N. E. S.; no. 1995, pycnidia, Danville, Ky., N. E. S.; no. 2032, pycnidia, Lexington, Tenn., N. E. S.; no. 2255, pycnidia, Sardis, Miss., S. and S.

No morphological characters have yet been found to distinguish this variety. It is therefore separated on its cultural characters, which are marked and constant. The plant was first collected by T. E. Snyder, of the Bureau of Entomology.

ENDOTHIA LONGIROSTRIS Earle, 1900, in Muhlenbergia, v. 1, no. 1, p. 14.

SYNONYM:

Perithecia: *Diatrype radicalis* (Schw.) Fries, Mont., 1855, *in* Ann. Sci. Nat. Bot. 4, t. 3, p. 123. Not Schw.

TYPE SPECIMEN.—No. 4340. A. A. Heller, Plants of Porto Rico. In Herb. N. Y. Bot. Garden.

PYCNIDIA.—Stromata corticular, erumpent, gregarious, sometimes confluent, 1 to 3 mm. in diameter, subcoriaceous, surface orange rufous to chestnut, interior zinc orange; pycnidia consisting of irregular labyrinthiform cavities opening by a single large pore or irregular rupture at the apex of the stroma; sporophores slender, somewhat tapering upward, mostly 8 to 10 μ long; pycnospores oblong elliptic, hyaline or yellowish in mass, when expelled forming a stout spore horn or tendril, colored like the stroma on the outside, 2 to 4 by 1 to 1.5 μ.

PERITHECIA.—Stromata the same as those producing pycnidia, but larger and frequently confluent, forming linear series in crevices in the bark; perithecia arising usually at the base of the pycnidial stroma, mostly 3 to 10 in the separate stromata, membranous, 300 to 400 μ in diameter, mostly in a single irregular series, prolonged into long necks, 1.5 to nearly 1 cm. long, sec. Earle, internally black, externally same color and structure as the stroma; ostiole acute; asci oblong cylindric to fusiform, 25 to 35 by 5 to 7 μ, mostly 30 by 6 μ; ascospores overlapping uniseriate to irregularly biseriate, hyaline, ovoid to ovoid elliptical, 6 to 8.5 by 3 to 4 μ, mostly 7 to 7.5 by 3 to 3.5 μ.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal have a uniform cadmium orange to xanthine orange color. The entire surface is covered with a compact growth, irregularly ridged. Tiny mars orange spore masses are scattered irregularly over the surface. Cultures of this species closely resemble *E. fluens mississippiensis* on this medium, being distinguished by the smaller and much less numerous spore masses. The medium is changed to amber brown just below the mycelium, shading into mars yellow; whereas, in the case of *E. fluens mississippiensis* the color of the medium is very little changed.

TYPE LOCALITY.—"Calcareous hills east of Santurce, Porto Rico, altitude 10 ft."

GEOGRAPHICAL DISTRIBUTION.—Porto Rico and French Guiana.

EXSICCATI.—Pycnidia and perithecia: Heller, Plants of Porto Rico, no. 4340.

This species, which appears to be subtropical or tropical in its range, is known at present from only three collections, the type collection from Porto Rico, a collection by Prof. N. Wille, No. 816, Porto Rico, distributed by the New York Botanical Garden, from which the cultures were obtained; and one made by Leprieur, No. 392, in French Guiana, and determined by Montagne as *Diatrype radicalis* (Schw.). A specimen of this collection apparently labeled by Montagne and preserved in the Delessert Herbarium at Geneva has been examined and found to agree with the type material of *E. longirostris*. It is readily distinguished from *E. tropicalis* by its smaller ascospores and pycnospores, and from *E. fluens* by its narrower and more acute ascospores and the long, slender necks of the perithecia.

ENDOTHIA TROPICALIS Shear and Stevens sp. nov.

SYNONYMS:

Diatrype gyrosa Berk. and Broome, 1875, *in* Jour. Linn. Soc. [London], v. 14, p. 124.

Nectria gyrosa Berk. and Broome, 1877, *in* Jour. Linn. Soc. [London], v. 15, p. 86.

Cryphonectria gyrosa (Berk. and Broome) Sacc., *in* Syll. Fung., v. 17, p. 784. 1905.

Endothia gyrosa (Schw.) Fckl., Höhnel, 1909, *in* Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., Abt. 1, Bd. 118, Heft 9, p. 1480.

TYPE SPECIMEN.—No. 2807 S. and S., on *Elaeocarpus glandulifer*, Hakgala, Ceylon, Coll. T. Petch, August, 1913.

PYCNIDIA.—Stromata corticular, pustular to pulvinate, usually gregarious or scattered, rarely confluent, 1 to 5 mm. in diameter, early becoming friable, orange chrome when fresh to sanford brown when old and weathered; pycnidia consisting of numerous irregular cavities in the stroma; sporophores mostly simple, clavate, tapering above, 6 to 10 μ long.; pycnospores continuous, oblong to cylindric, very variable in size and shape, pale yellowish in mass, 3.5 to 7 by 1.5 to 2.5 μ.

PERITHECIA.—Stromata the same or similar to those bearing pycnidia; perithecia black, membranous, collapsing when dry, 5 to 50 or more in a stroma; 250 to 500 μ diameter, irregularly arranged in one to three layers, bearing slender necks which penetrate the stroma and project 0.25 to 1 mm., terminating in acute ostioles; asci oblong or subclavate, nearly sessile, 40 to 50 by 7 μ; ascospores irregularly biseriate, subelliptical, obtuse, not constricted at the septum, hyaline with a gelatinous envelope, 7.5 to 10.5 by 3.5 to 5 μ, mostly 8 to 10 by 4 to 4.5 μ.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show small numerous, thickly scattered pycnidia and spore masses very similar to *E. parasitica.* The mycelium is orange buff to apricot orange. This species differs from *E. parasitica* in culture, chiefly in the brighter color of its mycelium.

HOST.—Rotten logs and stumps of *Elaeocarpus glandulifer.*

TYPE LOCALITY.—Hakgala, Ceylon.

GEOGRAPHICAL DISTRIBUTION.—Only known from Ceylon at present. One other collection of this species, No. 290 G. H. K. T. [Thwaite], N. Eliya, Ceylon, 6,000 feet, has been examined in the Kew Herbarium.

Through the kindness of Mr. T. Petch, of Peredeniya, the writers have received two large collections of this fungus. Some of the material was in a living condition and enabled the writers to obtain pure cultures for comparison with the other species of Endothia. This species is closely related to *E. parasitica*, but is readily separated by its larger ascospores and larger and more variable pycnospores and its nonparasitic habit.

ENDOTHIA PARASITICA (Murr.) P. J. and H. W. And., 1912, in Phytopathology, v. 2, no. 6, p. 262

SYNONYMS:

Diaporthe parasitica Murrill, 1906, *in* Torreya, v. 6, no. 9, p. 189.

Valsonectria parasitica Rehm, 1907, Asc. Exs., no. 1710.

Valsonectria parasitica Rehm, 1907, *in* Ann. Mycol., v. 5, no. 3, p. 210.

Endothia gyrosa var. *parasitica* Clint. 1912, *in* Science, n. s., v. 36, no. 939, p. 913.

Endothia gyrosa (Schw.) Fckl. Höhnel, 1909, *in* Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., Abt. 1, Bd. 118, Heft 9, p. 1480.

TYPE SPECIMEN.—Herbarium N. Y. Bot. Garden, on *Castanea dentata*, Bronx Park, New York City, Nov. 26, 1905, Coll. W. A. Murrill.

PYCNIDIA.—Stromata corticular, slightly erumpent to truncate conical, usually separate and gregarious, frequently confluent in more or less linear series especially in old rimose bark, 0.75 to 3 mm. in diameter by 0.5 to 2.5 mm. high, varying from capucine yellow when young to auburn when old and weathered; pycnidia consisting of irregular cavities in the stroma, 100 to 300 μ in diameter; sporophores mostly simple, subclavate, acute at the apex, usually 12 to 20 by 1.5 μ, more elongated filaments sometimes reaching 50 μ or more being frequently found among the normal sporophores; pycnospores, oblong to cylindric, rounded at the ends, 3 to 5 by 1.5 to 2, mostly 3.5 to 4.5 by 1.5 to 2 μ, pale yellowish in mass under the microscope; old spore tendrils coral red.

PERITHECIA.—Stromata the same or similar to the pycnidial stromata; perithecia dark, membranous, globose to flask shaped, collapsing when dry, 5 to 50 or sometimes more in a stroma, 300 to 400 μ in diameter, irregularly arranged in one to three layers and bearing slender necks projecting above the stroma, 300 to 600 μ, colored like the stroma on the outside and terminating in acute ostioles; asci oblong elliptical to subclavate, nearly sessile, 30 to 60 by 7 to 9 μ, mostly 40 to 50 by 8 μ; ascospores irregularly biseriate, ellipsoid, obtuse, sometimes constricted at the septum, hyaline, with a gelatinous envelope, 7 to 11 by 3.5 to 5 μ, mostly 8 to 9 by 4 to 4.5 μ.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal have a white to pale orange yellow surface mycelium and produce numerous minute pycnidia and pale yellow spore masses. It is distinguished from its nearest relative, *E. tropicalis*, by the lighter color of the mycelium.

HOSTS.—*Castanea dentata*, *C. sativa* and cult. vars., *C. pumila*, *Castanea mollissima* from China and *Castanea japonica* from Japan, *Quercus alba*, *Q. prinus*, *Q. velutina*, Acer sp.

It is also reported on *Rhus typhina* and *Carya ovata* by Anderson and Rankin.

TYPE LOCALITY.—Bronx Park, New York City.

GEOGRAPHICAL DISTRIBUTION.—Southern Maine to Ohio and southward to North Carolina; also Missouri, Iowa, Nebraska, British Columbia, China, and Japan.

ILLUSTRATIONS.—Murrill, 1908, *in* Torreya, v. 8, no. 5, p. 111, fig. 2; Petri, 1913, *in* Atti R. Accad. Lincei, Rend. Cl. Sci. Fis., Mat. e Nat., s. 5, v. 22; sem. 1, fasc. 9, p. 656, fig. 4; Heald, 1913, *in* Penn. Chestnut Tree Blight Com. Bul. 5, pl. 13; Clint. 1913, *in* Conn. Agr. Exp. Sta. Rpt., 1911/12, pl. 28, fig. c, f, i, and k; P. J. and H. W. And., 1913, *in* Penn. Chestnut Tree Blight Com. Bul. 4, p. 22, fig. 2, B and D; P. J. And. and Rank., 1914, *in* N. Y. Cornell Agr. Exp. Sta. Bul. 347, p. 562, fig. 89.

EXSICCATI.—Pycnidia and perithecia: Rehm, Asc., 1710; Wilson and Seaver, Asc. and Low. Fun., 3; Bart. Fun. Col., 2926; all on *Castanea dentata*.

This species is closely related in its morphological characters to all the species of section 2 of the genus. It is most likely to be confused with *E. fluens*, but shows constant differences, though slight, in size and shape of ascospores. They are predominantly broader and more uniform in shape, as shown by the table of measurements on page 35. In its active parasitic condition on Castanea it can always be distinguished by the presence of the mycelial "fans" in the inner bark, as shown in Plate VIII. It has been confused with *E. gyrosa* through an erroneous identification of that species.

MORPHOLOGY AND DEVELOPMENT.

MYCELIUM.

By far the most striking mycelial character is the production by *E. parasitica* of yellow or buff fan-shaped formations of mycelium in the cambium and bark of the host. These "fans" vary from 1 mm. to 1 cm. or more in width, and are composed of radiating hyphæ closely pressed together to form a continuous layer. (Pl. VIII.) So constant are these mycelial fans in their occurrence and so characteristic in their appearance that they furnish the most reliable field character for distinguishing *E. parasitica* from related species and may quite properly be regarded as a specific character when the fungus is growing in living trees.

Anderson and Anderson (2, p. 204) first called attention to the fact that these fan-shaped formations of mycelium are absent from *E. fluens*. Rankin (62, p. 248) states that when the fungus grows saprophytically or while the tree is dormant these fans are not produced. Anderson and Rankin (6, p. 565) report that in inoculations on *Quercus alba* and *Q. prinus*, *E. parasitica* produced the typical mycelial fans.

Anderson (1, p. 14) considers that the occurrence of these fans is associated with the parasitic habit of the fungus. In his opinion single hyphæ do not possess the power of penetrating the living cells, but the fungus grows on the injured and dead cells about a wound until a quantity of mycelium is accumulated, when it "*en masse* pushes through the living tissues of the bark." This view is also held by Keefer (45, p. 193), who adds that "the action of the advancing mycelial mats seems to be physical rather than chemical, and the cells are mechanically broken to pieces."

Rankin, however, states (62, p. 248) that "The host cells, just in advance of the edges of the fan, are disintegrated and form a distinct gelatinous band, which can be seen with the naked eye." This observation suggests to the writers that some toxic or enzymatic action upon the cells of the host probably occurs before the cells are actually invaded by the fungus hyphæ. Careful investigation of this point should go far toward determining the causes of the parasitism of this fungus. Whatever the cause or function of these fans, they are very characteristic, and the writers have found them invariably in diseased material of Castanea in America, as well as in that from China and in two specimens of *E. parasitica* on Quercus.

A similar mycelial formation, fanlike in form,[1] is produced by *Armillaria mellea* in the bark of roots attacked by this fungus. Excellent specimens of the Armillaria mycelial fans have been presented to the writers by Prof. Wm. T. Horne, of the University of California.

STROMATA.

Under the name *Melogramma gyrosum*, in which they included specimens of both *Endothia gyrosa* and *E. fluens*, the Tulasnes (83, pp. 87–89) described the structure of Endothia in some detail. Their description was based chiefly on abundant local material of *E. fluens* collected on *Carpinus betulus* L. during several years, but they also used material sent by Guepin from western France, pycnidial material on chestnut from Italy, American material sent by Schweinitz to Brongniart and preserved in the Paris Museum, and specimens from Carolina sent by Berkeley. According to the Tulasnes (83, p. 87)[2] the stromata are "developed singly and emerge gradually as so many scattered points with fibers radiating in all directions, soon swell into a yellowish cone, rupture the epidermis above them,

[1] Since this manuscript was completed a very similar mycelial formation has come to the writers' attention. As figured by Nowell (50), pl. 1, *Rosellinia pepo*, when growing under the bark of lime trees, forms mycelial fans resembling those of *Endothia parasitica*.

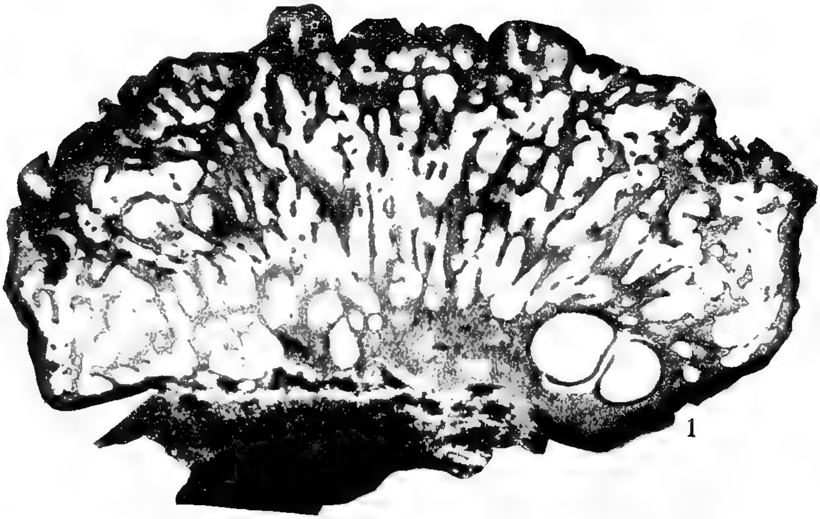
[2] The portions in quotations are rather free translations of the authors' Latin.

and put forth a very blunt apex. All are composed of a corky, parenchymatous, very dense, soft yellow material. The mature ones attain a diameter of 3 to 4 millimeters and a height of 1 to 2 millimeters, and on the somewhat reddish, and finally rusty red to yellow top, they are marked by black points, the ostioles." The Tulasnes observed that before the stromata reached their full size the pycnidial cavities were formed within them, sometimes "widely open," sometimes "narrow labyrinthine," and that through one or many openings in the top of the pycnidia, the long, twisted, orange tendrils, composed of mucus, and innumerable thin linear spores were expelled. "Perithecia are developed chiefly in stromata destitute of spermogonia, or more often with only a few * * * they arise very abundantly and irregularly, some barely buried in the yellow corklike substance, others lower down and seemingly located in the bark of the host itself."

Although the Tulasnes included all their material under a single species, they noted that the pycnidial stromata of the American specimens (really *Endothia gyrosa*) differed considerably from the European (*E. fluens*). In describing the former, they say (83, p. 88) "The American fungus is said to grow in the bark of Fagus and Juglans * * * as a whole it abounds with numerous, very small spermatia. Wherefore if it is very thinly sectioned, the pieces, examined with a compound microscope, show cavities just as if you had before your eyes the smallest Gautieria or Balsamia." The Tulasnes do not try to distinguish definitely between stroma and mycelium, but merely state that the stromata develop within the mycelium.

Ruhland (67), who was the next writer to discuss the morphology of a species of Endothia, defines the various portions of the fungus body in detail. According to his definition (p. 16) a "stroma (in distinction from mycelium) is the sum total of that part of the vegetative portion of the fungus body, which, without serving exclusively for absorption, takes part in the formation of the fruit body." He sets aside Fuisting's (36, p. 185) division of the fungus body into an epistroma and a hypostroma, as essentially nothing but the distinction of "conidial layers" and "perithecial stroma."

Ruhland divides the fungus body into an ectostroma and an entostroma. The ectostroma grows "on the upper surface of the parenchyma of the bark, between it and the periderm, and is composed of a generally wide-lumened plectenchyma which does not possess the power of absorption." This portion has the following functions: "The formation of the conidia, the opening and breaking off of the periderm, and the stimulation of the development of the entostroma." The entostroma, on the other hand, according to Ruhland, "lives in the parenchyma of the bark, and while young is in a high degree



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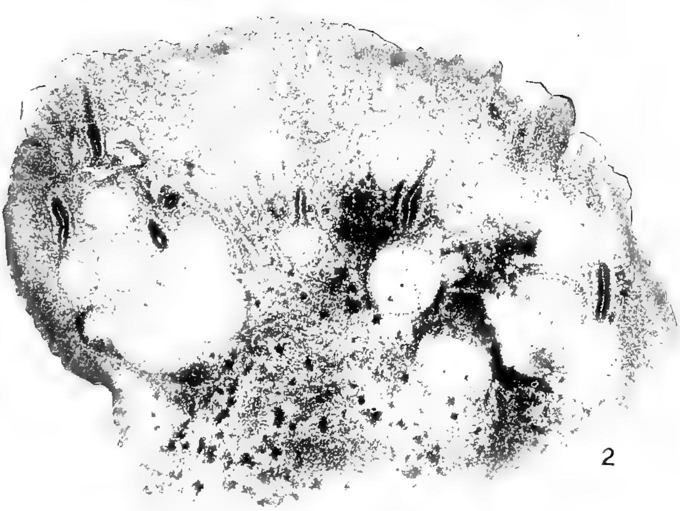


2

ENDOTHIA GYROSA. VERTICAL SECTIONS OF STROMATA ON BEECH. × 32.

FIG. 1.—SHOWING NUMEROUS PYCNIDIAL CAVITIES AND TWO MATURE PERITHECIA.
FIG. 2.—SHOWING MATURE PYCNIDIA AND PERITHECIA SIDE BY SIDE.

Except where otherwise indicated, the photomicrographs of stromata are from unstained sections cut with a freezing microtome.

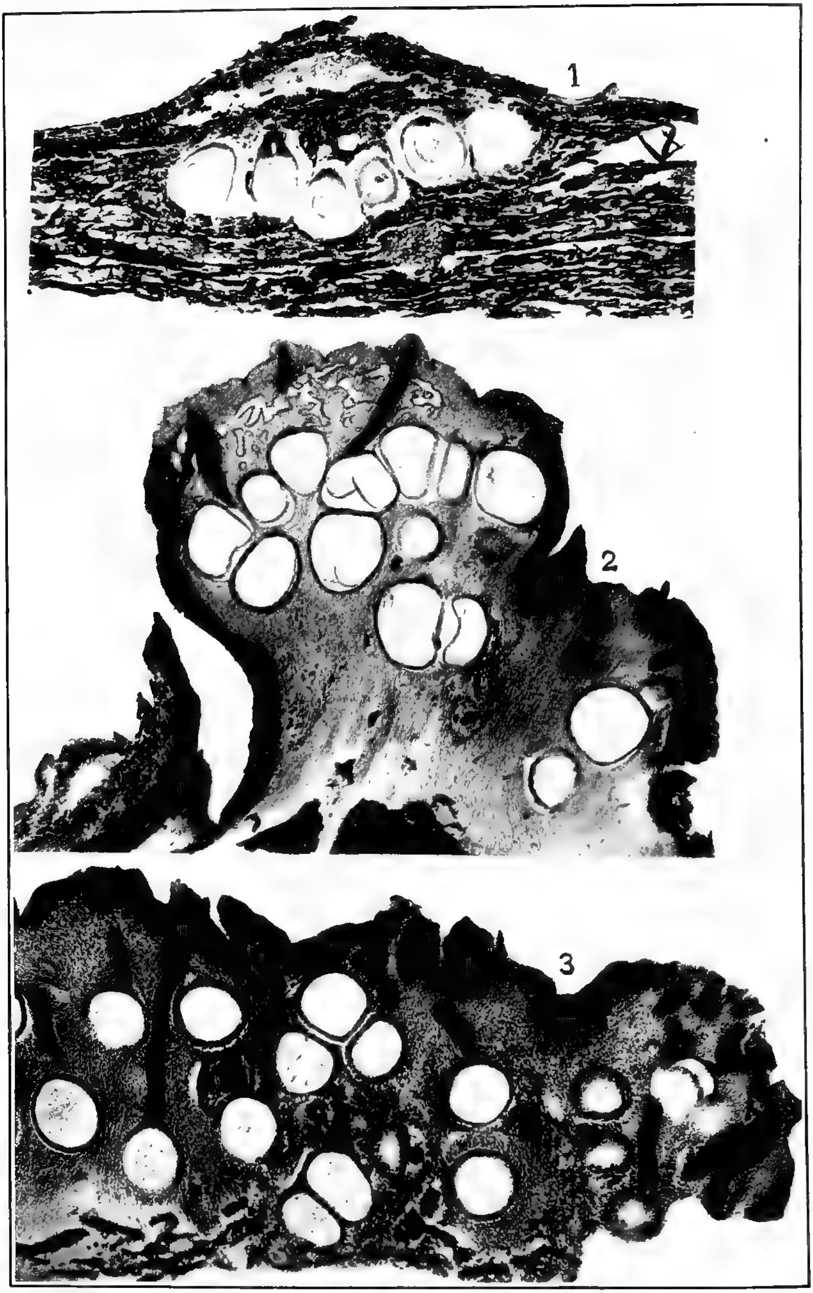
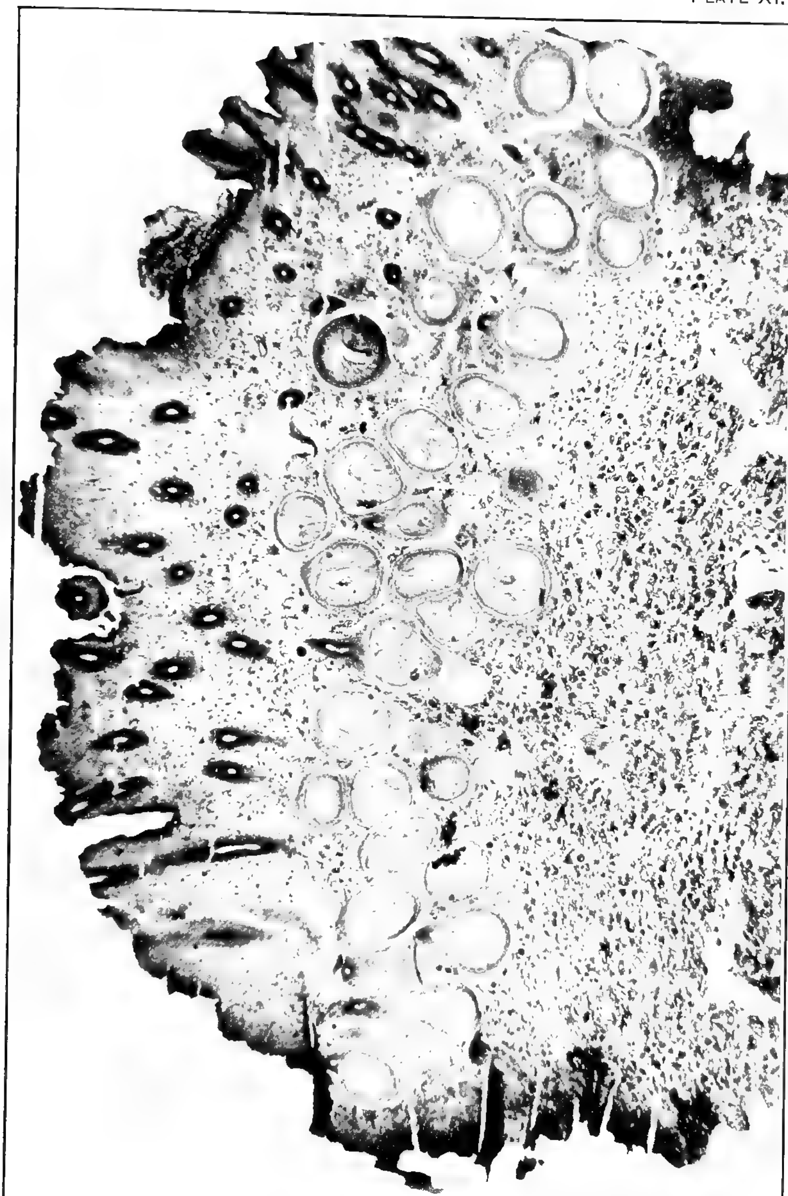
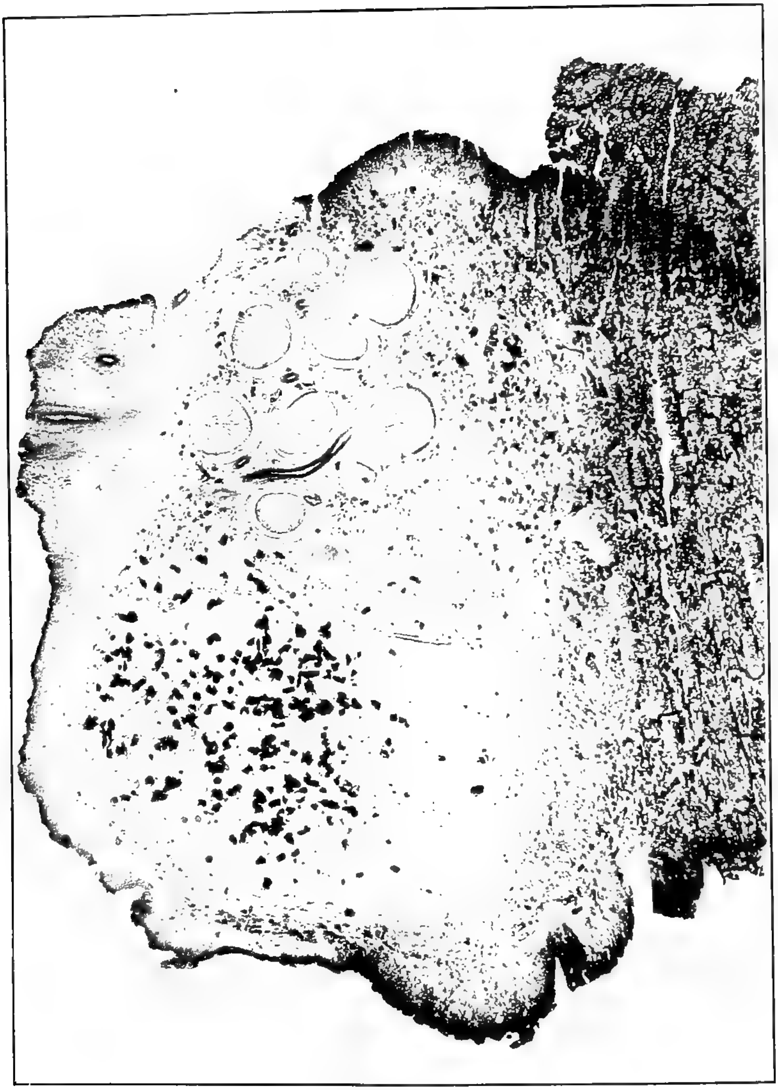


FIG. 1.—ENDOTHIA FLUENS. VERTICAL SECTION OF A STROMA FROM ITALY, SHOWING YOUNG PERITHECIA IN A SINGLE LAYER. × 49. FIG. 2.—ENDOTHIA GYROSA. VERTICAL SECTION OF A STROMA ON BEECH, SHOWING MATURE PYCNIDIA WITH MATURE PERITHECIA BELOW THEM. × 32. FIG. 3.—ENDOTHIA GYROSA. VERTICAL SECTION OF A PORTION OF A LARGE STROMA, SHOWING PERITHECIA IRREGULARLY ARRANGED IN SEVERAL LAYERS.



ENDOTHIA SINGULARIS. VERTICAL SECTION OF A STROMA, SHOWING PERITHECIA ONLY. × 32.

Paraffin section stained with Bismarck brown.



ENDOTHIA SINGULARIS. VERTICAL SECTION OF A STROMA, SHOWING BOTH PYCNIDIA AND PERITHECIA. × 32.

Paraffin section stained with Bismarck brown.

capable of absorption, a power which it retains relatively permanently." In addition to its absorptive function the entostroma forms the pseudoparenchymatic cover for the perithecial walls.

Ruhland studied herbarium material from the Royal Botanic Museum of Berlin and specimens from Saccardo and Cesati, and described it under the name of *Endothia radicalis* (Schw.) Fr. (*E. fluens* of the present writers). He distinguishes an ectostroma, shaped like a truncated cone, consisting of fine, thin-walled hyphæ, so closely interwoven that the whole structure has a comparatively firm quality. Among these hyphæ are crystals of calcium oxalate. As soon as this ectostroma breaks through the bark there is formed near the middle a short-lived 1-chambered pycnidium. Below this ectostroma (height 0.5 to 0.6 mm., diameter 0.7 to 1 mm.) the entostroma grows out as a mycelium through the upper portion of the bark. Ruhland says, "The entostroma with us does not produce perithecia, but remains wholly mycelial." He studied the perithecial stage in Cesati's specimens, however, and concludes that the perithecia originate without much change in the size of the entostroma and at a considerable distance, about 1 mm., below the ectostroma. The long necks then penetrate through the overlying entostroma and into the ectostroma to the base of the now functionless pycnidia. The upper portion of the ectostroma is then quickly killed and thrown off.

Pantanelli briefly described the stromata of the genus Endothia, and pointed out several morphological characters which he considers distinctive of *E. parasitica* in contrast to *E. fluens*. Aside from spore characters, which will be discussed later, Pantanelli (60, p. 870) considers that *E. parasitica* is characterized by numerous stromata, at first embedded in the bark, finally free; by pycnidial cavities numerous and irregularly arranged in various planes in the stromata deep in the bark; pycnidial stromata 1.1 to 1.2 mm. in height and 2.1 to 2.2 mm. in diameter; ascogenous stromata, height 1.8 to 2 mm., length 2.5 to 3.4; width, 3 to 3.2 mm.; perithecia arranged in two or three layers; necks of perithecia averaging 1.25 mm., with inconspicuous ostioles; walls of the perithecia uncolored or light brown.

Endothia fluens, on the other hand, has isolated stromata, chiefly outside the bark; pycnidia aggregated, regularly arranged in a single superficial series; pycnidial stromata, height 0.4 to 0.5 mm., diameter 1.1 to 1.3 mm.; ascogenous stromata, height 1.1 to 1.4 mm., length 2.5 to 3.2 mm., width 1.2 mm.; perithecia arranged in a single row; necks of perithecia averaging 0.45 mm.; ostioles prominent; walls of the perithecia black.

Anderson (1, pp. 17–24) described the development of the fructifications of *Endothia parasitica* in detail. He studied the growth of the pycnidia in pure culture and made sections of perithecial stromata growing on bark.

According to Anderson, the pycnidium originates as a mass of densely intertwined hyphæ, in the center of which numerous pycnospores are cut off. The crowding of these spores increases the size of the pycnidial cavity and crowds the outer hyphæ together to form a sort of wall. The ostiole is formed in the top by the loosening of the hyphæ. The stroma always starts as a loose growth of hyphæ around the pycnidium. It does not precede, but follows the first stages in the development of that organ. A fluffy growth of light-yellow mycelium surrounds the pycnidium and covers it over. If these are embedded and sectioned, they will be found to contain a loose tangle of undifferentiated hyphæ surrounding a central pycnidium. But as soon as the cork layer is broken the stroma undergoes a change. There is a rapid increase in size and at the same time a differentiation of the cells at the tips of those branches which reach the exposed surface. These cells now become shorter and thicker, acquire heavier walls, and are densely crowded together, so that in cross section they appear as a pseudoparenchymatous tissue. The layer thus formed covers all the exposed surface of the stroma and also grows up around the necks of the perithecia. The stroma increases very rapidly in size and a mass of stromatic tissue is formed beneath the pycnidia, which are thus pushed out through the cork layer into the periphery. The primordia of the perithecia are formed usually in the tissues of the bark below the base of the original pycnidium, but at times are formed well up in the stroma. Usually 15 to 30 perithecia mature in a stroma.

According to the writers' observations, the Tulasnes' description (83, pp. 87–89) is substantially correct so far as it goes. They, of course, placed pycnidial material of *Endothia gyrosa* in the same species with *E. fluens*, but, as already noted, they observed the difference in the structure of the stromata and aptly compared the pycnidial stroma of *E. gyrosa*, as seen in section, to a Gautieria.

The division of the stroma into ectostroma and entostroma made by Ruhland (67, p. 16) has, at least in the species of Endothia, no validity whatever. While it is true that pycnidia usually occur in the portion of the stroma first developed and perithecia often develop below them, this is by no means an invariable rule; and while stromata are developed which contain only pycnidia, other stromata apparently produce only perithecia or no spores whatever. Certainly no portion of the stroma can be distinguished which invariably produces only perithecia or only pycnidia. On the contrary, there is great variation in the relative position and time of appearance of the two types of fruiting structures. Also, while the pycnidial cavity is sometimes small and simple, as described by Ruhland, it is more often large and much convoluted. (See Pls. XV and XVI.)

While the writers, of course, agree with Pantanelli (60) that *Endothia parasitica* and *E. fluens* are distinct species, many of the stromatic characters which he describes are so variable as to be unreliable. In an examination of a large number of specimens the writers have been unable to find any constant difference in the arrangement or structure of the pycnidial stromata. This seems to depend chiefly in both species on the character of the bark and the moisture conditions. As to size, while the stromata of *E. parasitica* examined average somewhat larger than those of *E. fluens*, the range of the pycnidial stromata is about the same in the two species, varying from 0.4 to 2 mm. in height and from 0.2 to 3 mm. in length.

The ascogenous stromata are also very variable in size. Those measured by the writers varied in height from 0.5 to 2 mm. in *Endothia parasitica* and from 0.5 to 2.3 mm. in *E. fluens*. In width the perithecial stromata were from 1 to 2.5 mm. in both species, while there is apparently no method for determining their length, since on thick-barked trees continuous narrow masses of perithecial stromata are often formed in the crevices of the bark. These stromatal masses frequently extend from 5 to 10 cm., and while they are in all probability formed by the fusion of several stromata there is no way of determining how far each extends.

The arrangement of the perithecia mentioned by Pantanelli (60) as a specific character seems to depend on the nature of the bark of the host. When the bark is thin and easily ruptured the stromata tend to spread out so that the perithecia occur in a single layer, while if the bark is thick and deeply ridged the stromata are thicker and the perithecia occur in two or more layers. That this is not a specific character is clearly shown by Plate XVI. Figures 1 and 3 of this plate show a stroma of *E. parasitica* and of *E. fluens*, respectively, both with three layers of perithecia, while Plate XVI, figure 2, and Plate X, figure 1, show stromata of both species with perithecia arranged in a single layer.

Although, as already indicated, the stromata of each species are very variable, they are sufficiently distinct so that the native American species may readily be distinguished in the field.

The stromatic characters of *Endothia gyrosa* and *E. singularis* are much more distinct than those of the other species. The stromata of *E. gyrosa* are erumpent, irregularly subglobose, with a rather roughened surface. They are usually from 1.5 to 2 mm. in height and vary from 1.5 to 3 mm. in width. The stromata of *E. singularis* are much larger than those of any other species of Endothia, being usually from 2 to 4 mm. in length and 3 to 5 mm. or more in diameter. They are decidedly erumpent, rather regular, and subglobose in outline. The contents of the stromata are brick red in color and are very powdery when old.

The stromata of *Endothia fluens*, *E. fluens mississippiensis*, and *E. parasitica* resemble each other so closely that the species are practically indistinguishable on this basis. All these species are characterized by partially embedded, confluent stromata which vary greatly in outline, depending on the nature of the bark of the host. As already stated, they vary from 0.4 to 2 mm. in height and from 0.7 to 5 mm. or more in length where confluent. *E. tropicalis* and *E. longirostris* resemble this group in their stromatic characters.

Pycnidia.—The pycnidia of *Endothia gyrosa* and *E. singularis* are very distinctive also. The pycnidial cavities of *E. gyrosa* are narrow and so irregularly convoluted that in a section of the stroma the cavities vary in width from 0.03 to 0.3 mm., averaging about 0.15 mm. On the whole, however, they are much narrower than those of *E. fluens* or *E. parasitica.* A section of a pycnidial stroma of *E. gyrosa* shows numerous irregular, rounded to elongate chambers separated by narrow walls. The pycnidial cavities of *E. singularis* (Pl. XIII) are minute, 0.03 mm. in diameter, nearly spherical, evenly distributed through the stroma and separated at first by comparatively thick walls, which disintegrate and become powdery when the stroma is old.

So far as the writers have been able to determine, the "tendrils" of pycnospores so characteristic of *Endothia fluens* and *E. parasitica* are not formed in either *E. gyrosa* or *E. singularis.* Mature pycnidial stromata of *E. gyrosa* when placed in a moist chamber exude numerous droplets containing spores and scattered well over the surface of the stromata. The writers have been unable to produce any such change by placing the pycnidial stromata of *E. singularis* in moist chambers, and it seems probable that the pycnospores of *E. singularis* are set free by the breaking down of the outer walls of the stromata. As already mentioned, the inner partitions are friable, so the spores are readily scattered by the wind.

The pycnidial cavities of *Endothia fluens* and *E. parasitica*, and apparently all the other species of this section of the genus, vary from 0.2 to 0.3 mm. or more in diameter and may consist of a single chamber rather regular in outline (Pl. XIV, fig. 1) or of an irregular cavity consisting of many chambers (Pl. XV, fig. 3) more or less completely separated from one another. These species differ from *E. gyrosa* in that the pycnospores are usually discharged through a single opening near the top of the stroma and emerge in a single twisted tendril.

Development of the stromata.—The writers have not followed the development of the stromata in culture, but an examination of numerous sections of *Endothia singularis*, *E. gyrosa*, *E. fluens*, and *E. parasitica* and a study of the three latter species under field conditions on various hosts shows that their development is by no means as uniform as indicated in Anderson's description (1).

According to Anderson, the pycnidium develops first, and about the young pycnidium the stroma is quickly formed, while the perithecia arise later, usually in the lower portion of the stroma. This may perhaps be considered the typical course of development, and pycnidia are often found above the perithecia, but all variations occur. A large stroma may be developed without a sign of a pycnidium (Pl. XV, fig. 2). In some cases there is a considerable portion of the stroma above the pycnidial cavity (Pl. XIV, fig. 2), or the pycnidial cavities may be surrounded by a thick stroma (Pl. XIV, fig. 4, and Pl. XV, fig. 1). Sometimes, on the other hand, they are large and irregular, with little stroma (Pl. XV, fig. 3).

The perithecia by no means uniformly arise below the pycnidia, but the two often occur side by side in the same stroma (Pl. IX, fig. 2; Pl. XIV, fig. 3; and Pl. XII). Sometimes, even, the perithecia are above the pycnidia (Pl. XIV, fig. 2). There seems to be no constant relation either as to the relative number of pycnidia or of perithecia in a single stroma. Sometimes the pycnidial portion is much larger (Pl. IX, fig. 1); sometimes the perithecia predominate (Pl. X, fig. 2); and sometimes the two portions are practically equal (Pl. XII).

A like variability apparently occurs in the sequence of the fruiting bodies. As the figures show, the pycnidia sometimes develop after the perithecia; the reverse order is frequent; while in several sections (Pl. XII, and Pl. XIV, fig. 3) the two types of fruiting bodies were side by side and were producing mature spores abundantly at the same time. Just what factors determine the production of each type of spore or prevent or delay spore production is unknown. It seems probable, however, that climatic influences may prevent the development of ascospores in many cases. The action of climate may be very indirect, however, for no ascospores of any species have yet been obtained in artificial cultures, though *Endothia fluens*, *E. fluens mississippiensis*, *E. tropicalis*, and *E. parasitica* produce pycnospores abundantly on a variety of media. Certainly, climatic factors would not account satisfactorily for the fact that pycnidia and perithecia are produced at the same time in adjacent stromata, or even in different parts of the same stroma.

The size of the perithecia is rather uniform in the various species (Pl. X, fig. 3, and Pls. XI and XVI), being about 0.35 mm. in diameter. They are typically globose to pyriform, but are usually more or less irregular on account of crowding. This pressure may be so great as to produce almost any shape, and such perithecia sometimes measure 0.5 mm. in the greatest diameter and 0.1 mm. in the shortest.

SPORE MEASUREMENTS.

The spore measurements recorded here were made by Miss Tiller. In the case of dried specimens, the spores were first soaked for three hours in lukewarm water and then mounted in the potassium-glycerine-copper medium, prepared according to the following formula:

1 part 2 per cent potassium acetate in water.
1 part 40 per cent glycerine in alcohol.
Copper acetate sufficient to color.

In the case of fresh specimens they were mounted directly in the same medium. The measurements were made with a Zeiss filar eyepiece micrometer and a Zeiss 3 mm. 1.40 N. Ap. oil-immersion objective. Only approximate accuracy is claimed for these results, on account of the difficulty of overcoming the motion of the spores in a fluid medium. The results are, however, believed to be fairly comparable, as practically all were measured under the same conditions and treatment, and the margin of error is presumably rather uniform. The differences in size of pycnospores do not appear to be sufficient, however, to furnish diagnostic character for most of the species.

The number of measurements of ascospores of *Endothia fluens* and *E. parasitica* is much larger than of the other species, as special attention was first given to these two species on account of their great similarity. In order to make the measurements of these species comparable to the others, the total number of spores of each length has been calculated in the percentage of the total number of spores measured.

METHOD OF TABULATION.

For better comparison, the spore measurements have been tabulated by half microns, all the spores in each specimen coming within 0.2 of a micron of each unit or half being grouped together; e. g., all the spores having a length of 7.3, 7.4, 7.5, 7.6, and 7.7 microns are included under the heading 7.5. The tables thus show at a glance the number of spores of a given length per specimen. The widths have been tabulated in the same way.

For a better comparison of the shapes of the ascospores of *Endothia parasitica* and *E. fluens*, the relative ratios of length to width in each spore have been calculated, the width being considered unity. The ratios of length to width were then tabulated by tenths; that is, all the spores in each specimen having a ratio of length to width from 1.76 to 1.85 microns are included under 1.8. The relative shapes of the spores in each specimen are thus clearly shown.

TABLE I.—*Measurements of pycnospores and asci of Endothia.*

PYCNOSPORE MEASUREMENTS.

Specimens.	Number per specimen having the given length or width.															Total.
	Lengths (microns).											Widths (microns).				
	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	1	1.5	2	2.5	
Sphaeria gyrosa Schw., Herb. Mus., Paris	2	3	6	**11**	4	....	....	....	....	....	....	9	**15**	2	....	26
S. gyrosa Schw., Herb. Schwaeg.	....	....	5	**9**	3	....	....	....	....	....	....	5	**11**	1	....	17
Endothia gyrosa on beech, Alcorn, Miss., No. 1796	....	....	10	**11**	3	....	....	....	....	....	....	5	**18**	1	....	24
E. singularis, No. 1939	....	....	4	**6**	4	....	....	....	....	....	....	....	5	**9**	....	14
E. fluens, Sowerby	....	....	....	8	**11**	6	....	....	....	....	....	....	8	**17**	....	25
E. fluens on chestnut, Fort Payne, Ala	....	....	1	6	**12**	5	1	....	....	....	....	....	6	**19**	....	25
E. fluens, Lugano, Switzerland	....	....	1	3	**5**	2	1	....	....	....	....	....	**8**	4	....	12
E. fluens mississippiensis, No. 1706A	....	....	2	5	**8**	1	....	....	....	....	....	....	7	**9**	....	16
E. longirostris	2	3	**4**	**4**	1	....	....	....	....	....	....	6	**8**	....	....	14
E. tropicalis	....	....	....	2	5	**6**	3	3	2	....	4	....	3	**19**	3	25
E. parasitica, No. 1696	....	....	1	6	**11**	6	1	....	....	....	....	....	12	**13**	....	25

LENGTHS OF ASCI (MICRONS).

Specimens.	No.	Number per specimen having the given length.								Total.
		25	30	35	40	45	50	55	60	
Endothia fluens on Castanea	1702	2	8	**11**	1	....	....	....	....	22
Do	1737	....	1	**14**	11	....	....	....	....	26
Do	1741	....	5	**6**	....	....	....	....	....	11
Do	1729	....	4	**16**	6	....	....	....	....	26
E. fluens on dead Castanea	1715	....	7	**16**	3	....	....	....	....	26
E. fluens on Castanea, Stresa, Italy	1656	....	6	**16**	1	1	1	....	....	25
E. fluens on Quercus	1711	2	**16**	7	....	....	....	....	....	25
Do	1927	2	10	**12**	....	....	....	....	....	24
E. fluens mississippiensis, Blue Mountain, Miss	1806	....	5	**14**	3	....	....	....	....	22
E. parasitica on Castanea	1710	....	1	....	1	**2**	....	....	....	4
Do	1739	....	....	5	**10**	**10**	1	....	....	26
E. parasitica, China	2151	....	....	....	2	**14**	4	4	3	27
E. gyrosa on Quercus	1709	1	**7**	....	....	....	....	....	....	8
E. gyrosa on Liquidambar	....	**19**	6	....	....	....	....	....	....	25
E. singularis, Palmer Lake, Colo	....	4	**15**	5	....	....	....	....	....	24
E. longirostris, Porto Rico	....	6	**13**	3	3	....	....	....	....	25
E. longirostris, French Guiana	....	6	**10**	1	....	....	....	....	....	17
E. tropicalis	....	....	....	....	....	**6**	5	3	2	16

WIDTHS OF ASCI (MICRONS).

Specimens.	Number per specimen having the given width.							Total.
	4	5	6	7	8	9	10	
Endothia gyrosa	....	....	**8**	2	....	....	....	10
E. singularis	1	**8**	2	....	....	....	....	11
E. fluens, Europe	....	....	2	**6**	4	....	....	12
E. fluens, America	....	....	1	**6**	4	....	....	11
E. fluens mississippiensis	....	....	2	**6**	2	....	....	10
E. longirostris, Porto Rico	....	2	**7**	2	....	....	....	11
E. longirostris, French Guiana	....	....	3	3	3	....	....	9
E. tropicalis	....	....	....	2	**6**	2	....	10
E. parasitica, China	....	....	....	1	**7**	2	....	10
E. parasitica, America	....	....	....	....	**6**	4	....	10

PYCNOSPORES.

The pycnospores of all the species are oblong elliptic to cylindric in shape and so small as to make accurate measurement very difficult. Slight but apparently constant differences in their size in certain groups of species may, however, be traced. These differences are clearly shown in Table I.

Endothia gyrosa, *E. singularis*, and *E. longirostris* have smaller pycnospores than the other species, the most frequent lengths being 3 and 3.5 μ. The pycnospores of *E. singularis* are slightly broader than those of *E. gyrosa* and *E. longirostris*, being 1.5 to 2 μ, as against 1 to 1.5 μ in the last two species.

Endothia fluens, *E. fluens mississippiensis*, and *E. parasitica* are even more closely similar in the size of their pycnospores than in that of their ascospores, the most frequent size being 4 by 2 μ. The pycnospores of *E. tropicalis* are much larger and more variable in size and shape than those of other species. They range from 3.5 to 7 μ in length and from 1.5 to 2.5 μ in width.

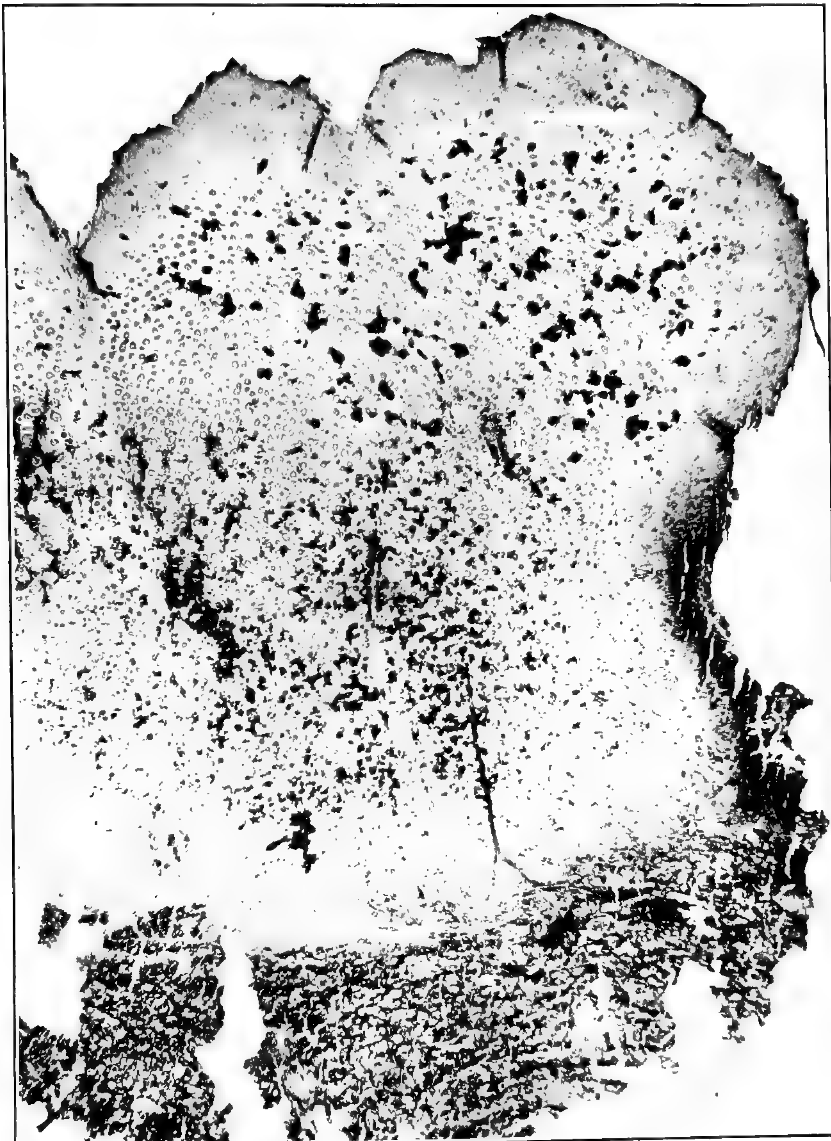
ASCI.

The writers have not attempted a study of the origin and early development of perithecia or asci in any of the species of Endothia. Work on this subject has been published by Anderson and Rankin (6), for *Endothia parasitica*, but the nuclear phenomena and origin and development of the ascogenous hyphæ are not yet entirely clear. The part termed a trichogyne by these authors seems more likely to be the initial stage in the development of the neck of the perithecium than the relic of an organ of fertilization.

The asci appear almost or quite sessile in most species, and though varying considerably in size and shape, as indicated in Table I, are usually oblong elliptic or subclavate, having a sort of inner membrane inclosing the ascospores and some thin granular matter extending to the apex of the ascus, where a slight thickening appears, as described and illustrated by Anderson for *Endothia parasitica*. A similar condition is found in various species of Pyrenomycetes and probably functions in some way in connection with the discharge of the ascospores. The asci are generally wider and slightly longer in *E. parasitica* than in *E. fluens* and other members of section 2. The asci of *E. gyrosa* are shorter than those of any other species. *E. tropicalis* has the longest asci. The asci of none of the species show a very wide range of variation, as Table I also indicates.

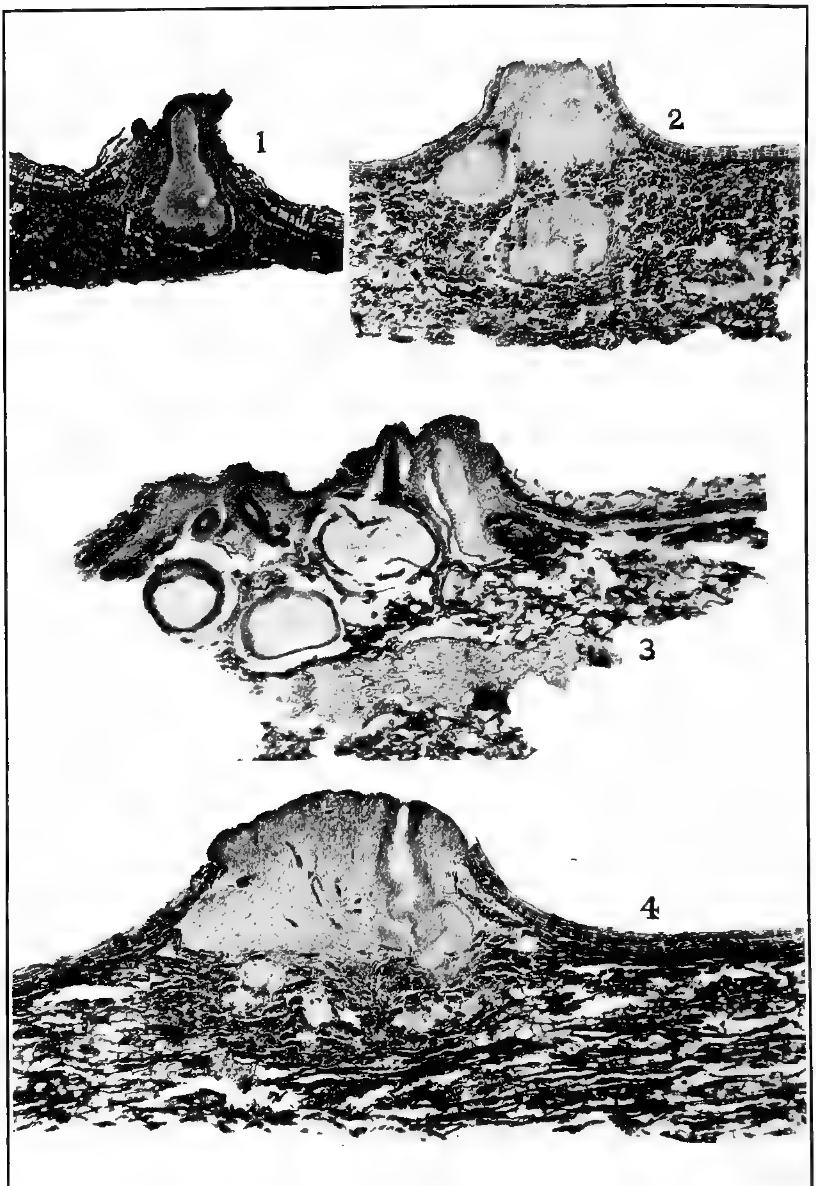
PARAPHYSES.

Most students of Endothia have reported paraphyses wanting in this genus. Anderson (1, p. 33, fig. 32) and Anderson and Rankin (6, p. 579, fig. 83) report paraphyses present and figure what they



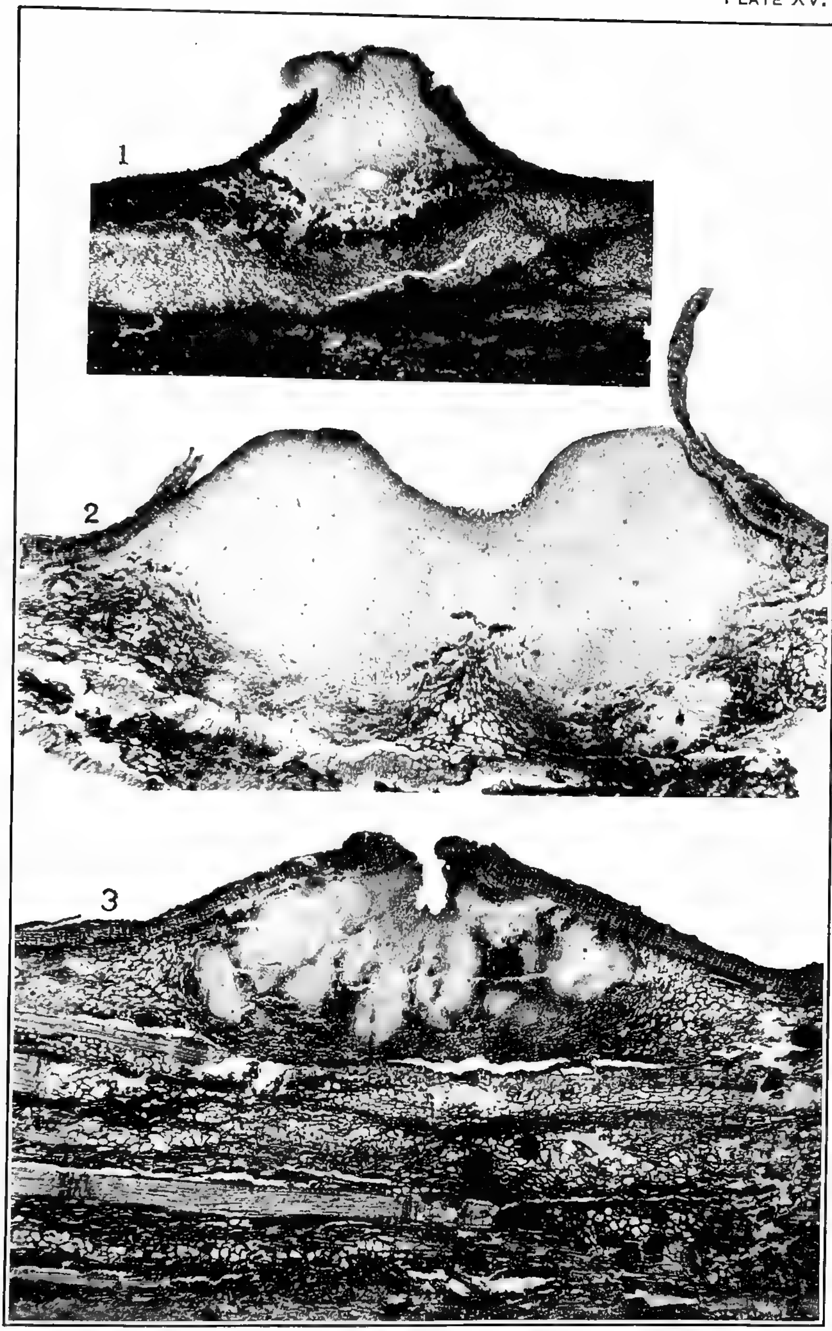
ENDOTHIA SINGULARIS. VERTICAL SECTION OF THE MAJOR PART OF A PYCNIDIAL STROMA. × 32.

Paraffin section stained with Bismarck brown.



ENDOTHIA FLUENS. VERTICAL SECTIONS. × 49.

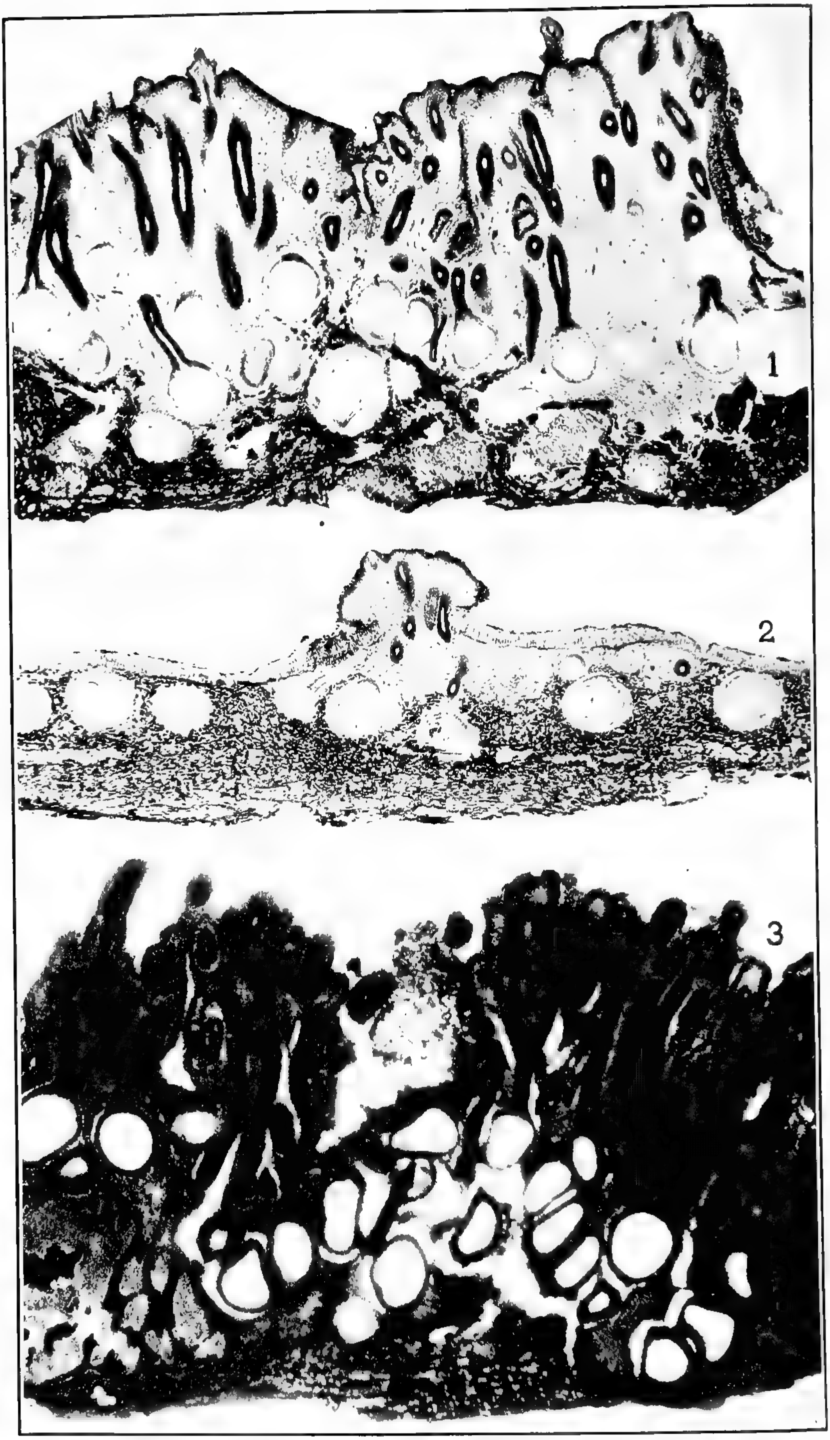
FIG. 1.—SIMPLE PYCNIDIUM WITH VERY LITTLE STROMA, FROM ITALY. FIG. 2.—STROMA FROM ITALY, SHOWING A PERITHECIUM ABOVE A PYCNIDIUM. FIG. 3.—STROMA FROM AMERICA, SHOWING A MATURE PYCNIDIUM AND PERITHECIA SIDE BY SIDE. FIG. 4.—STROMA, SHOWING A SINGLE PYCNIDIUM AND FUNDAMENTS OF PERITHECIA BELOW.



ENDOTHIA PARASITICA. VERTICAL SECTIONS OF STROMATA. × 49.

FIG. 1.—SHOWING A YOUNG, SIMPLE PYCNIDIAL CAVITY AT THE BASE. FIG. 2.—IN WHICH NEITHER PYCNIDIA NOR PERITHECIA HAVE BEGUN TO DEVELOP. FIG. 3.—WITH IRREGULAR CHAMBERED PYCNIDIA.

All the above are about the same age—four months after inoculation.



ENDOTHIA PARASITICA AND E. FLUENS. VERTICAL SECTIONS OF STROMATA. × 20.

FIG. 1.—E. PARASITICA. SHOWING PERITHECIA ARRANGED IN SEVERAL IRREGULAR LAYERS. FIG. 2.—E. PARASITICA, SHOWING PERITHECIA ARRANGED IN A SINGLE LAYER. FIG. 3.—E. FLUENS, FROM ITALY, SHOWING PERITHECIA ARRANGED IN SEVERAL LAYERS.

regard as an early stage of their development. They describe them as branching frequently and very crooked, extending around the perithecium as well as upward. The writers have searched in all the species studied for evidence of the presence of paraphyses, but have never seen anything resembling paraphyses as they occur in closely related Pyrenomycetes. If they occur, they would seem to be of an unusual character and difficult to recognize or else are evanescent, disappearing before the asci are mature.

ASCOSPORES.

The ascospores furnish one of the most marked characters for the separation of the genus into sections (Plate XVII). In section 1 they are more or less cylindric and sometimes curved. In section 2 they are more or less elliptic, being broadest in *Endothia parasitica* and narrowest in *E. fluens* and *E. longirostris*. The greatest variation in size and shape of ascospores occurs in *E. fluens*, as indicated by the measurements given in Table II. Anderson (1), Clinton (18), and Heald (39) describe and figure the ascospores of *E. parasitica* as very obtuse and constricted at the septum. The writers have but rarely seen spores of this form. This may perhaps be due in part to different methods of treatment or to the age and condition of the material. Most of the ascospores studied by the writers have been mounted in the fluid medium described on page 30. Fresh specimens have also been studied in water mounts, but with the same general result. The writers are of the opinion, therefore, that the figures of the authors cited above do not represent the most common and characteristic form of ascospores of this species. (Compare Plate XVII, figs. 7 to 15.)

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TABLE II.—*Measurements of ascospores of Endothia.*

Specimens.	No.	Number per specimen having the given length or width. Lengths (microns). 6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	Widths (microns). 1.5	2	2.5	3	3.5	4	4.5	5	Total.
Endothia gyrosa on Liquidambar, Cyprus, Tenn.	1797			1	15	13	22	22	11	7	5	4	1			57	42	2					101
E. singularis on Quercus utahensis, Palmer Lake, Colo.				3	10	9	23	27	11	11	2	2		1	6	77	15	1					99
Sphaeria radicalis, Fries herbarium		12	15	33	24	5	1	1										52	34	5			91
Endothia fluens on Castanea dentata:																							
Taylorsville, N. C.	1729	5	6	12	25	18	18	8	3	2		1					1	23	43	28	3		98
Connellsville, Pa.	1702	12	18	19	24	13	9	3	1									40	57	2			99
Forest, Va.	1741	3	6	12	27	8	22	16	3			1					1	34	47	15	1		98
Monticello, Va.	1737		2	10	16	19	21	16	9	4	1		1					1	25	65	8		99
E. fluens:																							
On Quercus coccinea, Blacksburg, Va.	1927		7	25	27	6	5	1										7	40	24			71
From dead Castanea dentata, Asheville, N. C.	1715	2	15	18	19	19	12	8	1			1						25	62	8			95
On stump of Castanea vesca, Stresa, Italy	1656			8	12	13	31	17	6	7	3	1	2	1				3	30	67	1		101
On Castanea vesca, Como, Italy	1637			10	18	18	24	16	8	2	1	1						42	47	9			98
Do.	1655	1	1	12	26	19	15	18	5	2	1							37	51	12			100
Total		23	55	126	194	133	157	103	36	17	6	5	3	1			2	212	402	230	13		859
Per cent		2.6	6.4	14.6	22.6	15.5	18.3	11.9	4.9	1.9	0.7	0.6	0.3	0.1			0.2	24.7	46.7	26.7	1.4		
E. pseudoradicalis		4	13	28	27	16	11	1										29	57	14			100
E. fluens mississippiensis:																							
On Castanea dentata, Blue Mountain, Miss.	1782		3	9	11	10	8	5	1	1		1						7	36	6			49
Do.	1806	4	2	18	13	5	8	1										20	27	4			51
Total		4	5	27	24	15	16	6	1	1		1						27	63	10			100
E. longirostris:																							
Porto Rico		6	10	28	31	14	10	1										50	47	3			100
French Guiana		7	14	24	36	11	6											28	60	10			98

Endothia tropicalis:																						
Ceylon					3	9	22	35	20	9	2								5	43	48	9	100
Do.					2	9	17	35	20	13	4								1	28	50	21	100
E. parasitica:																						
On Castanea sp., Santunying, China	2151			8	17	18	26	18	8	3	1	1							6	27	52	15	100
On Castanea dentata—																						
From Pantanelli[1]	1658			3	8	15	19	21	15	7	4	3								17	39	39	95
Gordonsville, Va.	1739			7	17	16	32	21	10	7	3	1							3	43	59	9	114
Odenton, Md.	1710				3	20	26	38	6											13	74	6	93
Total				18	45	69	103	98	39	17	8	5							9	100	224	69	402
Per cent				0.4	1.1	1.7	25.6	24.4	10.0	0.4	0.2	0.1							0.2	24.9	55.8	17.2	

Specimens.	No.	Number per specimen having the given ratio of lengths to widths.																	Total.
		1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	
Sphaeria radicalis, Fries's herbarium			1	3	6	10	17	19	9	10	14	2							91
Endothia fluens:																			
North Carolina	1729		2	3	16	8	8	16	15	8	6	4	3	5	2	1	1		98
Do.	1715			3	6	11	12	9	12	15	11	8	3	2	2	1			95
Pennsylvania	1702		1	4	10	12	12	24	14	8	7	3	3				1		99
Virginia	1741			2	4	10	12	10	7	9	13	13	7	6	2	2	1		98
Do.	1927		1	6	16	16	12	13	3	3	1								71
Do.	1737			4	15	18	16	7	14	11	6	3	4			1			99
Total, American			4	22	67	75	72	79	65	54	44	31	20	13	6	5	3		560
Per cent			0.7	3.9	12.0	13.4	12.9	14.1	11.6	9.7	7.9	5.5	3.6	2.3	1.1	0.9	0.5		
Endothia fluens:																			
Stresa, Italy	1656			5	4	11	23	13	12	13	1	6	4	3	3	2		1	101
Como, Italy	1637					1	7	8	12	10	11	20	12	9	4	2	2		98
Do.	1655				2	3	11	12	12	17	12	13	7	5	2	1	2	1	100
Total, European				5	6	15	31	33	36	40	24	39	23	17	9	5	4	2	299
Per cent				1.7	2.0	5.0	13.8	11.1	12.1	13.4	8.0	13.1	7.7	5.7	3.0	1.7	1.4	0.7	
Endothia parasitica:																			
On Castanea sp., Santunying, China	2151	2	11	17	33	22	9	3	2	1									100
From Pantanelli[1]	1658	2	8	16	29	23	8	8											95
Gordonsville, Va.	1739		10	18	31	24	12	6	3	2	1	4	1	2					114
Odenton, Md.	1710		1	14	37	25	12	3	1										93
Total		4	30	65	130	94	41	20	7	3	1	4	1	2					402
Per cent		1	7.5	16.2	32.4	23.4	10.0	5.0	1.7	0.7	0.2	1.0	0.2	0.5					

[1] Specimens of American material sent by Pantanelli, of Rome, Italy.

PHYSIOLOGY.

CULTURAL STUDIES.[1]

During the past three years the writers have had under observation more than 4,000 cultures of the several species of Endothia on more than a dozen artificial media, as well as on sterilized twigs of many kinds. Throughout this work the writers have been impressed with the uniformity of the behavior of the organism in culture and the certainty with which the various species could be distinguished on any of the media used.

Cultures of *Endothia parasitica*, for instance, from specimens sent from China or British Columbia were absolutely indistinguishable from cultures made on the same medium from local material. Transfers made from stock cultures which had been kept on artificial media for two years were identical with transfers from freshly collected material. The same remarkable constancy held for the other species. Cultures from material collected in different localities or from different hosts were identical, not only in appearance but, so far as the writers were able to determine, in temperature and moisture relations also. As previously noted, this is in marked contrast to the senior writer's experience with the species of Glomerella and it is believed differs from the experience of many investigators of fungi.

No less striking is the certainty with which the several species may be distinguished on any medium tried. *Endothia parasitica*, *E. tropicalis*, and *E. fluens* and its variety *mississippiensis* are very closely related morphologically. Moreover all except *E. parasitica* have, as near as could be determined, much the same relation to their hosts. Yet each species has distinctly and readily recognized characters on culture media.

It should not be imagined, however, that the differences are recognizable at once as clearly distinctive characters. The differences at first glance might readily be considered fluctuating variations. But the fact that the characters remain constant through hundreds of generations and have never varied toward one another makes them worthy of recognition as specific characters.

In a previous paper (77) the writers described their results with cultures of *Endothia parasitica*, *E. fluens*, *E. fluens mississippiensis*, and *E. gyrosa* on a number of culture media. At that time the work of other investigators was reviewed and the methods of preparing the various culture media and making the cultures described. Since the publication of that paper, however, cultures of two more species, *E. tropicalis* and *E. singularis*, have been secured and about 2,000 additional cultures of the various species made. In addition to the culture media mentioned in the previous paper (77, p. 10), the writers

[1] The cultures described were all grown at ordinary laboratory temperatures in the winter, about 20° to 24° C.

have grown the organisms on sterile twigs of many species and on liquid media.

As stated above, the various species of Endothia are distinguishable on any medium tested. White corn meal in flasks has, however, been most used by the writers in identification work and for keeping stock cultures. All the species grow readily on this medium and may be determined with certainty within 10 days under ordinary conditions of growth. In addition, the medium is cheap, easily prepared, and does not dry out so quickly as agar media in tubes, so cultures may be kept alive much longer without transfers. Almost equally good for purposes of identification are rice and oatmeal in flasks, corn-meal agar, and potato agar.

The distinguishing characteristics of the various species in culture have been described rather fully in the previous publication and may be briefly summarized, as follows:

CULTURES ON CORN-MEAL AGAR (UNSLANTED TUBES).

Corn-meal agar proved the best agar medium for the production of pycnospores and showed constant differences in the cultural characters of the various species. The most characteristic differences appeared in cultures from six to eight weeks old on unslanted tubes. (See Pl. XXI, figs. 2 to 7.)

Endothia gyrosa at this age showed a rather abundant, felty white mycelium, flecked with capucine buff, but there were no pycnidia. In older cultures small pycnospore threads were sometimes produced. Usually before the cultures were 10 days old the medium was changed to a delicate lavender just below the mycelium, and below this to a light olive green. A few days later the lavender disappeared and the green deepened to olive green.

Endothia singularis grew more slowly than any other species. Within three weeks, however, the mycelium covered the entire surface. It was smoother than *E. gyrosa* and nearly white, with raw umber spots where the mycelium touched the glass. The medium was changed to a light hellebore green one-half inch below the top.

Endothia fluens, as pointed out in the previous paper, produced an abundant deep-chrome mycelium, with usually one or two rather small pycnidial pustules.

Endothia fluens mississippiensis produced a scant surface growth of mycelium, between cadmium yellow and raw sienna in color. The upper one-half centimeter of the agar became reddish orange. The pycnidial pustules were more numerous than those of *E. fluens*, but smaller and more scattered than those of *E. parasitica*.

Endothia longirostris at the end of six weeks had a scant, webby, orange, aërial mycelium growing against the glass. Mycelium on the surface of the medium was very scant, orange to cadmium yellow in color, with scattered tiny xanthine orange to orange spore masses. The color of the agar changed to medal bronze just beneath the mycelium, shading into orange citrine below.

Endothia tropicalis at the end of six weeks showed a thinly felted mycelium, white to capucine orange, with numerous small, scattered pycnidial pustules. The ring of mycelium against the glass was light orange yellow, as contrasted with white in *E. parasitica*.

Endothia parasitica gave a scanty white growth of surface mycelium, with several prominent pycnidial pustules clustered near the center and of a slightly darker shade than the "raw sienna" of Ridgway.[1]

CULTURES ON POTATO AGAR (SLANTED TUBES).

Potato agar was used by the Andersons (3) to distinguish *Endothia parasitica* from *E. fluens*. The writers have used it extensively and found it a very useful medium for distinguishing the species. As stated in the previous paper (77, p. 11), however, unless this medium was very carefully prepared it varied greatly in acidity and probably in other respects, with resultant variations in the behavior of the organisms. Spore production was not so abundant on this medium as on many others. The preparation of this and other media is described in the paper cited.

Endothia gyrosa.—This species developed rather slowly, producing a fairly abundant aerial growth, which was felty rather than fluffy. The color was white, flecked with capucine buff, and no spore masses were produced.

Endothia singularis.—This species grew even more slowly than *E. gyrosa.* On cultures made from conidia, growth was hardly perceptible at the end of three days. Mycelial cultures at the end of one week showed less growth than *E. gyrosa,* but did not differ greatly from it in either color or texture. At the end of one month the mycelium was slightly more fluffy and decidedly less in amount than that of *E. gyrosa.* Most of the surface was a very light buff color, with sometimes a few spots of capucine orange to English red.

Endothia fluens.—Pycnospore streak cultures of this species varied somewhat as to the amount and time of appearance of color, probably due to the variations in the acidity of the medium referred to above. Many tubes showed an orange color in one week, while others produced no orange whatever. In no case did cultures of *E. fluens* produce the "brassy" metallic surface appearance so characteristic of *E. parasitica.* Pycnidia were few and more scattered than in *E. parasitica* and did not begin to appear until the third or fourth week. A slight amount of warbler-green color sometimes appeared in the medium at this age, but never so conspicuously as in *E. parasitica.*

Endothia fluens mississippiensis.—This produced a less fluffy aerial mycelium along the spore streak than *E. parasitica.* After five or six days the fungus showed an orange color by transmitted light, and was indistinguishable in this respect from *E. parasitica.* The character of the surface was somewhat different, however, and by reflected light appeared xanthine orange. When two weeks old this form differed still more markedly from *E. parasitica* in color, being grenadine red by transmitted light and showing no spore masses.

E. longirostris.—At the end of one week this produced a white, fluffy growth scattered in small patches over the surface of the medium. This later became rather close in texture, especially near the base of the agar slant. No spores were produced on this medium.

Endothia tropicalis.—At the end of one week this showed less growth than *E. fluens,* covering about a third of the surface of the medium, while the other covered nearly the entire surface. The mycelium was closely matted and a very pale buff (paler than any in Ridgway). At the end of one month

[1] In the descriptions of cultures comparisons were necessarily made with cultures in flasks or tubes. This of course made comparison more difficult and somewhat less accurate than if the material had been removed from the container.

E. tropicalis covered the entire surface with a thin layer of surface mycelium, considerably darker in color than when one week old.

Endothia parasitica.—At the end of three or four days at room temperature this showed a short, fluffy, white, aerial growth along the streak. The surface of the mycelium was orange by transmitted light, while by reflected light it was between raw sienna and antique brown at the sides. Within six days the mycelium, especially at the base of the agar slant, took on a peculiar metallic "brassy" appearance, due apparently in part to the character of the mycelium and in part to the minute water drops scattered over the surface. This portion of the culture was light orange yellow by reflected light and orange by transmitted light. This metallic appearance has been found to be the most constant and reliable distinguishing character of *E. parasitica* on potato agar. In 12 to 14 days small pycnidial pustules appeared in the upper portion of the tubes, and the agar just below the mycelium became warbler-green, changing later to olive green.

CULTURES ON CORN MEAL (IN 100 C. C. ERLENMEYER FLASKS).

Endothia gyrosa.—Mycelial cultures one week old showed a growth of rather compact mycelium covering nearly one-half the surface of the medium. The mycelium was ochraceous buff near the point of inoculation, shading into white at the margin. There was no discoloration of the medium and no spore masses were seen.

Cultures of the same kind one month old showed an abundant, rather thick growth, having the surface mostly covered with somewhat irregular tubercular masses, suggesting immature pycnidial stromata similar to those found in *E. radicalis*, but smaller and producing no spores. The surface of the culture was capucine buff, that of the tubercles honey yellow to Isabella. The dark color was apparently due in part to numerous superficial water drops. A portion of the medium was changed to perilla purple.

Endothia singularis.—Mycelial cultures one week old covered only one-third of the surface. The growth was mostly white and fluffy, with ochraceous buff near the center.

At the end of one month the growth had entirely covered the surface. The mycelium varied in color from cadmium orange to capucine buff, the color being distributed over the surface in patches. The corn meal was changed to perilla purple near the center. No spores were produced.

E. singularis was readily distinguishable from *E. gyrosa*, which it resembled more closely in culture than any of the other species, by the rate of growth and the color and nature of the surface of the mycelium. *E. singularis* grew more slowly than *E. gyrosa*, was rather brighter in color (cadmium orange), and the surface of the mycelium was decidedly more even, lacking the tubercular masses characteristic of *E. gyrosa*.

Endothia fluens.—Cultures at the age of one week showed a growth of loose, fluffy mycelium covering one-half of the surface of the medium. The mycelium was deep chrome to light orange yellow at the point of inoculation, passing through perilla purple and light pinkish lilac and fading into white at the margin. Occasionally the medium was changed to perilla purple near the center. No spores were present.

Cultures one month old showed a compact growth, with a nearly smooth surface. The color ranged from light cadmium to empire yellow. The whole mass of the medium was perilla purple. Spore masses were rarely present at this stage, but shortly afterwards a few large erumpent stromata were formed, which extruded spores in thick masses.

Endothia fluens mississippiensis.—Cultures one week old showed an orange-chrome growth a little more than half covering the surface of the medium. The superficial growth was very similar to that of *E. parasitica.* There was no discoloration of the medium and no spore masses were found.

The same organism one month old produced a growth with a compact, rather uniform surface, the superficial portion having a coarse, matted, webby appearance, which was most noticeable about the margin. The color of the mycelium was cadmium orange to xanthine orange, while that of the medium was unchanged. Spore masses were much more numerous than in *E. fluens*, but smaller and less numerous though very similar to those of *E. parasitica.*

E. longirostris.—Cultures one week old covered about one-third of the surface of the medium. The mycelium was short, fluffy, white, with only a tiny spot of cadmium orange near the point of inoculation. At the end of six weeks the entire surface was covered with a compact growth rather uniform in texture, cadmium orange to xanthine orange in color. The surface was irregularly ridged, giving it a wrinkled appearance, with tiny mars orange spore masses irregularly scattered over the surface. This species closely resembles *E. fluens mississippiensis* on this medium, being distinguished from that variety by the smaller and much less numerous spore masses. The medium is changed to amber brown just below the mycelium, shading into mars yellow in the lower portions.

Endothia tropicalis.—At the end of one week this showed less growth than either *E. parasitica* or *E. fluens*, covering about a third of the surface. The mycelium was matted close to the surface and was a very pale buff (paler than any of the buffs shown in Ridgway). No pycnidia were present.

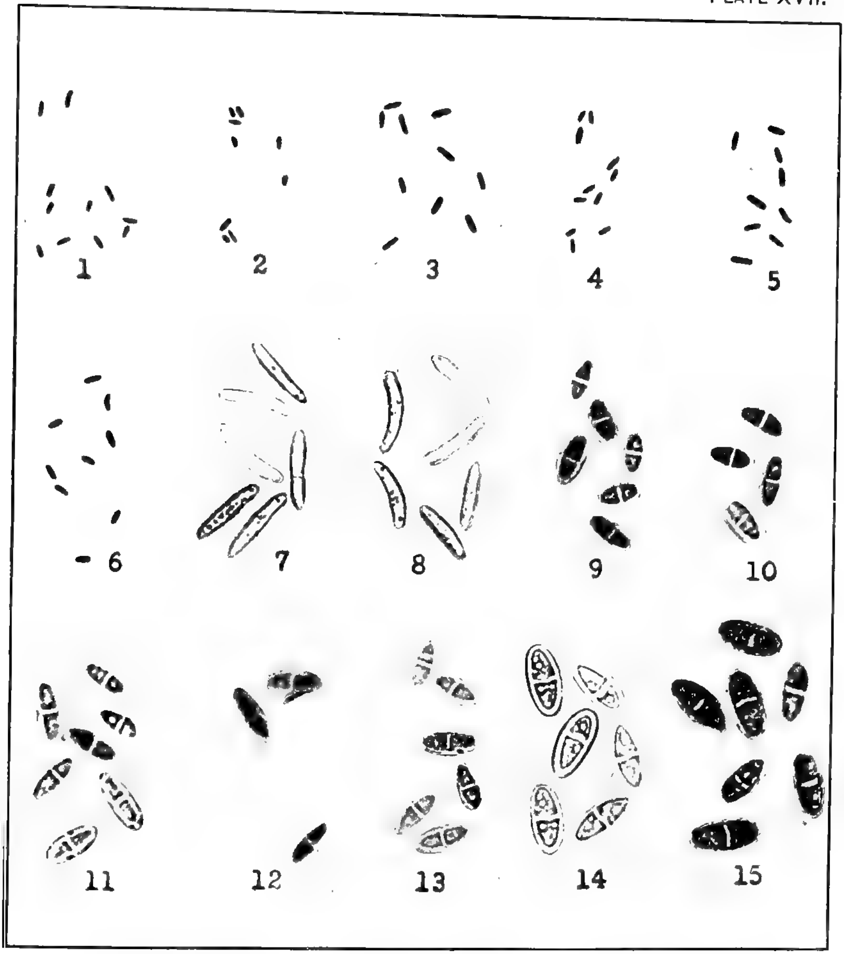
At the end of one month's growth the surface was entirely covered with a closely felted mycelium and small, numerous, thickly scattered spore masses, more closely resembling those of *Endothia parasitica* than any other species. The mycelium was orange buff to apricot orange, and orange chrome against the glass. The color of the medium was unchanged.

Endothia parasitica.—In cultures one week old the growth on corn meal covered about one-half of the surface of the medium. The outer margin was pure white, the remainder buff yellow below, with a superficial white growth above. A few small pustules with spore masses occurred near the point of inoculation. The medium was uncolored.

Cultures one month old showed a compact growth, nearly smooth on the surface. The superficial mycelium was pale orange yellow. The pale yellow-ocher spore masses were minute, very numerous, and nearly covered the surface. The medium was slightly greenish about the sides of the flask just beneath the mycelium.

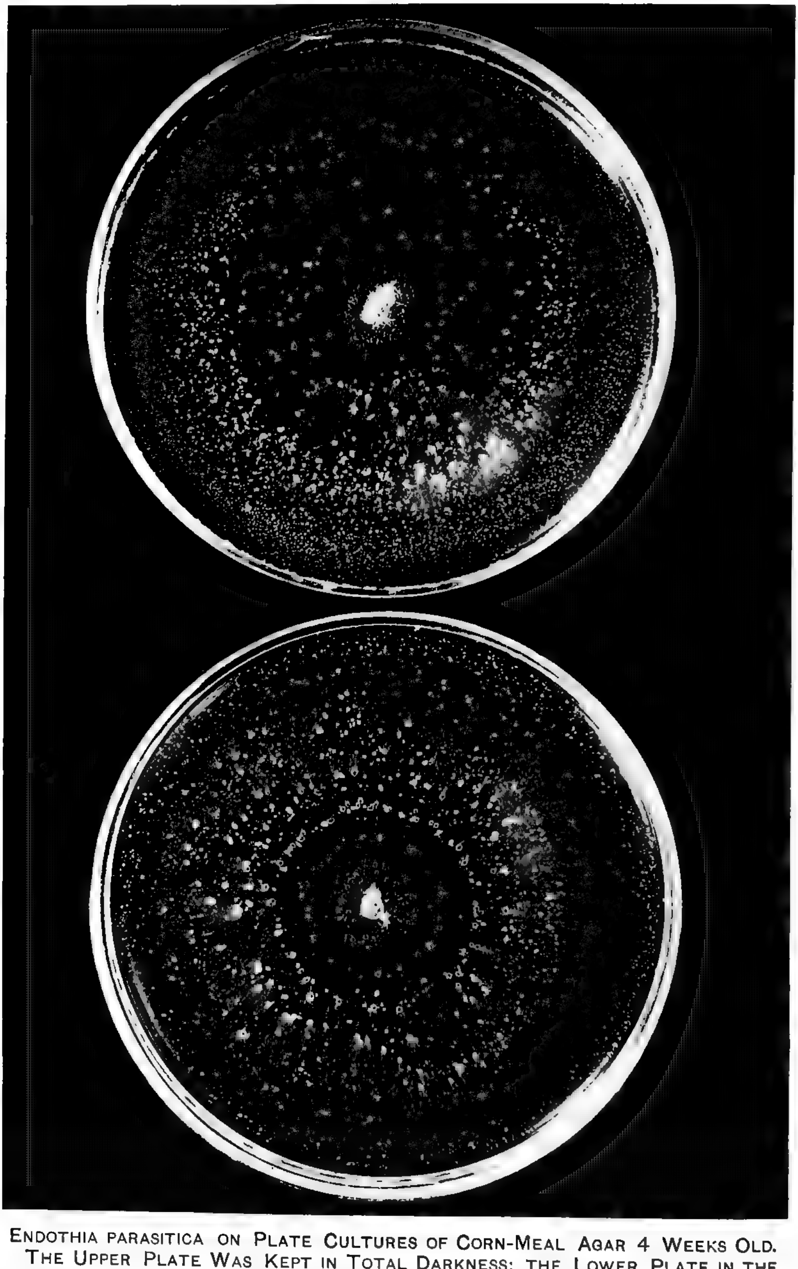
DISTINGUISHING CHARACTERS OF THE VARIOUS SPECIES ON CORN MEAL IN FLASKS.

The color reactions of the various species on corn meal are very striking. *Endothia fluens* (Pl. XXI, fig. 1*b*), as noted above, changes the whole mass of the medium to perilla purple in less than a month. *E. gyrosa* and *E. singularis* also produce this color change, but somewhat more slowly. *E. fluens mississippiensis*, *E. tropicalis*, and *E. parasitica*, on the other hand, in hundreds of cultures have wholly failed to produce any purple color. This furnishes an easy and reliable method of distinguishing *E. parasitica* from *E. fluens*

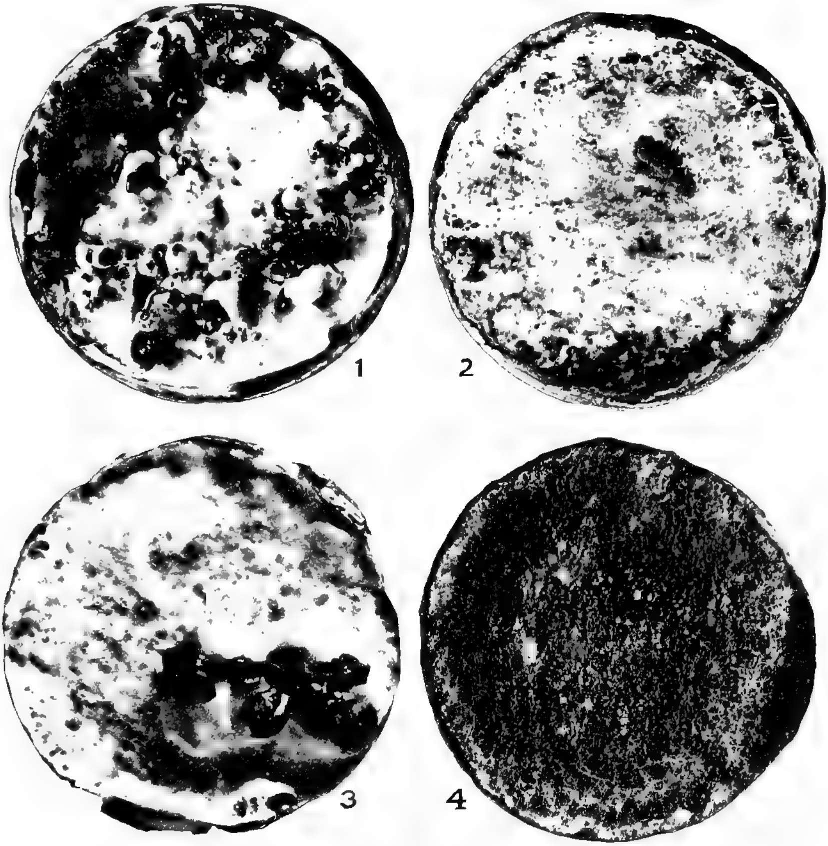


PHOTOMICROGRAPHS OF PYCNOSPORES AND ASCOSPORES OF ENDOTHIA.

FIGS. 1 TO 6.—PYCNOSPORES: 1, ENDOTHIA GYROSA; 2, E. SINGULARIS; 3, E. FLUENS; 4, E. LONGIROSTRIS; 5, E. PARASITICA (AMERICAN); 6, E. PARASITICA (CHINESE). FIGS. 7 TO 15.—ASCOSPORES: 7, E. GYROSA; 8, E. SINGULARIS; 9, SPHAERIA RADICALIS, FROM SCHWEINITZ'S SPECIMEN IN FRIES'S HERBARIUM; 10, ENDOTHIA PSEUDORADICALIS; 11, E. FLUENS; 12, E. FLUENS MISSISSIPPIENSIS; 13, E. LONGIROSTRIS; 14, E. TROPICALIS; 15, E. PARASITICA.

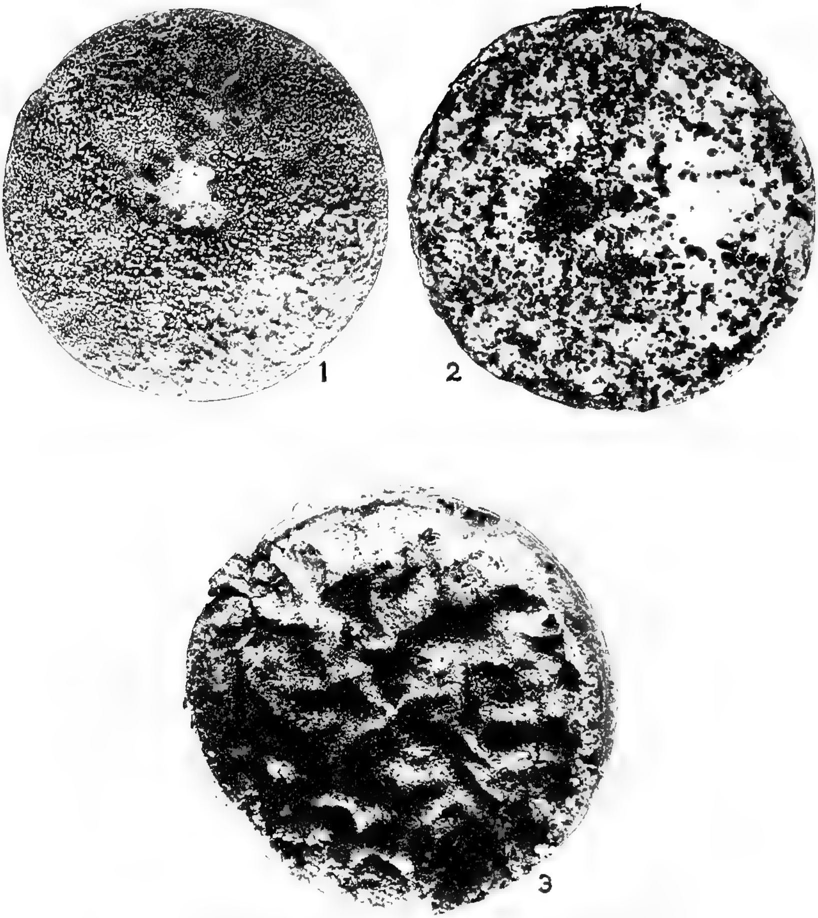


ENDOTHIA PARASITICA ON PLATE CULTURES OF CORN-MEAL AGAR 4 WEEKS OLD. THE UPPER PLATE WAS KEPT IN TOTAL DARKNESS; THE LOWER PLATE IN THE DIRECT LIGHT OF A NORTH WINDOW.



ENDOTHIA SPECIES ON WHITE CORN MEAL (10 GRAMS OF CORN MEAL TO 20 C. C. OF WATER). CULTURES 2 MONTHS OLD.

FIG. 1.—ENDOTHIA GYROSA; FIG. 2.—E. SINGULARIS; FIG 3.—E. FLUENS; FIG. 4.—E. FLUENS MISSISSIPPIENSIS.



ENDOTHIA SPECIES ON WHITE CORN MEAL (10 GRAMS OF CORN MEAL TO 20 C. C. OF WATER). CULTURES 2 MONTHS OLD.

FIG. 1.—ENDOTHIA TROPICALIS; FIG. 2.—E. PARASITICA; FIG. 3.—E. LONGIROSTRIS.

(Pl. XXI, fig. 1) in field work when fructifications of the species are wanting or doubtful.

Aside from the differences in color, the most conspicuous and important characteristic of these fungi in corn-meal cultures is found in the fructification. Clinton (18, pl. 26) has already mentioned and illustrated similar differences in cultures of these organisms on agar in Petri dishes. In *Endothia parasitica* the pycnidia and spore masses are small, numerous, thickly scattered, and embedded in the mycelium. *E. fluens*, on the other hand, forms few, large, erumpent stromata, with spores extruding in thick, elongated masses. *E. tropicalis* closely resembles *E. parasitica* in number, size, and arrangement of pycnidia and spore masses, but differs in color of mycelium. *E. fluens mississippiensis* appears somewhat intermediate between *E. parasitica* and *E. fluens* in regard to the character and abundance of the pycnidia and in color of the growth. These peculiarities have been very uniform and constant in all the cultures on this medium and if they could be coordinated with regular morphological differences in nature would justify the separation of this form as a species. (See Pls. XIX and XX.)

CULTURES ON LIQUID MEDIA (IN 100 C. C. FLASKS).

Some difficulty was experienced at first in growing the species of Endothia satisfactorily on a liquid medium. Abundant growth was obtained on a medium suggested by Dr. Mel. T. Cook. This is a modification of the liquid medium No. II as given by him (19).

Cook's liquid medium, No. II, is prepared as follows:

Into 500 c. c. of distilled water put 15 grams of glucose and 20 grams of peptone steamed at 100° C. for three-fourths hour; into another 500 c. c. of distilled water put 0.25 gram of dipotassium phosphate and 0.25 gram of magnesium sulphate, steamed for 20 minutes; filter both 500 c. c. into same receptacle, steam 10 minutes, put into flasks, about 30 c. c. in each flask, and autoclave.

All species grew readily on this medium, *Endothia parasitica* even producing pycnospores. At the end of one month's growth the several species were readily distinglished on this medium and may be briefly described as follows:

Endothia gyrosa.—Growth scanty; did not form a continuous mat, but remained in small bunches, giving an almost flocculent appearance. The mycelium appeared white when removed from the culture solution, but the solution itself was honey yellow.

Endothia singularis.—Growth even less abundant than *E. gyrosa;* formed small brown knots against the glass. Mycelium buff, and the medium was changed to honey yellow.

Endothia fluens.—Growth somewhat more abundant and less closely matted than *E. parasitica*, entirely submerged; mycelium white; liquid unchanged in color.

Endothia fluens mississippiensis.—Growth slightly less abundant than in *E. parasitica;* submerged except at the very edges; much lighter in color, being reddish brown.

Endothia tropicalis.—This differed markedly from either *E. parasitica* or *E. fluens.* The mycelium formed a thin felt over the surface, white to salmon orange in color, with no change in the medium.

Endothia parasitica.—Mycelial growth very abundant, closely matted, chiefly submerged, but slightly arborescent in one or two small areas, which remained above the surface. Color, dark greenish brown.

CULTURES ON STERILIZED TWIGS (IN TUBES).

Early in this work it was noted that all the species of Endothia grew readily on sterilized chestnut twigs in test tubes. Later, tests were made with twigs from a number of common, woody plants. Twigs of *Acer saccharum*, *Alnus rugosa*, *Betula papyrifera* and *B. lenta*, *Carpinus caroliniana*, *Cornus florida*, *Fagus grandifolia*, *Fraxinus americana*, *Ostrya virginiana*, *Populus grandidentata*, *Prunus serotina*, *Rhus glabra*, *Tilia americana*, and *Tsuga canadensis* were collected in New York State early in June, placed in test tubes with a few cubic centimeters of distilled water and sterilized in an autoclave. All the species of Endothia were tested, and all grew on every species of twig except Tsuga. The difficulty of completely describing this series may readily be seen from the fact that each species of Endothia had a different appearance on every kind of wood.

In general it may be stated that *Endothia gyrosa* and *E. singularis* grew more slowly than the other species and produced no spores, while all the other species produced spores on most hosts. The mycelium of *E. parasitica* was usually white, especially on the bark. *E. gyrosa* and *E. singularis* produced various shades of buff, while *E. fluens*, *E. fluens mississippiensis*, and *E. tropicalis* developed a much more brightly colored mycelium, usually showing yellow or orange shades.

MOISTURE RELATIONS.

In an earlier paper (77, p. 7) the writers reported tests with *Endothia fluens* and *E. parasitica* on media containing various percentages of water. It was observed that pycnospore production began earliest and was most abundant on the media containing the least moisture.

Aside from this the writers have thus far been unable to make definite tests as to the moisture relations of these fungi. However, incidental observations in connection with the light tests (p. 43) and temperature tests (p. 45), as well as results of field experiments, particularly those at Woodstock, N. Y., make it apparent that the amount of available moisture is a very important factor in the fructification of the fungus.

LIGHT RELATIONS.

The relation of light to pycnospore production in *Endothia parasitica* was first discussed by Anderson (1, p. 20). He says—

> When plate cultures are grown in total darkness on chestnut-bark agar, no pycnidia are developed, while on plates made at the same time and grown in the light, the usual rings of pycnidia appear (fig. 57). Experiments were also tried in which the plate was left in darkness until about half covered with mycelium and then brought into the light. Circles of pycnidia were developed, beginning with the ring which marked the outermost limit of the colony when removed from the dark chamber. The concentric rings which always appear on agar cultures are due to the alternation of night and day.

Later, in a bulletin by Anderson and Rankin (6, p. 592), the same results are attributed to D. C. Babcock.

Up to the time the above-mentioned work was published the writers had grown about 3,000 cultures of the several species of Endothia on various media in flasks and tubes. Practically all of these cultures had been kept in dark cases and *Endothia parasitica* had produced pycnidia abundantly on most of the media used. It seemed desirable, therefore, to determine whether wholly different light relations existed when the fungus was grown on plates. The following series of tests was accordingly made, using *E. parasitica* only.

LIGHT TESTS OF CULTURES ON PLATES.

In experimenting with plate cultures in order to check up the results reported by Anderson and Rankin (6, p. 592) it was noted that there was great variation in the rate at which the cultures dried out. There was considerable variation in this respect in different plates kept side by side, apparently due to differences in the Petri dishes, and a marked difference between cultures kept in light and those kept in darkness. Since a causal relation between lack of moisture and abundant spore production had already been shown, it seemed probable that this might influence the results of the light tests in plate cultures. In fact, in a few cases the cultures kept in the light did produce spores earlier than those kept in darkness. Accordingly, in order to eliminate at least in part this fact which seemed to obscure the possible effect of light, a method was sought of equalizing the loss of moisture. In the following series half the plates were placed under a plain bell jar and the other half under a bell jar of equal size but darkened by being covered inside and out with heavy black paper, such as is used to wrap photographic plates. The two bell jars were then set side by side in front of a north window. By this means the conditions were made much more uniform as to temperature and moisture. There was still a slight difference in the rate of drying and undoubtedly at times a difference in the temperature of the light and dark plates, but probably not sufficient to interfere seriously with the experiments.

Series 1. On corn-meal agar plates under bell jars.—In nine days there was no distinguishable difference between the plates in light and darkness, a few spore masses occurring near the middle of each.

In 18 days most of the light plates showed a central ring of spore masses and a zone of scattered spore masses near the edge. The dark plates showed a few small spore masses near the center, and scattered about the outer portion were the small masses of mycelium which usually constitute the early stages of pycnidial formation.

In 30 days the number of spore masses had increased somewhat in both sets of plates, but more in the darkened plates, so that the number of spore masses was about equal in all the plates. The two sets of plates were fairly uniform as to the arrangement of the spore masses. Plate XVIII shows a typical example.

Series 2. On chestnut-twig agar plates under bell jars.—After nine days the cultures in light and darkness were alike. No spores had yet appeared in either set.

In 30 days there were a few spore masses on nearly all of the plates, there being no difference between those in light and those in darkness either in number or distribution.

Series 3. On corn-meal agar and chestnut-twig agar under bell jars.—In this test the plates were piled alternately, first a corn-meal and then a chestnut-twig agar plate, so that the two media would be under conditions as nearly identical as possible. The plates were inoculated as before and left untouched for 18 days and after that were examined daily. After 18 days all the corn-meal plates showed spore masses in practically equal numbers, while the chestnut-twig agar plates showed no spore masses whatever. There was no apparent difference in the growth on either medium between the plates in light and those in darkness.

At the end of 25 days the cultures on chestnut-twig agar plates showed numerous small masses of mycelium, indicating the formation of pycnidia. No difference was perceptible between the dark and light plates.

In 28 days, from 100 to 150 of these pycnidia in each plate were extruding spore masses. The light plates showed in general a larger mass of spores than the dark plates, but this was not marked, certainly no greater than was accounted for by the unavoidable difference in radiation and the consequent difference in moisture. This difference in the moisture of the medium was clearly shown each morning by the greater amount of moisture condensed on the covers of the darkened Petri dishes.

At this time (after 28 days) four corn-meal agar plates which had been wrapped in four layers of heavy black photographic paper and placed on a window sill were opened and examined. In spite of the cold weather prevailing during this test and the consequent low temperature of the room at night, these plates contained an average of nearly 200 well-developed spore masses.

At the end of 35 days the chestnut-twig agar plates which had been kept in the light showed an average of 160 spore masses, while those kept in darkness showed an average of 130 spore pustules, a comparatively small difference in favor of the light plates. There was, however, a wide difference between the various plates in each series, and it was impossible in most cases to distinguish cultures grown in the light from those grown in darkness either by the number, size, or arrangement of the pycnidia and spore masses.

From these experiments it is evident that pycnidia are produced abundantly in total darkness on chestnut-twig agar as well as on other favorable media. There is no perceptible difference in the amount of spore production or in the arrangement of pycnidia between cultures kept in total darkness and those kept in the light during the day if the temperature and evaporation remain the same in both. Continued observation of numerous cultures grown both in daylight and in darkness has convinced the writers that light has no perceptible effect on mycelial growth either in amount, nature, or color production. It seems evident, therefore, that light is a negligible factor in the growth and fructification of these fungi.

TEMPERATURE RELATIONS.

In an earlier paper (77, p. 9) the writers published the results of three series of tests made to determine the temperature relations of three species of Endothia. Since the publication of that paper cultures of other species and additional material of some of the species from widely separated localities have been secured. Four series of temperature tests including this new material were made on solid media.

TESTS ON SOLID MEDIA.

In these tests cultures of *Endothia gyrosa*, *E. singularis*, *E. fluens*, *E. fluens mississippiensis*, and *E. parasitica* were tried on corn-meal agar in slanted tubes, oatmeal in flasks, and potato agar in slanted tubes. The cultures tested were from specimens chosen from the extremes of the known ranges of the fungi and from their different hosts. No difference could be detected in the various cultures of the same species, even in those from widely separated localities and from different hosts. Cultures appeared to have the same temperature relations whether made from spores or mycelium. The results may be briefly summarized as follows:

At 41° and 39° C. there was no growth in any species. Cultures removed from the incubator at the end of 11 days and kept at room temperature showed no growth.

At 35° C., *Endothia gyrosa, E. singularis,* and *E. parasitica* showed a slight development within 2 days, but at the end of 11 days it was still slight and abnormal in appearance. *E. fluens* and *E. fluens mississippiensis* showed no growth at this temperature.

At 31° C., *Endothia gyrosa, E. singularis,* and *E. parasitica* appeared about the same as at room temperature for the first four days. At the end of six days these species showed somewhat less growth than at room temperature, while at the end of two weeks the growth was less in extent and markedly less freshly colored than that at room temperature. *E. fluens* and *E. fluens mississippiensis* showed somewhat less growth than at room temperature even in 4 days, and markedly less at the end of 2 weeks.

At room temperature (which at this time varied from 20° to 24° C.) the growth was much as described in the previous paper. Within 11 days growth was practically complete and in 14 days there was abundant spore production in *Endothia parasitica.*

At 18° and 16° C., all species showed considerably less growth than at room temperature, but there seems to be little difference in the comparative growth of the various species at these temperatures. At 13° the growth was decidedly less than at 16° C. but was fairly normal in appearance in all the species except that *Endothia fluens mississippiensis* failed to produce the characteristic color at this temperature.

At 9° C. there was a very slight growth in all species.

At 7°, 5°, and 2° C. there was no growth whatever. Cultures removed to room temperature at the end of 11 days developed normally and at about the same rate as in newly made cultures.

These additional tests seemed to confirm the results already published (77, p. 27); that is, growth was best in all species at ordinary room temperature, about 20° to 24° C. The minimum temperature for all was about 9°, and all failed to grow at 7° C. The maximum temperature for *Endothia gyrosa, E. singularis,* and *E. parasitica* appeared to be about 35°, while the maximum for *E. fluens* and its variety *E. fluens mississippiensis* was apparently about 32° C. At all the temperatures tried *E. singularis* grew much more slowly than any of the other species.

It was noted that cultures kept at 7°, 5°, and 2° C. showed no growth, but when removed to room temperature developed normally, while cultures kept at 41° and 39° C. failed to grow when removed to room temperature. This seemed to indicate that the fungi are more susceptible to heat than to cold, and such is perhaps the case. There was, however, the additional factor of moisture involved, for while the agar of the cultures kept at 7° and lower was in apparently the same condition at the end of 11 days as when first inoculated, the agar of the cultures kept at 41° to 39° C. was considerably dried. This raised the question as to whether the drying out of the agar had not affected the growth of the fungi in those cultures kept above room temperature as much as the higher temperatures themselves.

The same idea was suggested by the fact that several of the species grew for a few days at 31° C. as well as they did at room temperature, and then fell behind. It seemed possible that this falling off in the rate of growth might be due, at least partly, to more rapid drying of the agar at 31° C., or possibly to the more rapid development of some toxin, as was suggested by Balls (7) to explain a similar observation on the "soreshin" fungus. These observations threw doubt upon the accuracy of the writers' previous conclusions, and made it seem possible that the optimum temperature of the species of Endothia might be well above room temperature. This could only be determined accurately by some method which would control temperature without altering the supply of moisture. Some months after the above tests were concluded it was discovered that the various species of Endothia would grow readily on several liquid media. Consequently, several series of tests on liquid media were run parallel to those described above, except that the tests were continued for only four days. Experiment showed that at the higher temperatures the medium became considerably reduced by evaporation if left for a longer period.

TESTS ON LIQUID MEDIA.

In the series of tests on liquid media, all the species of which cultures had been obtained were grown on Cook's medium (see p. 41) both in tubes and in flasks, using ten tubes and six flasks at each temperature. The cultures of *Endothia gyrosa* and *E. singularis* were made with bits of mycelium from pure cultures. The other species were grown from conidia and the cultures were kept for two days at room temperature, in order to allow the conidia to germinate before being placed in the temperatures to be tested.

The following temperatures were used for making the tests: 40°, 37.5°, 35°, 29°, and 27°, and room temperature which was fairly constant at about 22°, 17°, 12°, 9°, 7°, 3°, and 2° C. There was some variation in the temperature of the incubators and refrigerators used, but in most cases they did not vary more than 1 degree above or below the temperature indicated. At 40° there were occasional traces of growth, especially in *Endothia parasitica*, but this may have occurred when the incubator dropped to 39° C. There is no regular and continued growth at this temperature.

At 37.5° C. there was perceptible growth in all the species. This is in striking contrast to the results on solid media, as no species grew at a temperature above 35° C. on solid media.

At 35° C. *Endothia parasitica* showed practically the same amount of growth as at 27° and 29° C. for the first three days, but fell behind after that. *E. fluens* showed less growth at 35° than at the lower temperatures. These two species were the only ones tested at 35° C.

At 27° and 29° C. growth was markedly more abundant than at 37.5°, and in most of the species was more abundant than at room temperature. In *Endothia gyrosa* and *E. fluens mississippiensis* the growth at 27° C. was apparently equal to that at room temperature. At 22° C. (room temperature) all species developed much more rapidly than at the lower temperatures. At 17°, 12°, and 9° C. there was progressively less and less growth. At 7° C. and lower there was no growth whatever.

While these tests are not wholly satisfactory and must be regarded only as approximations, they are of some interest. Below 7° C. there is no growth in any species.

It is evident that there is a considerable range of temperature, from below 20° to well above 30° C., within which the species of Endothia grow readily. Within this range there may be a definite optimum for each species, but this has not yet been determined. For *Endothia parasitica* the optimum appears to be at 27° C. or above, and the same may be true of the other species.

At 40° C. or above no growth occurs. There is considerable evidence, however, that *Endothia fluens* is less resistant to the higher temperatures than either *E. parasitica* or *E. gyrosa*. After several of the tests the flasks were kept at room temperature for some days. It was found that all developed normally except those which had been kept at 40° and 37.5° C. These developed more slowly than those which had been kept at lower temperatures. It was particularly noticeable also that *E. parasitica* and *E. gyrosa* developed practically as well after being kept at 40° as at 37.5° C., while cultures of *E. fluens* which had been in 37.5° developed fairly well; but if kept at 40° for three days they entirely failed to develop.

DISTRIBUTION OF THE SPECIES OF ENDOTHIA.

During the past two years the writers have studied over 600 specimens of Endothia from various parts of the world. The greater number of these specimens have naturally come from the United States. The maps (figs. 1–4) show the known ranges of the various species in this country. Each dot on a map represents a locality from which the species has been collected. Frequently, of course, many specimens have come from a single locality; hence the number of dots by no means represents the number of collections.

In the case of *Endothia parasitica*, the dark portion represents the area over which the blight is practically continuous; that is, practically all the stands of chestnut are either diseased or dead. The dots represent known isolated infections and the solid line marks the botanical limit of the chestnut.

Endothia gyrosa is known only from the United States, but has a range in this country wider than that of any other species. As shown in figure 1, it has been found as far north as central Michigan, east to Connecticut, on the Pacific coast near San Francisco, and on the Gulf of Mexico. There is, however, a very great difference in the abundance of this species at different points. In the southeastern United States—that is, the region south of central Indiana and southern Virginia and east of central Arkansas and Louisiana—this species occurs in great abundance wherever its hosts are found. Broken branch stubs and exposed roots of Liquidambar, Fagus, and Quercus are covered with fructifications of this fungus. This is especially true of roots exposed by erosion or excavation which have suffered mechanical injury through the tramping of men or cattle. Farther north in Maryland, New Jersey, and Connecticut only an occasional specimen is found. Three days' search in southern Con-

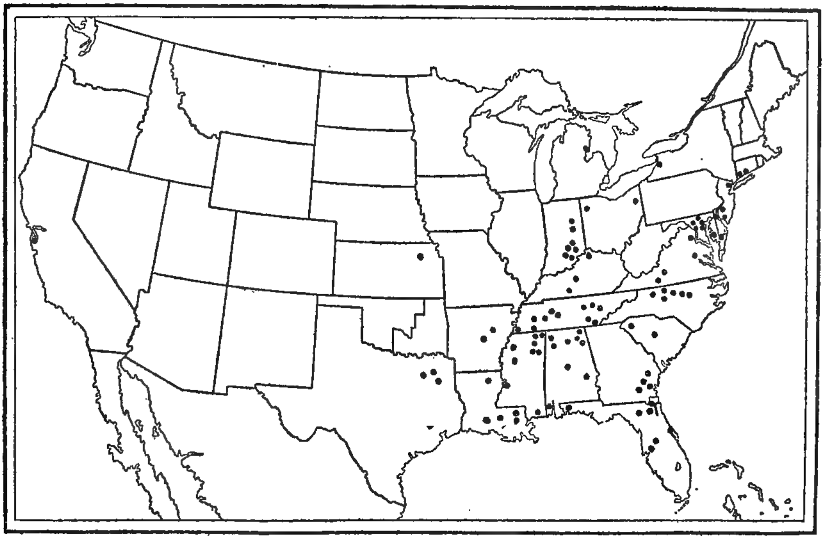


FIG. 1.—Outline map of the United States, showing the distribution of *Endothia gyrosa*.

necticut, for example, yielded only two specimens, both on Liquidambar, showing pycnidia only.

Endothia singularis is known at present only on oaks in the dry foothill regions of Colorado and New Mexico. Bethel, in a letter, states that it is very abundant in certain localities in Colorado.

Endothia fluens has long been known to occur in both Europe and America. Recently, through the kindness of Dr. Y. Kozai, director of the Central Agricultural Experiment Station, Nishigahara, Tokio, Japan, the writers received four specimens of fungi on chestnut. One of these, collected by S. Tsuruta on October 14, 1914, in the Province of Totomi, was the pycnidial stage of an Endothia, which when cultured proved to be *E. fluens*. Ascospore material of this species has since been collected by Meyer at Nikko, Japan, on the bark of *Pasania* sp.

Endothia fluens, while common to Europe, Asia, and America, has a much more limited range in the United States than *E. gyrosa*. It is fairly common on Castanea and Quercus from southern Pennsylvania and Ohio to northern Mississippi and Alabama. In southeastern Pennsylvania it has been found so far only on roots of Quercus, and in northern Mississippi and Alabama only on *Castanea dentata*.

Endothia fluens mississippiensis was first sent to the writers from Corinth, Miss., by Mr. T. E. Snyder, of the Bureau of Entomology, and has since been collected in only four other localities, three near the northeastern corner of Mississippi and one in central Kentucky.

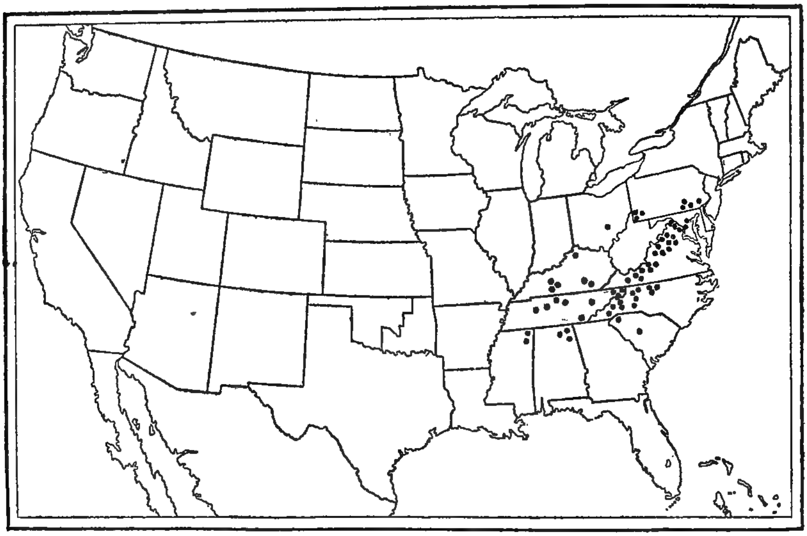


FIG. 2.—Outline map of the United States, showing the distribution of *Endothia fluens*.

As both *Endothia gyrosa* and *E. fluens* were collected in this country nearly a century ago by Schweinitz, it seems altogether probable that they are indigenous species which may have already reached the limits of their natural ranges in this country.

While the maps (figs. 1–4) do not give by any means every locality where Endothia is to be found and specimens are likely to be collected at many points outside the present known range, the writers feel justified in assuming that these maps represent the limits of the territory where *Endothia gyrosa* and *E. fluens* may commonly be found. This is especially true in the eastern portion, where the field has been rather thoroughly worked. It is unlikely, for instance, that *E. fluens* occurs abundantly in southern Alabama and Georgia, where *E. gyrosa* was found so commonly. Southeastern Pennsylvania must be somewhere near the northern limit for *E. fluens*, for the writers' four collections in that region are the result of six days' search. At the northeastern limit of *E. gyrosa*, Clinton (15, p. 79) found only a single specimen after two years' search, and the writers have looked for it in all the other New England States without finding a single specimen. The report of *E. gyrosa* from Massachusetts by Hitchcock (42, p. 63) has already been shown to be a probable error in identification.

FACTORS INFLUENCING DISTRIBUTION.

HOST RELATIONS.

Just what determines the present ranges of the species can not, of course, be positively decided, but some relation to certain external factors may be traced. Neither species has the same distribution as

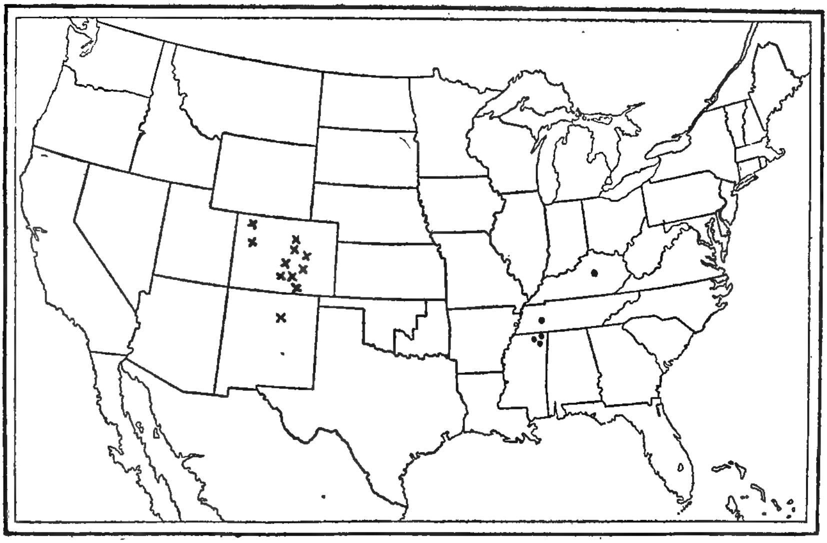


FIG. 3.—Outline map of the United States, showing the distribution of *Endothia fluens mississippiensis* and *E. singularis*. The dots indicate collections of *E. fluens mississippiensis* and crosses indicate collections of *E. singularis*.

its hosts. Quercus and Fagus are both abundant farther north than *Endothia gyrosa* has yet been found, while Quercus is abundant north and south of the known range of *E. fluens*. It may be worthy of note, however, that *E. gyrosa* extends north as far as Liquidambar is found. Perhaps more significant is the relation of the range of *E. fluens* to that of the chestnut. As will be seen from a comparison of the maps (figs. 2–4), *E. fluens* is not found abundantly at any point outside the natural range of the chestnut. Especially interesting is the fact that the southeastern limits of *E. fluens* and *Castanea dentata* are practically coincident, for in this region *Endothia fluens* was found only on Castanea, never on Quercus. This suggests the possibility that Castanea may be the original and favorite host of *Endothia fluens*.

SOIL CONDITIONS.

Greater opportunity for infection seems to be an important factor in the greater abundance of Endothia in the South. By far the most favorable places of infection, especially for *Endothia gyrosa*, are bruised or broken but still living roots. Soil, cultural, and climatic conditions combine to make these many times more abundant in the Southern States than elsewhere. The more sandy and easily eroded soil, usually without turf, subject throughout the winter to the action of wind and rain, leaves innumerable oak roots exposed, which are readily injured by vehicles and the tramping of horses and cattle, leaving wounds suitable for the entrance of Endothia. In the

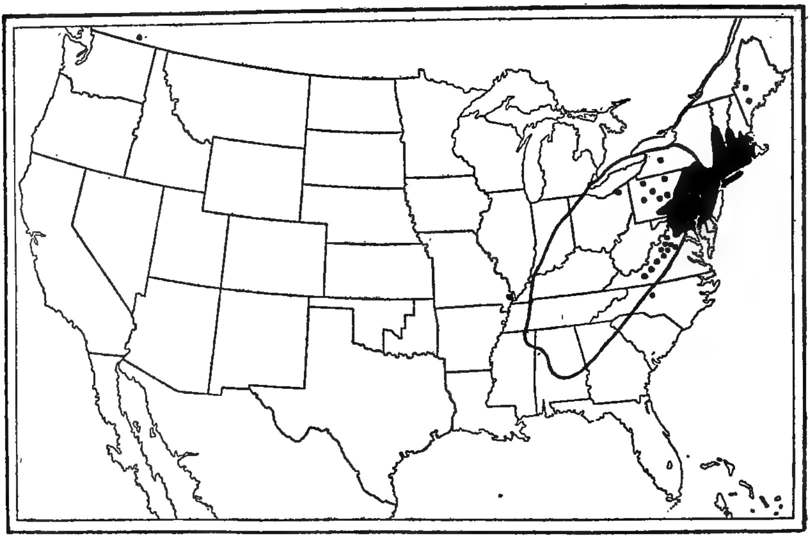


FIG. 4.—Map of the United States, showing the distribution of *Endothia parasitica* in December, 1915. The solid portion shows the area in which *E. parasitica* is generally present. The dots indicate scattered infections. The heavy line shows the limits of the range of *Castanea dentata*.

North, the more rocky soil, frequently covered with sod, protected through much of the winter by snow, makes exposed roots much less common, and the roots so exposed are rather less subject to mechanical injury. In the writer's experience the most favorable localities for collecting *E. gyrosa* are the unfenced public squares of Southern towns, where partial grading, erosion, and constant traffic have left hundreds of oak roots exposed, and the pastures of southwestern Indiana, where the roots of Fagus are often found injured by cattle.

COMPETITION AMONG FUNGI.

The writers' extensive field studies and observations have convinced them that competition among fungi must be considered as a factor in determining their distribution. As already stated, while *Endothia fluens* occurs on Quercus, it has been found toward the southwestern limit of its range (northern Mississippi and Alabama) only on Castanea, and in Tennessee the writers have sixteen collections of this species on Castanea and only three on Quercus. In this same region, *E. gyrosa* is everywhere abundant on Quercus. In numerous inoculations with *E. gyrosa* and *E. fluens* on oak it has been found that *E. gyrosa* is more generally successful than *E. fluens*. Moreover, *E. gyrosa* occurs abundantly on Liquidambar and Fagus in this region, thus providing more numerous sources of infection for this species than for *E. fluens*. It seems highly probable, therefore, that *E. gyrosa*, with its greater affinity for oak and greater opportunity for infection, may occupy the available oak roots to the exclusion of *E. fluens*, even though climatic conditions are favorable for the growth of the latter species. Castanea rarely serves as a host for *E. gyrosa;* consequently, on this host *E. fluens* meets with little competition and is very abundant.

In the northeastern limit of its range, *Endothia fluens* has been found only on oak roots. Whether it grows naturally on chestnut in this region can not well be determined, since practically all the chestnut trees here are dead or badly diseased with *E. parasitica*. *E. gyrosa* is rare in this region, but *E. fluens* here evidently comes into competition with *Valsa frustum-coni* (Schw.) Curtis, which is common on exposed roots of various species of Quercus.

CLIMATE.

Since none of the species of Endothia in America extends to the limits of its host species, climate probably has an important part in determining their present ranges.

In this connection it is of interest to compare several life zone and climatic maps which have been published with the range maps of the various species of Endothia. The map entitled "Life zones of the United States," by C. Hart Merriam (50, pl. 14), is based largely on a study of animal life. Merriam deduces from his studies the conclusion that the northward distribution of animals and plants is determined by the total quantity of heat and their southern distribution by the mean temperature of the hottest part of the year. The life zones which he outlines show, however, a striking relation with the known ranges of Endothia in America. With the exception of a single locality for *Endothia gyrosa* in Michigan, all the known localities for *E. gyrosa* and *E. fluens* fall within the Upper Austral and Lower Austral zones. All the known localities for *E. fluens* and all the region where *E. gyrosa* has been found abundantly fall within the humid divisions of these zones. The northeastern limits of the Upper Austral coincide very closely with those of *E. gyrosa;* its limits in Pennsylvania include the northern localities known for *E. fluens*, while the southern limits of this zone coincide closely with the southern limit of *E. fluens*.

The Livingstons (47) have published maps based on temperature summations and temperature efficiencies, as well as maps in which isoclimatic lines of temperature are combined with precipitation indices and evaporation indices for the mean frostless season.

While no very definite relations between these maps and the ranges of Endothia can be traced it is noteworthy that the localities where *Endothia gyrosa* is known to be abundant are all south of or near the 600 line of temperature efficiency, and only one collection of *E. gyrosa* has been made north of the 400 line. *E. singularis*, on the other hand, has thus far been found only north of the 400 line.

Zon's map (86) of vegetal regions of the United States is based on periods of growth and rest. The regions where *Endothia gyrosa* and *E. fluens* are abundant are all south of the line which marks the northern limit of seven months' vegetation. In fact this coincides very closely with the northern limit of *E. fluens*, and no specimen of *E. gyrosa* showing ascospores has been found farther north.

The relations pointed out above strongly suggest the possibility of some causal connection between climatic conditions and the present ranges of Endothia species, but just what factors may limit the spread of the species is not yet determined. The temperature tests recorded on pages 45 to 48 throw little light on this problem, for the maximum and minimum temperatures are about the same in the various species. *Endothia fluens* seems to be less resistant to the effects of high temperature (40° C.), but it is difficult to see that this fact alone has any direct bearing on the question of distribution.

DISCOVERY OF ENDOTHIA PARASITICA IN CHINA.

For eight years after its discovery in the New York Zoological Park in the summer of 1904, *Endothia parasitica* was known only from eastern North America. During this time two quite different opinions as to the origin of the fungus were advanced. Some investigators maintained that *E. parasitica* was an indigenous fungus (15); others that it had been imported from some foreign country, probably oriental (51, 52.) In the fall of 1912, however, pycnospore material was sent from Agassiz, B. C., by H. F. Güssow, Dominion Botanist of Canada. Cultures made from this material were identical with *E. parasitica*, and a series of inoculations on *Castanea dentata* produced typical cankers. Later, a large quantity of material collected at Agassiz by Dr. James R. Weir was received, which included a few ascospores. These proved to be typical *E. parasitica*.

A brief description of the identification of other specimens of *E. parasitica* from Agassiz is given by Faull and Graham (29). These writers report that in the material sent them in the summer of 1913 there were no perithecia, but that the pycospores were typical *E. parasitica* and the characteristic mycelial fans were present in the bark. Cultures of the fungus proved it to be identical with *E. parasitica*. They also state (p. 203) that the chestnuts grown at Agassiz "are of oriental, European, and American origin. The stock was purchased from nursery firms located in New Jersey, Ohio, and California. One of these at least 'was a heavy importer of oriental trees and shrubs'." They suggest that it "is significant that a connection with the Orient exists."

In support of this view, the statement of Mr. Sharpe, who had charge of planting the nut orchard at Agassiz, may be given. Dr. Weir visited Mr. Sharpe at Salmon Arm, B. C., and Mr. Sharpe stated definitely to him that he would be willing to furnish affidavit to the effect that in the main or entirely the chestnut trees in the nut orchard were originally imported from the Orient; in fact, a part of the trees, according to Mr. Sharpe, undoubtedly came from Japan or China and were shipped to Agassiz in the original wrappings, which consisted of the peculiar mats and casings of those countries.

In a letter accompanying the specimens from British Columbia Güssow states that "these trees may be regarded as absolutely isolated. There is no other chestnut tree anywhere round it for 500 miles and more." It seems highly probable therefore that *E. parasitica* was carried to this locality on nursery stock, perhaps as suggested by Faull and Graham and by Weir by importation from the Orient.

The following spring (1913) Mr. Frank N. Meyer, agricultural explorer, discovered this fungus in Chihli Province, China, under such conditions as could leave no doubt that it is indigenous there. The account of this discovery and its corroboration in this country was published by Fairchild (27), and also by the writers (76).

As outlined by Fairchild (27), Meyer first found the diseased chestnuts near Santunying, a small town 1½ days journey by cart from a railroad, northeast of Peking in Chihli Province, between Tsunhuatcho and Yehol.

A small specimen of diseased chestnut bark from this region was inclosed in a letter from Mr. Meyer which was received by Mr. Fairchild on June 28, 1913. From this specimen, which showed only pycnospores, cultures were obtained, which proved it to be true *E. parasitica*. On July 23 more Chinese specimens were received from the same locality, as well as from Scha Ho in the same Province. These included a large canker on a chestnut branch about 6 cm. in diameter, which agreed in every respect with cankers produced on varieties of Japanese chestnuts in this country (Pl. XXII).

Other specimens in this collection showed well-developed perithecia and ascospores. The ascospore measurements made at the time, as well as the cultures of the Chinese fungus and the inoculation experiments on *C. dentata*, are described in the previous paper by the writers (76, p. 296).

Shortly after this first series of inoculations was made subcultures of the Chinese material were sent to several investigators who had been studying the chestnut-bark disease, in order that the Endothia from China might be tested as soon as possible under American conditions by inoculations at various points throughout the known range of the disease.

A series of inoculations was made by Prof. J. Franklin Collins at Martic Forge, Pa., on July 14, 1913, using American and grafted Paragon and grafted Japanese chestnut trees. Another series of inoculations, 56 in number, was made at the same locality September 10, 1913, by Dr. Caroline Rumbold on grafted Paragon chestnuts. Twenty inoculations were made on native chestnuts at Anderson, Pa., October 2, 1913, by Dr. F. D. Heald and R. A. Studhalter. Inoculations with the Chinese Endothia were made at Leesburg, Va., on both *Castanea dentata* and *C. pumila* by G. Flippo Gravatt and J. T. Rogers, August 16, 1913.

All these investigators made duplicate inoculations with American material, and all agreed that the Chinese fungus was identical in its effects on the host with the American chestnut-blight fungus. During the season of 1914 numerous inoculations with material from China were made by the writers at various points in New Hampshire, Massachusetts, Connecticut, New York, Delaware, and Maryland, while others have been made in Rhode Island by Prof. Collins with the same results.

ADDITIONAL CHINESE SPECIMENS.

Since the publication of the previous paper (76) additional specimens of *E. parasitica* from China have been received from Meyer; one collected at Changli, Chihli Province, China, October 13, 1913, by Mrs. Mary S. Clemens; a quantity of material collected by Meyer himself in the village of Tachingko, near Taianfu, Shantung, China, March 21, 1914; and another collected by him at Yatyeko, Shensi, China, September 2, 1914. A few cankers have also been sent by Meyer, collected by him at Shihbonshan, near Hangchow, Chekiang Province, China, June 26, 1915. The label on this specimen bears the further comment, "very destructive in this locality." Cultures have been made from all these specimens and have invariably proved to be identical with cultures of *E. parasitica* found in this country.

AN OLD CANKER CAUSED BY ENDOTHIA PARASITICA ON A BRANCH OF CASTANEA MOLLISSIMA.

Collected by Frank N. Meyer, May 31, 1913, near Santunying, Chihli Province, China.

FIG. 1.—JAPANESE CHESTNUT AT NIKKO, JAPAN, FROM WHICH THE CHESTNUT BLIGHT FUNGUS (ENDOTHIA PARASITICA) WAS COLLECTED BY F. N. MEYER, ON SEPTEMBER 17, 1915.

FIG. 2.—TWO BRANCHES OF A JAPANESE CHESTNUT. THE LARGER (TO THE LEFT) WAS BROUGHT TO THIS COUNTRY BY F. N. MEYER, AND FROM IT ENDOTHIA PARASITICA WAS ISOLATED.

As Tachingko is 300 miles south of Changli, where *E. parasitica* was first collected by Meyer, and Yatyeko is 500 miles west of Tachingko, it seems highly probable from the collections that *E. parasitica* is widely distributed in China (fig. 5).

Meyer, writing from Hangchow, July 1, 1915, refers as follows to the condition of the chestnuts in that locality:

Well, I have a few interesting discoveries to report. First, there are many specimens of *Castanea mollissima* scattered at the bases and on the lower slopes of the hills around here, and these chestnuts are seriously attacked by the bark fungus, and in my estimation are going to succumb to it these coming years. The chinquapins (*Castanea* spp.), however, which are very abundant on the higher and more sterile hill slopes, seem to be immune;

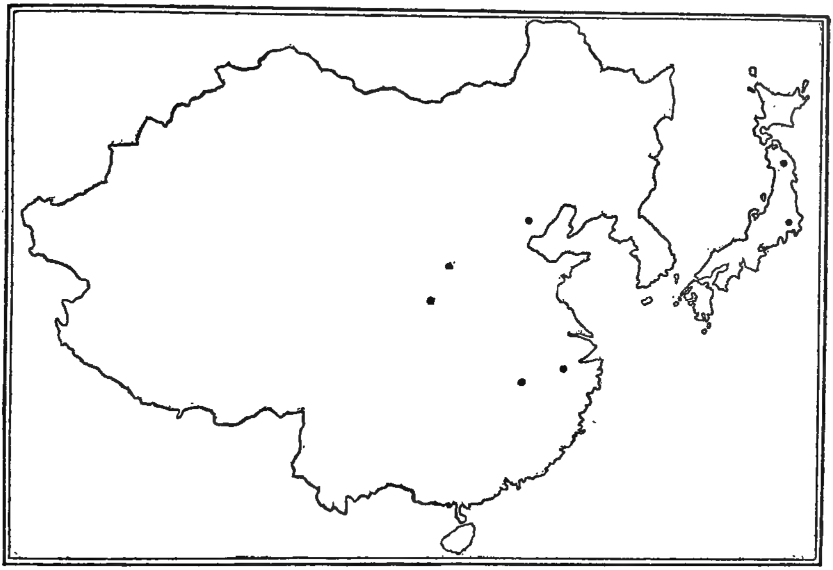


FIG. 5.—Outline map of China and Japan, showing the localities in which *Endothia parasitica* has been found.

at least I did not see any evidences of damage or even of attacks. This brings another interesting point to my mind. I was told in Nanking that various missionaries at Kuling, the great summer resort in central China for missionaries, were cutting down their chestnuts, as the tops were all dying, due to borers working underneath the bark.

Meyer has since stated to the writers that he believes the destruction of the chestnut at Kuling is due to *Endothia parasitica* rather than to borers.

In the writers' earlier publication the following statement was made (76, p. 297):

The Chinese organism has thus been shown to be practically identical with the American in all its morphological and physiological characters and in the production of the typical chestnut blight and the pycnidial fructifications of the fungus. There is apparently but one other requirement that could be made according to the strictest pathological canons to perfect the proof in this case, and that is the production of typical ascospores of *E. parasitica* on the lesions produced by the inoculations.

The last requirement has now been fulfilled. Specimens collected February 15, 1915, from inoculations made September 20, 1913, on chestnuts in Virginia, near Point of Rocks, Md., with Chinese material, show perithecial stromata with typical ascospores of *E. parasitica*, thus completing the evidence.

DISCOVERY OF ENDOTHIA PARASITICA IN JAPAN.

More than two years after his original discovery of *Endothia parasitica* in China (June 3, 1913), Meyer also discovered the fungus in Japan. A brief account of his discovery has already been published by the writers (78). It may be sufficient here to state that following the discovery of *Endothia parasitica* in China the writers endeavored by correspondence to obtain the fungus from Japan. While not successful in obtaining *Endothia parasitica*, the writers did receive several specimens of fungi, including species of Endothia on species of Castanea. These, together with several specimens of fungi found on chestnut nursery stock from Japan, make it clear that there are in that country several Pyrenomycetes other than *Endothia parasitica* more or less parasitic on Castanea.

Meyer first discovered the chestnut-blight fungus in Japan at Nikko, September 17, 1915, on wild trees of *Castanea crenata* Sieb. and Zucc. A photograph of the trees from which he collected specimens of *Endothia parasitica* is shown in Plate XXIII, figure 1, and a branch from which the diseased material brought to the United Sates was taken is shown in Plate XXIII, figure 2.

Shortly after Meyer's arrival in Washington in December, 1915, the specimens collected at Nikko were turned over to the writers for study. Examination at once showed cankers and mycelial fans typical of *Endothia parasitica*. The material also contained typical pycnospores and ascospores of the fungus. Cultures made from single ascospores on various culture media proved to be identical with those of *Endothia parasitica* found in this country and in China, thus establishing beyond question the identity of the fungus.

Meyer's observations as to the resistance of the Japanese chestnuts to this disease are of great interest. He states that the trees vary considerably as regards their power of resistance, but that in general the Japanese chestnut is even more resistant to *Endothia parasitica* than is the Chinese chestnut (*Castanea mollissima*).

As announced in the same publication (78), *Endothia parasitica* was collected by Dr. Gentaro Yamada at Morioka, northern Japan. These specimens, which show typical cankers as well as ascospores of the fungus, were received by the writers on January 8, 1916.

PRESENT DISTRIBUTION OF ENDOTHIA PARASITICA IN AMERICA.

The present range of *Endothia parasitica* in America, as shown by the map (fig. 4), is probably merely the extent to which it has been able to spread in the time since it was first introduced.

Whether *Endothia parasitica* was introduced into one locality or several is uncertain, but the studies of Heald (40, 41) and others have shown clearly that the spores of *E. parasitica* are carried by the wind, by insects and birds, and on nursery stock, which would account for its wide distribution and for its occurrence in isolated localities, long distances away from the main body of the disease. It also makes it seem probable that the fungus will continue to spread with some rapidity.

Certainly, there is no evidence that any factor, climatic or otherwise, is likely to prevent the spread of this fungus into the large area of chestnut south of its present range. On the contrary, the duplicate inoculations made by the writers show clearly that the fungus grows more rapidly at the southern limit of its present range than farther north, where it is much more common. The longer growing season in the South is also no doubt an important factor.

In this connection, it may be noted that Köppen (46), in his map of the vegetation regions of the earth, places the portion of China where *Endothia parasitica* has been found indigenous in the same climatic region as that portion of the United States where it is now doing such destructive work. He designates this region as the "Hickory" division of the mesotherms.

HOST RELATIONS OF THE SPECIES OF ENDOTHIA.

ENDOTHIA GYROSA.

Endothia gyrosa occurs commonly on Liquidambar, Fagus, and Quercus, occasionally on Castanea, and has been found on Vitis in Alabama, but the writers were unable to obtain fresh material from this host.

While Fagus and Quercus are, of course, closely related, it seems remarkable that a fungus should be abundant on hosts so different as Liquidambar and Quercus, yet so rare on any other host as to be only once reported. It seemed possible, indeed, that the fungus on Liquidambar, while morphologically and culturally identical with that on the various other hosts, might prove to be physiologically different. In order to obtain more definite information on this point, several series of cross inoculations were made.

It had been observed that *Endothia gyrosa* was found most frequently on the cut or broken ends of branches or on exposed, bruised, or broken roots. In making inoculations, therefore, a small branch, 1 inch or less in diameter, was cut off about 6 inches from the main trunk. Mycelium from corn meal in flasks was placed on the cut end of the stub and covered with wet cotton, over which oiled paper was tied. In about two weeks the paper and cotton were removed. In all cases. branches similar to those inoculated were cut as checks.

TABLE III.—*Inoculations with Endothia gyrosa.*

Source of fungus and date.	Host inoculated.	Number of inoculations.	Number successful.	Remarks.
Fagus:				
May 8, 1913	Castanea	6	3	Pycnospores first observed on Oct. 16.
May 29, 1913	Fagus	3	3	Pycnospores first observed on Aug. 29 for two and on Oct. 10 for the third.
Sept. 15, 1913	Liquidambar	5	2	No growth until the spring of 1914; pycnidia scattered and small on Oct. 13.
Do	Quercus	4	2	No growth until spring; well developed on Oct. 13, 1914.
Apr. 2, 1914	Fagus	4	0	
Do	Quercus	4	0	
Do	Castanea	4	2	Pycnidial stromata well developed on Oct. 13, 1914.
May 23, 1914	do	4	4	Do.
Do	Liquidambar	4	0	
Do	Quercus [1]	4	0	
Do	Fagus	4	3	Do.
Quercus:				
May 29, 1913	do	3	3	Pycnospores first observed on Aug. 29, 1913.
Do	Liquidambar	4	2	Very slight indications of growth on Aug. 29, 1913; a few pycnidia with spores on Oct. 16.
Sept. 15, 1913	do	8	0	
Do	Castanea	4	2	Large well-developed pycnidia on Oct. 13, 1914.
Apr. 2, 1914	Fagus	4	0	
Do	Quercus [1]	4	0	
Do	Castanea	4	4	Large abundant pycnidial stromata on Oct. 13, 1914.
May 23, 1914	do	4	4	Abundant well-developed pycnidial stromata on Oct. 13, 1914.
Do	Liquidambar	4	0	
Do	Quercus [1]	4	0	
Do	Fagus	4	3	
Castanea:				
May 29, 1913	do	3	3	Pycnospores first observed on Aug. 29, 1913.
Do	Liquidambar	3	3	Slight indications of pycnidial formation on Aug. 29, 1913; pycnospores on all on Nov. 17, 1913.
Apr. 2, 1914	Fagus	4	0	
Do	Quercus [1]	4	1	Large well-developed pycnidial stromata on Oct. 13, 1914.
Do	Castanea	4	3	Scattered, fairly well-developed pycnidia on Oct. 13, 1914.
May 23, 1914	do	4	4	Abundant well-developed pycnidia on Oct. 13, 1914.
Do	Liquidambar	4	0	
Do	Quercus [1]	4	0	
Liquidambar:				
May 29, 1913	Fagus	3	0	
Do	Liquidambar	3	3	Pycnospores first observed on Aug. 29.
Sept. 15, 1913	Fagus	8	5	No evidence of growth until the spring of 1914; pycnidia few and small on Oct. 13.
Do	Castanea	6	2	No growth until the spring of 1914; pycnidia small on Oct. 13.
Do	Quercus	6	0	
Apr. 2, 1914	Fagus	4	0	
Do	Quercus [1]	4	0	
Do	Castanea	4	0	
May 23, 1914	do	4	0	
Do	Liquidambar	4	4	Abundant pycnidia on Oct. 13, 1914.
Do	Quercus [1]	4	0	
Do	Fagus	4	0	

[1] The species used in this case was *Quercus prinus*, which proved to be an exceedingly unfavorable host for *Endothia gyrosa*.

Inoculations with *Endothia gyrosa* were also made on numerous hosts from which it had never been reported. Six or more inoculations were made on each host, in the manner described above, except that a part of each series was left unwrapped. The following inoculations showed no growth whatever: Those made in Virginia, April 4, 1914, on *Cornus florida*, *Fraxinus americana*, *Juglans cinerea*, *Ilex opaca*, *Sassafras variifolium;* in Maryland, April 17 and 22, 1914, on *Carya glabra*, *Cornus florida*, *Liriodendron tulipifera*, *Nyssa sylvatica*, *Sassafras variifolium*, and *Quercus alba;* and in New York, July 11, 1914, on *Betula alba*, *Prunus serotina*, *Populus tremuloides*, *Rhus glabra*, *Salix* sp., and *Sassafras variifolium.* On *Acer pennsylvanicum* and Carya two out of the six inoculations developed a few stromata. These were found only on the tissue injured by the cut and there was no evidence of parasitism.

On Castanea, Fagus, Quercus, and Liquidambar, however, a branch inoculated as described above dies back rather faster than the checks. This would indicate, as suggested by Clinton (18, p. 419), that *E. gyrosa* is a weak parasite; that is, that it is able to invade injured and dying tissue.

It is evident from Table III that *Endothia gyrosa* coming from any of the four hosts named will, under favorable circumstances, grow on any of the others. Several other interesting facts are brought out by the table. Inoculations made with material from Liquidambar grew in general more rapidly on Liquidambar than on any of the other hosts. In many cases, material from Liquidambar failed to grow on Castanea, Fagus, and Quercus, and even when inoculations were successful growth was somewhat slower and pycnidial production less abundant.

On the other hand, inoculations from Fagus, Quercus, and Castanea usually grew less rapidly on Liquidambar than on any of the other three hosts. This is, of course, what would be expected from the systematic relationships of the host species, and while the inoculations made are too few to permit any definite conclusions they are nevertheless suggestive. As shown by Table III, *Quercus prinus* proved a very unfavorable host for *Endothia gyrosa.*

In all cases inoculations made in the fall (Sept. 15) failed to show any growth until the following spring. This corresponds with the results in inoculations of *Endothia parasitica*, but it is, of course, impossible to determine whether this failure to grow is due to the dormant condition of the host or to unfavorable weather conditions. Perhaps correlated with the results just noted are the unusually poor results obtained from inoculations made in the early spring. It will be noted that inoculations made on April 2, 1914, were in general much less successful than those made on May 23, 1914, in exactly the same locality and in many cases on the same hosts.

ENDOTHIA SINGULARIS.

The material of *Endothia singularis* distributed by Sydow as *Calopactis singularis* was on *Quercus gambellii* Nutt. The writers have seen abundant material on this species as well as specimens on *Q. utahensis* (A. DC.) Rydb., *Q. leptophylla* Rydb., and *Q. nitescens* Rydb. Specimens on the latter two hosts were sent by Bethel, who, in a letter, reports finding this species also on *Q. pungens* Liebm.

All of these species except *Quercus leptophylla* are chaparral-forming shrubs growing at an elevation of 4,000 feet or more. There is at present no evidence that the fungus is parasitic on any of the species.

Inoculations with the mycelium of *Endothia singularis* were made on Fagus and on *Quercus alba*, *Q. velutina*, *Q. rubra*, and *Q. palustris*, as well as on *Q. ilicifolia* on Overlook Mountain in the Catskills. No growth has, however, been noted in any case.

ENDOTHIA FLUENS.

When these investigations were commenced, the writers thought that the Endothia found in Europe might be the same as *Endothia parasitica* found in America. Inoculations were accordingly made in Maryland during October, 1912, with cultures from material collected on the chestnut by the senior writer at Stresa, Italy, and Etrembieres, Switzerland, using material of *E. fluens* sent by P. J. Anderson from Pennsylvania; also material of that species and of *E. parasitica* collected in Virginia as checks. In this case, as in all others where no special mention is made of the method, inoculations were made by cutting through the bark to the wood with a sharp knife. The inoculating material was then inserted with a freshly cut twig and the wound tied up either with cord or rubber bands. If cord was used it was cut away within two to four weeks. The rubber bands became loosened by exposure to the weather within about the same time.

Inoculations were made with all the above material on sprouts of *Castanea dentata* and *Quercus prinus*. The results are summarized in Table IV.

TABLE IV.—*Inoculations of Endothia in Maryland in October, 1912.*

Fungus.	Host inoculated.	Number of inoculations.	Number showing growth.
Endothia parasitica	Castanea dentata	32	28
Do	Quercus prinus	6	0
E. fluens:			
European	Castanea dentata	14	14
American	do	26	23
Do	Quercus prinus	12	9

The inoculations were examined every 10 days until December 1 and monthly thereafter throughout the winter. There was no perceptible growth until the last of April, when several of the inoculations of *Endothia parasitica* showed slight sunken areas. By May 20 all inoculations checked as showing growth (last column of table) showed the slight yellowish elevations of the bark which indicate the beginnings of pycnidia. On August 30 all the inoculations of *E. parasitica* checked as showing growth had spread rapidly and attacked the living tissues of the host, producing typical cankers with mycelial fans and abundant pycnidia.

No signs of growth were noted in the inoculations of *Endothia fluens* until about the middle of May, 1913, when most of them showed signs of pycnidium formation. By August 30 all those marked as showing growth had produced characteristic pycnidia with spores, which when cultured proved to be typical *E. fluens*. In no case, however, did this fungus spread for any appreciable distance beyond the injured portion or show signs of active parasitism. These results agree with those given by Anderson and Anderson (2, p. 206) with American material of *E. fluens*, and have since been fully confirmed by further observation.

During the summer of 1914 about 1,100 inoculations of *Endothia fluens* from both European and American sources and of *E. fluens mississippiensis* were made on Castanea sprouts. In no case was there any evidence of active parasitism, as in *E. parasitica*.

Although *Endothia fluens* has been found in Europe on a considerable number of deciduous host plants (as recorded on p. 18), the writers have thus far failed to find it in this country on any except Castanea and Quercus. It seemed possible that the European strain of the fungus might be somewhat more plurivorous[1] in its habits than the American. In order to throw some light on this point, the following inoculations were made:

On March 31, 1914, 10 inoculations were made, half of European and half of American material, at Francis, Md., on the following hosts: *Alnus rugosa, Betula nigra, Carpinus caroliniana, Carya glabra, Fagus grandifolia, Liriodendron tulipifera,* and *Liquidambar styraciflua.* Pycnidia appeared only on *Carya glabra* and *Carpinus caroliniana.* Of the inoculations which actually produced pycnidia, four on Carpinus and three on Carya, one of each was the European strain.

On April 22 inoculations were made with American material of *E. fluens* at Kensington, Md., on *Acer rubrum, Carya glabra, Cornus florida, Fagus grandifolia, Prunus serotina, Quercus prinus, Sassafras variifolium, Vaccinium* sp.,

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[1] This term is proposed to apply to fungi occurring on two or more hosts or substrata and may be applied to all fungi except true parasites. It is derived from *plus* (plur-), more, and *vorare,* to devour. Compare omnivorous already in use for fungi.

The term pleioxonous might be derived from De Bary's proposed word pleioxony and applied to true parasites having the power to invade more than one species of host plant, and the term plurivorous restricted to nonparasitic organisms.

and *Vitis* sp. Of these, *Acer rubrum* and *Carya glabra* gave numerous small pycnidia.

On July 10 the following hosts were inoculated at Woodstock, N. Y., with *E. fluens* from Europe: *Acer rubrum, A. pennsylvanicum, Carya ovata, Corylus americana, Fraxinus americana, Hamamelis virginiana, Kalmia latifolia, Populus grandidentata, Prunus serotina, Rhus glabra, Salix* sp., *Sassafras variifolium,* and *Syringa vulgaris.* Each host was inoculated in six or seven places, but all failed to develop except two inoculations on *Acer pennsylvanicum* and one on *Corylus americana.*

The results cited above are so largely negative that they prove very little except that the European strain shows no special affinity for these hosts in America.

ENDOTHIA FLUENS MISSISSIPPIENSIS.

Only five collections of *Endothia fluens mississippiensis* have thus far been made, three on *Castanea dentata* and two on *Quercus* sp. From the results of the inoculations its host relations appear very similar to those of *E. fluens.* The results are shown in Table V.

TABLE V.—*Inoculations with Endothia fluens mississippiensis on Castanea and Quercus.*

Source of culture.	Host inoculated.	Date.	Number of inoculations.	Number showing pycnidia.
Castanea	Castanea	Jan. 20, 1912	8	8
Do	do	May 8, 1913	4	4
Do	do	do	4	4
Do	Quercus prinus	do	9	7
Do	Castanea	Apr. 18, 1914	12	10
Quercus	do	do	12	10

The inoculations of January 20, 1912, showed no signs of growth until early in May, when the first signs of pycnidium formation were observed. The inoculations with *Endothia fluens mississippiensis* made May 8, 1913, showed within three weeks discolored areas near the cut which were larger than those about the check cuts. On July 25, 1913, all of the inoculations of *E. fluens mississippiensis* marked "successful" showed the beginnings of pycnidium formation. By August 30, 1913, they were producing pycnospores, which when cultured proved to be *E. fluens mississippiensis.*

Inoculations were made in April, 1914, for the purpose of comparing the material collected on oak with that collected on chestnut. No difference was detected, and there was no indication of active parasitism. This form behaved in this respect exactly as did the *E. fluens* from Virginia both on *Castanea dentata* and *Quercus prinus.*

A series of inoculations parallel to that made with *E. fluens* was made with *E. fluens mississippiensis.* The same hosts were used, and in most cases the dates and places of the inoculation were the same. The results of all that showed any growth are given in Table VI.

TABLE VI.—*Inoculations with Endothia fluens mississippiensis on Acer and Carya.*

Location.	Host.	Number of inoculations.	Number showing pycnidia.
Woodstock, N. Y.	Acer rubrum	6	3
Do	Carya glabra	6	2
Francis, Md	....do	6	1
Kensington, Md	Acer rubrum	1	1
Do	Carya glabra	2	2

As in *Endothia fluens* the growth was confined to the injured tissues, and there was no evidence of parasitism.

ENDOTHIA TROPICALIS.

The material of *Endothia tropicalis* from which the writers secured their cultures, was collected by T. Petch in Ceylon. As the species of Endothia in the Northern Hemisphere are chiefly on members of the Fagaceæ, Petch's statements with regard to hosts are of considerable interest. In a letter of March 6, 1914, he writes:

> We have no Fagaceæ native in the island. We have introduced various species of *Quercus* and *Castanea*, but subsequent to Thwaite's discovery of this fungus. I do not think there can be any doubt that the fungus is native to Ceylon * * *
>
> Of the speciments now sent * * * those in the packet * * * are from a tree which was producing shoots from the base. This tree is *Elaeocarpus glandulifer* Mast. From the bark and habit, I believe that all my "finds" of *Endothia* have been on this species.
>
> In the accounts of the American chestnut disease, I notice that several authors speak of "cankers," and give their rate of growth. I never see "cankers" (Krebs) on the Ceylon trees. The bark appears to die regularly and smoothly from above downward, and is quite unbroken except for the minute cracks through which the stromata emerge.

Inoculations.—As already noted, ascospores of *Endothia tropicalis* resemble those of *E. parasitica* even more closely than do those of *E. fluens*. This fact, together with its similarity on culture media and its oriental origin, led the writers to fear possible parasitic tendencies.

Inoculation experiments were accordingly made only on the chestnut and under carefully guarded conditions. In all, about 30 inoculations were made on 2-inch chestnut sprouts, using the methods described for other species.

Of 25 inoculations made in May and June, practically all had developed a few pycnidial stromata by October 20. These stromata were a somewhat brighter orange than those of *E. fluens* or *E. fluens mississippiensis*, and the spores when cultured produced typical *E. tropicalis*. In no case, however, was there any evidence of parasitism.

ENDOTHIA PARASITICA ON HOSTS OTHER THAN CASTANEA.

The first collection of *Endothia parasitica* on a host other than Castanea of which the writers have any knowledge is that made by J. Franklin Collins at Martic Forge, Pa., June 30, 1909. As announced by Dr. Metcalf at the Boston (December, 1909) meeting of the American Phytopathological Society, the specimen consisted of a small dead branch of *Quercus velutina* with several spore tendrils typical of *E. parasitica.* This material, which consisted of a terminal branch with leaves still retained, was at once sent to the laboratory at Washington, and cultures obtained from it were subsequently used in making numerous inoculations on *Castanea dentata* on Long Island, N. Y., in July, 1909. On November 17 of the same year, Metcalf reported that the inoculations were entirely successful and had produced typical lesions, thus establishing without question the identity of the fungus.

Fulton (37, p. 53) reports *E. parasitica* on the dead bark of *Quercus alba* and *Quercus velutina*, but found no evidence that the fungus produces in any sense a disease of such trees. Clinton (18, p. 428) mentions cultures from three different species of Quercus and (p. 376) reports specimens on *Quercus alba*, *Q. rubra*, and *Q. velutina.*

Anderson and Babcock, as quoted by Anderson and Rankin (6, p. 564), found *Endothia parasitica* on *Quercus velutina*, *Q. alba*, *Q. prinus*, *Rhus typhina*, *Acer rubrum*, and *Carya ovata*, but it seemed parasitic only on *Quercus alba.* They made inoculations with materials isolated from Castanea on *Quercus prinus*, *Q. velutina*, *Q. alba*, *Q. coccinea*, *Rhus typhina*, *Acer rubrum*, *Liriodendron tulipifera*, and *Carya ovata.* Two trees of Rhus were girdled and killed by the growth of the fungus. On *Quercus alba* the fungus seemed slightly parasitic, but none of the trees were killed. The fungus grew and produced spore horns on the wounded tissue near the point of inoculation on all the hosts except Acer and Liriodendron.

Rankin (62, p. 238) also made inoculations with *Endothia parasitica* from Castanea on *Quercus prinus*, *Q. rubra*, *Q. alba*, *and Q. coccinea.* He found that the mycelium advanced into the living tissues for a short distance in a few cases, but that in no case were typical cankers formed. Pycnidia were produced abundantly on the injured tissues of all the hosts.

During the course of this work only four specimens of *Endothia parasitica* on hosts other than Castanea have come to the writers. One was on chestnut oak (*Quercus prinus*) collected by F. W. Besley, at Towson, Md., December 26, 1911; one from *Quercus velutina*, at Germantown, Pa., as well as one from white oak (*Quercus alba*), at Kennett Square, Pa., were collected by S. B. Detwiler; and one from dead maple, *Acer* sp., at Florence, Mass., by Roy G. Pierce.

The specimen collected by Besley on *Quercus prinus* showed the fan-shaped mats of mycelium typical of *E. parasitica* on Castanea species. The fungus had apparently girdled the tree. The specimen on *Quercus alba*, collected by Detwiler, was similar to one on *Quercus prinus* in appearance and came from a dead tree which had apparently been killed by the growth of the fungus. The specimens on *Acer* sp. and on *Quercus alba* were received in the spring of 1914, and cultures isolated from them were used in making inoculations for the purpose of determining whether the fungus had either lost or gained in virulence by passing through other hosts.

INOCULATION EXPERIMENTS.

The cultures secured from Acer and Quercus, together with one made from Castanea at about the same time, were inoculated into three separate sprouts of *Acer rubrum*, *Castanea dentata*, and *Quercus prinus*. The sprouts chosen were of nearly the same size, 2 inches in diameter, and similarly situated, and each was inoculated in five places, with two check cuts above. The inoculations were made the usual way on March 31, 1914, and were examined at least once a month during the summer.

None of the inoculations on Quercus produced any growth whatever. On Acer the inoculations with the culture from Quercus all failed to develop; one of the inoculations with the culture from Acer showed a few pycnidia, while four of the inoculations with material from the chestnut developed a few pycnidia. On Castanea the three series of inoculations were almost identical, every inoculation producing a typical canker.

Of course, these inoculations are too few to be conclusive, but it is evident that there was no decrease in virulence on the chestnut in passing through Acer or Quercus and that no particular affinity for either Acer or Quercus was gained. On the maple, in fact, the culture direct from chestnut produced the most growth.

In addition to those listed above, numerous inoculations were made in order to determine whether *Endothia parasitica* had any parasitic tendencies on other deciduous hosts.

These inoculations were all made during the spring of 1914 by the usual method of cutting well through the bark and inserting mycelium and spores from a pure culture, usually on corn meal. The wounds were then wet, some bound with wet cotton, others with paraffin paper, and about half were left unwrapped.

Seven or more inoculations were made on April 4 in Maryland on *Alnus rugosa*, *Betula nigra*, *Carpinus caroliniana*, *Fagus grandifolia*, *Kalmia latifolia*, *Liriodendron tulipifera*, and *Liquidambar styraciflua*, none of which developed. Inoculations were also made on April

22 in this locality on *Acer rubrum*, *Carya glabra*, *Cornus florida*, *Fagus grandifolia*, *Liriodendron tulipifera*, *Quercus prinus*, *Sassafras variifolium*, *Vaccinium* sp., and *Vitis* sp. without success. On April 18, the following hosts were inoculated in Virginia: *Acer rubrum*, *Betula nigra*, *Benzoin aestivale*, *Carpinus caroliniana*, *Carya glabra*, *Cornus florida*, *Fagus grandifolia*, *Liriodendron tulipifera*, *Prunus serotina*, *Quercus alba*, *Ulmus americana*, and *Vitis* sp. Each host was inoculated in from four to six places. Of these, pycnidia were produced only on *Acer rubrum*, *Carpinus*, and *Liriodendron*. A similar series was made on the same hosts in the same place on May 27. Inoculations on one tree of *Quercus alba* showed undoubted evidence of parasitism and is described below.

On July 9 and 11 from five to fourteen inoculations were made on each of the following hosts at Woodstock, N. Y.: *Acer rubrum*, *Betula alba*, *Carya ovata*, *Fagus grandifolia*, *Fraxinus americana*, *Hamamelis virginiana*, *Juglans cinerea*, *Kalmia latifolia*, *Nyssa sylvatica*, *Ostrya virginiana*, *Populus grandidentata*, *Prunus serotina*, *Rhus typhina*, *Quercus rubra*, *Salix* sp., *Sambucus canadensis*, and *Sassafras variifolium*. Pycnidia appeared on *Acer rubrum* and Ostrya only. The fungus made considerable growth on two plants of *Rhus typhina*, partly girdling branches one-half inch in diameter and producing distinct fans. The fans were, however, much smaller than those usually found in Castanea. Inoculations were made at Avon, Conn., July 15, on *Acer saccharum*, *Betula alba*, *Carya glabra*, *Cornus florida*, and *Ostrya virginiana*. Pycnidia developed only on Ostrya. The successful inoculations with *Endothia parasitica* are shown in Table VII.

TABLE VII.—*Successful inoculations in 1914 with Endothia parasitica on hosts other than Castanea.*

Locality.	Date.	Host.	Number of inoculations.	Number successful.[1]
Virginia	Apr. 18	Acer rubrum	9	7
Do	...do	Carpinus caroliniana	6	2
Do	...do	Liriodendron tulipifera	6	1
Do	May 27	Quercus alba	4	4
New York	July 11	Acer pennsylvanicum	14	4
Do	...do	Ostrya virginiana	6	2
Connecticut	July 15	...do	15	4

[1] Inoculations producing pycnidia are classed as successful.

It must be noted that while pycnidia were produced in the cases listed as successful, there was no indication of parasitism, nor did the growth extend beyond the tissue injured by the cut except in Quercus and Rhus.

Out of about 400 inoculations with *Endothia parasitica* on hosts other than Castanea, about 70 of which were made on different species of Quercus, chiefly *Q. prinus* and *Q. alba*, only one case has been noted in which the fungus assumed a typically parasitic rôle. The data in this case may be summed up as follows: Four inoculations were made May 27, 1914, on a small tree of *Quercus alba*. This tree was suppressed, and although when cut down it showed about 30 annual rings it was only 16 feet high and about 2 inches in diameter. It was in a moist, shady locality close beside a stream, and in spite of its small size was apparently healthy. The inoculations were made in the usual way from a culture of *E. parasitica* on corn meal. On August 1 it was noted that all four inoculations were producing pycnidia, and in at least one case typical fans had been developed. On October 15 all four cankers had more than half girdled the seedling. No observations were made during the winter, but at the time the leaves had reached half the normal size, in the spring of 1915, the tree was completely girdled. On July 1 this tree presented an appearance closely similar to that of a small chestnut tree girdled by *Endothia parasitica*. All the leaves above the point of inoculation were dead and remained attached to the branches. Below the girdled portion, water sprouts had developed, as has been frequently described for chestnut trees affected with *E. parasitica*. Cultures made from this tree showed the fungus to be typical of *E. parasitica*. Whether this case of parasitism was due to unusual virulence on the part of the fungus or to unusual susceptibility on the part of the host is, of course, merely a matter of conjecture; the latter alternative seems, however, somewhat more probable, as other inoculations with this strain of the fungus on *Q. prinus* and *Q. alba* failed to show similar results.

In addition to the above, a somewhat similar observation has been made by the writers near Amherst, Mass. In connection with other work, a sprout of *Quercus prinus* about an inch in diameter was inoculated with *Endothia gyrosa* on July 15, 1914. When this inoculation was made the tree was partly (about one-fourth) girdled. *E. gyrosa* developed normally and by October 1, 1914, had produced several pycnidial stromata. No change was apparent when the inoculations were examined in May, 1915.

E. parasitica was abundant in the region, however, and apparently gained entrance through the cuts originally made, for when the plat was next visited, August 17, 1915, the sprout appeared quite dead, though still retaining its full-sized dead leaves. Further examination showed numerous pycnidia of *E. parasitica* in addition to those of *E. gyrosa* near the region of the original inoculation. The pycnidia of *E. parasitica* were on all sides of the stem, while those of *E. gyrosa* were confined to the portion above the cuts made in inoculating. The mycelial fans typical of *E. parasitica* were abundant also. These observations leave no doubt that the tree was girdled and killed by *E. parasitica.*

Endothia parasitica in exceptional cases undoubtedly attacks other hosts than Castanea, producing cankers and sometimes causing the death of the host. The results of the inoculations just recorded appear to indicate that some unusual conditions of host or parasite must obtain in such cases. Whether such a combination of conditions or factors will ever become sufficiently frequent to lead to serious destruction of Quercus or other forest trees remains to be determined.

ENDOTHIA PARASITICA ON CASTANEA SPP.

Although found occasionally on species of other genera, *Endothia parasitica* is dangerously pathogenic only on members of the genus Castanea. The parasitism of this fungus on the American chestnut (*Castanea dentata*) was first proved by Murrill (57) and has since been demonstrated by numerous investigators.

When *Endothia parasitica* was discovered in the United States it was considered by some investigators to be a native fungus which had suddenly become parasitic, and various theories were advanced to account for the supposed unusual susceptibility of the host. As enumerated by Clinton (18, p. 391), the factors suggested include winter injury, drought injury, fire injury, weakened condition due to continued coppicing, and reduced amounts of tannic acid due perhaps to weather conditions.

Continued study by many investigators in different localities has, however, fully confirmed the observation originally made by Metcalf and Collins in 1910 (53) that "a debilitated tree is no more subject to attack than a healthy one" and that *Endothia parasitica* is actively parasitic on the healthiest specimen of *Castanea dentata* in case there is opportunity for wound infection. The writers have personally made over 1,200 inoculations of *E. parasitica* on *Castanea dentata* without finding a single individual that showed any resistance.

CASTANEA ON LIMESTONE SOILS.

Not only are all trees susceptible, but so far as is known no condition of soil, altitude, or moisture renders them more resistant to the disease. The idea has been held by some writers that chestnuts grown on limestone soils were immune to the disease, and the planting of chestnut orchards on such soils was advocated. This view is held by Gulliver (38, p. 53), who sums up his observations in two regions in Pennsylvania as follows:

In every series of tracts taken from limestone to overlying shale soils, the percentage of blight is least at a comparatively short distance * * * from the edge of the limestone. Tracts on soils derived from limestone which show the highest percentage of blight seem to be those where the soil has become acid from underground drainage. Chestnut trees on soils derived from other alkaline rocks show less blight than is found in the trees on shale soils with limestone underneath.

On the other hand, Detwiler (24, p. 67) reports observations in the Lizard Creek valley which seem to show that these relations do not always occur. He says—

> A belt of limestone borders Lizard Creek valley on the south, and the per cent of infection is as high in that region as elsewhere. Infection centers have been found near limestone quarries, where the roots of the chestnut penetrated to bedrock.

Actual proof or disproof of the truth of this idea was peculiarly difficult, since chestnut is but rarely found growing naturally on calcareous soils. During the summer of 1914, however, a careful study of the chestnut on certain portions of limestone areas in western Maryland and western Connecticut was made. These localities were chosen because they were convenient in connection with other work, the blight had been present for several years in both States, and thorough State geological surveys made the location of the limestone areas very easy. The two States also are sufficiently far apart to eliminate sources of error that might arise from local weather conditions.

In western Connecticut chestnut was abundant on glacial till over the Stockbridge limestone of this region. Chestnut was also growing directly over limestone at various points near Danbury, Twin Lakes, Chapinville, and Lakeville. Several localities near the latter place were kindly pointed out by Dr. George E. Nichols. Near Danbury every tree examined showed the blight in a more or less advanced stage, while near the other towns, all in the northwest corner of the State, nearly 50 per cent of the trees were blighted. About 30 inoculations were made on sprouts in this region, and all except two developed cankers quite as rapidly as did check inoculations made on the trap ridge west of Hartford.

Chestnut is very rare on the Shenandoah limestone in the Hagerstown and Frederick valleys of western Maryland. A number of chestnut trees were, however, located growing on limestone soil near Frederick Junction and Adamstown in the Frederick valley. The disease was already established west of Adamstown, where 20 per cent of the chestnuts were either diseased or dead. Twenty-two inoculations were made on nine chestnut sprouts in these two regions, and all developed typical cankers quite as rapidly as the checks made in similar sprouts growing over Baltimore gneiss 50 miles east.

RECESSION OF THE CHESTNUT IN THE SOUTHERN STATES.

While it has been definitely proved that *Endothia parasitica* is pathogenic on healthy chestnut trees, one of the points brought forward by the advocates of the "weakened host" theory seems to be fully established; that is, that the chestnut trees have suffered severely in the southern Appalachian regions previous to the present epidemic, in some cases being practically exterminated, so that the range is now considerably less than formerly. The evidence on this point has been summarized by Clinton (18, pp. 408–413). Various writers quoted by him cite fire injury and borers and other insects as causes for this recession.

Long (48, p. 8) considers a root rot due to *Armillaria mellea* as "very probably an important factor in the gradual recession of the chestnut" in North Carolina. It seems probable that all of the above-mentioned factors, and perhaps others, have played a part in the destruction of the chestnut in this region.

RELATIVE SUSCEPTIBILITY OF SPECIES OF CASTANEA.

The importance of *Castanea dentata* as a timber and nut tree and its abundance in eastern North America, where the blight is prevalent, has made the chestnut blight an object of much investigation. Descriptions of the nature and importance of the disease, the rate of its spread, methods of distribution, and attempted methods of control have been given in detail by Anderson (1–5), Clinton (12–15), Heald (39–41), Metcalf (51 and 52), Metcalf and Collins (53), Rankin (62), and others. It may be sufficient here to state that the fungus enters the host through a wound in the bark, probably never or very rarely through lenticels or natural cracks, grows chiefly in the cambium, penetrating for only short distances into the wood, and kills the tree or branch by girdling. Once a tree is attacked, it is only a question of time till it succumbs.

The chinquapin (*Castanea pumila*) was found by Murrill (58) in 1908 to be attacked by *Endothia parasitica.* Rogers and Gravatt (65) in 1915 made inoculations of *E. parasitica* on *C. pumila* and found that the parasite grew as rapidly on this host as on *C. dentata.* They attribute the apparent resistance of the chinquapin to its comparative freedom from bark injury, a view also held by other writers. Pantanelli (60) and Metcalf (52) have proved that the European chestnut is readily susceptible to the disease.

The only chestnuts thus far observed which show any resistance to *Endothia parasitica* are those of oriental origin. Metcalf (51) first pointed out the resistance of the Japanese chestnut. This observation has since been confirmed by Clinton (18, p. 375), who "failed to produce the disease in a Japanese variety in the [Conn.] station yard, although the bark was inoculated in 16 different places."

Van Fleet (84), in describing the spread of the chestnut blight in his breeding plats at Washington, D. C., says (p. 21): "The Asiatic chestnuts and the chinquapin-Asiatic hybrids are plainly highly resistant."

Morris (56) sums up eight years' observation of the effect of the chestnut blight on 26 species and varieties of chestnuts at Stamford, Conn., as follows:

> Every one of the 5,000 American chestnut trees became blighted * * * None of [the grafted varieties or seedlings of European and Asiatic varieties appear] to be as vulnerable as the American chestnut, but most of mine are now dead. Korean chestnuts and chestnuts from the Aomori regions in Japan resisted the blight until six years of age. Since that time they have shown a marked tendency to blight, but resist it better than does the American chestnut * * * None of the American species of chinquapin * * * has blighted with the exception of two limbs * * * None of the specimens of *Castanea alnifolia* [or] * * * of *Castanea mollissima* has blighted, but these latter include only five trees.

These observations as to the resistance of the oriental varieties of chestnut when grown in America are of particular interest in connection with the observations of Meyer in the region where he discovered *Endothia parasitica* native. In his letter to Fairchild, written from Santunying, China, June 4, 1913, Meyer makes the following notes with reference to the effect of the blight in that region:

> This blight does not by far do as much damage to Chinese chestnut trees as to the American ones * * *
>
> Not a single tree could be found which had been killed entirely by this disease, although there might have been such trees which had been removed by the ever-active and economic Chinese farmers * * *
>
> Dead limbs, however, were often seen and many a saw wound showed where limbs had been removed. * * *
>
> The wounds on the majority of the trees were in the process of healing over * * *
>
> Old wounds are to be observed here and there on ancient trees.

Meyer's photographs taken near Santunying substantiate his statements. Certainly no specimens of *C. dentata* in a blight-infested region in this country could survive to the age of the Chinese chestnuts shown in his photographs.

That the Chinese chestnuts are by no means uniformly resistant, however, is clearly shown by Meyer's later notes. On the label of a package of *Endothia parasitica* collected on chestnut at Tachingko, Shantung, China, March 21, 1914, he writes, "Trees very severely attacked, many dying off," and in a letter written from the same place he says, "A serious canker; many of the trees here were killed by it."

Further evidence that the virulence of *Endothia parasitica* on Chinese chestnut differs in different parts of China is found in subsequent communications from Meyer. From a point near Chingtsai, Chekiang, China, on July 15, 1915, he writes: "All around Hangchow and west of it one finds the chestnut trees seriously attacked by this destructive bark fungus."

On July 11, 1915, near Changhua, Chekiang, China, he comments, "With the exception of near Taianfu, Shantung, chestnuts are much more severely attacked in the Chekiang Province than either in Chihli, Shansi, or Shensi. Could the greater humidity of central China be of assistance to a more vigorous development of this destructive fungus?"

COMPARISON OF HOST RELATIONS.

It will be seen from the above description of the host relations of the various species that while some other members of the genus (*E. gyrosa*, e. g.) may have slight parasitic tendencies, *Endothia parasitica* alone is an active parasite. The contrast is still more striking in the section of the genus to which *E. parasitica* belongs, for *E. fluens* and *E. fluens mississippiensis*, which resemble *E. parasitica* so closely in their morphological characters, and to a less degree on culture media, and are common on Castanea, are almost purely saprophytic. This fact is established by the work of Anderson (2), Clinton (18), and others, and by two years' field observations and several thousand inoculations made by the writers and their colleagues.

The host relations of the parasite are equally striking. Although *Endothia parasitica* is so pathogenic on *Castanea dentata* that this tree has been practically exterminated over several hundred square miles of its natural range and its extinction is threatened, the fungus has been only occasionally found as even a weak parasite on the closely related genus Quercus, and never, to the writers' knowledge, on Fagus.

During the course of this work the writers have been continually impressed with the possibilities of a physiological study of *E. parasitica* and one or more closely related species which might throw some light on the fundamental question of the nature and cause of parasitism. No other case is known to the writers of a virulently parasitic fungus and a closely related purely saprophytic one which will grow readily and fruit on a large variety of artificial media, which are readily distinguishable on those media, and remain constant for hundreds of generations.

SUMMARY.

The pathological and economic importance of this group of fungi was first recognized when the chestnut-blight fungus was discovered in New York in 1904.

This organism was first referred to the genus Diaporthe, but was later shown to belong to the genus Endothia.

The specific identity, relationships, and native home of this parasite were at first uncertain. Some pathologists considered it a native organism which was attracting attention and causing injury chiefly by reason of the weakened condition of the chestnut trees. Others believed it to be of foreign origin. Its recent discovery in China and Japan has settled this question.

To determine positively the identity of the organism, a thorough study was made of the types or authentic specimens of all the species of Endothia obtainable. As a result of this work a revision of available species of the genus is presented. This is based upon the field and laboratory study of over 600 collections. Over 4,000 cultures have also been studied.

Endothia gyrosa (Schw.) Fr. is the type of the genus, which is naturally divided into two sections, chiefly by the character of the ascospores. In section 1 they are short, cylindric to allantoid, and continuous or only pseudoseptate. This section contains two species, *E. gyrosa* and *E. singularis.*

Section 2 has oblong-fusiform to oblong-ellipsoid uniseptate ascospores. This contains four species and one variety, *Endothia fluens*, *E. fluens mississippiensis*, *E. longirostris*, *E. tropicalis*, and *E. parasitica.* *E. tropicalis* is a hitherto unrecognized species.

Radiating layers of yellowish or buff mycelium situated in the bark and cambium of the host are found to be constant and distinctive characteristics of *Endothia parasitica.* None of the other species studied shows this character.

All species of the genus possess a stroma having a distinctive yellow to reddish color.

There is no division of stroma into distinct layers, as described by some authors. Pycnidia or perithecia may arise in any portion of the stroma. Most commonly where pycnidia and perithecia are both present the pycnidia are above the perithecia, though the reverse arrangement is sometimes observed and all intermediate conditions frequently occur.

The stromata of the species of section 1 are larger, more erumpent, and contain more numerous pycnidia than those of section 2. *Endothia singularis* is especially striking in this respect. The stromata of section 2 are smaller and very similar in all the species.

The pycnidia consist of more or less irregular chambers or locules in the stroma.

The pycnospores are small in most species and furnish no very distinctive specific characters. The pycnospores of *Endothia tropicalis* are, however, constantly larger and more variable in size than those of the other species.

Paraphyses have been described by some authors, but have never been observed by the writers.

The ascospores in the species of section 1 are very similar in size and shape. Those in section 2, though similar, have been found by thorough study and careful measurement to show constant though slight differences, as indicated in the tables of measurements and ratios.

Numerous cultures of all the species on a variety of media show that each species has constant and distinctive characters of growth and color.

All the species grew equally well in light or darkness, and no decided differences in temperature relations have been demonstrated.

The species appear to have well-defined geographic limits of distribution, which have been approximately determined for the American species. The distribution of the species does not coincide with that of the hosts, but seems to be determined in part by soil and climatic conditions.

Endothia fluens has the widest distribution, being frequent and widely distributed in Europe and the eastern United States, and also occurring in Asia.

Endothia parasitica is evidently of oriental origin. Specimens have been received from five rather widely separated localities in China and from two localities in Japan. In the eastern United States it is now abundant from Maine to North Carolina and is rapidly spreading south and west. It has already destroyed most of the chestnut trees within a radius of 100 miles of New York City.

The species have rather definite host relations.

Endothia gyrosa has been found on five genera of plants, viz, Castanea, Fagus, Liquidambar, Quercus, and Vitis.

Endothia singularis occurs, so far as known, only on Quercus species.

Endothia fluens has been found in America only on Castanea and Quercus, but in Europe it occurs on Alnus, Carpinus, Castanea, Corylus, Quercus, and Ulmus, and has been reported on Aesculus, Fagus, and Juglans.

Endothia fluens mississippiensis has been found only on Castanea and Quercus.

Endothia tropicalis is known only on Elaeocarpus.

Endothia parasitica has been found on Acer, Carya, Castanea, Quercus, and Rhus, but at present is only known as a serious parasite on Castanea.

Upon the American species of Castanea it is actively parasitic under all the conditions of soil and climate observed. Oriental species of chestnut are more or less resistant to the disease both in America and their native homes.

None of the species except *Endothia parasitica* has thus far been found to be actively parasitic.

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of oats decreased less than 1 per cent. Oats made up 10.2 per cent of the harvested crop acreage in 1919, the percentage increasing slightly during the five years.

The acreage of hay was affected in a peculiar way by the radical changes that occurred during this census period. In the eastern and central portions of the country, where there was considerable abandonment of farm land, and for the most part a decrease in the proportion of farm land in harvested crops, the acreage of hay actually increased. This is to be accounted for largely by the fact that when farm land is abandoned so far as cultivated crops are concerned, there is already considerable acreage of hay and in most cases some new seeding which next year is added to the hay acreage. The increase in the acreage of this crop is therefore to be interpreted mainly as a result of a change toward less intensive utilization of the land. In some of the Western States the increase is due in part to the increasing importance of livestock in the local farming.

Changes in Cotton Acreage

Cotton acreage decreased in all the States from South Carolina to Louisiana except Alabama. The increase in Alabama is interpreted as a revival of agriculture after the panic caused by the advent of the boll weevil. The decrease in Georgia, South Carolina, and Florida was very large. Only in Georgia, however, did the relative importance of cotton decline during the period.

Along the northern border of the Cotton Belt, and particularly in the West, there was a phenomenal increase in cotton acreage. Texas, which in 1919 had the lion's share of the crop, increased the acreage during the period 44.5 per cent. For the country as a whole there was an increase of 16.2 per cent.

These increases were the result of the high prices for cotton that prevailed during most of the war years and for some years afterwards. The increase appears to have gone too far, for at the present time the situation of the cotton grower is critical because of low prices.

Further changes in type of farming are required to balance the agriculture of many sections. We now have a surplus of all the major crops. Cotton, hay, and oats are in the worst position.

W. J. SPILLMAN.

CHESTNUT Blight is Unchecked

Of the numerous foreign plant diseases which have gained entrance into this country, none has been more destructive than the chestnut blight, a fungous disease from Asia. In the last 25 years millions of acres of chestnut growth have been killed by the blight and the remaining American chestnuts in the East face certain destruction.

The chestnut-orchard industry of the New England and the Middle Atlantic States has been practically destroyed by the blight and there remain only rare trees of the American and European chestnuts or their hybrids and a small percentage of the more resistant Japanese chestnuts. Unfortunately the killing of the chestnut forest growth and orchards does not result in the self-extermination of the disease, as many of the roots of the killed chestnuts remain alive and send up sprouts which continue to spread the disease for many years. Consequently chestnut orchardists in the eastern half of this country can expect the blight to be an important factor, though losses

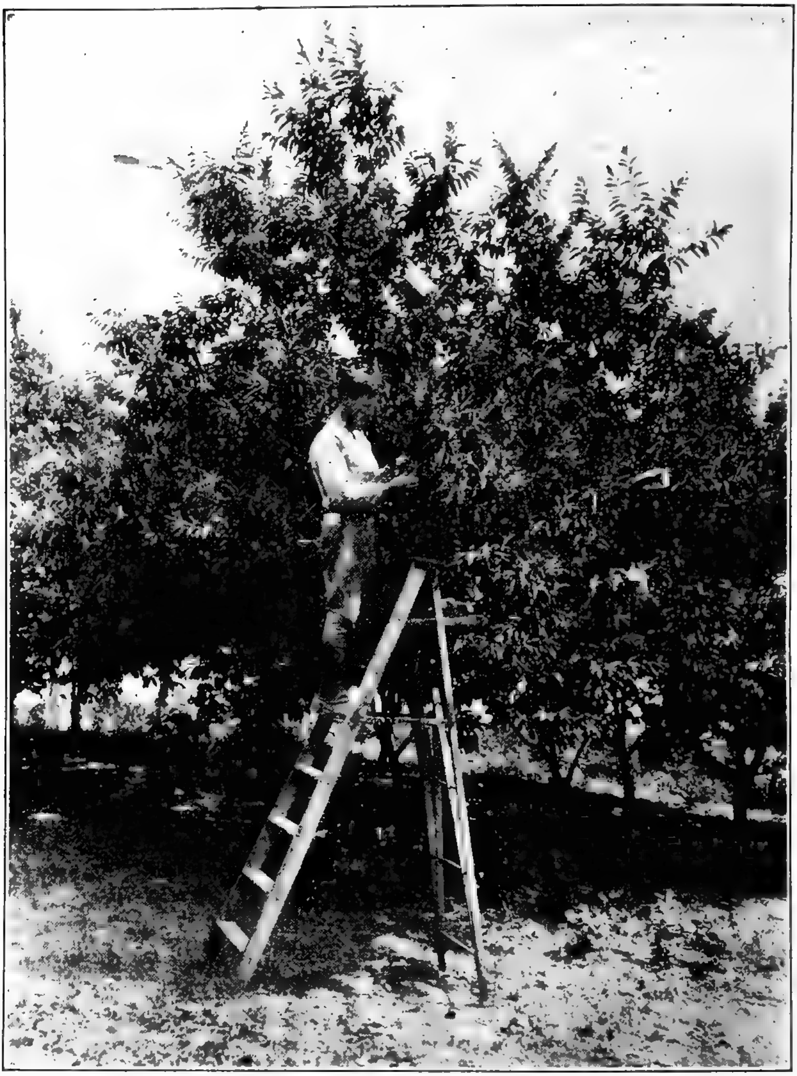

Fig. 41.—A view of an orchard of hairy Chinese chestnuts planted by Doctor Van Fleet at Bell, Md. This species is being crossed with other species of chestnut. Many of the trees in this orchard have never had deep cankers which justified treatment, although the blight has been present in the orchard for the last 12 years

from this diseases may be insignificant in localities where chestnut and chinquapin are not native.

Experience in the department chestnut orchard at Bell, Md., indicates that in orchard practice the blight can be controlled on various strains of the hairy Chinese chestnut, *Castanea mollissima*, (fig. 41) at a reasonable cost. A simple treatment which has given satisfactory results with this species consists of cutting out every spring the trunk infections which reach into the cambium region and painting the cuts. The majority of the trees do not require the removal of infections every year, while some few trees frequently have deep cankers. In orchards where the blight is being eradicated, much more frequent, careful, and drastic treatment is required. It is important in both the control and the eradication of the blight to keep the trees in vigorous condition. Although the blight can be controlled on the hairy Chinese chestnut, other factors such as the sale price of the nuts and the chestnut weevils, for which there is no satisfactory control at present, must be considered by the prospective orchardist.

Successful inoculations on varieties and species of chinquapins from different parts of the Gulf States and Arkansas show that the blight will eventually spread over the chinquapin area of the South. These shrubs will be a source of infection for orchards considerably outside the range of native American chestnut. As the chestnut blight is carried for long distances in various ways, there is no assurance that even the chestnut orchards of the Pacific coast will remain free from the disease. Orchardists and inspectors in that region should be on the watch for the blight, as young infections can be easily and completely eradicated, whereas older ones can be eradicated only with much greater difficulty.

Ornamental Chestnut Trees

The planted American chestnuts of the Northeast have largely disappeared, and those of the southern Appalachians and the Ohio Valley are doomed. Owners who are dependent upon these trees for shade should take immediate steps to plant resistant chestnuts or other kinds of shade trees to replace the native chestnuts when they die. Many strains of the Japanese and hairy Chinese chestnuts are sufficiently resistant to the blight to be grown as shade trees with very little treatment, whereas others are rather susceptible and require considerable treatment. The natural beauty of these trees, together with their production of edible nuts, makes them very desirable for planting in many situations. A few trees of the hairy Chinese chestnut will supply the farmer's family with sweet nuts.

Most of the chestnut forest growth north of Virginia and east of the Allegheny River has been killed by the blight, and that of the southern Appalachians and Ohio Valley will be destroyed in the near future. As shown by Figure 42, the blight is now present throughout most of the range of the commercial chestnut. It is spreading more rapidly in the South than it did in the North, and already over one-fifth of the chestnut stands of the southern Appalachians are 80 per cent or more infected. Forecasts based upon the present distribution of the disease and its past rate of spread indicate that the major part of the remaining chestnut trees will be infected or killed by 1930. As the distribution and spread of the blight are somewhat irregular, each owner must watch his stand in order to determine the amount of infection in it.

Owners should make plans to utilize their chestnut poles before they are killed by blight, because killed poles will usually not be accepted by purchasers. Very severe financial losses have been suffered by many owners of standing poles, who failed to cut them before they were killed. Chestnut trees suitable for lumber should preferably be cut before they are killed, although such trees are not so much reduced in value as dead poles. To a limited extent chestnut which has been dead for many years has been utilized for making tannin extract, but the yield of extract from a given area is much reduced by the loss of sapwood and partial decay of the heartwood.

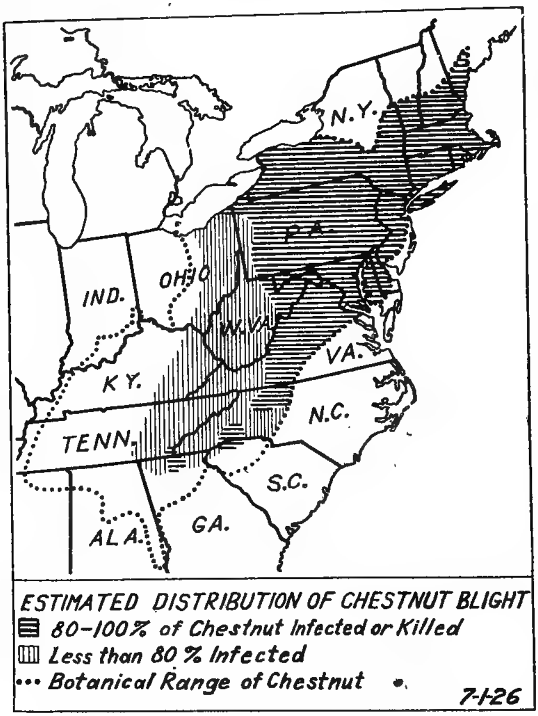

FIG. 42.—Map showing distribution of the chestnut blight. In the eastern part of the heavily infected zone nearly all of the trees are dead, while on the western edge of this zone most of the trees though infected are alive. In the zone shown as less than 80 per cent infected, the percentage of infected trees ranges from less than 1 to 80

Future for Tanning Unpromising

The future of the American chestnut as a source of tanning supplies is not promising. In regions where the blight has been present for many years some trees, which are much more resistant to the disease than the general average, have been located, but still more resistant trees must be found before it will be possible to recommend their planting.

The hairy Chinese chestnut, however, has possibilities as a source of tannin because of its resistance to blight and its high tannin content. Analyses of this species made by the Bureau of Chemistry and chestnut-extract companies show that its tannin content is higher than that of the American chestnut. However, the growth of this tree in China and in a few plantations in this country indicates that it is not so good a forest tree as the American chestnut.

Although America produces an excess of many farm products, it at present imports annually approximately 25,000,000 pounds of chestnuts as the domestic production from chestnut orchards is very small. This country also imports about one-half of the vegetable tannin supplies used in making leather, and with the passing of the American chestnut, whose wood yields approximately one-half of our domestic production of tanning materials, the United States will probably be dependent upon foreign countries for 75 per cent of its vegetable tanning supplies. In France the growers of chestnut not only receive a material income from the nuts, but also sell the mature trees and the trees removed in thinning to the tanning-extract companies. Such a combination may in the future prove profitable in this country since the hairy Chinese chestnut, which is not so prolific in nut production as the European chestnut, has a higher tannin content.

G. F. GRAVATT.

CHESTNUT Blighted Wood Good for All Timber Uses The chestnut blight has robbed northeastern forests and wood lots of one of our best all-around timber trees, and is sweeping relentlessly southward through all the Atlantic States. In a comparatively few years chestnut will be gone entirely from our eastern woodlands. What can the woods owner with chestnut trees a part of his timber crop do about it?

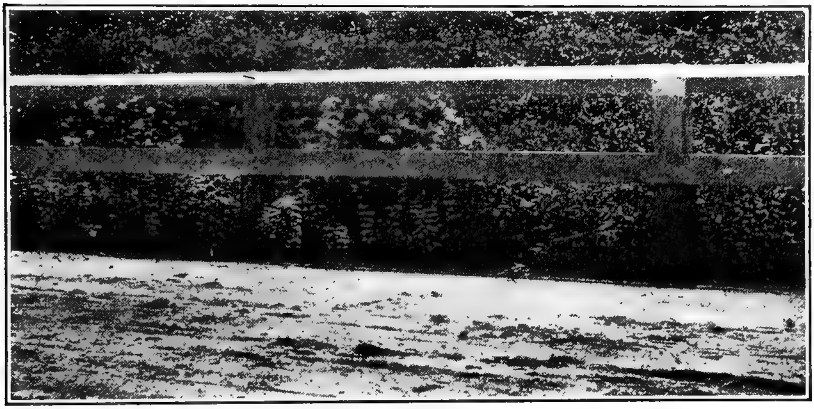

FIG. 43.—Getting the good of a doomed species. This fence, constructed in part of blight-killed chestnut, has for 14 years given testimony to the soundness of this wood

The living tree can not be saved, but the valuable wood can. The blight itself does not affect in any way the strength of chestnut wood. If the wood is harvested before fungi and worms attack the dead tree, the timber is as good for all purposes as any ever cut from a thrifty, unblighted chestnut. However, if this timber, living or dead, is to be saved, it must all be cut and used in the next 15 years.

Even where the blight has not yet entered, the chestnut in farm woods and larger tracts should be disposed of at the first opportunity, regardless of whether the trees are at full maturity. Where the blight has entered, some knowledge is needed of the uses to which the wood may be put, according to the degree that the wood has been attacked by wood-destroying organisms. These uses may be summarized as follows:

Sound wood, trees two years dead or less.—Use for round products, as poles, piling, construction timbers, mine timbers, highway and railway round fence posts, hewed ties, and all the uses that follow where sapwood is not objectionable.

Sapwood decayed but heartwood sound, trees dead two to four years.—Use for sawed products, as box and yard lumber, mill products, coffins and caskets, furniture, core stock (veneer), cabinet work, woodenware novelties, and slack cooperage. Where lumber is to be kiln dried, there is no fear that decay will spread, for this process sterilizes the lumber effectually.

Sapwood decayed and heartwood checked but fairly sound, trees four to six years dead. Tannin wood, pulp wood, farm fence posts. lumber or timbers for temporary construction. Wood less sound can be used for fuel. This class of material should never be supplied for the purposes listed in the preceding paragraphs. Where this has been done it has in some regions brought about an embargo on all chestnut.

Chestnut constitutes about 25 per cent of the woods and forests on 33,000,000 acres in the Appalachian region, and represents in merchantable timber fifteen to twenty billion board feet. To utilize this timber before it is destroyed is a national obligation. To delay doing so will in many instances result in a considerable loss to the owner.

R. D. Garver.

CHINESE Jujube in Southwestern United States The Chinese jujube (*Ziziphus jujuba*) has been grown in northern China since ancient times. It is one of the five principal fruits of that country, and many excellent varieties have been developed by the Chinese. The tree is deciduous, rather small, and somewhat spiny, with firm, shining-green, oval or oblong leaves 1 to 3 inches long. (Fig. 44.) The fruit is a drupe, elliptic or oblong, up to about 2 inches long, with a thin dark-brown skin, and crisp, whitish flesh of sweet, agreeable flavor, inclosing a hard two-celled point stone. (Fig. 45.)

Although a few seedling trees were grown in the United States as early as about 1837, it was not until Frank N. Meyer, agricultural explorer, visited China in 1908 that scions of large-fruited varieties were introduced. As a result of Meyer's work there are now established in California and the Southwest a number of the best and largest-fruited forms of the jujube.

The fruiting of these varieties in this country has stimulated interest among fruit growers and others, especially in Texas and California, and there is an ever-increasing demand not only for propagating material, but also for information concerning culture and utilization of the fruits.

The tree has withstood successfully temperatures as low as —22° F., and as high as 120°. It reaches its best development where the weather is dry, the sunshine brilliant, the nights warm, and the summers long and hot. Large areas of the southwestern United States, therefore, are well adapted to jujube culture. Because of its habit of late flowering, the jujube is free from injury by spring frosts and bears regularly and abundantly. In respect to soil requirements, the jujube has shown that it thrives in sandy alkaline soil and also in heavy nonalkaline soils, but the best results are obtained on sandy loams and lighter soils.

Varieties of the Jujube

Of the many different varieties introduced by Meyer from China, four have been selected as being distinctly superior to all the others.

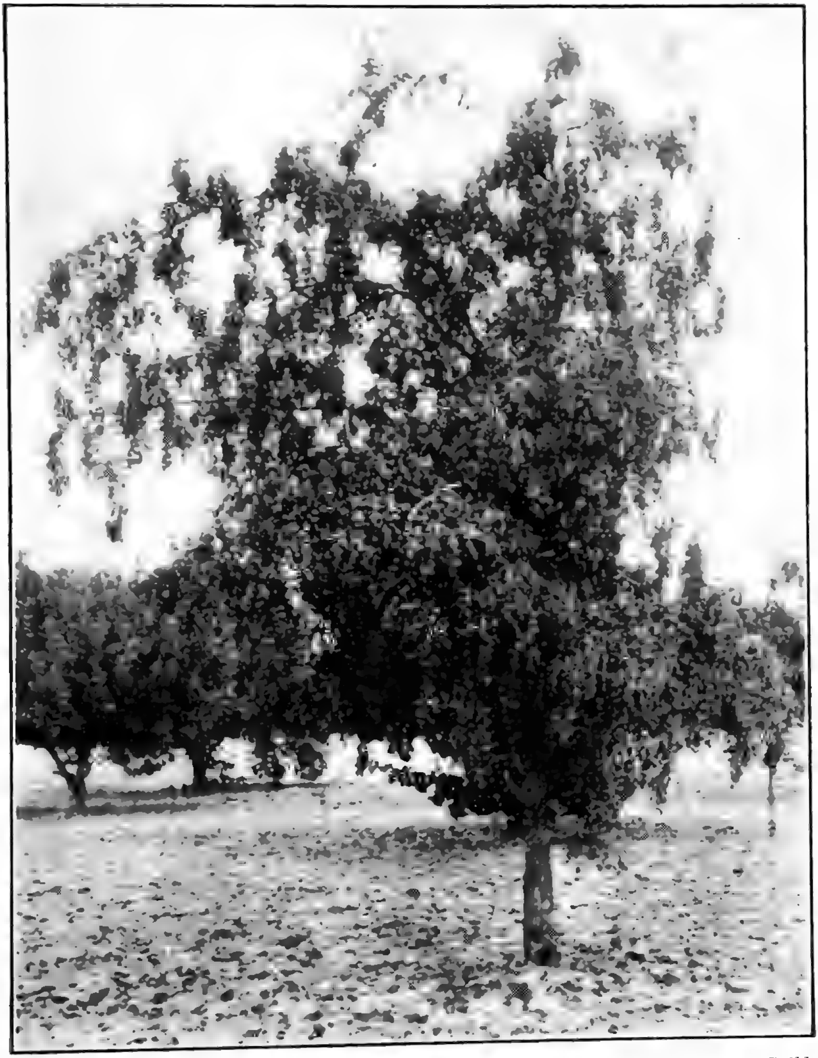

FIG. 44.—Fruiting tree of the jujube at the plant introduction garden, Chico, Calif. This tree is about 18 years old and is a heavy bearer

These are the Mu Shing Hong (S. P. I. No. 22684), the Lang (S. P. I. No. 22686), the Sui Men (S. P. I. No. 38245), and the Li (S. P. I. No. 38249). These varietal names are the ones sent in by Meyer with his notes. The largest of these is the Li, whose rounded-oval fruits are sometimes 2 inches long and nearly that much in diameter.

The Li also has the smallest pit, considered in relation to the amount of flesh. For general purposes, it is probable that the Lang is the best variety. Its pear-shaped fruits are produced in abundance and

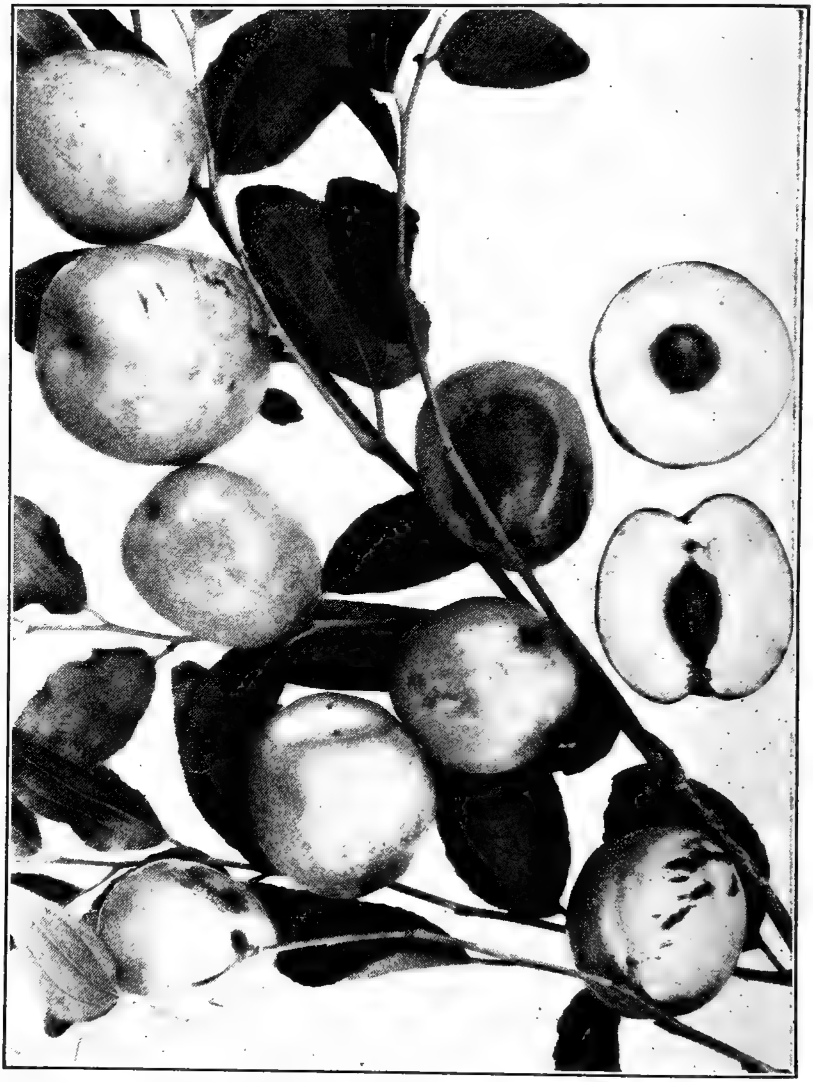

FIG. 45.—Fruits of the Li jujube (S. P. I. No. 38249) grown at the plant introduction garden, Chico, Calif. This variety has the largest fruits of any grown in the United States, has a relatively small stone, and processes well

are easily processed in sirup. This variety is also one of the most readily propagated. Although these are considered the best varieties at present, there are several others which may prove to offer particular advantages after further trials.

The jujube is used in several ways. It may be eaten fresh or the dried fruits may be ground and added to bread or cake as a seasoning, or used to make a mock mincemeat. The fresh fruits may be made into a jujube butter. Excellent sweet pickles may be made from the skinned whole fruits. The most satisfactory method to utilize the fruits, however, is as a confection. The skin is punctured or scored in some manner and boiled in sirup, the scoring allowing the sirup to penetrate the fruit easily. This scoring may be done with old safety-razor blades held together by bolts with thin pieces of cardboard between the blades. Or a board may be driven full of nails with the points barely projecting from one side, and the fruits punctured by rolling over the points.

How Sirup is Made

The sirup is made by using 1 or 2 parts of sugar to 1 of water, according to taste, the lighter sirup allowing more of the fruit flavor to be retained. The perforated fruits are then placed in the sirup and boiled from 20 to 35 minutes, the larger fruits requiring the longer boiling. The fruits are then allowed to cool in the sirup, after which they are boiled again for the same length of time. Then the fruits are taken out and allowed to dry on trays, either in the sun or by artificial means. Drying should be carried to a point where the fruits are firm, but not too hard.

The jujube compares very favorably with the fig in point of edible matter, total sugars, acid, and ash, and contains more protein than the date. It is therefore of high food value.

The immediate future of the jujube is in its culture as a home fruit, and as such it should appeal to growers and residents generally in the drier portions of the Southern and Western States.

C. C. THOMAS.

CHINESE Elm in American Horticulture

Among the many valuable contributions of northern China to American horticulture the Chinese elm (*Ulmus pumila*) stands out as one likely to prove of increasing value to certain sections of the United States. First introduced in 1908 by Frank N. Meyer, agricultural explorer, from near Peking, Chihli, China, the tree is established in a number of places in this country, and seeds and plants are offered for sale by several nurseries in the South and West.

It is a rapid grower, with slender, almost wiry branches. The leaves are elliptical and smaller than those of the American elm. If allowed to assume its natural habit, the Chinese elm develops numerous branches along its trunk, making a rather dense growth from near the base and resembling in some instances large shrubs. It is one of the first trees to leaf out in the spring and the last to shed its leaves in the fall. Throughout the long season the leaves remain a beautiful green and are remarkably free from the usual plant diseases and insect injuries so common in many of the other elms.

Tree is Very Hardy

It is very hardy and has proved valuable under a greater variety of climatic and soil conditions than any tree yet introduced. Very favorable reports have been received from practically every section of the country. It has proved winter hardy in most trials in the Dakotas, Minnesota, New York, Montana, and other Northern

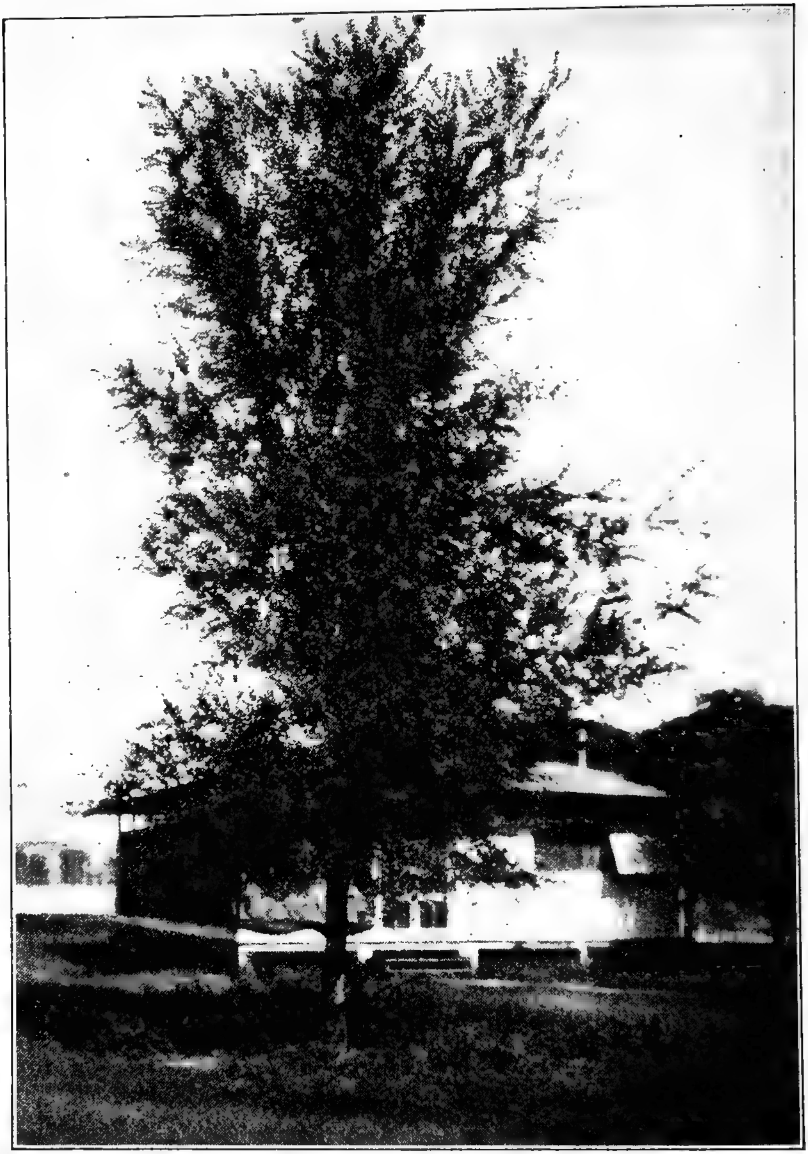

FIG. 46.—A 6-year-old tree of the Chinese elm (*Ulmus pumila*) grown near Yuma, Ariz. One of the few trees which can survive the trying climatic conditions of that region

States. Its resistance to drought, alkali, and extremes of temperature render it an especially valuable tree in the Great Plains region where desirable shade trees are few, in the semiarid South and

UNITED STATES
DEPARTMENT OF AGRICULTURE
DEPARTMENT CIRCULAR 370

Washington, D. C. May, 1926

CHESTNUT BLIGHT IN THE SOUTHERN APPALACHIANS

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and
R. P. MARSHALL
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CONTENTS

The parasitic fungus which causes the disease of chestnut known as the blight or bark disease was brought into the United States from Asia on small nursery trees before this country had enacted plant-quarantine laws. As is often the case with introduced plant and insect pests, the chestnut-blight organism proved to be a more virulent parasite in the home of its adoption than in its native habitat. Millions of acres of chestnut, dead and dying as a result of this introduction, bear mute testimony to the need of proper plant-quarantine laws. The chestnut blight was first observed and recognized as a new disease in this country at New York City in 1904, though it must have been present for some time previous to that date.. To-day the chestnut north of the Potomac River and east of the Allegheny Mountains has been laid waste by the blight fungus. The remaining American chestnut stands of the southern Appalachian Mountains face certain destruction.

This circular gives the known distribution of the disease, as determined by a partial survey made during the summer and fall of 1924 and 1925 by several members of the Office of Forest Pathology. State and national foresters, pathologists, county agents, and many private individuals have assisted in this survey work, and the con-

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tinuation of this cooperation is necessary in order to secure needed information with the limited funds available for inspection. Forecasts on the future spread of the blight also are given.

SYMPTOMS OF THE DISEASE

In stands recently attacked the first evidences of the disease are generally to be found on the smaller branches and at the bases of young sprouts from stumps. When such branches and sprouts are killed by the blight during the growing season the dead leaves and burs adhere tenaciously, forming characteristic "flags," which are very helpful in locating infections from a distance. These show up in summer in striking contrast with the healthy green leaves and in winter with the defoliated remaining portions of the trees. Close examination will determine whether these flags are due to the disease or to mechanical injuries. If the symptoms are caused by the blight, prominent lesions on the branch, trunk, or even exposed roots indicate the growth of the parasite within the bark. These areas of diseased bark vary in size, color, elevation, and the fruiting structures produced.

The cankers are generally elliptical in outline at first. Because the growth of the fungus is slightly more rapid up and down the stem, the longer dimension of the lesion lies in that direction. When the two edges of the lesion meet around the stem (Pl. I) the resulting ring of diseased tissue cuts off the flow of sap. The foliage above such a girdle wilts, turns yellow, and dies. Usually it does not fall, but remains persistent for a considerable period. There is usually a development of sprouts or suckers below the girdle (Pl. II).

The cankered areas may be either sunken below or swollen above the surrounding bark, or they may be combinations of the two. On smooth bark the lesions are sharply demarked, sometimes even appearing as though outlined with black pencil lines. The margin may be raised or slightly water-soaked when the fungus is advancing rapidly. It is usually regular, but in some cases it is so irregular as to resemble amœboid flow, as shown to a slight extent in Plate I. At times the reddish orange color of young cankers stands out in striking contrast with the green bark, but both normal and diseased barks darken with age, and the coloration of the canker becomes less conspicuous when it assumes its usual red-brown to sepia tones. With increasing age cankers generally become rough, split, and cracked, with peeling bark (Pls. III and IV). The sunken cankers, which are generally smooth barked at the center, often develop roughened raised margins. Mature portions of cankers are dotted with fruiting structures, which most commonly resemble orange or red-brown pinheads. These fruiting bodies are more conspicuous on smooth lesions, but are also evident in the cracks of rough cankers.

Many cankers show the points at which the fungus organism entered the bark. Wormholes, cicada stings, and mechanical injuries are favorite points of attack. Diseased twigs frequently carry infection into larger parts. Sprouts are commonly infected where spores and moisture collect at their bases.

In chestnut stands where blight has been established for a number of years the effect of the disease is so striking as to be evident to the most casual observer (Pls. V, VI, and VII). Dying limbs with attached browned leaves and burs seem scorched by fire. Branches and trunks stand dead. Sprouts grow from the bases of blight-killed trees. In turn, they too become infected. Insects and sap rots attacking the dead trees cause the bark to peel and add to the somberness of the picture.

When the bark is peeled back from a canker the infected part is typically found to contain numerous flattened layers of branching mycelium known as fans (Pl. VIII). Their presence is one of the best diagnostic symptoms of chestnut blight. Specimens should be examined for them when any doubt exists as to whether or not a diseased condition is due to blight.

This test is especially valuable in distinguishing between injury caused by blight and that due to root rot, for the latter is the disease with which chestnut blight is most often confused. Root rot is general in southern chestnut at the lower elevations. Unlike the recently introduced blight, it is of long standing. Its prevalence accounts in part for the recession of chestnut, which is known to have been taking place during the past 75 years. In advanced stages root rot occasionally kills the entire tree at once, but more often produces the bare top branches known as a staghead. Early stages of root rot are easily confused with the blight, especially during drought. Viewed from a distance the symptoms of this stage of the disease differ from those produced by blight only in being less sharply confined to particular limbs and in the foliage being more yellow in appearance. Closer inspection should show no cankers with their characteristic fans if the injury is due to root rot. Chestnut blight does not attack roots which are covered by soil.

CAUSAL ORGANISM

The fungus *Endothia parasitica* (Murr.) A. and A. growing within the bark and outermost wood layers of the American chestnut (*Castanea dentata* Borkh.) causes the disease known as chestnut blight. The vegetative part of the fungus, which is made up of very numerous closely appressed threadlike strands, is called the "mycelium." It grows through the bark, pushing out and extending much as the roots of higher plants force themselves into soil. As the fungus penetrates, it brings about the death of the invaded bark. The mycelium within this dead area is buff colored, but where it extends into the living bark at the margin of the lesion it is often white. The term "fans" has been applied as descriptive of these thin spreading plates of fungous growth.

When well established the fungus fruits. The reproductive bodies formed, corresponding to the seeds of higher plants, are known as spores. Two types of spores are produced by the chestnut-blight fungus. Both kinds arise from pustules, which in dry weather resemble orange or red-brown pinheads dotted over the surface of the cankers (Pl. IX, A).

During damp weather certain pustules produce tiny yellow, coiling hairlike tendrils called "spore horns" (Pl. X), which are composed of myriads of spores about the size of bacteria. These spores are borne within the pustule in such numbers that when moist they are forced out in a slender serpentine mass, much as paste is squeezed from a tube. Spores of this type are sticky. They adhere to birds and insects coming in contact with them and thus may be carried long distances. Rain dissolves the spore horns and so spreads infection on trees already diseased.

Pustules producing the second type of spore differ from those producing the first in that during wet weather they are dotted with very small openings rather than surmounted by spore horns. The openings, which are often at the end of small protuberances (Pl. IX, B), are the mouths of flask-shaped structures. Within the flasks the spores are borne, definitely arranged in groups of eight 2-celled spores. Each group is inclosed in a thin transparent club-shaped sac. Under suitable conditions the sacs escape through the neck of the flask. When free the sacs burst in miniature explosions, throwing the spores into the air. Thus freed the spores are carried by air currents, often to great distances.

The enormous numbers in which both types of blight spores are produced, together with the fact that they are adapted for different methods of dissemination, give insight into one aspect of the difficulty of halting such a foreign invader once it became widely established and began its march.

SPREAD OF THE BLIGHT

The original infection spread rapidly from its center at New York City, and later from other centers. It soon spread over New England, but made its most rapid advance from New York City in a southwesterly direction along the southeastern slopes of the Blue Ridge and Allegheny Mountains.

Even in a given direction advance is not uniform. Not only does the blight fungus spread from infected trees to healthy ones near by but it is often carried for many miles—sometimes hundreds of miles—on shipments of chestnut lumber or nursery trees, by migrating birds, wind-blown insects, or the air itself. Under favorable conditions such spores may produce new centers of spread known as spot infections or advance infections. The rapid progress of the blight over the chestnut area is largely due to the starting of these advance spot infections many miles ahead of the main infection area. These advance spots rapidly enlarge and run together, forming a continuous infected area. The method of the delay and control work in Pennsylvania and other States was to locate and eradicate these advance infections. For instance, the eradication of the large Georgia-Tennessee spot infection when it was still small would have resulted in delaying the time of the death of the chestnut growth of that part of the southern Appalachians for many years, as the main infection area is still hundreds of miles north of this large infected area. The work in Pennsylvania resulted in marked delay in the spread of the disease westward across that State. Valleys or other areas with limited chestnut growth also delay the spread. Conversely, certain tracts of timber located within the infected area may for a time be disease escaping and be little infected by the fungus.

Their condition and location materially affect the rapidity with which trees become infected. Those along the edges of woods and roads and isolated trees are not only more exposed to spores of the fungus but also have more mechanical injuries. Various mechanical injuries and the work of insects afford places of entry for the parasite.

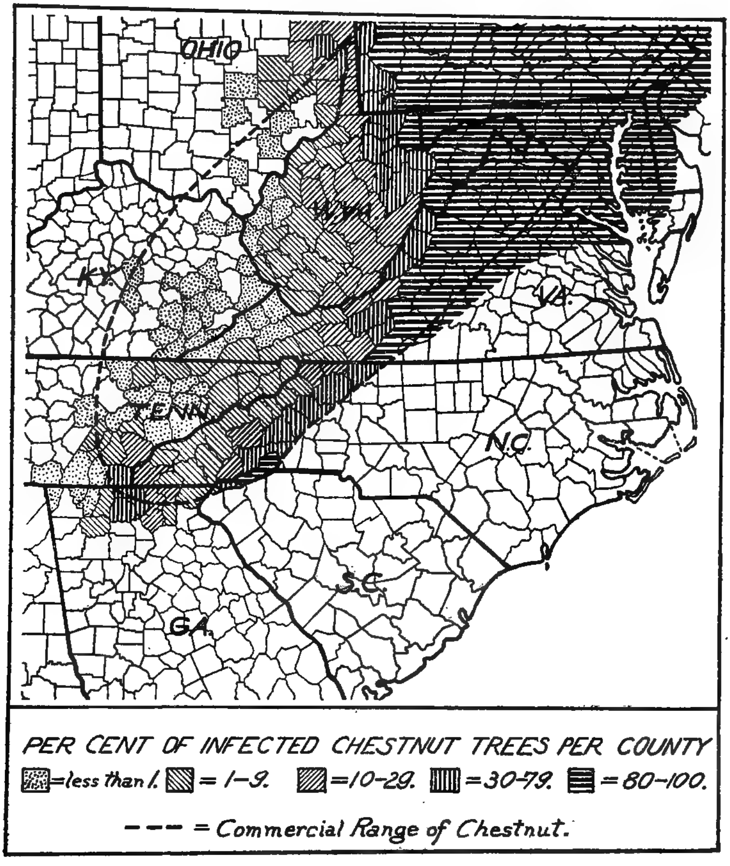


FIG. 1.—Map showing the known distribution of chestnut blight in the southern Appalachians in March, 1926

PRESENT DISTRIBUTION

The distribution of the chestnut blight in the southern Appalachians is shown on a map (fig. 1), which presents the data from the incomplete survey of 1924 and 1925, supplemented by the reports of numerous cooperators. Table 1 briefly summarizes the survey of 1925. The degrees of infection which the table and map show are based upon the average percentage of chestnut trees infected within a given county (fig. 1). The actual degree of infection within a county varies greatly. For example, a county noted on the map as having an average of 50 per cent blight may contain tracts where the actual infection is less than 5 per cent and other tracts where the extent of the infection may be 95 per cent.

TABLE 1.—*Summary of the 1925 survey of 200 of the more important chestnut counties in the southern Appalachians*

Extent of blight (percentage of trees infected)	Number of counties inspected							
	Georgia	Kentucky	North Carolina	South Carolina	Tennessee	Virginia	West Virginia	Total
No infection	3	8	0	0	1	0	0	12
Less than 1 per cent	3	14	0	0	14	5	4	40
1 to 9 per cent	4	0	11	1	15	6	14	51
10 to 29 per cent	3	0	5	0	1	4	20	33
30 to 79 per cent	2	0	7	2	1	6	8	26
80 to 100 per cent	0	0	1	1	0	27	9	38
Total	15	22	24	4	32	48	55	200

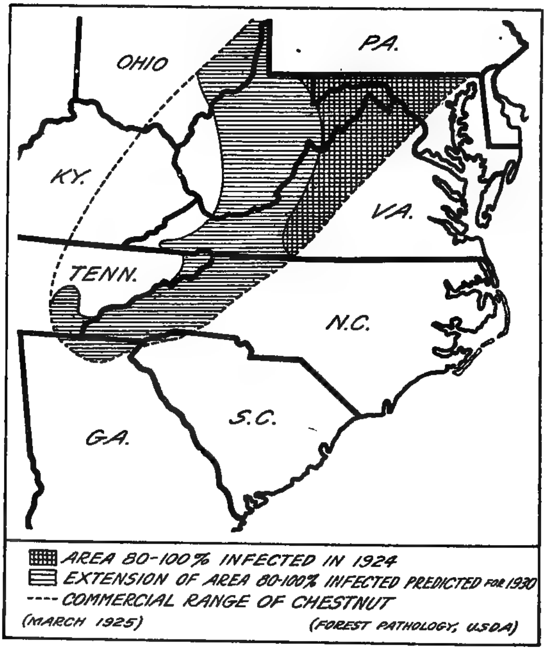
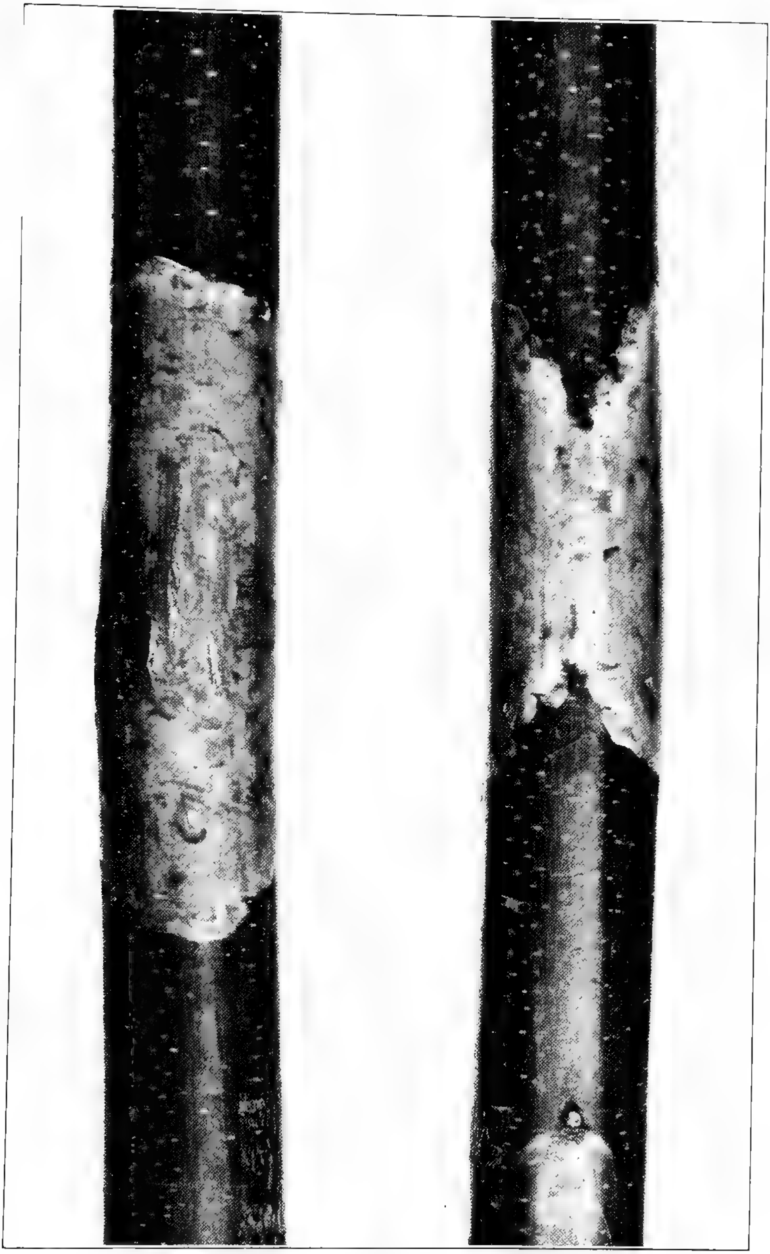


FIG. 2.—Map forecasting 80 per cent chestnut-blight infection in the southern Appalachians

There are probably many inaccuracies in these estimates. Some of the counties within the commercial range of chestnut (fig. 1) have not yet been inspected. In most of those which were entered the inspection consisted of a single automobile trip across the county, which afforded a view of but a fractional part of the chestnut stand for the entire county. The necessary adherence to a county basis did not increase the accuracy of mapping the distribution of the blight. The distribution presented on the map is based merely upon the best averages available in March, 1926. The need for each individual owner of woodland to examine his chestnut stands and determine roughly the present status of blight in them can not be emphasized too strongly.

FUTURE SPREAD OF THE BLIGHT

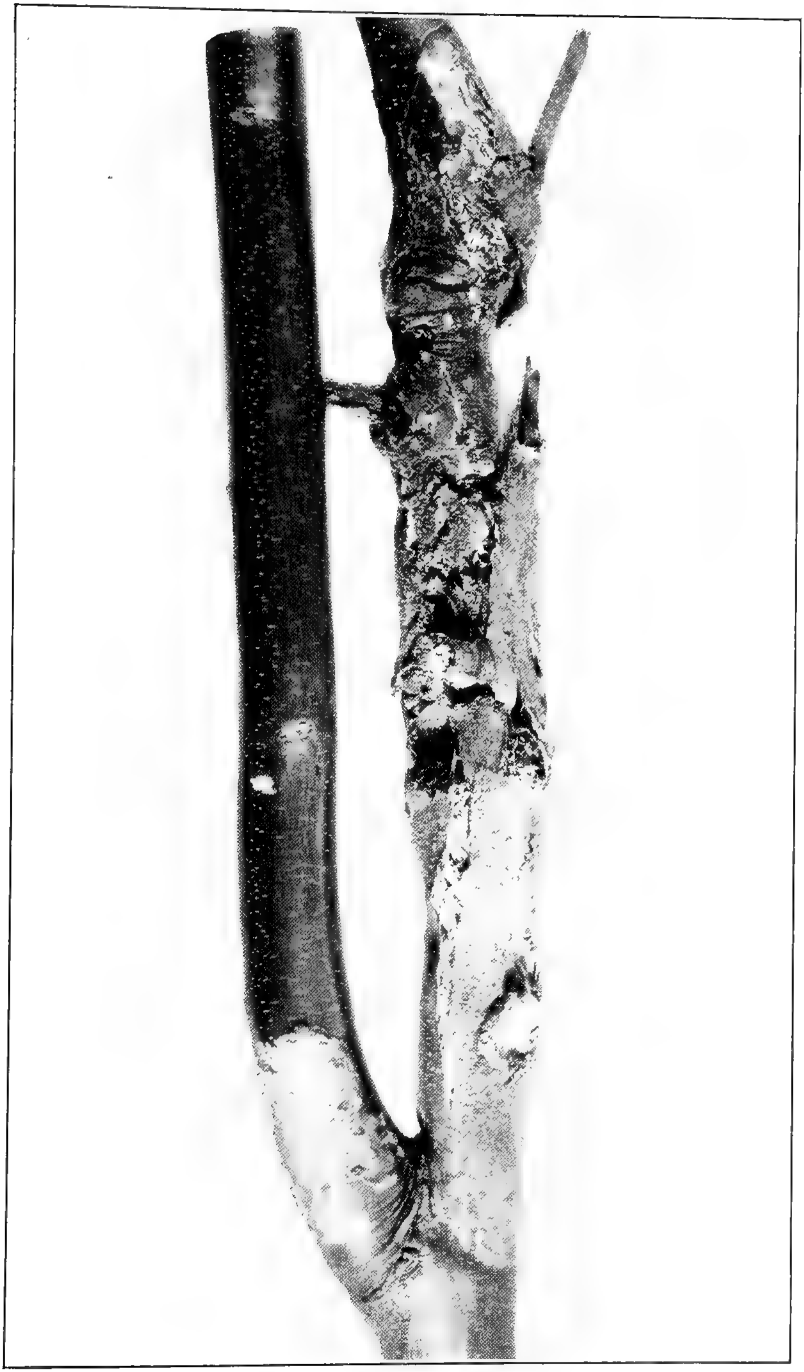
In the early stages of infection the presence of blight in chestnut stands is not evident to the casual observer. At first, only a few of the smaller branches and sprouts are killed. A 1 per cent infection, for example, since it refers to the presence of one or more infections on one in every hundred chestnut trees, actually represents a diseased condition of a very small fraction of the total branch spread.



A YOUNG CHESTNUT-BLIGHT CANKER

The girdling of a sprout by the meeting of the two edges of the lesion has just been completed. (Natural size)

A CHESTNUT BRANCH, SHOWING THE DEVELOPMENT OF SPROUTS BELOW A BLIGHT GIRDLE



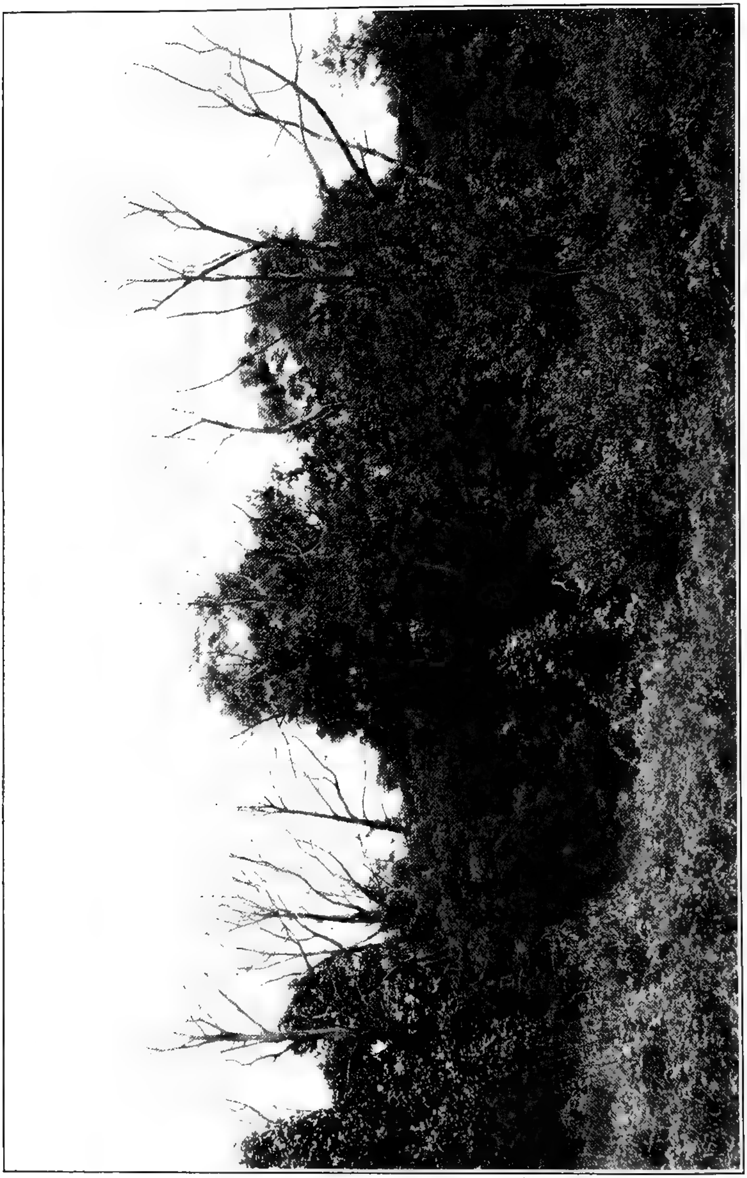
A CHESTNUT BRANCH, SHOWING A YOUNG BLIGHT CANKER AT THE BASE OF A SIDE BRANCH IN CONTRAST WITH THE ROUGH SPLIT OLDER CANKER ON THE MAIN STEM

(One-half natural size)

A CHESTNUT-BLIGHT CANKER WITH SWOLLEN EDGES AND WITH THE DEAD BARK PEELED FROM THE WOOD IN THE CENTER

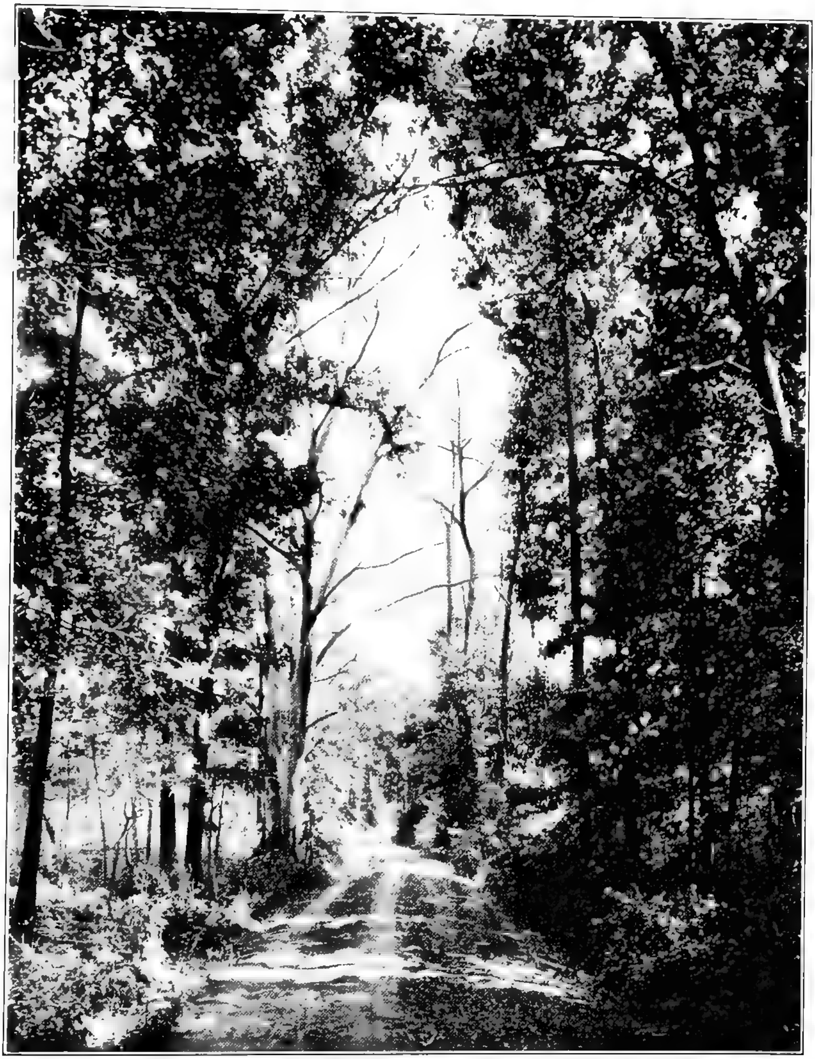
A CHESTNUT TREE ALMOST KILLED BY BLIGHT

The abundant development of sprouts along the trunk is often found



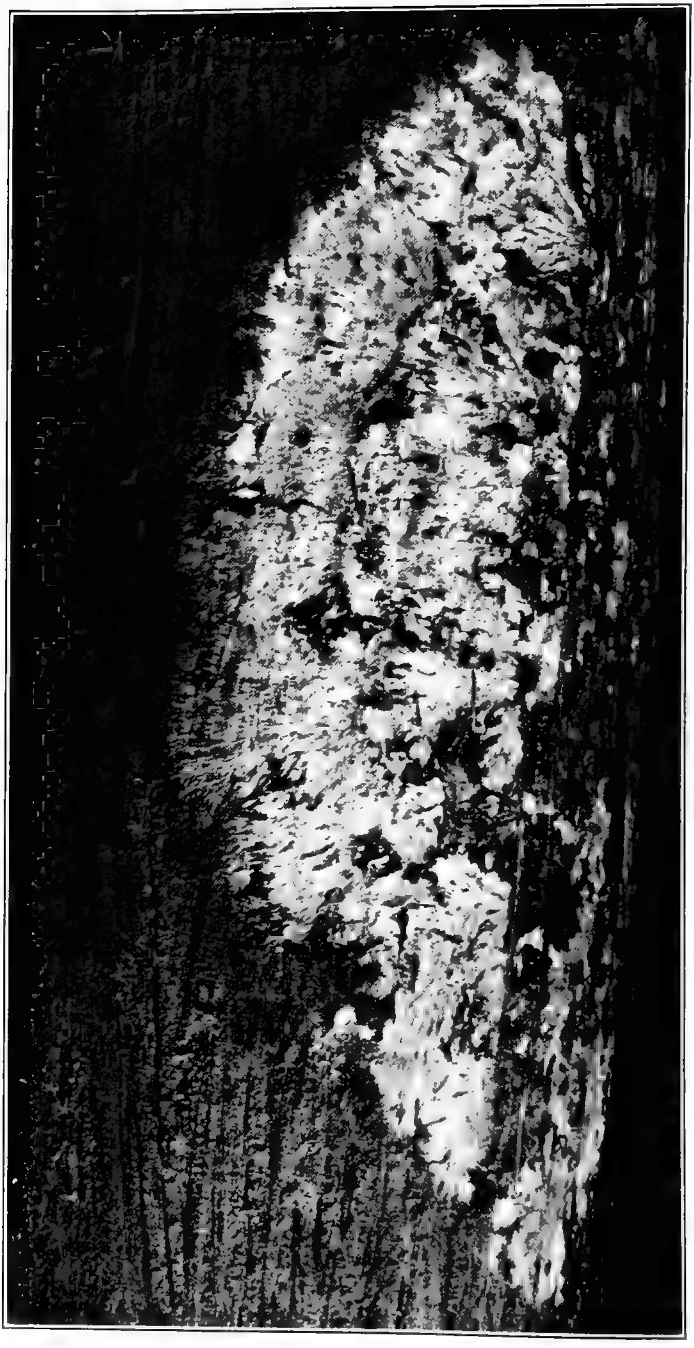
CONDITION OF CHESTNUT GROWTH NINE YEARS AFTER IT REACHED THE STAGE OF 80 PER CENT INFECTION

The uninjured trees are species other than chestnut



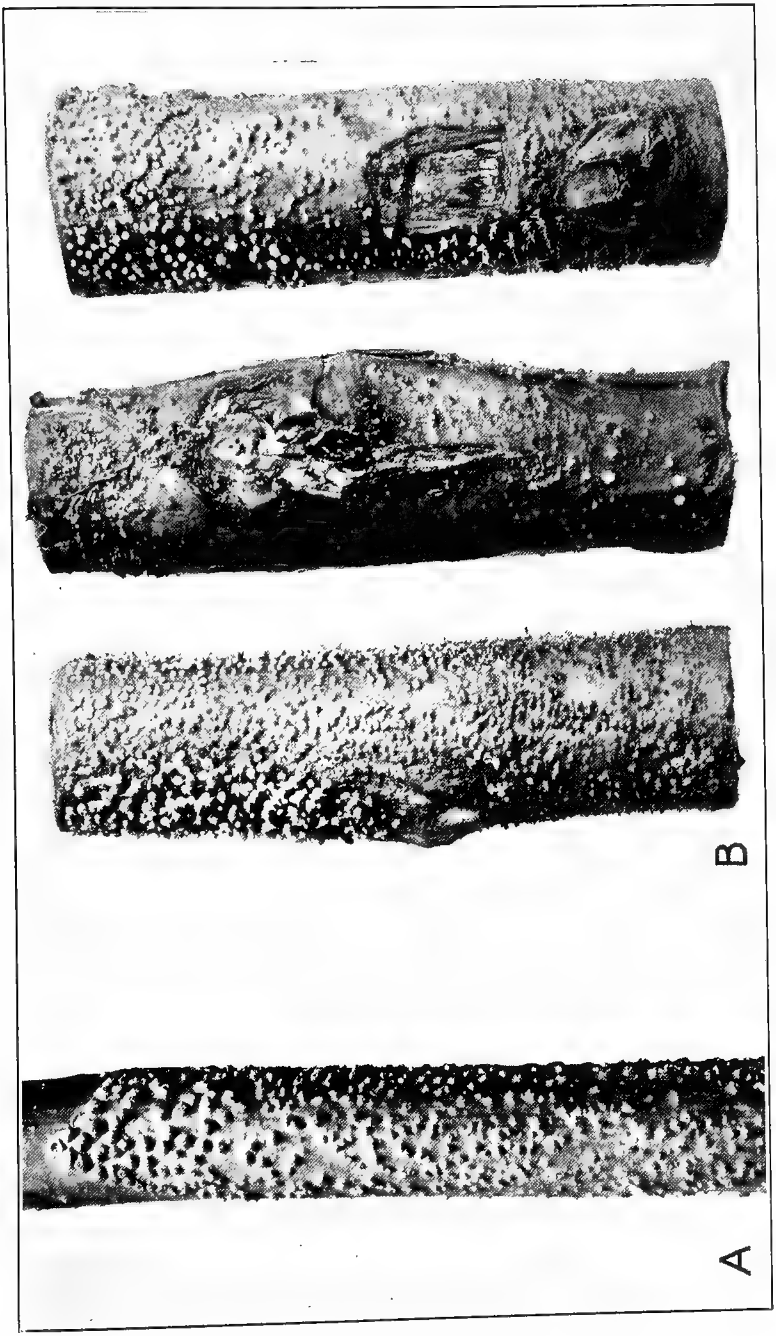
CHESTNUTS WHICH HAVE BEEN DEAD FROM FOUR TO SIX YEARS

Most of the bark has fallen, the sapwood is decayed, and checks in the wood are numerous



FANS OF WHITE OR BUFF-COLORED MYCELIUM OF CHESTNUT BLIGHT

These fans are exposed by peeling back the outer bark of the tree and constitute the most reliable evidence of the presence of the blight fungus



BLIGHT PUSTULES ON CHESTNUT

A, Chestnut-blight canker showing the fruiting pustules of the causal fungus, which in dry weather often resemble orange or red-brown pinheads. B, Necks of the flasklike structures may be seen protruding from some of the blight pustules

HAIRLIKE SPORE HORNS WHICH COIL OUT FROM CERTAIN OF THE BLIGHT PUSTULES DURING DAMP WEATHER

(12 times natural size)

The infection spreads rapidly. In general, from two to six trees will be found blighted for every one which had the disease the preceding season. Since the severity of attack as well as the number of trees infected increases, the presence of the parasite rapidly becomes evident.

When approximately 80 per cent of the chestnut is attacked, the killing effect of the fungus is shown by the presence of scattered dead and half-dead trunks as well as numerous dead limbs and branches. At this stage of the disease the lumberman and the farmer are usually aware of the need of prompt cutting. The class in which 80 per cent or more of the trees is infected has been selected as desirable for use in forecasting the spread of the disease. (Pl. VI.)

There are two methods of predicting the time a given area will become 80 per cent blighted. By one method the percentage of infection in a locality is multiplied by an annual factor, giving the period which may be predicted as required for that stand to become 80 per cent blighted. The second method consists in plotting the extension of the 80 per cent zone at the same rate it is known to have advanced in the past. In extending to the southwest across the State of Virginia this rate was approximately 24 miles a year. Its extension to the west across the valleys and ridges was less rapid. In forecasting the future spread by this method allowance must be made for any outstanding spot infections, for they, too, will throw out waves of the disease. In making the forecasts for the accompanying map (fig. 2), the two large spot infections, one in the Saluda Mountains and the other in northern Georgia, were allowed for.

These methods have been combined in preparing the forecast map. (Fig. 2.) Like the 1924 distribution map, from which it was prepared, the forecast map is not to be thought of as dealing with individual wood lots. It treats of the area as a whole. Nor is its accuracy, even as a whole, to be considered assured. It is based upon limited surveys and dependent on average conditions. The possible existence of large spot infections in counties not yet examined or only partially covered is a source of probable error. At present it is believed that by 1930 well over half the counties of the southern Appalachians will be 80 per cent blighted and that by 1935 nine-tenths of them will have passed that stage. New forecasts will be made when the available information from future surveys indicates that changes are needed. Owners of chestnut timber should make plans in advance to secure proper utilization before deterioration causes heavy losses.

DETERIORATION

A tree trunk girdled by the blight dies, just as girdled branches die; and, as with the branches, the larger the trunk to be girdled the longer the fungus requires to kill the part. In general a large part of the chestnut in a blighted stand will die within from two to five years following the reaching of the 80 per cent infection stage. A few trees, however, will be blight-killed when the tract is 80 per cent infected, and others will not be dead six years after that stage is reached.

The effect of girdling by blight is similar to that produced when a tree is ringed with an axe. The tree is killed, but its value for timber is not lessened. Tests made by the Forest Products Laboratory show that the chestnut blight alone does not impair the strength or durability of the wood. Like the ringed tree, however, blight-killed chestnut is subject to deterioration when not promptly used. This deterioration is brought about by secondary causes. Wood-decaying fungi promptly establish themselves in the areas of bark and sapwood which have been killed, sometimes even before the tree itself is completely dead. Within two years, and oftentimes even sooner, areas of sap rot are present. Insects burrowing under the bark and through the sapwood spread the rot-producing organisms and loosen the bark. In from four to five years following the death of the tree most of the bark and part of the rotted sapwood slough off, leaving the trunk bare (Pl. VII). While the sap rot is at work other deterioration takes place. The timber becomes dry and brittle. It is harder to cut, and breakage in felling is more frequent. Checking begins in from two to five years after the tree dies, small trees checking more rapidly than large ones. Excessive checking greatly reduces the value of the timber for purposes other than fuel or extract wood. Many timber worms gain entrance through blight cankers and at other places when the tree is dying, thus reducing the grade of lumber from such trees.

Where a considerable part of the stand is chestnut, fire conditions become increasingly critical with the accumulation of bark, dead sprouts, and fallen branches at the bases of dead trees. Fires not only often destroy part of the dead standing chestnut but also, on account of the intensity with which the accumulated dead material burns, frequently destroy other tree species in the stand. Adequate fire protection in the southern Appalachians would materially assist in the effort to utilize the chestnut growth and would materially prolong the life of the chestnut-extract industry.

SALVAGE AND UTILIZATION

North of the Mason and Dixon line from 10 to 40 per cent of the value of the standing chestnut was lost through deterioration which followed blight. In the South, where the stand contains a larger proportion of chestnut, heavier loss threatens unless the rate of cutting is immediately increased. Eventual destruction of all commercial chestnut by the blight is inevitable. Consequently each owner of chestnut is forced to decide for himself what part of his timber can be salvaged at a profit. He must weigh the value of the material, the difficulty of getting it out and ready for market, its transportation to the point of sale, and the labor and equipment available for performing the task within a limited time.

The problem of quickly utilizing the chestnut timber from the 33,000,000 acres of the southern Appalachians, where the species represents 25 per cent of the stand, is one phase of the chestnut-blight problem which the Forest Service and State and extension forestry departments are endeavoring to solve.

This country already feels the early stages of the increasing scarcity of timber. A large part of our lumber supply is hauled thousands of miles to market. Yet in the southern Appalachians, fairly close to the large consuming markets, we face the prospect of the loss through deterioration, before it can be used, of vast quantities of chestnut suitable for sawed products. The wholesale price of chestnut lumber, at least of the lower grades, is hardly sufficient to pay the cost of marketing. The situation emphasizes the need of employing chestnut on a national scale for purposes where it is practicable to substitute it for that of species not in need of immediate cutting.

Chestnut lends itself to the most varied usage of any timber species growing in the southern Appalachians. It is already used for extract wood, lumber, poles, ties, mine props, piles, fence posts, cordwood, and pulpwood, and it offers the possibility of increased employment.

Sawed chestnut lumber is much in demand, but because of the blight the market tends to be glutted. The wood is light and easily worked. It can be used for many purposes where its coarse grain and lack of extreme strength do not make it undesirable. Its increased use for sheathing, framing, interior work, and most of all for the manufacture of boxes, packing cases, and crates would do much to conserve other timber supplies.

Telephone and telegraph poles command the highest prices paid for chestnut. From the standpoint of utilization it is particularly fortunate that poles can be marketed at less cost than any chestnut product of equal value. Pole cutting is not dependent on any other lumbering operation, and no expensive equipment is necessary. The likelihood of flooding the pole market is serious, though the number of chestnut trees suited to the purpose is limited. Pole specifications of length, straightness, moderate diameter, and freedom from knots, rots, and injuries are so exacting as to exclude much material. Except on tracts where sprouts from the stumps of cut-over stands are of pole size, few poles are produced per acre. In short, poles represent the chestnut product selling for the highest price and at the same time are easily removed. Timber owners would do well to follow the practice of the Forest Service in the national forests in the southern Appalachians, where all chestnut suitable for poles is cut as a first measure of utilization.

The manufacture of chestnut extract affords the most feasible outlet for much of the stand. Extract plants are already established strategically over the southern Appalachian district. This industry, by far the largest consumer of chestnut, uses enormous quantities of the wood. It disposes of trees and parts of trees that are worthless except as acid wood. The limbs as well as trunks are used, so that little waste remains in the woods to increase the fire hazard. Best of all, from the standpoint of the present situation, even the prolonged standing of dead timber does not exclude its use for this purpose.

While it simplifies utilization, the tannin-extract industry at the same time presents one of the most important problems arising from the present situation. The American chestnut supplies approximately one-half of this country's production of tannin for leather manufacture. With this species facing extermination, to what future source of raw material must this vital industry look?

What other valuable species can be used to reforest the land once occupied by the chestnuts? This is an important silvicultural problem. The best means of bringing about the replacement of the chestnut with other valuable species of trees is being studied by the Appalachian Forest Experiment Station at Asheville, N. C., in cooperation with various States. State and extension foresters are rendering assistance to private owners in planning for the utilization of their chestnut stands.

BLIGHT-RESISTANT CHESTNUTS

Since direct control of chestnut blight is impracticable, the discovery of suitable strains of chestnut resistant to the disease is highly desirable. Individual native chestnuts show differences in susceptibility to attack, but the number of trees actually surviving in regions where blight has been present longest is very small. Search for many years has disclosed only a few native specimens. Some of these trees are being propagated and further studied with the hope of developing a strain of American chestnut sufficiently resistant to attain maturity in the presence of the disease. It has been found that the numerous living trees which occur on tracts recently blight-killed are generally disease-escaping rather than disease-resistant; for this reason search for resistant specimens is profitable only on areas where all but very exceptional chestnut trees have been dead from the disease for a number of years. Reports of such resistant trees are desired. The Office of Forest Pathology records all such trees reported and inspects them as field work permits.

A number of Japanese and Chinese species and strains of chestnut have been brought to this country in the hope of obtaining a tree which will thrive despite the chestnut blight. None of the trees so far imported and tested have proved immune, but the Japanese chestnut (*Castanea japonica*) and the hairy Chinese chestnut (*C. mollissima*) have considerable natural resistance. A number of these trees are known to have survived the blight, and reports of others are desired. Strains of these oriental chestnuts show marked differences in susceptibility, and it is impracticable to control the blight on some of the very susceptible ones. However, most of the oriental trees can be saved by systematically cutting out any cankers which may appear and painting the wounds. Detailed information will be supplied by the Office of Forest Pathology to anyone interested in treating such trees.

Most of the imported chestnuts so far tested have been suited for orchard culture rather than timber production. Other strains and additional species of Asiatic chestnut are being introduced by the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry. There is reason to expect that ultimately among these introductions, resistant native strains, or crosses among these various forms, a tree will be found which possesses sufficient resistance to grow to timber size in the presence of the disease.

SUMMARY

The chestnut blight is caused by a fungus introduced into this country on nursery stock from Asia. The organism attacks the bark of the chestnut and forms cankers. These ultimately girdle and kill the parts affected, the dead foliage remaining persistent.

A county by county survey begun in 1924 and still in progress has discovered infections at the southern limit of commercial chestnut. Westward the spread of the disease has been less rapid than southward. It is believed that by 1930 more than half, and by 1935 nine-tenths, of the counties in the southern Appalachians will have reached the stage at which more than 80 per cent of their trees will be infected.

No practical control is known, but if salvaged before deterioration sets in the lumber from blight-killed trees is equal to that cut from live trees. Great need exists for increased cutting and use of chestnut, so that this timber may be utilized and other species conserved.

Search is being made for native and foreign chestnuts resistant to the disease in the hope of finding a tree suitable for partially replacing our rapidly disappearing stands.

year later, when one of the first publications on this disease appeared, it was evident that a serious problem was at hand, a problem involving the future welfare of our great American chestnut forests. The onsweep of the devastating bark disease is a matter of history. It spread rapidly through all the chestnut regions of the eastern United States and, according to specialists in the department, has now reached the southern limit of commercial chestnut growth in northern Georgia and northwestern South Carolina. It appears from all the evidence at hand that it is only a question of a few years when our former great chestnut forests will be extinct and we shall have to look elsewhere for materials to meet the needs this valuable tree has in the past provided. While the blight was devastating the chestnut forests, orchards of chestnuts in the New England and Middle Atlantic States were also wiped out, so that there is no longer any orchard culture of consequence east of the Allegheny Mountains.

When it first became evident that the chestnut blight was a menace of the first magnitude, renewed interest was aroused in foreign explorations for the purpose of discovering new forms that might be of use in meeting the situation. From 1903 to 1912 numerous lots of Chinese and other chestnuts were received, grown, and distributed in the course of the foreign plant introduction work. Meanwhile the origin of the chestnut-blight fungus remained unknown, and it was not until the spring of 1913 that it was discovered in China under conditions that left no doubt that its original home had been found. The discovery was made by the late Frank N. Meyer, agricultural explorer of the Bureau of Plant Industry, United States Department of Agriculture. He found the disease attacking the Chinese hairy chestnut (*Castanea mollissima*), and also evidence that this chestnut was resistant in varying degrees. From 1913 until the present time the search in foreign fields for blight-resistant chestnuts and related species has continued.

In 1921 J. F. Rock began systematic work in agricultural explorations for the Bureau of Plant Industry, United States Department of Agriculture, that year confining his activities mainly to Siam and Burma. In August, 1922, Mr. Rock undertook an extensive and detailed search for new chestnuts and related species in the Province of Yunnan, western China. This Province lies north of Siam and on the northeastern border of India. The country is difficult of access. It is a region of magnificent mountains, high plains, large and small valleys, deep gorges, and rushing waters. The climate is unlike anything in this country, subtropical in the lowlands, with clouds, fogs, and snows on the high elevations, with which the country abounds. At the higher elevations, 5,000 to 12,000 feet, the winter temperatures are not low, but the snows are heavy.

Mr. Rock spent several weeks in the primeval forests of this interesting region, collecting large quantities of seeds, which were carefully packed and started on their long and hazardous journey late in the fall. After many vicissitudes the seeds reached Washington, closing a chapter of one of the most extensive undertakings of the kind on record. Mr. Rock remained in the region through the winter, spring, and summer of 1923, and was enabled in September, 1923, to make another collection of nuts thought to be those of a chestnut. This was one of the most successful shipments of this explorer, and resulted in obtaining nearly 6,000 little trees from the seeds sent in.

On several occasions the Office of Foreign Plant Introduction has secured the services of J. H. Reisner, of Nanking University, Nanking, China, for the purpose of collecting various seeds and plants. Professor Reisner, through his association with the College of Agriculture and Forestry, has been in a position to make a careful study of the chestnuts in that part of China. A number of large shipments of nuts have been received from him; and these, having been packed properly, reached the department in excellent condition. Practically all these seeds were those of the Chinese hairy chestnut (*Castanea mollissima*).

In July, 1924, P. H. Dorsett, long connected with the work of the Office of Foreign Plant Introduction, left for northeastern China, accompanied by his son, James H. Dorsett. The explorations made by Dorsett and Dorsett have resulted in procuring additional chestnut material, including nuts from wild and cultivated trees from the regions north and northeast of Peking.

In view of the great interest in substitutes for our native chestnut that may prove able to withstand the blight and be utilized in breeding work, looking to the supplying of timber, tannin, and food, it has seemed desirable to bring together certain data bearing on the species already introduced or that may be introduced. This seems particularly necessary, inasmuch as there is considerable confusion and some misunderstanding as to the real merits of the introductions heretofore made.

BOTANICAL CONSIDERATIONS

The substitute trees referred to belong to a group of five genera scattered rather widely over the world: (1) Beech trees, belonging to the genus Fagus; (2) chestnuts (Castanea); (3) oaks (Quercus); (4) Lithocarpus, and (5) Castanopsis. In this circular only the Castaneas, or chestnuts, and the species of Castanopsis will be considered. The latter we may call evergreen chinquapins, because their leaves are not shed in the fall.

The genus Castanea, containing the chestnuts, is confined to the Northern Hemisphere and embraces nine known species, of which four occur in the United States, one in southern Europe, one in Japan, and three in China. A few of the species are shrubby. Others, like our own American chestnut, the Chinese hairy chestnut, and the Chinese timber chinquapin, grow into tall trees. The leaves of the chestnuts are deciduous; that is, they fall at the approach of cold weather. The bark is usually deeply furrowed, and the wood is porous. The nuts are borne in spiny burs, which on maturing split into two to four valves (fig. 1).

The genus Castanopsis is closely related to Castanea and includes 25 or more species, one of which, namely, *Castanopsis chrysophylla*, "erroneously called the golden-leaf chestnut," occurs along the western slopes of the Cascade Mountains in Oregon and in the coast ranges of California. Nearly all the species of Castanopsis are found in southeastern Asia. Twenty-two species are described by King as being Indo-Malayan forms.[1]

The species of Castanopsis are trees, many growing to large size; the foliage is evergreen. The nuts are usually small and somewhat

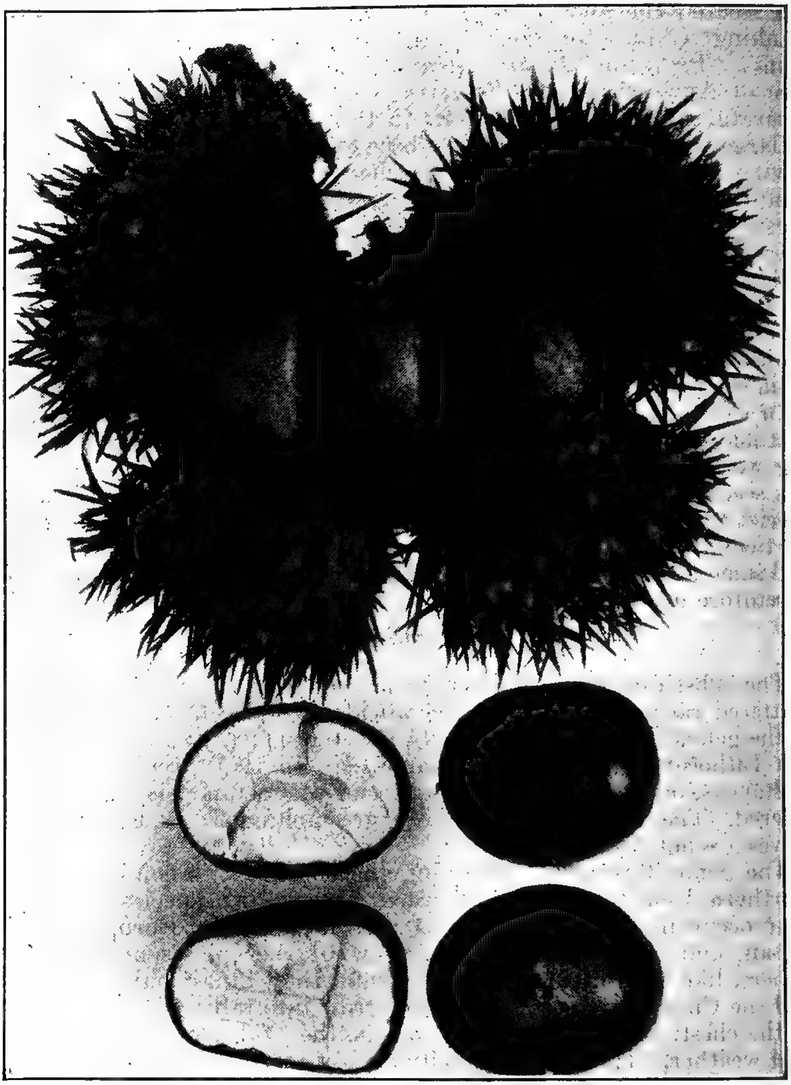


FIG. 1.—Bur and nuts of the Chinese hairy chestnut (*Castanea mollissima* Blume). Collected by Dorsett and Dorsett in Chihli Province, China, October 11, 1924. Slightly reduced. (P29560FS)

resemble acorns; they mature the second year and are borne in burs covered by stout spines.

[1] KING, G. THE INDO-MALAYAN SPECIES OF QUERCUS AND CASTANOPSIS. Ann. Roy. Bot. Gard. Calcutta, vol, 2, pp. 17–107, pls. 15–104. 1889.

The promising members of the two genera will be briefly described, summarizing as concisely as possible the results obtained and the possible economic uses of the various forms already introduced or worthy of introduction.

CHESTNUTS

(*Castanea* spp.)

The botanical characters of Castanea have already been noted. This genus is by far the most important economically, as most, if not all, of the species probably will grow in any region where our native form thrives.

CHINESE HAIRY CHESTNUT

(*Castanea mollissima* Blume)

Reference has been made to some early introductions of chestnuts from China by Brill and the probability that these were *Castanea mollissima*. These introductions, made in 1901, were inventoried and recorded in the usual way and later distributed. All traces of these trees have disappeared. According to E. H. Wilson,[2] *Castanea mollissima* was introduced at the Arnold Arboretum, near Boston, Mass., by C. S. Sargent, who procured seeds in 1903 in the market at Peking, China.

The records of the Office of Foreign Plant Introduction show that more than 25 importations of this chestnut have been made. It was not until 1913, however, that it was recognized by the office as a distinct species and called by its right name. Prior to 1913 it was listed and distributed under the name *Castanea sativa*, which is the common chestnut of Spain, Portugal, Italy, and other countries in southern Europe and northern Africa.

Castanea mollissima is distributed over most of northern and central China. It is found in the eastern and also in the far western Provinces, including Yunnan, where it was collected by Rock. In a wild state the chestnut constitutes a considerable part of the forests of certain regions. The districts where it seems to be cultivated most extensively are found to the north and northeast of Peking. Considerable areas are given over to the cultivation of this tree in Chihli Province, and from the records at hand it has for many years been an important source of food there. According to Meyer and others who have visited the chestnut regions in China, it is the practice to plant the trees in large or small areas here and there along the bases of hills and on the sloping foothills (fig. 2). In the native forests the trees grow to a height of 40 to 60 feet, with trunks 3 to 6 feet in girth. The nuts closely resemble our native species in size, color, sweetness, and flavor (fig. 1). There is much variation in the species as to size and quality of nuts and size and vigor of trees. Evidently there are numerous horticultural types. From Meyer's studies it would appear that there is variation in its ability to resist blight in the native orchards and forests.

According to Meyer's notes, it is the practice of the Chinese growers to give special attention to the trees with respect to treatment for blight. The diseased areas are cut out and scraped with a great

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[2] SARGENT, C. S. PLANTAE WILSONIANAE. Vol. 3, p. 194. 1916.

deal of care. Evidences of treatments of this kind were found by Meyer on trees believed to be at least 300 years old. There is no evidence from Chinese sources as to the continuous fruitfulness of the trees; that is, whether they are annual bearers or bear fruits only in certain years.

At the beginning of 1914, and at intervals since that time, extensive importations of the nuts of this tree have been made by the Bureau of Plant Industry, and seedlings have been grown from them at several of the plant-introduction gardens. In some instances the seeds have been stratified in the usual way in beds in the open ground, the nuts being allowed to freeze where practicable, and early in the spring they have been lifted and planted in drills or nursery rows. This has been the practice where the seeds were received fresh and were not badly infested with weevils.

FIG. 2.—A grove of old trees of the Chinese hairy chestnut near Santunying Chihli Province, China. Note how the trunks and limbs have had the bark scraped off. This is partly to protect the trees against insects and diseases. (P5846FS)

Another method, and one which is more dependable, consists in sowing the seeds as soon as practicable after being taken from the tree, using flats or a bench in a greenhouse where a little bottom heat can be given. The temperature of the house is kept low; in fact, it is best that night temperatures do not exceed 40° F. As rapidly as the seedlings germinate and make a few leaves, five or six are planted in a 6-inch pot, setting them around the rim. The seedlings are carried through the winter in this fashion, and as soon as the weather is suitable in spring, usually about May 10 to 15, the balls of soil containing the little trees are lined out in a nursery. The seedlings are not broken apart in this operation, and the balls are set as close as they will stand. The following fall the seedlings may be lifted, separated, stored, and the next spring lined out in nursery rows for the second year's growth. Usually seedlings grown by this method are more easily transplanted, as the roots are inclined to be fibrous, making it less difficult to handle the trees. Despite all precautions, the seedlings do not take very kindly to these practices. They must be handled with care and are not so easily transplanted as are fruit trees, such as pears, apples, and cherries.

During the past 10 years something over 10,000 nursery-grown seedlings of *Castanea mollissima* have been distributed to all parts of the United States. No serious efforts have been made to set out these trees in orchard blocks. A good many have gone to public parks, others have been placed in the hands of foresters, and considerable numbers have found their way into test nurseries and the gardens of private experimenters. Efforts to determine what has happened to these trees show that fully nine-tenths of them have been lost. Drought, frost, fire, and lack of adaptability to climate are set down by those who received the trees as the principal causes of their death. A good many cooperators of the department report that blight caused the death of many trees, although numbers report that these trees have resisted blight, whereas the American chestnut in the same neighborhood succumbed.

In 1912 the late Walter Van Fleet, of the Bureau of Plant Industry, established a test orchard of chestnuts at Bell, Md., 15 miles northeast of Washington, D. C. This orchard was planted with *Castanea mollissima* seedlings, also a number of hybrids produced by Doctor Van Fleet, and a collection of selected types, the selections being largely from the Japanese chestnut (*Castanea crenata*). About 900 of the *Castanea mollissima* trees were planted, the seedlings being grown from seeds sent from Tientsin, China, in 1911.

The country around Bell was at one time the home of forests of our native chestnuts. A good many old trees were still standing in the neighborhood at the time of planting the orchard. Nearly all of these old trees have been killed by blight. The Chinese hairy chestnuts (*Castanea mollissima*) and a good many of Doctor Van Fleet's hybrids and selections are still living and growing well (fig. 3). Marked differences have developed in the seedlings of *Castanea mollissima*. Some produce larger nuts than others; some are more vigorous than others. One or two trees are steady bearers, while some are shy bearers.

There is little information at present that would encourage the belief that the Chinese hairy chestnut may be utilized as a substitute for our native species in the production of timber or for tanning purposes. To provide future timber and tannin supplies for this country is a complex economic problem that must be viewed from many angles and can not be discussed here. As a possible source of a valuable food crop and perhaps poles, posts, and similar timber, *Castanea mollissima* seems well worthy of study and extension. The tree lends itself readily to orchard or intensive culture and begins to bear when 6 or 7 years old. The trees for orchard culture may be planted as close as 14 by 14 feet, but 18 by 18 feet is better. Such trees should be pruned sparingly. Experience has shown that the head should be formed early, followed by limited pruning later. The trees do best when left to grow naturally. See Figure 3, showing natural growth on the left and pruned growth on the right. The trees should have good culture, like the apple, peach, and pear. They can not be left to care for themselves with much hope of success.

The United States Department of Agriculture, through the Bureau of Plant Industry, is endeavoring to establish this promising tree in the region formerly occupied by our native species. Up to this time dependence has been placed on Chinese sources for our seed supply, and this is becoming more and more precarious. As a first step, it would seem important to establish a considerable number of small orchards, mainly for the production of home-grown seeds. In the spring of 1926 and in 1927 the Office of Foreign Plant Introduction will be in a position to supply limited numbers of young *Castanea mollissima* trees for experimental orchard planting

Fig. 3.—A young orchard of Chinese hairy chestnuts at Bell, Md. Trees on the right pruned; on the left unpruned. Pruning wounds should be treated to prevent infection. (P24253FS)

in regions east of the Allegheny Mountains where blight occurs. Trees can not be sent outside of the regions indicated on account of the danger of spreading blight. It is planned to limit the plantings to about 1 acre in each locality. Planting trees 18 by 18 feet will require 134 to the acre. They will need to be cultivated and the ground planted to some suitable green-manure crop for the first four or five years. After that it will likely be best to put the orchard in grass except directly under the trees. Details of this plan of cooperative planting will be furnished on request.

To those interested in breeding and selection work the Chinese hairy chestnut offers promising material. Crosses between *Castanea mollissima* and our native chinquapin (*C. pumila*) might well be worth while. Such crosses have already been made (fig. 4). One in particular should be mentioned. It was made by the late Doctor

Van Fleet, and the original tree is growing at the Bell (Md.) garden. This tree is more than 10 years old and for the past five

FIG. 4.—Hybrid chestnut (about two-thirds natural size). A cross between the Chinese hairy chestnut and one of our native chinquapins. The tree yields fine nuts, bears abundantly every year, and has shown marked blight resistance. (P35503FS)

years has borne heavily each year. The nuts are about double the size of our native chestnuts and are sweet and palatable. The tree has shown no signs of blight. This tree and others are being made the subject of breeding and pathological studies by G. F. Gravatt, in charge of the chestnut-blight investigations of the Office of Forest Pathology.

To extend the range of the chestnut southward, further crosses might be made between *Castanea mollissima* and *C. alnifolia*, the

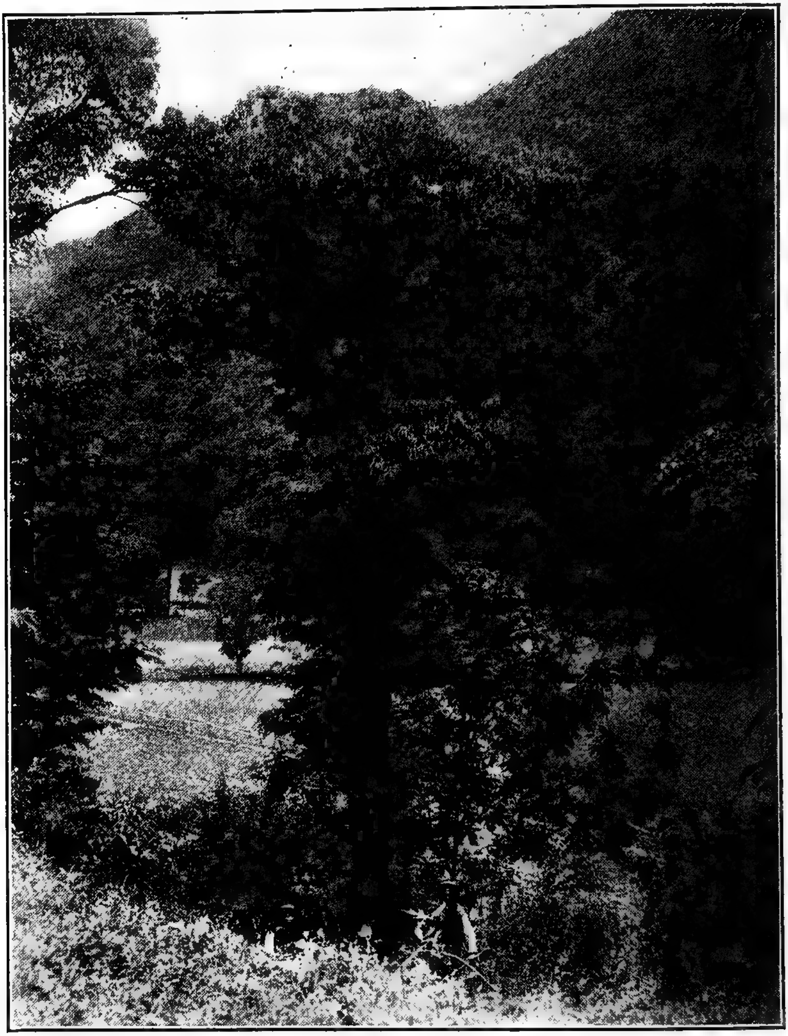

FIG. 5.—Chinese timber chinquapin (*Castanea henryi* (Skan) Rehder and Wilson). A large timber tree from western China well worthy of introduction. (Photographed by E. H. Wilson, of the Arnold Arboretum)

latter being a shrubby chinquapin found along the Atlantic coast from North Carolina to southern Georgia. Both of these chinquapins are very resistant to blight. When material is available, crosses might be made between *C. mollissima* and *C. henryi*, the timber chinquapin of China (fig. 5).

Crosses between the Chinese hairy chestnut and the Japanese chestnut (*Castanea crenata*) might yield valuable hybrids, the latter being very resistant and yielding nuts of good size.

Data as to the location of bearing trees providing suitable material for breeding will be furnished on request.

EUROPEAN CHESTNUT

(*Castanea sativa* Miller)

The European chestnut has been cultivated and used for centuries in many parts of the world. It is one of the most widely distributed nut-food trees. It may have come from eastern Asia. Certain it is that it was well scattered throughout the south of France at the beginning of the Christian era. It was early introduced into Britain, probably by the Romans, and became so well established that it behaves like a native tree. The nuts were easily transported and early introduced into the United States. There are records of grafted trees and small grafted orchards in this country before the Revolutionary War. The early Spanish colonists scattered the trees throughout their possessions, and the species thus became established in many Spanish countries. It was taken to the Philippines by the Spaniards, and according to P. J. Wester ancient trees are still occasionally met with in old monastic gardens on those islands.

The European chestnut grows to a large size, often attaining a height of 90 feet or more with a girth of 20 to 30 feet. The leaves are oblong-lanceolate, with rather coarse serrations. The nuts are larger than those of the Chinese hairy chestnut and our own American species. The shell is dark brown and is usually tough and leathery. The quality of the nut is rather indifferent and does not compare favorably with our own chestnuts and a number of other species that will be mentioned later.

The Office of Foreign Plant Introduction has made several importations of this chestnut, but nothing new has developed as a result of this work. Considerable areas were planted to this chestnut in Pennsylvania, Delaware, and on the Eastern Shore of Maryland prior to the advent of the blight, by which most of these orchards have been swept out of existence. As blight has not invaded the Pacific coast, trees of the European chestnut are now found in the valleys of Washington, Oregon, and California. There are also scattered plantings in sections west of the Allegheny Mountains, but most of these are hybrids and not pure types of *Castanea sativa.*

Because of the rather indifferent quality of the nut and its susceptibility to blight, there would appear to be no great future for this chestnut in this country except as a possible source of supplying timber and tannin when planted outside of our native chestnut region. There are numerous varieties, some of which are believed to be hybrids. It is possible that some of these hybrids, containing as they probably do the blood of our own native chestnut, might prove of value for further breeding work, using *Castanea mollissima* and possibly *C. crenata* and our own native chinquapin for crossing. There may be and doubtless are European varieties and types of this chestnut worthy of introduction for breeding and other purposes. The countries of eastern Asia and western and southwestern Europe might yield types worthy of further trial in this connection.

CHINESE TIMBER CHINQUAPIN

(*Castanea henryi* (Skan) Rehder and Wilson)

Little is known of this chinquapin except what has been published in comparatively recent times in some scattered botanical periodicals. It is known by various names—*Castanopsis henryi*, *Castanea sativa*, *C. vilmoriniana*, and *C. fargesii*. *Castanea henryi* has been known to botanists for 18 or 20 years. It is not found in general cultivation and has been introduced but sparingly into arboreta and botanical gardens. (Fig. 5.) According to E. H. Wilson, Assistant Director of the Arnold Arboretum, *C. henryi* is growing there and without sign of disease. A specimen planted by the late Doctor Van Fleet is growing at the United States Plant Introduction Garden at Bell, Md. This specimen was propagated from scion wood received through the courtesy of Prof. C. S. Sargent, of the Arnold Arboretum. This fine chinquapin was found by Wilson at a number of places in central China, and Sargent says[3] that the species is distributed from the neighborhood of Ningpo through the valley of the Yangtze River as far west as Mount Omei. On the mountains of western Hupeh and of eastern Szechwan it is common in woods.

According to Sargent this chinquapin grows to a larger size than any other Chinese species, and trees from 20 to 25 meters tall with trunks 1 to 3 meters are common. Occasionally trees 30 meters tall and 5 meters in girth of trunk are met with. The leaves are green on both surfaces and entirely glabrous except for a few appressed hairs on the under side of the primary and secondary veins. All the fruits we have seen contain a solitary nut, but it is probable that occasionally two occur, as they do in *Castanea pumila* Miller.

Van Fleet, in one of the latest of his publications, referring to this chestnut, said:

Recently there has been brought to light in the interior of China a chestnut species that may restore our timber production of this most desirable wood, if it should prove immune to disease. Unlike other Old World chestnuts, which form relatively small trees, this species, *Castanea vilmoriniana* (now known as *Castanea henryi*), grows 80 to 100 feet high with a straight, symmetrical trunk well adapted for all timber purposes. The nuts, according to the scant herbarium material that has reached this country, are of little consequence except for propagation, as they are only slightly larger than those of our wild chinquapins. This species is now established at the Arnold Arboretum near Boston, Mass., and scions worked on *C. mollissima* stocks are now vigorously growing at Bell Experiment Plot, making fine upright shoots.[4]

Meyer, in exploration work carried on just prior to his death, spent considerable time near Ichang in Hupeh Province. Among some of the last collections sent in by him were specimens of what may have been this chestnut. This material, however, failed to grow. Although Gravatt, of the Office of Forest Pathology, Bureau of Plant Industry, reports that he has infected this species with blight, from the fact that the disease has not been reported on the specimen at the Arnold Arboretum nor on the one at Bell, Md., it may, like our native chinquapin, be a resistant type. Such a fine

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[3] SARGENT, C. S. PLANTAE WILSONIANAE. Vol. 3, p. 197. 1916.

[4] VAN FLEET, W. CHESTNUT WORK AT BELL EXPERIMENT PLOT. North. Nut Growers' Assoc. Rpt. Proc. 11th Ann. Meet., pp. 16–21. 1920.

tree is well worthy of further study and introduction. It may prove very useful as a timber tree and possibly as a tannin-producing tree. These are matters, however, that must be determined by further experiment.

The use of *Castanea henryi* for breeding purposes is to be commended. Crosses with our native chestnut (*C. dentata*) may give size, resistance to blight, and nuts of good quality and large size, all characters much to be desired. Crosses of *C. henryi* and *C. mollissima* may also produce valuable results. The latter lacks qualities as a timber tree which might be provided by *C. henryi*. Both these forms being resistant to blight, they would be likely to make the resultant cross more valuable.

CHINESE DWARF CHINQUAPIN

(*Castanea seguinii* Dode)

While agricultural explorer of the United States Department of Agriculture, with headquarters at Ichang, Hupeh Province, China, Meyer collected this chestnut on November 16, 1917. The following is his original note sent with the seeds (S. P. I. No. 45949) on the date mentioned:

(No. 2459a. Ichang, Hupeh, China. November 16, 1917.) A shrubby chinquapin occasionally growing into a tree 25 to 40 feet high, occurring on mountain slopes here and there in central China often in great quantities. Sprouts only 2 feet high often produce nuts. It appears to be totally resistant to the bark fungus (*Endothia parasitica*) and may be of considerable value in breeding experiments such as Dr. Walter Van Fleet has been conducting for several years. This species seems to be more moisture loving than *Castanea mollissima*, but it grows well on the most barren mountain slopes. Chinese name *Moh pan li*, meaning "hairy board oak."

A few seedlings were grown and distributed from this lot of seeds; but, unfortunately, all have been lost. Wilson, collecting for the Arnold Arboretum, reports finding this chestnut in several localities in China. He raised a number of seedlings, but they were all lost by fire.

Sargent reports that this chestnut is very abundant on the hills and mountain sides throughout the Yangtsze Valley, from the neighborhood of Ningpo on the east to eastern Szechwan on the west. "It also grows in the Provinces of Shensi and Kweichow, but Wilson does not remember meeting with it in western Szechwan. Usually it is a bush or a low bushy tree, but under favorable conditions it forms a shapely tree from 12 to 15 meters tall, with spreading branches and a trunk 1 to 1.5 meters in girth."[5]

Castanea seguinii, like the timber chinquapin of China, may prove useful for breeding work. Its ability to resist blight is an important feature, and it would seem well worthy of further introduction and trial as a means of increasing our list of resistant and valuable chestnuts.

JAPANESE CHESTNUT

(*Castanea crenata* Sieb. and Zucc.)

The Japanese chestnut has been grown in this country for a number of years, but not so long as the European species. It is extensively grown in Japan and is widely used in that country as food for

[5] SARGENT, C. S. PLANTAE WILSONIANAE. Vol. 3, p. 195. 1916.

man; also for swine. In the fall the raw and roasted nuts are found offered for sale throughout the rural districts of Japan. School children are especially fond of them, and it is not uncommon to see the venders of hot roasted chestnuts gathered about the schoolhouses and doing a lively business at the noon hour. The tree is a vigorous grower, is blight resistant, and is very productive. The nuts are of rather indifferent quality, not comparing in sweetness and tenderness with the Chinese hairy chestnut and our own native species. A good many varieties have been developed by breeding and selection. Van Fleet gave much time and attention to selection for blight resistance. The Office of Foreign Plant Introduction has introduced the Japanese chestnut under 12 different S. P. I. numbers, and specimens of the trees listed under these numbers have been established at various places in the United States. This chestnut would seem to be of particular value as a possible source of improving our blight-resistant strains and procuring trees of vigor and considerable size that might be of value for forest planting. It may develop that crossing this strain with *Castanea mollissima* or with our native species will result in obtaining trees useful for tannin production as well as timber and nuts.

EVERGREEN CHINQUAPINS

(*Castanopsis* spp.)

The members of the genus Castanopsis are mostly subtropical, and it is doubtful whether they will play a very important part in the economics of nut and timber production throughout our present chestnut belt. Reference has already been made to the extensive collections made by Mr. Rock in the Province of Yunnan, China. Altogether 28 lots of seeds were received, which represent three or probably four species. Only one of these, *Castanopsis delavayi* Franchet, has been grown in sufficient quantity to warrant a general distribution. Several thousand plants of this species are being grown at the United States Plant Introduction Garden, near Savannah, Ga., where they are not subject to infection from the blight fungus, as the disease does not exist in that region. This will make possible a distribution outside of the present blight area, especially to the southward and on the Pacific coast, where it seems important to test this species.

Several additional species of Castanopsis were collected by Mr. Rock, and collections of these have been placed at a number of points in order to test their climatic range and to provide future sources of material for study, and especially for breeding work. The more important collections are located at the United States Plant Introduction Garden, Bellingham, Wash.; Forest Service Pacific Northwest Experiment Station, Stabler, Wash.; United States Plant Introduction Garden, Chico, Calif.; United States Plant Introduction Garden, Savannah, Ga.; and at Brooksville, Fla., and St. Leo, Fla.

The following brief descriptions of the Yunnan, China, forms are based largely on Mr. Rock's field notes.

CASTANOPSIS DELAVAYI

(*Castanopsis delavayi* Franchet)

A tree reaching 80 feet in height with trunk 2 to 3 feet in diameter. The bark is brown or gray. Even when young all parts of the tree are glabrous except for the under side of the shining leathery leaf, which is covered with dense silvery scales, like the leaf of an Elaeagnus, and is further distinguishable by being serrated only beyond the middle. The fruits are borne in axillary spikes, with 10 to 20 in each spike, and the burs are covered with about three concentric rings of sharp spines about half an inch long. There is generally but one nut in each bur, about one-half to two-thirds of an inch long and one-third to half an inch broad, ovoid or conical, looking much like a small filbert. Each nut contains two seeds, which is unusual for Castanopsis.

According to Rock, this is one of the noblest timber trees of Yunnan. It is not stated for what the timber is used, but the straight, long, unbranched trunk should contain a great many good board feet. The nuts, though as small as those of a chinquapin, are sweet; it is not stated by anyone that they are sold in Chinese markets.

This species apparently is not found outside of Yunnan Province, and in places even within the Province it is sometimes absent. Franchet, who first discovered it, mentions but two situations—wooded hills, Piiouse, and mountains above Tapintze. But Rock says it is found on the summit ridge of the Shweli-Salwin Divide at 8,000 feet and on the summit of a limestone range north of Likiang at an altitude of 8,200 feet. It is also very common on the Yangtsze River north of Likiang at Tungshan, Shiku, and Hgaza.

As for the region or regions where it may be expected to grow in this country, it is difficult, in the absence of climatic data from the mountains of Yunnan, to predict. Rock calls it "one of the finest and hardiest timber trees in this region," but that merely means hardy in Yunnan. It probably can not be counted on to succeed outside the Gulf States and California and possibly the coast region of Oregon.

CASTANOPSIS HYSTRIX

(*Castanopsis hystrix* DC.)

This species has been introduced and inventoried as S. P. I. No. 56768. Rock collected it in southwestern Yunnan, China. It has been reported from northern India where, in the Khasi Hills, it is said to grow at elevations of 2,000 to 3,000 feet. Rock's description follows:

[S. P. I. No. 56768.] A lofty tree 80 to 100 feet tall, with trunks 3 feet in diameter, found in the pine forests of the Shweli Valley 40 li (about 12 miles) north of Lungling at an altitude of 6,000 feet. The smooth fawn-colored bark is flaky, and the straight ascending branches give the tree an oblong appearance. The burs are in long densely packed spikes, and the involucres are covered with long soft green spines. The small nuts are borne singly or in twos. This is one of the finest forest trees of the region. According to the natives the wood is very durable and never attacked by insects.

OTHER SPECIES OF CASTANOPSIS

Four other species of Castanopsis collected by Rock should be noted. These were all found in Yunnan Province, western China.

[S. P. I. No. 56296.] A tall tree 70 to 80 feet in height, found on the slopes of the Likiang Snow Range at an altitude of 10,000 feet. The thick leathery leaves are silvery beneath, and the small edible nuts are sweet.

[S. P. I. No. 56298.] A tree 50 to 80 feet high, with a trunk 4 feet in diameter, found on the Salwin Ridge at an altitude of 8,000 feet. The dark-green elliptic leaves are brown beneath, and the small black nuts are edible and sweet.

[S. P. I. No. 56299.] A tree 40 to 50 feet high, with a trunk 1 to 2 feet in diameter, which grows in the mountains north of Tengyueh at altitudes of 7,000 to 8,000 feet. The broad oval leaves are pointed, with the upper half toothed, and the spines on the burs are arranged in concentric rings. The small nuts are edible and sweet.

[S. P. I. No. 56300.] A tree 60 to 80 feet high, with a trunk 2 to 3 feet in diameter, found in the mountains north of Tengyueh at altitudes of 7,000 to 8,000 feet. The small elliptical dark-green leaves are thick and leathery, and the burs, an inch in diameter, are covered with branched spines. Each bur contains two or three brown, pubescent, sweet edible nuts.

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THE NATURAL REPLACEMENT OF BLIGHT-KILLED CHESTNUT IN THE HARDWOOD FORESTS OF THE NORTHEAST[1]

By C. F. Korstian, *Associate Silviculturist, Appalachian Forest Experiment Station*, and Paul W. Stickel, *Assistant Silviculturist, Northeastern Forest Experiment Station, Forest Service, United States Department of Agriculture*[2]

INTRODUCTION

Chestnut (*Castanea dentata*) once formed almost half the second-growth sprout hardwood forests of southern New England, New Jersey, and central and southern Pennsylvania; on small areas it often formed 90 per cent of the total wood volume. Its destruction by the chestnut blight (*Endothia parasitica*) has radically changed the composition of these forests. The rapid growth, abundance, and prodigious sprouting capacity of chestnut, together with its intrinsic value for a wide variety of uses, made it the most promising of the northeastern forest trees until the rapid spread of the blight made its extinction inevitable (*12*).[3]

The total loss of such a species naturally introduces serious problems as to the future silvicultural management of the forests of which it was an important component. These problems apply both to the North, where the chestnut is already dead, and to those parts of the Southern Appalachian region where chestnut still furnishes abundant and valuable forest products, but where it is already doomed (*4, 5, 13*).

Knowledge of what is happening on blight-killed chestnut areas is necessary in order to appraise the future growth rate of the changed forests and to determine the period of restoration of these lands to their full productive capacity with species other than chestnut.

Studies of the effects of the blight upon forests containing chestnut and upon the character and amount of natural replacement were undertaken as a first step toward supplying such information.

RESULTS OF 1920 STUDY OF CHESTNUT REPLACEMENT

The first field study of the natural replacement of chestnut by other species was made by the Forest Service, United States Department of Agriculture, in 1920, in western Virginia, Maryland, eastern Pennsylvania, and northern New Jersey.[4] Advance growth of desirable species sufficient to restock the stands was generally found. Larger-sized reproduction was not always present—thereby sometimes delaying future merchantable stands—although there were no vacant areas of any appreciable extent after the chestnut died. In some

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[1] Received for publication Nov. 12, 1926; issued May, 1927.

[2] The writers wish to acknowledge the effective cooperation received during the progress of this study from Prof. R. C. Hawley, of the School of Forestry, Yale University; W. O. Filley, Forester, Connecticut Agricultural Experiment Station; W. M. Baker, Associate State Forester of New Jersey; and J. S. Illick, Chief of Information, Pennsylvania Department of Forests and Waters.

[3] Reference is made by number (italic) to "Literature cited," p. 648.

[4] Hodson, E. R. preliminary report on the silviculture of replacing the chestnut on blight-killed areas. [Unpublished manuscript.]

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stands, especially on the more favorable sites, advance reproduction was inadequate to restock the area at once. This, together with the presence of dense underbrush, suggested the possibility that the regeneration of desirable species might be long delayed, even if the value of the future forest were not permanently impaired.

OBJECT OF 1924 STUDIES

The 1920 study was followed in 1924 by somewhat similar but more intensive field studies of blight-depleted stands in the regions of earlier infection in southern New England and New Jersey. In addition, limited studies were made in Pennsylvania of the progress of replacement. The 1924 studies were extended to cover representative stands of different ages on the more important chestnut sites.

The primary object of these studies was to determine the progress of the natural replacement of the chestnut by other species, and to forecast as nearly as possible the impending changes in the composition of the stand.

In these studies the stands were examined for restocking and were then analyzed to determine the extent to which the replacing species are silviculturally desirable and economically valuable. These species were accordingly arranged in three classes.

Class 1—Desirable species: Red oak (*Quercus borealis*); white oak, (*Quercus alba*); black oak (*Quercus velutina*); chestnut oak (*Quercus montana*); hickory (*Hicoria* spp.); white ash (*Fraxinus americana*); sugar maple (*Acer saccharum*); sweet birch (*Betula lenta*); black cherry (*Prunus serotina*); yellow poplar (*Liriodendron tulipifera*); basswood (*Tilia glabra*); northern white pine (*Pinus strobus*); pitch pine [5] (*Pinus rigida*).

Class 2—Less desirable species: Scarlet oak (*Quercus coccinea*); red maple (*Acer rubrum*); beech (*Fagus grandifolia*); black gum (*Nyssa sylvatica*); aspen (*Populus tremuloides*); largetooth aspen (*Populus grandidentata*); eastern cottonwood (*Populus deltoides*).

Class 3—Undesirable species:[6] Dogwood (*Cornus* spp.); gray birch (*Betula populifolia*); bear or scrub oak (*Quercus ilicifolia*); sassafras (*Sassafras variifolium*); blue beech (*Carpinus caroliniana*); hop hornbeam (*Ostrya virginiana*); witch-hazel (*Hamamelis virginiana*); service berry (*Amelanchier canadensis*).

REPLACEMENT IN SOUTHERN NEW ENGLAND

Three areas were selected in Connecticut as representative of southern New England:

1. The Maltby tract of the New Haven Water Co., west of New Haven. (Figs. 1 and 2, A.) This tract has been under management since 1907, and has been described by Hawley (*8*, *9*).

2. The Meshomasick State Forest, north of Portland. Conditions in this forest have been described by Filley and Moss (*2*).

3. The Whittemore estate, adjacent to Lake Quassapaug, east of Woodbury—studied by Frothingham in 1910 (*3*).

Hawes (*7*) and Frothingham (*3*) have also described conditions in the second-growth forests of Connecticut before the chestnut was killed by the blight.

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[5] In Pennsylvania and New Jersey pitch pine is a class 1 species, but in New England it is very seldom associated with chestnut.

[6] Various other shrubs large enough to appear in the records were also included in this class.

STUDIES ON PERMANENT SAMPLE PLOTS

The Connecticut areas were selected for study largely because they contained permanent sample plots which were established in other studies. Records of some of these plots are available as far

FIG. 1.—A well-managed stand of second-growth hardwoods in southern Connecticut. The chestnut has been salvaged and the stand, now composed chiefly of oaks, has fully recovered and still contains ample advance reproduction

back as 1904, the year that the blight was first discovered in Bronx Park, N. Y. In the present studies the plots are identified by the same numbers used in the other studies. On these plots, each of which covered from one-tenth to one-fourth acre, all essential details, such as species, size, and position of each tree in the forest canopy, were recorded at each periodic examination.

To determine the effect of a reproduction cutting made in 1902, plots 321 and 323 were established in 1906 in a 45-year-old stand of second-growth hardwoods on the Maltby tract. All the chestnut

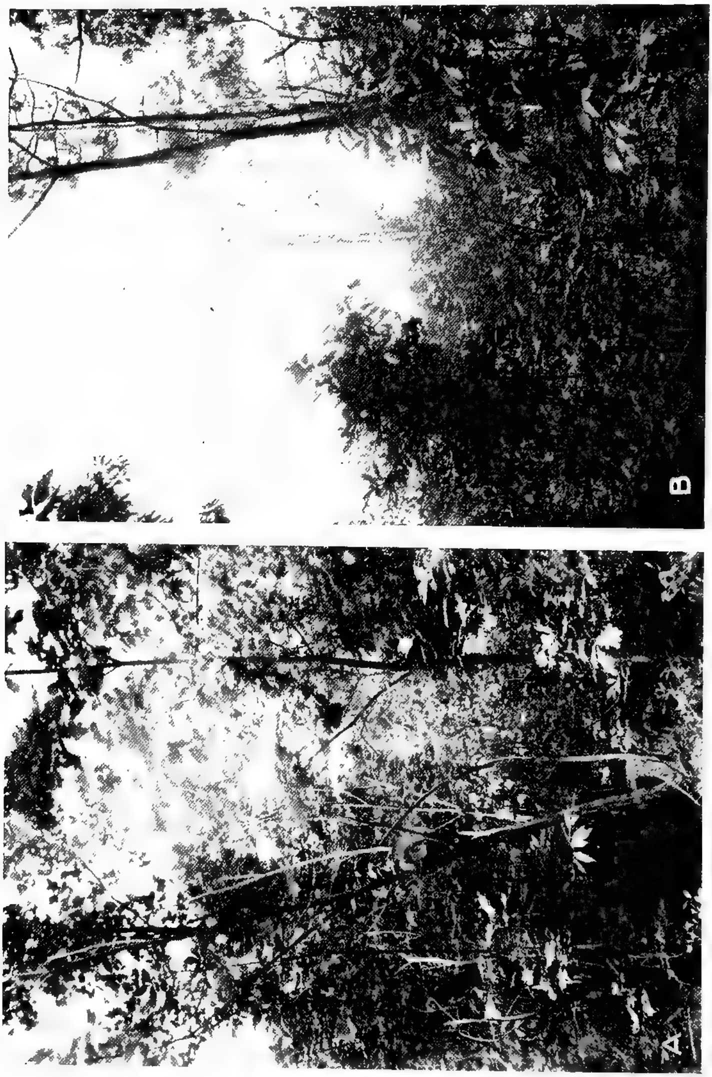

FIG. 2.—A, a young stand of hardwoods following clear cutting about 15 years before. The first three generations of chestnut sprouts have been killed by the blight and the overtopped fourth generation is heavily infected. The opening left by the chestnut has been completely filled by red oak, hickory, and yellow poplar, the crowns of which are interlaced (Maltby tract, southern Connecticut). B, a mixed stand of hardwoods and pitch pine in Sussex County, N. J. The blight-killed chestnut is being replaced by a dense growth of young hardwoods containing some young pitch pine and white pine in mixture

on these plots was cut and salvaged in 1913. Plot 474 was laid out in 1910 in a 45-year-old stand on the Whittemore estate. A heavy thinning ("C" grade) was made the same year. In 1915 an improvement cutting was made, taking out about 1 cord per acre. In this cutting, all of the dead and suppressed trees, most of the intermediate trees, and some of the codominant trees—those crowded from the side but with their crowns still in the upper story of the stand—were cut. Oak was left wherever practicable because it was then evident that the chestnut would not survive the blight. Plot 475 was located in the same stand, but received no special treatment

FIG. 3.—A, permanent sample plot in 1910, thinned to stimulate the growth of the stand. B, the same plot in 1924 after the blight-killed chestnut had been salvaged and the remaining stand improved by cutting out some of the less desirable individuals of other species. The material removed was used for railroad ties and charcoal

until the chestnut was salvaged in 1917–18 along with that on plot 474.

Plot 2 was laid out in 1910 in a 45-year-old stand of second-growth hardwoods on the Meshomasick State Forest, in which very little or no cutting had been done prior to that time. (Fig. 3.) Plot 4 was situated in the same locality, but in a 25-year-old stand. The first important cutting on either of these plots was made in 1924. It consisted of a chestnut salvage cutting combined with a light improvement cutting applied to the remaining stand, which ran heavily to oak. The main objects of the improvement cutting were to leave the area in the best possible condition and to favor red oak, chestnut oak, white ash, and hickory, and at the same time to keep down the proportion of red maple and other less desirable species.

At the time these plots were established the respective percentages of chestnut in the stand on the basis of basal area were as follows:

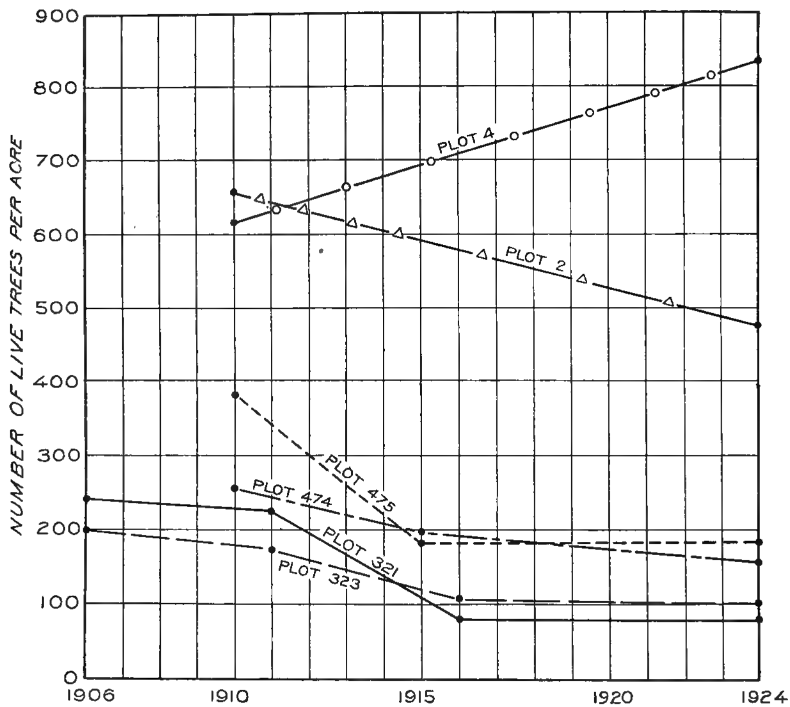

FIG. 4.—Progressive change in number of live trees per acre (1906–1924), due mainly to heavy mortality in chestnut between 1911 and 1916

Plot 321, 50; plot 323, 32.7; plot 474, 71.2; plot 475, 66.6; plot 2, 42.7; and plot 4, 44.2. At the last examination of these plots (in 1924) all essential details, such as species, size, and position of each tree in the forest canopy, were again recorded. After computing the detailed results of each successive examination it was possible to trace the history of the various changes taking place in the forest during the last 13 to 18 years. For each plot the progressive changes in total number per acre of live trees of all species 1 inch or more in diameter is shown in Figure 4. The change in basal area per acre of all live trees is shown in Figure 5.

Figure 5 shows the material decrease in basal area occurring between 1911 and 1915, when the chestnut dropped out of most of the stands. It must, however, be recalled that the improvement cuttings which removed some material other than the chestnut also reduced the growing stock to some extent. Plots 321 and 323 have shown a slight increase in basal area since 1916 in spite of the fact that a slight decrease in number of trees occurred. It is not surprising to find stands in which the basal area is still decreasing, even though the number of trees may be increasing. This is well illustrated by plot 4, in which the death of a small number of large chestnuts more

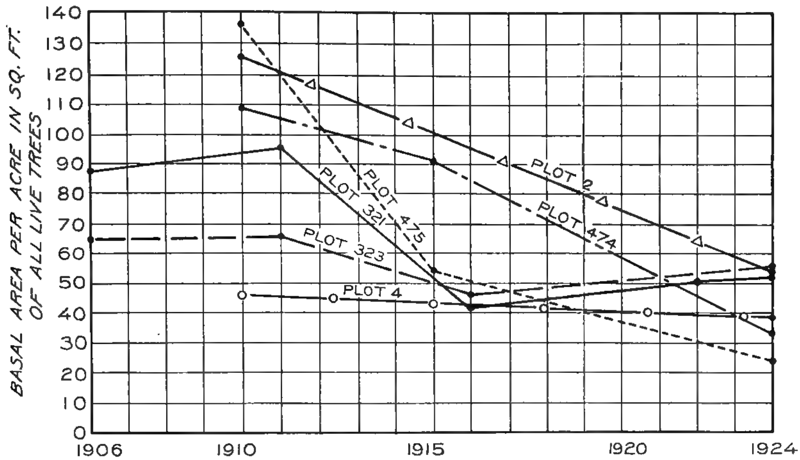

FIG. 5.—Progressive change in basal area per acre (1906–1924), due mainly to heavy mortality in chestnut between 1911 and 1916

than offset the gain in basal area of a large number of small trees which had just entered the measurable size class.

In order to generalize the results from these plots and bring out the significant changes caused by the chestnut blight, the data for all have been combined on an acre basis in Table 1, which summarizes

TABLE 1.—*Average number of live trees and average basal areas per acre for the dominant stands* [a]

Species	1910–11				1924			
	Trees per acre		Basal area		Trees per acre		Basal area	
	Number	*Per cent*	*Square feet*	*Per cent*	*Number*	*Per cent*	*Square feet*	*Per cent*
Chestnut	153.3	70.5	64.18	76.2	0	0	0	0
Red oak	22.0	10.1	9.13	10.8	38.0	28.6	16.45	42.2
Chestnut oak	22.0	10.1	5.25	6.2	52.7	39.7	14.48	37.2
White oak	9.4	4.4	1.97	2.3	9.4	7.1	2.07	5.3
Black oak	2.0	.9	.82	1.0	3.3	2.5	.94	2.4
Scarlet oak	8.0	3.7	2.75	3.3	5.3	4.0	3.31	8.5
Sweet birch	.7	.3	.13	.2	0	0	0	0
Red maple	0	0	0	0	8.7	6.6	.82	2.1
White ash	0	0	0	0	6.7	5.0	.32	.8
Hickory	0	0	0	0	6.0	4.5	.29	.8
Sugar maple	0	0	0	0	2.7	2.0	.26	.7
Total	217.4	100.0	84.23	100.0	132.8	100.0	38.94	100.0

[a] Includes dominant and codominant trees on permanent sample plots 321, 323, 474, 475, 2, and 4. Basal or cross-sectional area measured at 4.5 feet above ground.

the number of live trees and basal areas of the dominant stand as they were in 1910–11 and in 1924. The change in average basal area for the same six Connecticut plots is shown graphically in Figure 6. The outstanding feature of Table 1 is the increase in basal area of red oak and chestnut oak, together with an actual increase in the number of stems. The natural replacement of the original chestnut forests by stands running very largely to valuable oak is strikingly brought out by this table. While these plots were located in typical stands, some had been thinned one or more times before the 1910–11 records were taken. In 1910 the 217.4 trees per acre in the upper crown class ranged in size from 3 to 13 inches, breast high, averaging 8 inches; and now after the chestnut has died and the forest is beginning to rehabilitate itself, there are 132.8 trees per acre

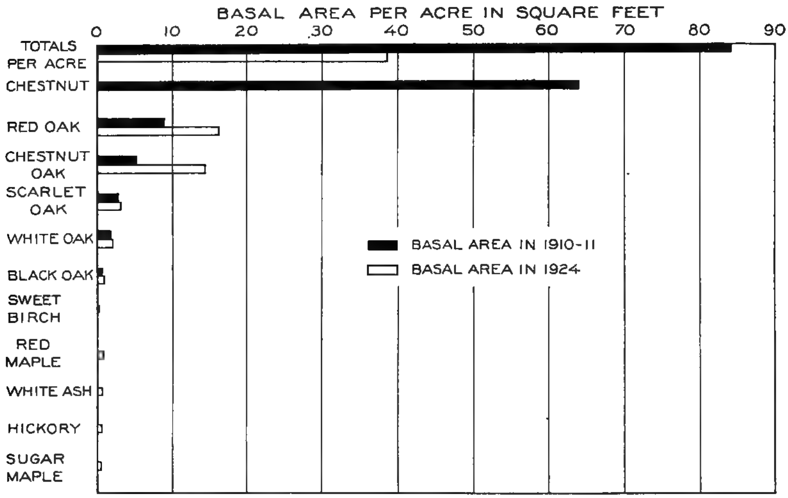

FIG. 6.—Change in basal area by species for the dominant part of the stand from 1910–11 to 1924 (graph based on averages from summary of six Connecticut plots)

in the upper crown cover, ranging from 2 to 15 inches in diameter and averaging 7.3 inches.

Permanent plots 319 and 320 are of particular interest. They are located on the Maltby tract in a stand which was clear cut about five years prior to their establishment in 1904. In 1909 chestnut comprised 24 per cent of the stand, while in 1924 the only living chestnut was sprout growth an inch or less in diameter and not more than 3 to 4 years old—overtopped, heavily infected, and dying. This area is now stocked at the rate of 785 trees to the acre in the upper crown cover, ranging from 1 to 6 inches in diameter.

The dominant stand on these plots is composed of 45 per cent class 1 species, 41 per cent class 2 species, and only 14 per cent class 3 species. Out of a total of 995 trees of class 3 species, 89 per cent are overtopped trees, which on account of their slow growth will probably not gain a position in the upper crown cover. In fact, some of these trees now in the overstory will in time be overtopped by the faster-growing species of classes 1 and 2.

A study of Figure 7, a sketch of the crown spread of the trees on permanent plot 320 in 1904, and Figure 8, a sketch of the same plot in 1924, clearly shows that the chestnut has completely disappeared from the dominant part of the stand, and that the crown cover of the dominant stand is already almost completely closed. From the standpoint of crown closure, this plot shows exceptionally good re-

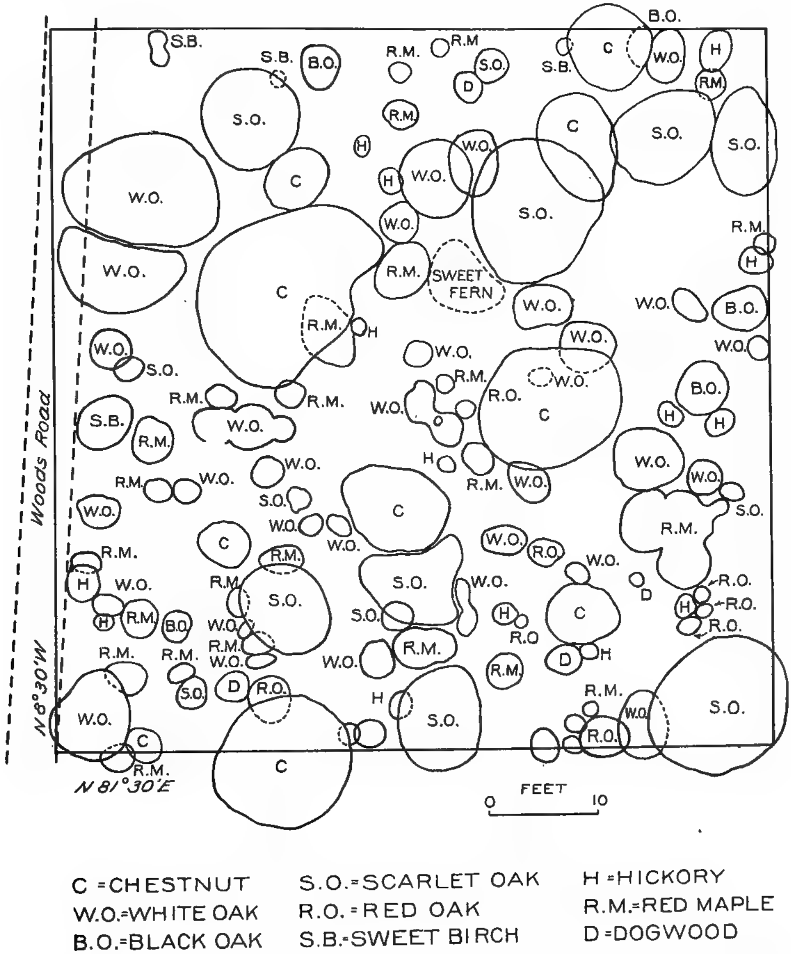

FIG. 7.—Crown spread of trees on permanent sample plot No. 320, as sketched in 1904 (Maltby tract)

covery. The amount of red maple in the upper crown cover of this stand is above the average for otherwise similar stands. Its preponderance is probably due to the fire which lightly burned over the area a few years after cutting. The fire favored the increase of red maple in the overstory, and dogwood in the understory. However, on sites of second quality, similar to this area, red maple is much less aggressive than it is on the better sites (*10*).

The decrease in the number of trees on most of the permanent plots is due not only to the loss of chestnut, but also to the removal of some of the less vigorous and less desirable individuals of the oaks and other species when the chestnut was salvaged. This reduction in forest growing stock or capital is partly offset by the increased growth of the oaks. Furthermore, it must be remembered that the openings left in the forest as a result of the death of the chestnut contain a significant number of seedlings and sprouts, mostly of the valuable species as yet too small to appear in the plot records. (Fig.

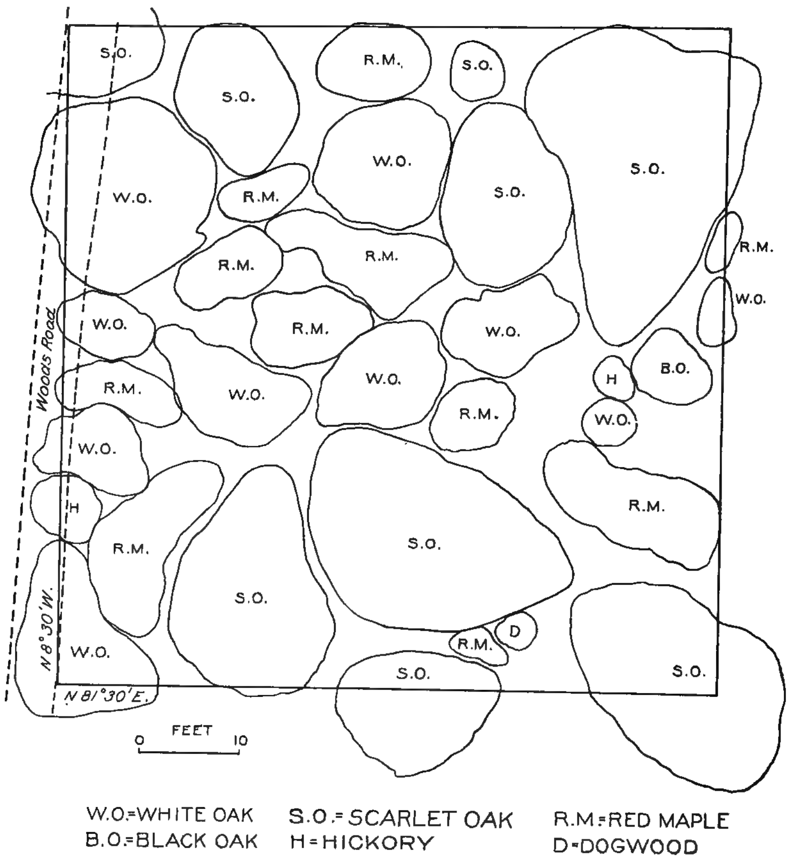

FIG. 8.—Crown spread of the stand on the same plot shown in Figure 7, as sketched in 1924. Because of the almost complete closure of the dominant stand, the overtopped trees were not mapped. The chestnut has completely disappeared from the overstory

9.) The results of a special study, aimed to determine specifically the nature and extent of restocking in the openings formerly occupied by chestnut, will be given on a subsequent page.

STUDIES ON TEMPORARY PLOTS

Records were made of the stands on 1 quarter-acre and 3 tenth-acre plots, and of the reproduction on 24 square-rod plots on the Maltby tract. The quarter-acre plot (No. 1) was laid out in a 60-year-old stand which contained about 35 per cent chestnut before it was killed by the blight. The dead chestnut poles are still standing and have sprouted very feebly. The dominant stand contains 96 trees to the acre, of which 96 per cent are class 1 species, 4 per cent are class 2, and none are undesirable. Red oak and white oak between 5 and 14 inches in diameter form over 87 per cent of the

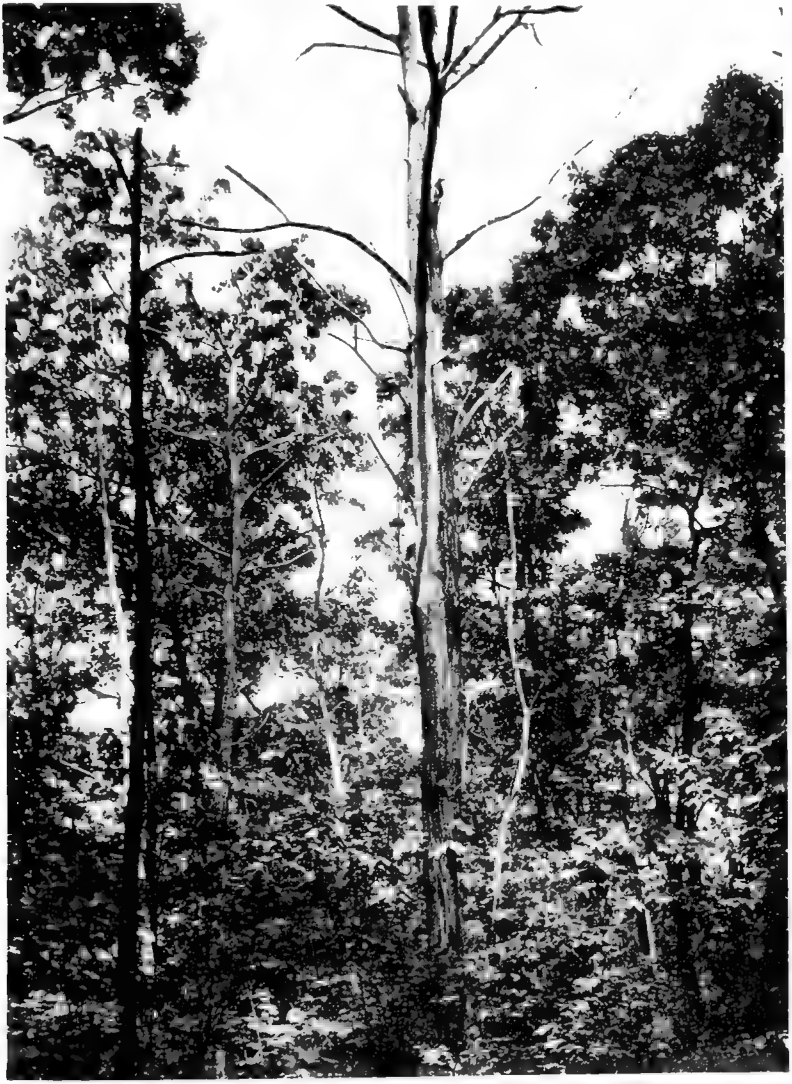

FIG. 9.—A blank in a stand of hardwoods left by the death of the chestnut. The surrounding oaks are filling it by an extension of their crowns. The crown cover will soon be completely closed. (Maltby tract, southern Connecticut)

dominant stand. The undesirable species are practically confined to the understory. The dominant stand is reinforced by a subordinate stand of 572 trees, of which 46 per cent are class 1 species and 15 per cent are class 2. It is therefore evident that although this stand is somewhat depleted, conditions are favorable for a satisfactory restocking.

Plots 2 and 3 were tallied in a 15-year-old stand which promptly followed clear cutting. The area had probably not been burned over since the cutting and received no subsequent treatment. Chestnut originally made up 30 per cent of the stand. The area now bears a dominant stand of 835 trees to the acre. In this stand class 1 species lead with 65 per cent, and class 2 species comprise 19 per cent; only 16 per cent of the overstory is made up of undesirable species. Here also red oak and white oak are preponderant in the overstory, with smaller quantities of hickory, beech, gray birch, sweet birch, black oak, red maple, scarlet oak, largetooth aspen, white ash, sugar maple, and basswood, in the order of their abundance. The understory contains 88 per cent of the total number of undesirable species. On the other hand it also has 1,075 trees of class 1 species, or 43 per cent of the total number, and 455, or 18 per cent, of class 2 species—more than enough to insure restocking with the better species.

Plot 4 was tallied in a stand that had been thinned quite heavily in 1906. All the chestnut was removed in 1913; the oaks were left until 1921, when they, too, were cut. The resulting stand, on an acre basis, has a total of 2,590 saplings, at present receiving practically full light from above. Of these, 32 per cent are class 1 species, 54 per cent class 2 species, and only 14 per cent class 3 species. Since red maple constitutes 34 per cent and dogwood 9 per cent of the overstory, cleanings or thinnings may be advisable to increase the proportion of the more desirable species in this stand. A similar operation in a permanent sample plot is shown in Figure 3. Scarlet oak, red oak, hickory, white oak, sweet birch, sugar maple, and beech follow in the order of relative abundance. These vary from 330 scarlet oak saplings to 110 beech. Of the class 1 species 72 per cent are in the overstory. Of the undesirable species 53 per cent are already overtopped. In the overstory 60 per cent of the class 1 species, 17 per cent of the class 2, and 19 per cent of the class 3 species are of seedling and the remainder of sprout origin. The combination of desirable species and desirable (seedling) origin is particularly noteworthy.

All the plots considered thus far fail to bring out clearly the nature and extent of replacement within the gaps left by the chestnut and the proportion of shrub or inferior species which may be taking the place of the valuable chestnut. To obtain this information 24 square-rod sample plots were laid out and tallied in Connecticut in 1924, and records were made of the forest-tree reproduction and of the larger or more abundant species of shrubs above 6 inches in height. Each plot was laid out so that the center of the clump of dead chestnut formed the center of the plot. Plots were tallied in four representative stands, varying from recently clear-cut stands (plot 4 above) to a 60-year-old stand in which the merchantable chestnut had not yet been salvaged (plot 1 above). The records of these plots are summarized in Table 2. Attention should be directed to the fact, not brought out in the table, that the live chestnut sprouts seldom attain a diameter of more than an inch. The third and fourth generations of sprouts were being killed by the blight at the time the tallies were made. Two or three sprout generations may still be expected on the clear-cut areas and on those on which the chestnut was salvaged before it died. Many of the clumps of chestnut which were not cut before the trees died have already ceased to sprout.

TABLE 2.—*Reproduction under blight-killed chestnut, southern New England* [a]

Plots		Average diameter of chestnut clumps	Chestnut reproduction per square rod			Other reproduction per square rod [b]					Percentage of area on which tallest saplings are found	
							Class 1 species		Class 2 species			
Nature	Number		Dead sprouts	Live sprouts	Live seedlings	All species	Sprouts and seedlings	Proportion of seedlings	Sprouts and seedlings	Proportion of seedlings	Class 1 species	Class 2 species
		Feet	*Number*	*Number*	*Number*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Stand clear-cut in 1921 (plot 4)	8	11.4	17.1	11.0	0.6	44.6	32	55	24	11	60	27
Stand clear-cut in 1908 (plots 2 and 3)	6	8.0	17.0	7.9	.0	24.7	60	74	18	15	79	0
Permanent plot 474 [c]	5	------	------	28.0	1.6	93.8	75	59	11	45	------	------
60-year-old stand (plot 1)	5	19.3	16.0	10.6	.0	43.4	41	69	3	57	67	33
Weighted averages	------	12.4	16.8	13.7	.5	49.6	49.8	63.5	15.4	28.7	67.8	20.1

[a] Summaries of tallies of 24 square-rod reproduction plots, grouped by stands of essentially similar age or treatment; Maltby tract, near New Haven, and Whittemore estate, near Woodbury, Conn.

[b] Class 1 species are: White oak, red oak, black oak, chestnut oak, white ash, hickory, sweet birch, black cherry, basswood, sugar maple, and yellow poplar. Class 2 species are: Scarlet oak, red maple, beech, and aspen. Class 3 species are included only in the total number of all species.

[c] For description see preceding section of text.

The most striking point brought out by Table 2, aside from the fact that the blanks are now filled by a much larger number of seedlings and sprouts than can possibly survive, is that practically half of the new reproduction is of desirable species and that about 65 per cent of these are species which at present have an economic value. Furthermore, on over two-thirds of the area represented by the plots the tallest saplings are class 1 species, and on another 20 per cent they are class 2 species. Over 63 per cent of the class 1 reproduction is of seedling origin.

The goodly portion of red oak in the replacement reproduction on so many of the plots is especially noteworthy. The importance of red oak, because of its rapid growth in height and diameter and the excellent character of its timber, has long been recognized by foresters (*3*, *6*). Spaeth (*15*) has classed both red oak and white ash as important species in replacing chestnut. There is little doubt that these species will increase rapidly in importance now that their formidable rival—the chestnut—has been destroyed. The second-growth hardwood type will be easy to maintain and will form the basis of future forest management on the better soils.

The most significant facts brought out by the 1924 Connecticut studies, as well as by those made in 1920, are that there is generally sufficient advance growth of valuable species to restock the stands, and that the blight-killed chestnut has been very largely replaced by oak. (Fig. 1.) On areas originally occupied by chestnut, oak reproduction was found very generally, together with reproduction of such other valuable species as hickory, white ash, sugar maple, and sweet birch. (Fig. 2, A.)

These studies, made under representative conditions, indicate that the blight-killed chestnut stands of southern New England are restocking naturally to silviculturally desirable and economically valuable species. These species are much in excess of the undesirable shrub-weed species. If, as is occasionally true, the more desirable species are outnumbered by the undesirable ones, they nevertheless, having the more rapid growth rate, will soon overtop the inferior species and partially or completely suppress them. It is also encouraging to note that in those cases where the total number of desirable species may not equal that of the undesirable ones, the desirable species in the overstory are already in excess of the others. Moreover, the tallest saplings in the gaps left by the death of the chestnut are mostly of desirable species, such as the oaks, hickory, and ash, rather than of shrub or weed species, such as dogwood, sassafras, blue beech, and gray birch.

REPLACEMENT IN NEW JERSEY

Since no permanent sample plots were available for study in New Jersey, it was necessary to resort wholly to temporary plots. Three quarter-acre plots were laid out in uneven-aged stands on the Stokes State Forest, in Sussex County, northwestern New Jersey. Chestnut, at the time of its death, comprised 30 to 60 per cent of the stand. In this locality the chestnut had been dead a shorter time (mostly less than five years) than in the regions to the south and east. The first generation of sprouts had died, and the second generation was appearing.

Plot 1 is located on a moist flat in what was originally an oak-chestnut-pine forest. The overstory of the stand contains 1,316 trees to the acre, of which 12 per cent are class 1 species, 40 per cent class 2 species, and 48 per cent class 3 species. The class 1 species, in the order of their abundance, are white oak, chestnut oak, and white pine, while the class 2 species, in the order of their importance, are red maple, scarlet oak, black gum, and largetooth aspen. In addition to these, the overtopped stand contains about 600 trees to the acre, some of which are capable of increased growth when released, or of filling the gaps left by the chestnut.

Plots 2 and 3 are located on a low ridge in an uneven-aged stand which originally was an oak-chestnut forest. These plots have an average stand of 1,879 trees to the acre in the overstory, of which 34 per cent are class 1 species, 18 per cent are class 2 species, and 48 per cent are class 3 species. Of the desirable species over 60 per cent are in the upper crown class. These stands are obviously in need of an improvement cutting aimed especially at increasing the proportion of desirable species, which was reduced about 20 years ago by a cutting that culled out most of the best pitch pine. Reproduction of desirable species is rather deficient because of the heavy cover of mountain laurel (*Kalmia latifolia*) and scrub oak. These undesirable species will in time be shaded out by the tree species, the scrub oak being the first to give way. With protection from fire the scrub oak is very short lived, for on account of its intolerance of shade it can not compete with any tree growth which overtops it (*1*). If the stand is allowed to develop without artificial treatment, it will eventually become an almost pure stand of the better species of oak, with some maple and a small quantity of pitch pine. It will, however, be more irregular, less well stocked with the better species, and slower in growth rate than with treatment. Although the pine is here somewhat more aggressive as a replacement species, particularly in filling larger openings left by the death of the chestnut, many of the pine seedlings are lacking in vigor and will probably be overtopped by the hardwoods.

Fifteen reproduction plots similar to the 24 small plots in the New England study were also laid out, the center of the plot coinciding with the center of the chestnut clump. The results obtained on these plots are summarized in Table 3. It is evident that there is an ample supply of forest-tree reproduction to fill the gaps, although the percentage of class 1 species is much lower than was found in southern New England. With less than half of the reproduction of species other than chestnut falling in classes 1 and 2, the desirability of modifying the composition of the stand is emphasized. It is encouraging, however, to note that the tallest saplings on slightly over 80 per cent of the area represented by the plots are either class 1 or class 2 species, although the percentage of class 1 is still small.

The stands studied in New Jersey were characterized by the presence of white pine and pitch pine, and by a higher percentage of the undesirable species in the overstory and a denser understory and undergrowth than those studied in Connecticut. (Fig. 2, B.) Although the chestnut is being replaced naturally for the most part by tree species, yet the presence of a relatively high proportion of undesirable species introduces important problems in connection with subsequent thinnings and improvement cuttings.

TABLE 3.—*Reproduction under blight-killed chestnut, New Jersey* [a]

Plots		Average diameter chestnut clumps	Chestnut reproduction per square rod			Other reproduction per square rod [b]					Percentage of area on which tallest saplings are found	
							Class 1 species		Class 2 species			
Nature	Number		Dead sprouts	Live sprouts	Live seedlings	All species	Sprouts and seedlings	Proportion of seedlings	Sprouts and seedlings	Proportion of seedlings	Class 1 species	Class 2 species
		Feet	*Number*	*Number*	*Number*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Uneven aged; oak-chestnut forest; flat ridge (plots 2 and 3)	10	20.4	18.8	20.8	2.1	55.2	23	96	22	84	20	56
Uneven aged; oak-chestnut-pine forest, flat (plot 1)	5	18.5	13.6	22.4	.6	45.8	13	61	34	75	27	64
Weighted averages		19.8	17.1	21.3	1.6	52.1	19.7	84.3	26	81	22.3	58.7

[a] Summaries of 15 square-rod plots tallied on the Stokes State Forest in northwestern New Jersey.
[b] Species in the order of their abundance are: Class 1, red oak, black oak, chestnut oak, white oak, hickory, sweet birch, white pine, and pitch pine; class 2, scarlet oak, red maple, black gum, and aspen; class 3 species are included only in the total number of all species.

An earlier sample-plot field study, made by Richards (*14*) in Somerset County, N. J., is of interest with respect to both his results and conclusions, the conclusions being at variance with those of the present studies. Chestnut oak was found to be the predominant species in the reproduction, amounting to 44 per cent on the ridge tops and 22 per cent on the slopes. On the ridge tops 11.8 per cent was hickory, 6.8 per cent red oak, and 3 per cent white ash. These four were the most valuable species, and comprised 65.6 per cent of the reproduction on the ridge tops. The remainder was made up of red maple, cherry, butternut (*Juglans cinerea*), birch, and sassafras. Reproduction on the slopes, in addition to chestnut oak, was made up of 6 per cent red oak and 10 per cent pignut hickory (*Hicoria glabra*), besides some cherry, maple, and butternut.

Because the desirable species, other than chestnut oak, were in the minority, Richards concluded that there was little reproduction in the way of desirable native species with which to form the new forest, and consequently recommended replacement of the chestnut by planting Norway pine (*Pinus resinosa*). However, Richards's study was mostly of areas cut over less than a year previously (a few of his plots had been cut over seven years), so that in all probability most of the reproduction he found was advance growth and much of the seedling growth prominent in the replacement had not yet become established. Had his study been made a few years later, on areas cut over for a longer time, he would probably have found more reproduction and a higher proportion of desirable species, and accordingly less occasion for the planting of pine.

REPLACEMENT IN PENNSYLVANIA

The studies of natural replacement were not so intensive in Pennsylvania as in Connecticut and New Jersey, since this problem was already being studied by J. S. Illick and assistants, for the Pennsylvania Department of Forests and Waters.

Two sixteenth-acre plots laid out near Lehigh Gap, Pa., in 1920, are of special interest. One plot was on an area which, at the time it was clear-cut three years before, contained 62 per cent chestnut. The new stand contained 9,424 live trees to the acre, of which 22 per cent were chestnut sprouts. Of the remaining live trees, 86 per cent were class 1 species, chestnut oak, white oak, and sweet birch; 14 per cent were class 2 species, scarlet oak, red maple, black gum, and cottonwood; and none were undesirable species. The other plot was located in a stand cut heavily for chestnut 25 years earlier. This stand originally included 93 per cent chestnut, but in 1920 the proportion of chestnut sprouts in the live stand had been reduced to 32 per cent, and by 1924 the chestnut had been entirely eliminated. The stand contained a total of 10,234 trees to the acre, exclusive of chestnut, of which 40 per cent were class 1 species, white oak, black oak, sweet birch, red oak, black cherry, and hickory; 55 per cent were class 2 species, red maple, scarlet oak, black gum, and cottonwood; and only 5 per cent were undesirable. These stands have obviously restocked mostly to desirable species, and almost as rapidly as the chestnut disappeared from the stand.

Stand records, obtained in company with T. E. Shaw, of the State Forest School in the Mont Alto Forest in Franklin County, show that on slopes where the chestnut had occupied 40 per cent or more of the original stand seedlings and sprouts of other species varied from 1,000 to 1,500 per acre. Of these, chestnut oak comprised 60 per cent, black oak 35 per cent, and white oak 4 per cent. Scattered red and scarlet oaks, white and pitch pines, and black locusts made up the remainder. Here the oaks, which in the original stand were second in number to the chestnut, have insured adequately stocked stands of second growth. Chestnut oak, pitch pine, and black locust (*Robinia pseudoacacia*) are also among the desirable species which are largely replacing the chestnut in Pennsylvania. Black oak, pignut hickory, sweet birch, mountain pine (*Pinus pungens*), and Virginia pine (*P. virginiana*) are others which are helping to fill the gaps, and are not to be despised (*11*).

The Pennsylvania studies also showed that the blighted areas are being restocked by natural reproduction, mostly of desirable species. The replacement is more complete and more satisfactory in moist situations than upon the drier slopes, for blanks on the moist sites are relatively less extensive and the associated species, such as yellow poplar, white ash, red oak, white pine, red maple, and white oak, more desirable. Upon the drier slopes the blanks are more extensive, and the associated species are less desirable.

SUMMARY

This paper presents the results of studies to determine the character and amount of natural replacement of blight-killed chestnut. They were begun in the earlier infected chestnut stands of the Northeast, where natural replacement is most advanced and could most easily be studied.

In southern Connecticut permanent sample plots established between 1904 and 1910, as well as temporary plots, were studied. In New Jersey it was necessary to resort wholly to temporary plots. Limited studies were also made in Pennsylvania.

The natural replacement of the forests, originally containing large quantities of chestnut, by stands running very largely to oak—red oak, white oak, chestnut oak, black oak, or scarlet oak—is strikingly brought out by these studies. An outstanding feature is the increase of red oak and chestnut oak both in number of trees and basal area. Such other desirable species as hickory, white ash, sugar maple, and sweet birch may be associated with the oak.

While the stands are for the most part still depleted in basal area they are recovering satisfactorily. From the standpoint of crown closure the areas studied also showed exceptionally good recovery. The stand remaining after the death of the chestnut, composed chiefly of oaks, has responded to increased light, and the crowns of these trees are very effectively closing the smaller openings left by the chestnut.

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U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1641

CHESTNUT BLIGHT

CHESTNUT BLIGHT, caused by a fungus brought into this country from Asia before 1904, is responsible for the death of millions of acres of chestnut growth in New England and the Middle Atlantic States. The disease spread rapidly to nearly all parts of the range of the native chestnut, and the remaining stands of the southern Appalachians face certain destruction.

The present known distribution, its symptoms, and the fungus that causes the disease are described.

The blight fungus itself does not have any effect upon the strength of chestnut timber, and blight-killed trees can be utilized for poles, posts, cordwood, lumber, and extract wood.

Search is being made for native and foreign chestnuts resistant to the disease in the hope of finding a tree suitable for replacing the rapidly disappearing stands. Seedlings of Asiatic chestnuts, which have considerable natural resistance even though not immune, are being tested in the United States.

This bulletin supersedes Department Circular 370, Chestnut Blight in the Southern Appalachians.

Washington, D. C. Issued November, 1930

CHESTNUT BLIGHT

By G. F. Gravatt, *Senior Pathologist*, and L. S. Gill, formerly *Associate Pathologist, Office of Forest Pathology, Bureau of Plant Industry*

CONTENTS

INTRODUCTION

THE PARASITIC FUNGUS, *Endothia parasitica* (Murr.) A. and A., that causes the disease of chestnut known as the blight or bark disease, was brought into the United States from Asia before this country had enacted plant-quarantine laws. As is often the case with introduced plant and insect pests, the chestnut-blight organism proved to be more virulent in the home of its adoption than in its native habitat. Chestnut blight was first observed and recognized as a new disease in this country at New York City in 1904, though it must have been present for some time previous to that date. The millions of acres of chestnut growth north of the Potomac River and east of the Allegheny Mountains have been killed by the blight fungus, and the remaining American chestnut stands of the southern Appalachian Mountains are heavily infected and face certain destruction.

SPREAD OF THE BLIGHT

The disease spread rapidly from its original infection center at New York City and later from other centers. It soon covered New England, but it made its most rapid advance in a southwesterly direction from New York City along the eastern slopes of the Blue Ridge and Allegheny Mountains.

The blight fungus not only spreads from infected trees to healthy ones near by, but often it is carried for long distances on shipments of chestnut poles or nursery trees and by birds or wind. Under favorable conditions such distribution of the fungus may result in new centers of spread, known as spot or advance infections. The rapid progress of the blight over the chestnut area is largely due to the fact that these advance infections become established many miles ahead of the main infection area. These advance spots rapidly enlarge, run together, and form a continuous infected area. The plan of the early work in Pennsylvania and other States was to locate and cut out these advance infections to delay the spread of the disease. The cutting-out work in Pennsylvania resulted in marked delay in the spread of the disease across that State.

The blight has now extended to nearly all parts of the range of the native chestnut. In the extreme southern and western parts of its botanical range there are probably a number of small healthy stands of chestnut, but the steady spread of the blight means that these will be infected soon. The disease reaches isolated small stands of native chestnut that are many miles from any other chestnut or chinquapin growth. As the southern chinquapins are susceptible to the blight, these bushes will serve as hosts for the disease in localities where no native chestnuts grow. The percentage of infection in the southern Appalachians can be expected to increase steadily until the stand is finally killed. Table 1, based on observations on certain areas in Maryland and Virginia, gives a fair idea of the general rate at which infection and killing can be expected to increase, after the stand reaches the stage of 1 per cent infection.

TABLE 1.—*Rate of increase in chestnut-blight infection after 1 per cent infection has been reached*

[Percentages based on studies made on a number of areas in Maryland and Virginia]

Period after infection reaches 1 per cent	Healthy	Infected: Infected but not dead	Infected: Dead	Infected: Total	Period after infection reaches 1 per cent	Healthy	Infected: Infected but not dead	Infected: Dead	Infected: Total
Years	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Years*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	97	3	0	3	8	5	80	15	95
2	90	10	0	10	9	1	69	30	99
3	80	20	0	20	10	0	45	55	100
4	60	40	0	40	11	0	25	75	100
5	40	60	0	60	12	0	15	85	100
6	20	78	2	80	13	0	10	90	100
7	10	85	5	90	14	0	5	95	100

PRESENT DISTRIBUTION

The estimated distribution of the chestnut blight in the southern Appalachians in December, 1929, is shown in Figure 1, which is based primarily on reports of cooperators and supplemented by very limited survey work by members of the Office of Forestry Pathology. The degrees of infection and killing are estimated upon a county basis, though the actual infection within a county varies greatly. For example, a county having an average of 50 per cent of its trees blighted usually contains areas where the actual infection is less than 5 per cent and others where it is over 95 per cent. In using the map it must be remembered that these figures on infected and killed trees are not the result of detailed surveys of each county but are merely estimates based upon the best available information in the fall of 1929.

No detailed records are available upon the prevalence of blight in the scattered tracts of chestnut timber in those parts of the Southern States outside the Appalachian Mountains where the species is of minor importance. In a general way it is known that a major part of this scattered growth has been killed in eastern Virginia; that a large percentage of it is infected in North Carolina, Kentucky, and Tennessee; and that a few scattered infections are present in Alabama and Georgia. Extensive inspection work would undoubtedly result in the finding of widespread infection in this scattered growth.

The blight has been reported on wild and planted chestnuts at a number of points in Indiana and Michigan. A large percentage of the chestnut growth in Ohio is infected or killed, the severity of infection being less in the southwestern than in the eastern part of the State.

Nearly all of the original chestnut trees have been killed in the Middle Atlantic and New England States. In the northern parts of New York and the New England States the blight has also killed many of the isolated trees at the extreme edge of the distribution area of the species. It has also been reported at a number of places in Ontario, Canada.

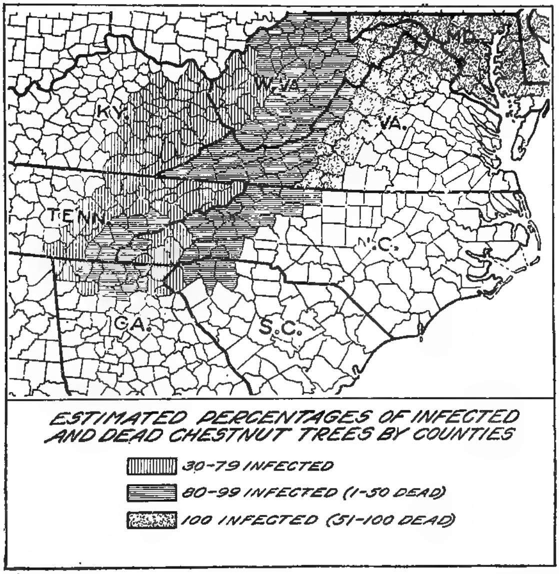


FIGURE 1.—Estimated distribution of blight in the more important chestnut counties of the southern Appalachians in December, 1929. Each year the degrees of infection and killing increase

SYMPTOMS OF THE DISEASE

The symptoms of blight are so characteristic that owners of chestnut should have no difficulty in recognizing the disease. The yellow or brown leaves of a dead branch, standing out in striking contrast to the green foliage, are usually the first-noticed indications of the presence of the chestnut blight. If the branch is killed in early spring, the dead leaves are smaller than normal ones (fig. 2), while if it is killed later in the season the leaves usually attain their full size. The dead leaves and burs of killed branches, which usually remain attached during the winter, afford a means of detecting blight infections at that time of year. Dead limbs without leaves or burs often indicate the presence of the blight. Occasionally dead branches with attached leaves result from causes other than the blight, but when the blight fungus, which is described in detail on page 7, is responsible, a close examination of the stem or branch will reveal the presence of a canker located on the branch or the trunk, usually somewhat below the lowest killed leaves. The sprouts or suckers that frequently develop below cankers aid in locating them. (Fig. 3.)

Cankers on smooth bark are easily recognized by their yellowish brown surface color, which contrasts sharply with the grayish green color of normal bark. The margin of the canker may be slightly raised in some cases, and in others it may have a water-soaked appearance, especially on vigorously growing shoots. Usually the margin of the canker is fairly regular (fig. 4), but

FIGURE 2.—An orchard chestnut partly killed in early spring. It shows very small leaves in contrast with normal ones

sometimes it is irregular. (Fig. 5.) There is less contrast between the appearance of the canker area and its margin on slowly growing shoots or twigs.

The cankered areas may be either sunken below or raised above the surrounding healthy bark, or a single canker may have both sunken and raised parts. When the fungus promptly kills the bark all the way through to the cambium and into the wood, there results on smooth shoots a sunken area, which usually has a smooth, uncracked surface; but when it fails to kill the cambium, new layers of bark cells are formed underneath the attacked area and an enlarged lesion results. The swollen cankers usually have a number of longitudinal fissures or splits. (Fig. 6.) Frequently cankers have a smooth sunken area of bark in the center (fig. 6) and raised margins with cracks and fissures in the swollen parts.

FIGURE 3.—A swollen blight canker with suckers developed below the infected area

On large thick-barked limbs and trunks a young blight infection causes very little change in the outward appearance of the bark. As the disease progresses abnormal splits or cracks often appear and expose some of the buff-colored infected inner bark, which is different in color from the surface bark. The presence of yellow, orange, or reddish-brown pustules about the size of a pinhead in

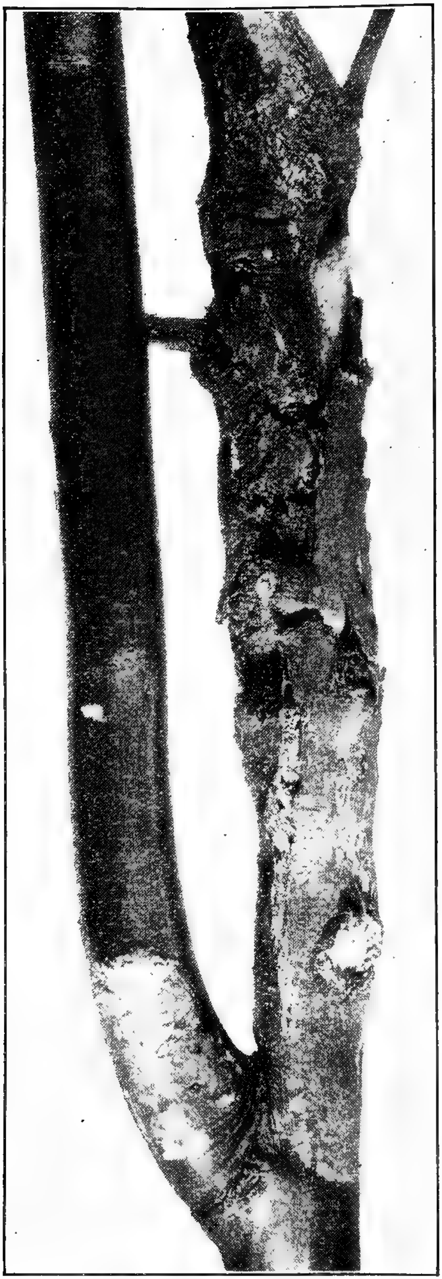


FIGURE 4.—Old blight canker spreading to a sprout. The canker developed there had a regular margin

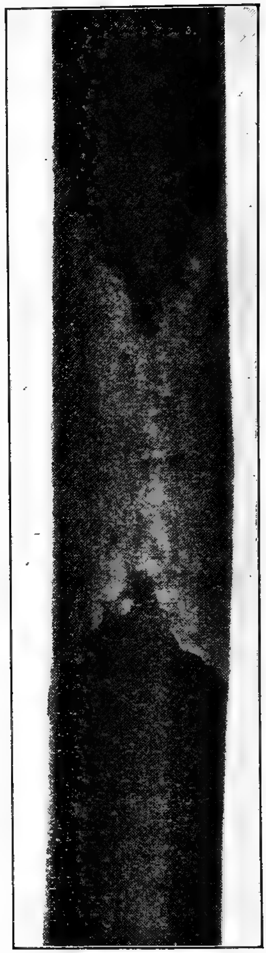


FIGURE 5.—A blight canker with an irregular margin. The fungus started on the opposite face of the limb and the two edges of the lesion have just grown together

the cracks or crevices of the thick bark is another indication of the disease. These pustules develop much more abundantly on the surface of cankers on smooth young growth than on those on thick-barked stems.

In many localities in the Southern States, especially at the lower elevations, many of the chestnut trees have died presumably from a root-rot disease that is quite distinct from the chestnut blight. Trees affected by the blight always have cankers that show the typical fruiting bodies and mycelial fans as described on page 7. (Fig. 7.)

THE CAUSAL ORGANISM[1]

The vegetative part of the blight fungus, which is made up of very numerous flattened threadlike strands, is called the mycelium

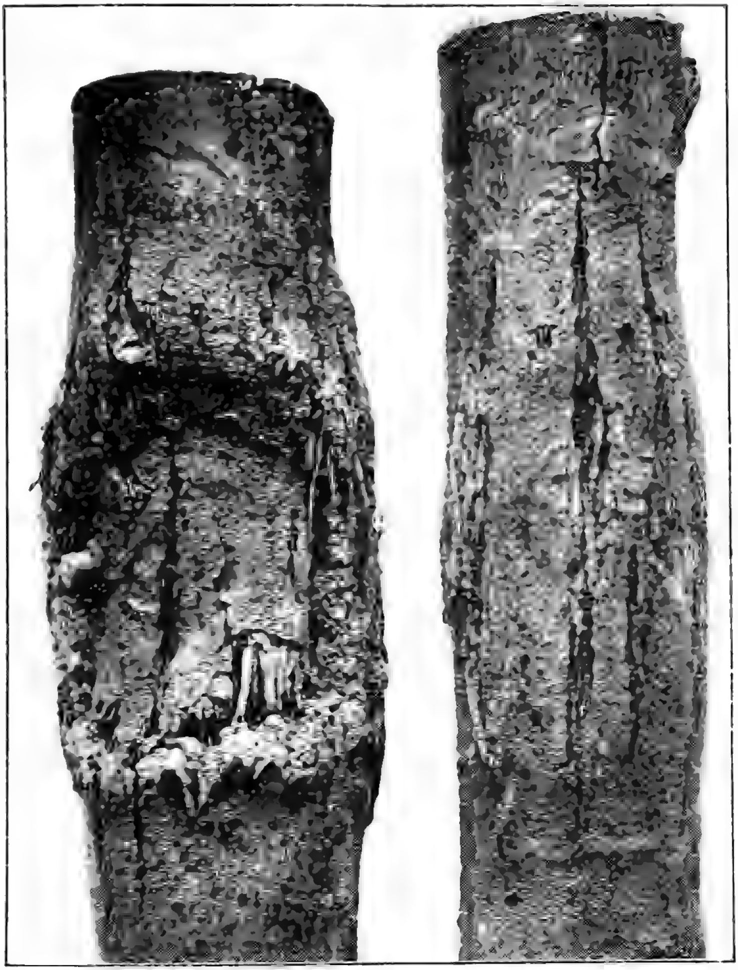


FIGURE 6.—The central part of the canker at the left is sunken where the fungus has killed the bark through to the wood. The canker at the right is slightly swollen with characteristic cracks.

It grows in the bark, extending much like the roots of plants in soil. As the fungus penetrates, it brings about the death of the invaded bark. The mycelium within this dead area is buff colored, but where it extends into the living bark at the margin of the lesion it is often

[1] SHEAR, C. L., STEVENS, NEIL E., and TILLER, RUBY J. ENDOTHIA PARASITICA AND RELATED SPECIES. U. S. Dept. Agr. Bul. 380, 82 p., illus. 1917.

FIGURE 7.—Mycelial fans of the chestnut-blight fungus. This is one of the most important diagnostic characters. Usually the mycelial fans are much less abundant than in this specimen

white. The term "fans" has been applied to describe these thin spreading plates of fungous growth. (Fig. 7.)

When well established the fungus fruits. The reproductive bodies formed, corresponding to the seeds of plants, are known as spores. Two types of spores are produced from pustules, which in dry weather resemble orange or red-brown pinheads dotted over the surface of the cankers. (Fig. 8.) During damp weather certain pustules produce tiny yellow, coiling, hairlike tendrils, called spore horns (fig. 9), which are composed of myriads of spores about the size of bacteria. These spores are borne within the pustule in such

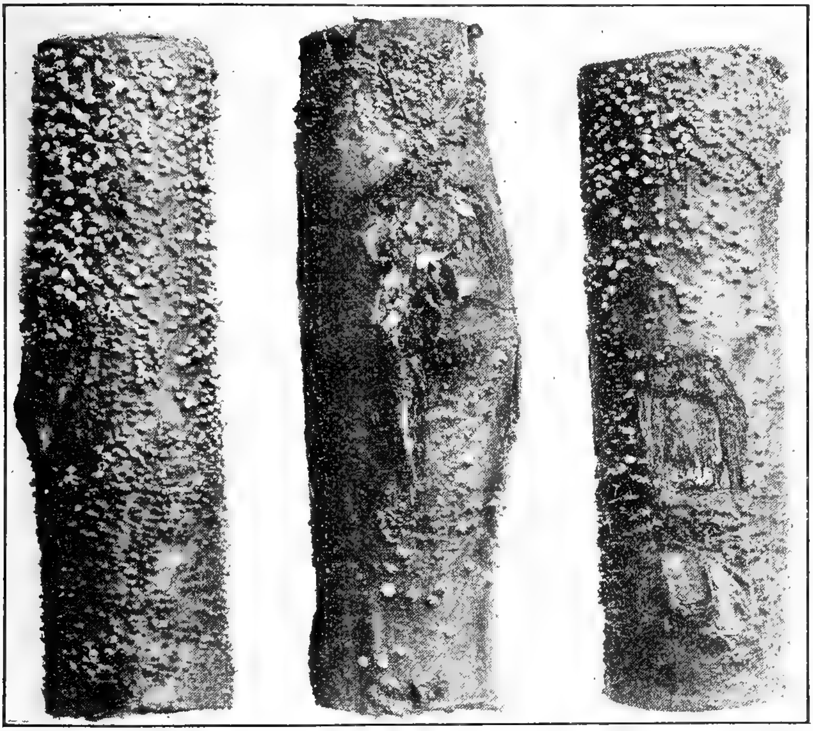


FIGURE 8.—Fruiting bodies of the chestnut-blight fungus

numbers that when moist they are forced out in a slender serpentine mass, much as paste is squeezed from a tube. Spores of this type are sticky when moist. They adhere to insects, birds, and animals coming in contact with them and thus may be carried long distances. Rain dissolves the dry spore horns and washes the spores into wormholes and wounds to start new cankers.

Pustules producing the second type of spore differ from those producing the first in that during wet weather they are dotted with very small openings rather than surmounted by spore horns. The openings, which are often at the end of small protuberances (fig. 8), are the mouths of flask-shaped structures. Within the flasks the spores are borne, definitely arranged in groups of eight 2-celled spores. Each group is inclosed in a thin, transparent, club-shaped sac. Under suitable conditions the sacs escape through the neck of the flask. When free the sacs burst in miniature explosions, throwing the spores into the air. Thus freed the spores are carried by air currents often to great distances.

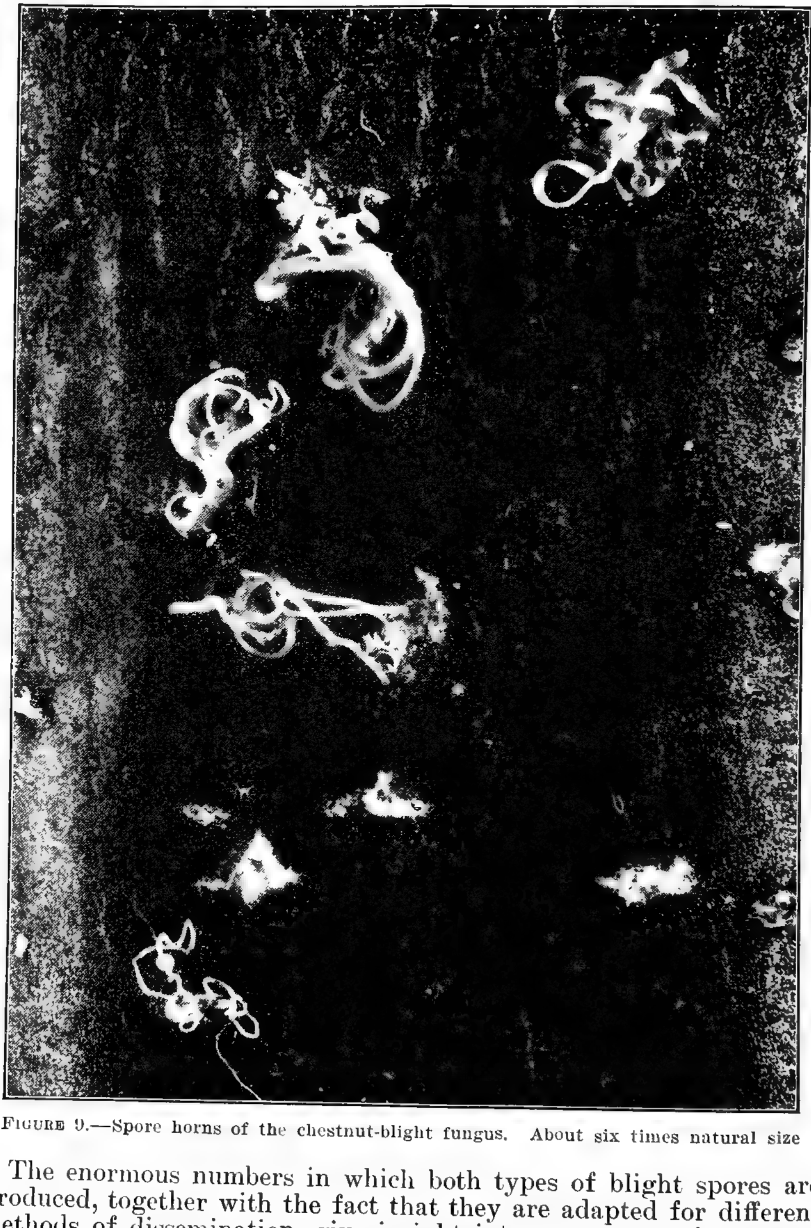


FIGURE 9.—Spore horns of the chestnut-blight fungus. About six times natural size

The enormous numbers in which both types of blight spores are produced, together with the fact that they are adapted for different methods of dissemination, give insight into one aspect of the difficulty of halting such a foreign invader once it becomes widely established and begins its march.

DETERIORATION OF WOOD

Tests made by the United States Forest Products Laboratory[2] indicate that for a year, or possibly two years, wood from blight-killed chestnut is as good as that from healthy chestnut. As the blight fungus itself does not appear to have any immediate or after effects upon the mechanical strength of the timber, the utilization value of a blight-killed chestnut should be no less than that of a tree ringed with an ax at the same time and left standing. Soon after the death from either cause, the loosening of the bark, which is accompanied by decay of the sapwood, becomes apparent. Figure 10 shows the average rate at which the bark was observed to loosen and

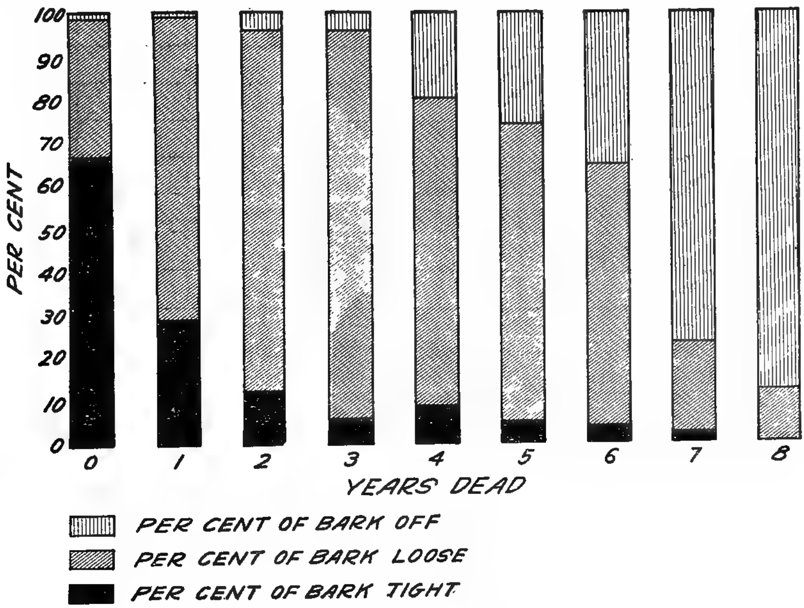


FIGURE 10.—Condition of bark on trees dead for periods of different length

fall from the first log of blight-killed trees at several localities in the southern Appalachians. The very rapid loosening during the first three years after death is brought about largely by insects and fungi, which finally cause it to slough off. Occasionally certain species of fungi also decay the heartwood to a depth of an inch or more. The amount of sound sapwood remaining on the first log during the first seven years after death is approximately the same as the amount of tight bark shown in Figure 10.

Since most of the loosened bark and decayed sapwood will be knocked off in felling operations, they can be considered almost a complete loss by the third or fourth year after death. The reduction in volume resulting from the loss of sapwood and bark on the trunks alone, where trees were cut into 5-foot sticks to a 4-inch minimum diameter for extract wood, is shown in Figure 11, which is

[2] A UTILIZATION GUIDE FOR BLIGHT-KILLED CHESTNUT. U. S. Dept. Agr., Forest Products Lab., Technical Note 224. [Multigraphed.]

based on 78 trees. It is evident that the loss in proportion to original volume is heaviest in trees under 8 inches in diameter. No data are available for trees above 17 inches, but allowing for a conservative increase in bark thickness with diameter, it is estimated that the loss will still closely approximate 20 per cent in the 30-inch diameter class.

The percentage of loss in limb wood will be consistently higher because of the greater proportion of small diameters. However, as the trunk volumes have been calculated to a 4-inch upper limit, the

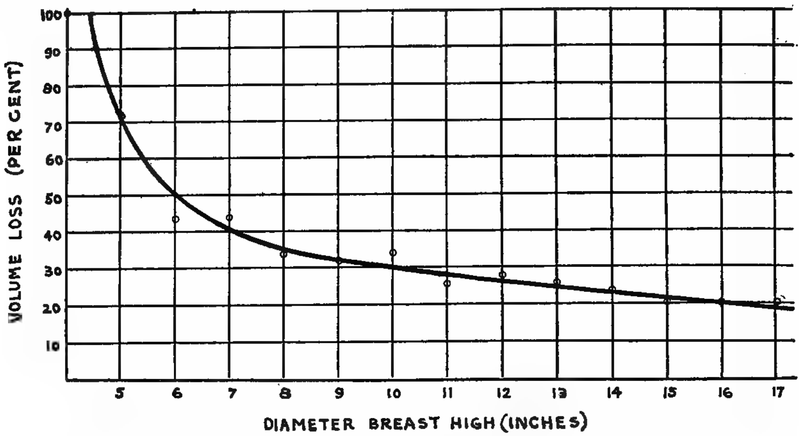


FIGURE 11.—Reduction in volume of extract wood in trunks resulting from loss of bark and sapwood

amount of wood remaining in the limbs is not great. Table 2 gives the amount of limb wood and the percentages of loss in 319 trees at one locality in North Carolina. The sapwood averages about one-fourth inch in thickness and comprises about one-third to one-fourth of the total amount lost.

TABLE 2.—*Limb-wood volumes and percentages of loss through bark falling and decay of sapwood*

Diameter breast high (inches)	Trees	Average volume of limb wood	Loss in bark and sapwood
	Number	*Cubic feet*	*Per cent*
15 to 19 inches	99	1.39	49
20 to 24	123	3.47	39
25 to 29	66	7.00	35
30 to 34	31	10.01	31

The heartwood of living chestnut is often attacked by certain fungi that cause it to decay. Some of these heart-rotting fungi are able to continue to decay the wood in standing dead trees, but how fast heart rot progresses in trees infected with rot before death is not known. In the case of sound trees there will probably be little danger of any material loss in volume from center rot for the first 10 years after death, and many standing trees have been found to be apparently sound 30 years after they have been killed. After 10 years, however, wind throw must be considered. Trees on the ground usually deteriorate more rapidly than those that remain standing. Their centers are frequently destroyed within a few years by insects in combination with decay. The time required for blight-killed trees to fall is dependent upon a number of factors, among which are soil type, local weather conditions, relief, exposure, and prevalence of root decay. Observations on a number of belted or girdled areas in the southern Appalachians indicate that less than 5 per cent of the trees blow over during the first 10 years after death. From 20 to 40 per cent of those dead between 10 and 20 years and from 60 to 100 per cent of those dead for more than 20 years blow over. These estimates were made on girdled stands, as blight-killed areas of sufficient age were not available in the South. It is possible that under natural conditions windfall would be much less, since the dead chestnut would receive protection from the surrounding trees of other species.

Where a considerable part of the stand is chestnut, fire conditions become increasingly critical with the accumulation of bark, dead sprouts, and fallen branches at the bases of dead trees. Fires not only destroy part of the dead standing chestnut but also, on account of the intensity with which the accumulated dead material burns, frequently destroy other species in the stand. Adequate fire protection in the southern Appalachians would assist in the effort to utilize the chestnut growth and would materially prolong the life of the chestnut-extract industry.

Serious checking usually does not occur so long as the bark persists. Reference to Figure 10 shows that on the average approximately 65 per cent of the bark still remains by the sixth year after death. Checking is most rapid during the first two years after the bark has fallen. During this period several checks over 5 feet in length and 1 inch deep develop at fairly regular intervals around the trunk. The increase in size and number of damaging checks is very slow thereafter.

In addition, dead wood is liable to become brittle with long years of seasoning on the stump. It may also suffer from attacks of timber worms, resulting in lumber of lower grade. Occasionally stains are found in the wood of dead trees.

UTILIZATION OF BLIGHT-KILLED CHESTNUT

The problem of utilizing the chestnut timber from the 33,000,000 acres of the southern Appalachians, where the species represents 25 per cent of the stand, is one phase of the chestnut-blight problem which the United States Forest Service and State and extension forestry departments are endeavoring to solve.

Chestnut lends itself to the most varied usage of any timber species growing in the southern Appalachians. It is already used for extract wood, lumber, poles, ties, mine props, piles, fence posts, cordwood, and pulpwood, and it offers the possibility of increased use. Sawed chestnut lumber is much in demand, but increased cutting, because of the spread of the blight, tends to glut the market. The wood is light and easily worked. It can be used for many purposes where its coarse grain and lack of extreme strength do not make it undesirable. Its increased use for sheathing, framing, interior work, and most of all for the manufacture of boxes, packing cases, and crates, would do much to conserve other timber supplies.

Telephone and telegraph poles command the highest prices paid for chestnut. However, some purchasers demand that the poles be cut green and that they be not seriously damaged by blight, while others only specify that the sapwood be sound on the butt. For these reasons it is advisable for owners to market their poles as soon as practicable.

The manufacture of chestnut extract affords the most feasible outlet for much of the stand. Extract plants are already established strategically over the southern Appalachian district. (Fig. 12.) This industry, by far the largest consumer of chestnut, uses enormous quantities of the wood. It disposes of trees and parts of trees that are worthless except as acid wood. The limbs as well as trunks are

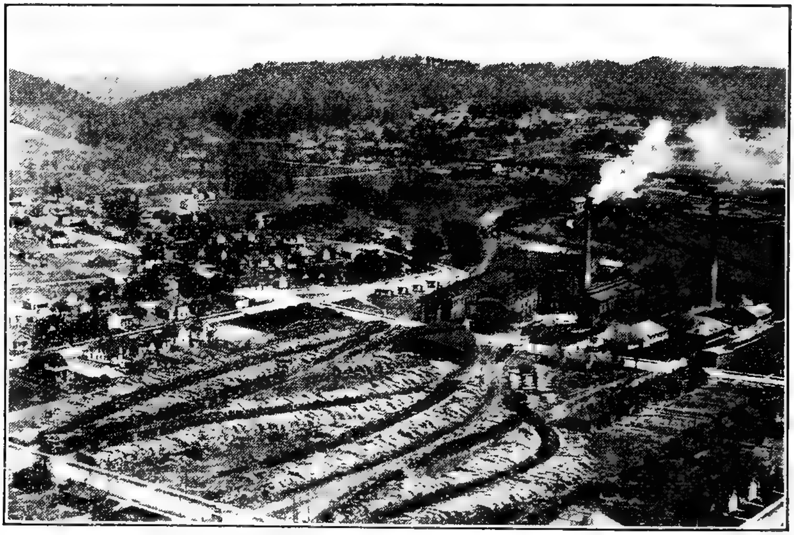


FIGURE 12.—A chestnut-extract plant. There are 21 chestnut-extract plants in the southern Appalachians, producing over one-half of the domestic supply of vegetable tannins

used, so that little waste remains in the woods to increase the fire hazard. Best of all, from the standpoint of the present situation, even the prolonged standing of dead timber does not exclude its use for this purpose.

Studies[3] have recently been carried out, in cooperation with the Bureau of Chemistry and Soils and with chemists of the chestnut-extract plants, on the tannin content of trees that had been killed by belting or by forest fires in a number of localities in the southern Appalachians. These trees are considered fairly comparable to blight-killed chestnuts. The studies indicate that the percentage of tannin in trees dead as long as 25 to 30 years is not materially less than that in living trees. Blight-killed trees lose their sapwood and bark within a few years after their death. However, the loss of the sapwood, which is thin and has a low tannin content (2 to 4 per cent), is of little importance. Even the loss of the bark, which has approxi-

[3] NELSON, R. M., and GRAVATT, G. F. THE TANNIN CONTENT OF DEAD CHESTNUT TREES. Jour. Amer. Leather Chem. Assoc. 24: 479–499. 1929.

mately the same tannin content as the heartwood (7 to 12 per cent), is not always a serious matter to the extract manufacturer, because peeled wood is necessary in some of the processes for utilization of the chips left after the extraction of tannin. Table 3 gives a brief guide for the utilization of chestnut.

TABLE 3.—*Condition and utilization of products from dead chestnut trees*

Number of years after tree died	Average condition of trees	Effect upon products (caused by death of tree)			
		Cordwood or extract wood	Poles (treated)	Poles and posts (untreated)	Lumber
1	Bark loosening and sapwood decaying on upper parts first infected.	Slight volume reductions from loss of bark in upper parts.	Nearly as good as green timber.	Nearly as good as green timber except for greater breakage in felling.	Nearly as good as green timber.
2 to 3	Bark loose and sapwood decaying on most of tree.	Loss of sapwood and bark practically completed. Volume loss 20 per cent on large trees and somewhat more on those under 10 inches.	Usually acceptable if sapwood remains sound on the butt.	do	Do.
4	Bark and sapwood all loose.	do	Not suitable	do	Do.
5	Bark off most of upper parts; checking beginning on exposed areas.	do	do	Value reduced, mainly on account of checking.	Loss in value and volume from checking; gradual increases in cull from decay.
6 to 10	Bark off; checking practically complete.	Practically no further volume loss.	do	do	Do.

BLIGHT-RESISTANT CHESTNUTS

Since direct control of chestnut blight is impracticable, the discovery of suitable strains of chestnut resistant to the disease is highly desirable. Individual native chestnuts differ in susceptibility to attack, but search for many years has shown that the number of trees actually surviving in regions where blight has been present the longest is very small. Some of these trees are being propagated and studied further with the hope of developing a strain of American chestnut sufficiently resistant to reach maturity in the presence of the disease. The numerous living trees occurring on tracts recently killed by blight are generally disease escaping rather than disease resistant. For this reason search for resistant specimens is profitable only in areas where all but very exceptionable chestnut trees have been dead from the disease for a number of years. Reports of unusually resistant trees—those that have not been severely injured by the blight—are desired. The Office of Forest Pathology records all such trees reported and inspects them as field work permits.

For a number of years after the chestnut trees in different localities were killed by the blight, the sprouts rarely reached a diameter of more than a few inches before they in turn were killed. Some sprouts now become much larger and frequently produce viable nuts before being killed by the blight. Other sprouts continue to grow and produce nuts in spite of the blight cankers on their stems. Just what will be the ultimate result of this struggle between host and parasite can not be definitely stated, though it is reasonable to expect that by selection among the seedlings growing from the nuts of the sprouts a quick-fruiting, moderately resistant strain of the American chestnut will finally be evolved.

Many owners in different parts of the country have written to the Department of Agriculture at Washington for advice on how to keep their chestnut sprouts alive. Whether sprouts should be treated or not is a question that the individual owner must decide, but in nearly all cases treating sprouts is a waste of time and money. Treatments have to be repeated, and as the trees become larger the cutting out of new infections becomes increasingly difficult. In most cases it is to be expected that the disease will finally kill the sprout or tree. The same expenditures made in planting and caring for Asiatic chestnut

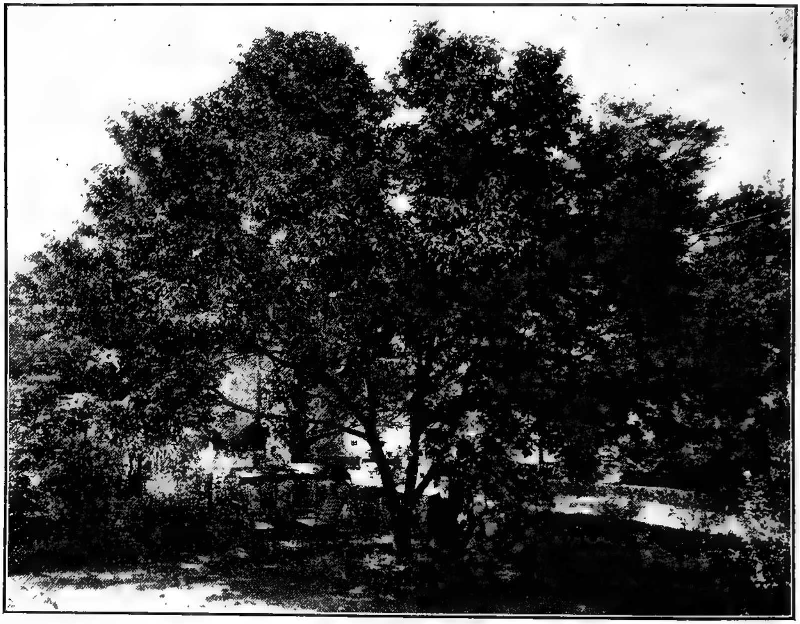


FIGURE 13.—An exotic chestnut tree, valuable for its beauty, shade, and edible nuts. The blight was cut out about five years ago, and it has not reappeared

trees will yield better returns in both nuts and shade. Figure 13 shows the effect secured with an exotic chestnut. To those who wish to work with the American chestnut for sentimental reasons, or because the sprouts are growing at hand on their land, suggestions for treatment will be sent upon request.

A number of strains of the Asiatic chestnuts have been brought to the United States by the Office of Foreign Plant Introduction [4] in the hope of obtaining a tree which will thrive despite the chestnut blight. None of the trees so far imported and tested have proved immune, but the Japanese chestnut (*Castanea japonica* Blume) and the hairy Chinese chestnut (*C. mollissima* Blume) (fig. 14) have considerable natural resistance to the disease. Private individuals

[4] GALLAWAY, B. T. THE SEARCH IN FOREIGN COUNTRIES FOR BLIGHT-RESISTANT CHESTNUTS AND RELATED TREE CROPS. U. S. Dept. Agr., Circ. 383, 16 p., illus. 1926.

have introduced Asiatic chestnuts, a large number of which are known to have survived the blight in various parts of the country, and reports of others are desired. Strains of these oriental chestnuts show marked differences in susceptibility, and it may not be practicable to control the blight on some of the very susceptible ones.

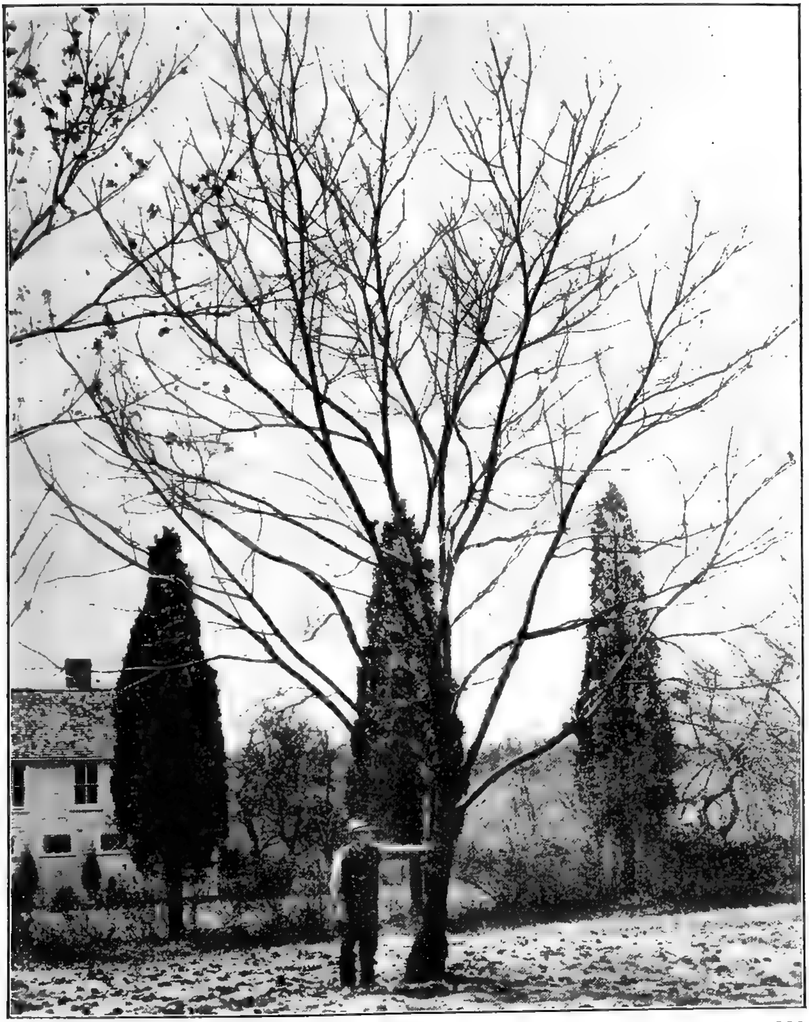


FIGURE 14.—A 17-year-old tree of the hairy Chinese chestnut growing at Bell, Md. This tree produced over a bushel of sweet nuts of good size in 1928, but only 2 quarts in 1929

However, most of the oriental trees can be saved by systematically cutting out any cankers that may appear and then painting the wounds. If the trees are kept in a vigorously growing condition, usually very little cutting out of cankers is necessary. Detailed information will be supplied by the Office of Forest Pathology, United States Department of Agriculture, to anyone interested in treating such trees.

Most of the imported chestnuts so far tested have been suited for orchard or ornamental purposes rather than for timber production. R. K. Beattie, of the Department of Agriculture, has been in Asia for the past two years securing nuts from the most promising trees of the forest types. Many thousands of seedlings from these forest trees are now growing in nurseries in the United States. These Asiatic chestnuts have shown marked resistance to the blight under

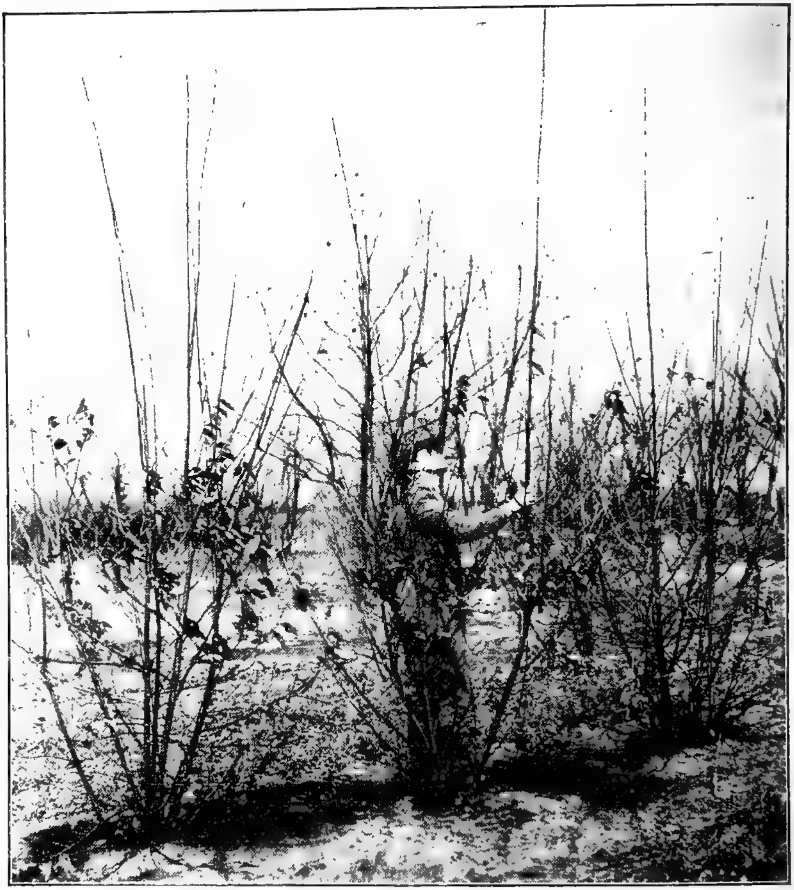


FIGURE 15.—Two-year-old coppice sprouts of hairy Chinese chestnut

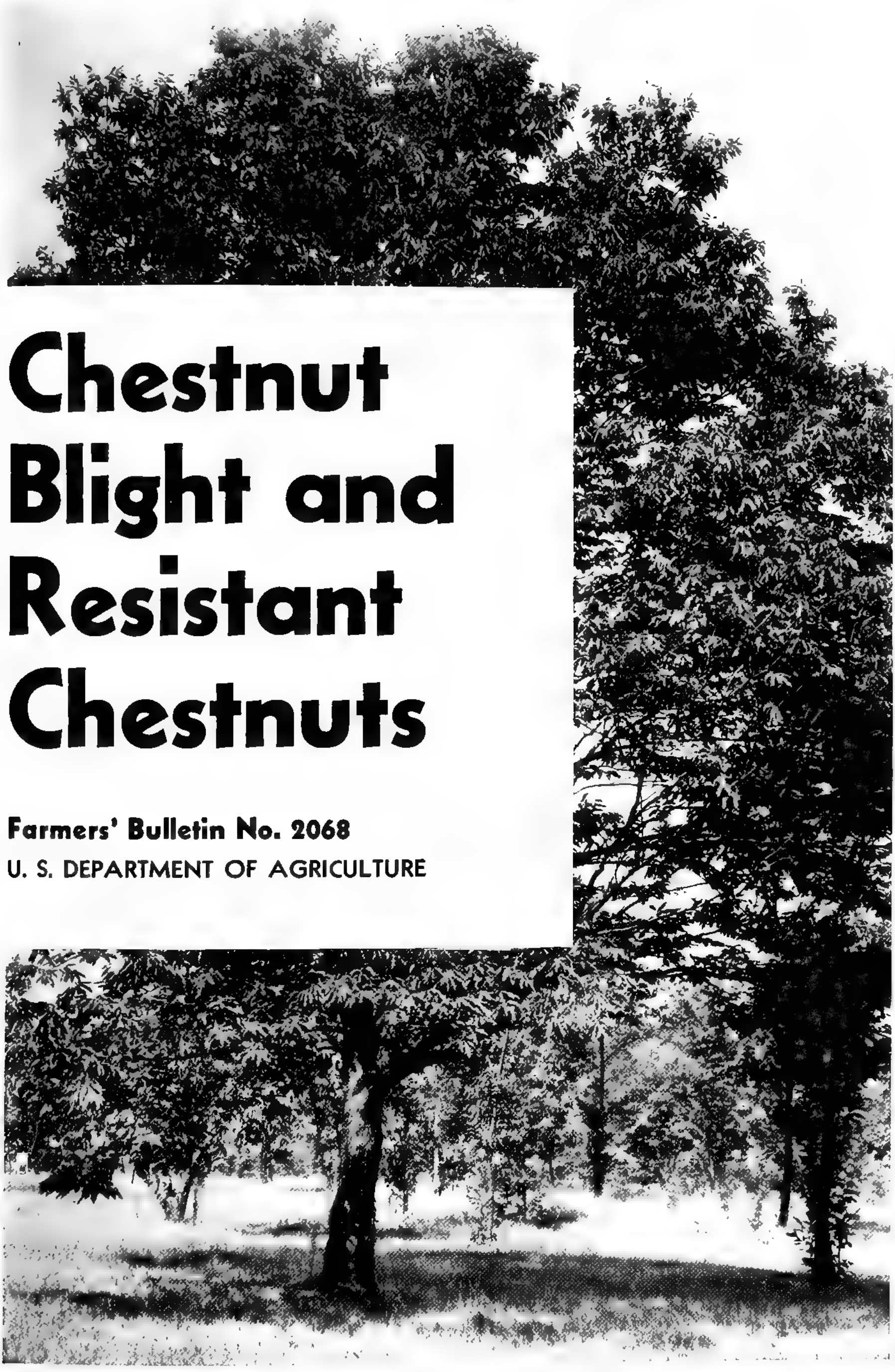
the climatic conditions of their native home, and it is to be expected that they will prove resistant in this country. They do not grow so tall or straight as the American chestnut grows, but it is hoped that in addition to providing a home supply of nuts for the farmer some strains will prove suitable for small telephone poles, fence posts, and extract wood. Many strains of them coppice readily, as shown in Figure 15. Preliminary analyses of the wood of these Asiatic chestnuts indicate that it contains as much tannin as that of the American chestnut, if not more.

U. S. GOVERNMENT PRINTING OFFICE: 1930

For sale by the Superintendent of Documents, Washington, D. C. Price 10 cents

Chestnut Blight and Resistant Chestnuts

Farmers' Bulletin No. 2068
U. S. DEPARTMENT OF AGRICULTURE



The American chestnut has been almost entirely destroyed by chestnut blight. However, roots of dead chestnuts continue to sprout. Farmers are asking about these root sprouts and their apparent resistance to chestnut blight. They are also inquiring about a replacement for this valuable tree species. Answers to these questions are given in this bulletin.

Contents

This bulletin supersedes Farmers' Bulletin 1641, Chestnut Blight.
Washington, D. C. Issued June 1954.

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 15 cents.

Chestnut Blight and Resistant Chestnuts

By the Section of Fruit and Nut Crops and Diseases, Horticultural Crops Research Branch, Agricultural Research Service[1]

THE CHESTNUT BLIGHT EPIDEMIC

Chestnut blight was first observed and recognized as a new disease in this country at the New York Zoological Park in 1904. Later a fungus[2] native to Japan, China, and Korea was proved to be the cause of this disease. Probably the blight fungus had entered this country on Asiatic chestnut nursery trees. Before 1912 we did not have a plant quarantine law. As is often the case with introduced pests, the blight fungus proved to be more virulent here than in the countries where it is native. The infection spread rapidly from its center at New York City. Soon it reached far into New England (fig. 1). Moving still more rapidly to the south, it advanced into the Allegheny Mountains and down through the Appalachians (figs. 1 and 2).

Birds, insects, and wind carried the blight fungus from infected trees to healthy ones, both nearby and far away. Shipments of infected nursery stock, seed, bark-covered poles, and rough lumber also carried it. New infection centers resulted, often many miles ahead of the main infected area. Advance spots rapidly enlarged and joined, forming continuous infected zones. Most of the early efforts at control by Pennsylvania and other States consisted in locating and cutting out advance infections. These efforts delayed the progress of the disease, but it soon became apparent that control was impracticable.

Less than 50 years after the blight fungus was discovered in this country, it had reached every part of the natural range of the American chestnut[2] (fig. 1). The chestnut killed is estimated to have been the equivalent of more than 9,000,000 acres of forest stands of pure chestnut. Isolated chestnut trees many miles from any other susceptible species were not safe from infection. Living old chestnut trees are now very rare.

Blight infections have been found in orchards and ornamental plantings of the American and European chestnuts in Washington, Oregon, California, and British Columbia. A few new infections are still occurring each year in two of the

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[1] Partially in cooperation with the Connecticut Agricultural Experiment Station, New Haven, Conn., and the U. S. Forest Service.

[2] Scientific names of trees and fungi are listed on pages 20–21.

irrigated European chestnut orchards in California, but blight control in other such orchards apparently has been successful in all cases. Every tree found to be infected is destroyed. In Washington, Oregon, and California, State officials inspect chestnut plantings for the blight and take measures to control it; they also rigidly enforce an embargo on shipment of chestnut nursery stock from the East. Control of the blight in the Pacific States is favored by the absence there of any native growth of chestnut and by the fact that the chestnut plantings are isolated from each other. Any suspected infection in a western State should be reported to the State plant pathologist.

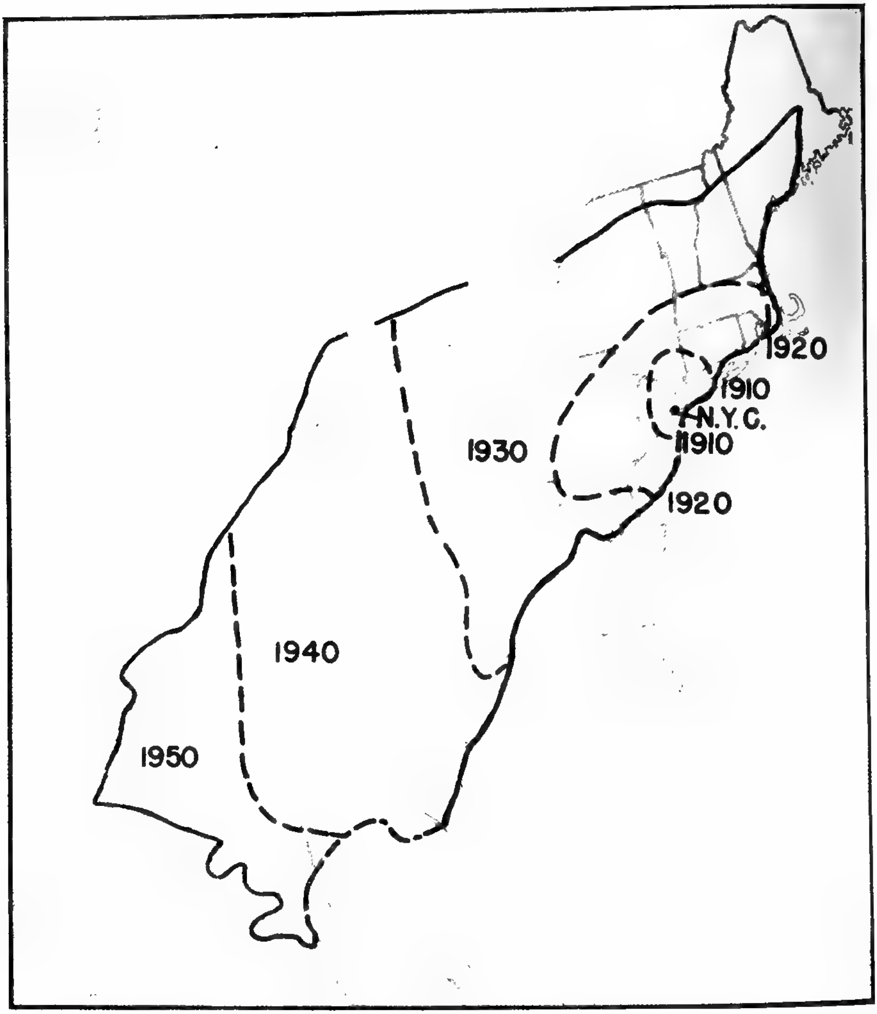

FIGURE 1.—Spread of the chestnut blight in the Eastern States. The solid line bounds the natural range of the American chestnut. Broken lines bound the areas within which the blight had killed at least half the American chestnuts at the dates indicated.

FIGURE 2.—Blight-killed American chestnut trees in the mountains of North Carolina.

SUSCEPTIBLE SPECIES

The chestnut blight fungus is most virulent on the American chestnut, but is only slightly less so on the European species.[3] It affects all the species of chinkapin native to the southeastern United States. Chinkapins range in size from small, low-growing shrubs to trees sometimes 2 feet or more in trunk diameter and 65 feet tall. Many chinkapins have been killed by the blight; however, chinkapins sprout from below ground level with such persistence and so frequently come up free of the blight that they may never be eliminated.

In greenhouse tests the blight fungus has killed the golden chinkapin, native to the Far West, and several Asiatic chinkapins.

The chestnut blight fungus grows and fruits on several species of oak in the United States; in many areas it seriously damages one of them—post oak, which has a standing volume of over 5 billion board-feet. Blighted post oaks have been found in various States from Connecticut to Florida and westward to Tennessee, always in areas where native chestnut had been blight killed. In post oak, open blight cankers, within which the wood is exposed, frequently result in death of treetops, but often the fungus grows in the outer bark only and does no

[3] The blight fungus is spreading rapidly in Italy and has entered Switzerland and Yugoslavia. The United States imports about 20,000,000 pounds of European chestnuts each year, chiefly from Italy. As the blight continues to spread, Europe will export fewer chestnuts.

damage. The fungus sometimes grows on dead chestnut oak, red maple, shagbark hickory, and staghorn sumac. In Europe, it has attacked three of the native oak species.

THE BLIGHT FUNGUS

The blight fungus grows mainly in the bark of chestnut trees, forming masses of flattened threadlike strands, called mycelia. Mycelial strands feed upon and kill the bark tissues. They advance through the bark much as plant roots advance through the soil, and form buff-colored mats or fans in the bark and cambium (fig. 3). The fungus continues to grow around chestnut trunks or limbs until it encircles them. The affected parts then die.

FIGURE 3.—Mycelial fans of the chestnut blight fungus, revealed by scraping away the outer bark from part of a cankered chestnut stem.

The fungus forms fruiting bodies, or blisters, in and on dying and dead bark. These blisters look like yellow, orange, or red-brown pinheads dotted over the surface of the cankers (fig. 4). They bear microscopic spores, which correspond to the seeds of higher plants. Spores of one type, called pycnidiospores, are produced within some of the blisters in great numbers. In damp weather they are forced out in slender sticky ribbons, much as paste is squeezed from a tube. They then form tiny yellowish or orange-colored hairlike tendrils, called spore horns (fig. 5). Spores of this type, being sticky, adhere to insects, birds, and other animals and thus may be carried for long distances. Rain washes them into wormholes and wounds in tree stems and branches, where new infections may develop.

Blisters producing spores of a second type, called ascospores, are made up of flask-shaped structures with very small openings. These spores do not form spore horns. They are borne within the flasks in groups of eight, each group enclosed in a thin, transparent sac. Under favorable conditions of moisture and temperature, the sacs push up through the neck of the flask and burst, throwing the spores into the air. Thus freed, the spores are carried by air currents, often for great distances.

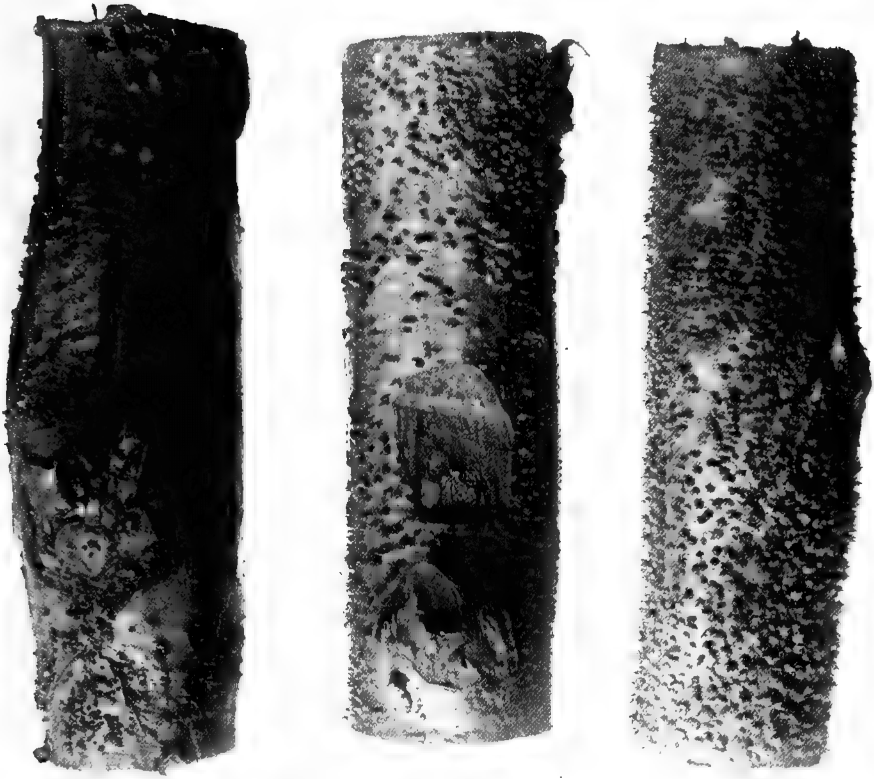

FIGURE 4.—Fruiting bodies (blisters) of the chestnut blight fungus.

SYMPTOMS OF THE DISEASE

Yellow or brown leaves on a blight-infected branch, in striking contrast with the normal green foliage, are usually the first noticed sign of the presence of chestnut blight. On a branch killed in early spring, the dead leaves are smaller than normal; on one killed later in the season, the dead leaves are full sized. The leaves and burs of a blighted branch usually remain attached during the winter. Dead chestnut branches with attached leaves do not, of course, always indicate chestnut blight. When the chestnut blight fungus is responsible for the dying, a canker can be found on the dead branch or the trunk, usually below the lowest killed leaves. Water sprouts, or suckers, frequently develop below the cankers and indicate canker location (fig. 6).

Yellowing, wilting, and stunting of leaves are symptoms of chestnut blight and also of Phytophthora root rot. This root rot is another fungus-caused disease that has been fatal to many native chestnuts and chinkapins in the South, especially at the lower elevations. Chestnut blight can be distinguished from Phytophthora root rot because blight-infected trees always have cankers and mycelial fans.

Young cankers on smooth-barked,

vigorously growing trees are easily recognized by their yellowish-brown to orange surface color, which contrasts sharply with the grayish-green color of normal bark (fig. 7). The cankered area may be sunken below the surrounding healthy bark, raised above it, or partly sunken and partly raised (fig. 8). After the fungus kills smooth bark through to the sapwood, a sunken canker is formed when the dead bark dries and becomes thinner than the living bark. Fruiting bodies of the fungus soon appear on the dead bark. Sometimes the infected bark of vigorous trees is not killed outright and new bark tissues grow, forming a swollen canker (fig. 8). Fruiting bodies of the fungus seldom appear on swollen cankers.

On thick-barked limbs and trunks a young blight infection causes very little change in the outward appearance of the bark. As the disease progresses, abnormal splits or cracks often appear in the thick bark, exposing some of the buff-colored infected inner bark, and fruiting bodies develop in bark splits or cracks.

FIGURE 5.—Spore horns of the chestnut blight fungus. (About 6 times natural size.)

FIGURE 6.—A swollen blight canker, with suckers below it.

DETERIORATION AND USE OF BLIGHT-KILLED CHESTNUT

Before the blight fungus attacked, chestnut made up 25 percent of the forest stands on 33,000,000 acres in the southern Appalachians. The timber was used for tannin extraction, lumber, poles, ties, mine props, piling, fence posts, cordwood, and pulpwood. Sawed chestnut lumber was much in demand.

The bark of blight-killed American chestnut begins to loosen about a year after the killing. After 8 years, about 90 percent of the bark has fallen off. Decay of sapwood accompanies the loosening of the bark, and as the sapwood sloughs off the heartwood begins to crack, or check. The heartwood of the American chestnut is so durable that blight-killed trees have frequently remained standing for 20 years or more.

FIGURE 7.—Blight canker encircling a smooth-barked chestnut limb. The infection started on the opposite side and the canker advanced around the limb in both directions.

Utilization of blight-killed chestnut was studied by the United States Forest Service and by forestry departments of States within the blight area. It was found that after the first few years the dead chestnut timber deteriorated at a rate averaging about 4 percent per year. Tests made by the United States Forest Products Laboratory showed, however, that the heartwood of chestnut trees dead for 1 to 8 years was almost as sound as that of healthy trees. Loss of bark and sapwood and the presence of checks and wormholes in the heartwood do not prevent utilization of chestnut that has been dead for as long as 20 or 30 years.

Even today some companies offer chestnut lumber for sale, and extract plants continue to use long-dead chestnut wood as a source of tannin. In fact, this wood is still the source of most of our domestic production of vegetable tannin, a material needed in tanning leather. By 1961, however, practically all the operable chestnut will be gone from Georgia, Kentucky, and Tennessee and the volume remaining in North Carolina, Virginia, and West Virginia will be extremely scattered and inaccessible.

SEARCH FOR BLIGHT-RESISTANT AMERICAN CHESTNUTS

In 1918, when it became apparent that direct control of chestnut blight in the Eastern States was impracticable, a search began for American chestnut trees and sprouts resistant to the blight. Individual native chestnuts have been found to differ little in susceptibility to the blight. Very few large chestnut trees still survive in regions where blight has been present for a long time. Seedlings from these trees have been tested but have proved to be susceptible to the blight.

The American chestnut produces many sprouts from the roots, especially after blight killing. Its roots are more blight resistant than the parts above ground. Therefore, chestnut sprouts are now found throughout the natural range of the American chestnut. Both sprouts

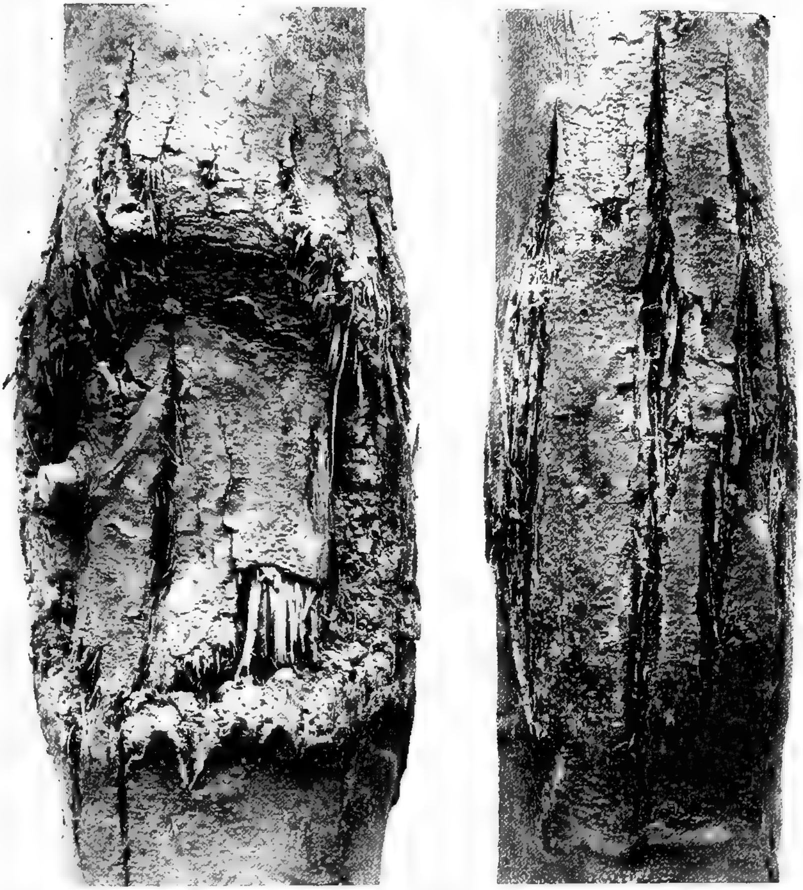

FIGURE 8.—The central part of the canker at the left is sunken where the fungus has killed the bark through to the sapwood. The canker at the right is slightly swollen and has the cracks characteristic of swollen cankers.

and seedling trees may escape the blight for a number of years, especially in localities where chestnut trees and blight infections are rare. Those that do so are not necessarily resistant and may eventually become infected with the blight and die as a result.

For a number of years after the chestnut trees in different localities were killed by the blight, the sprouts rarely reached a diameter of more than 2 inches before they in turn were killed. Now, in some of these localities some sprouts reach a diameter of 5 inches or more—a few of them even producing viable nuts—before they are killed by the blight. There are fewer blight fungus spores present to cause infection, because of the disappearance of many of the old blighted trees.

The United States Department of Agriculture and the Connecticut Agricultural Experiment Station are glad to receive reports of any large American chestnut trees that appear to be resistant after having been exposed to the blight for 25 years or longer. Such reports should be addressed to the United States Agricultural Research Service, Horticultural Crops Research Branch, Beltsville, Md., and the Connecticut Agricultural Experiment Station, New Haven, Conn.

BLIGHT-RESISTANT ASIATIC CHESTNUTS

Asiatic chestnut species, although not immune to the blight, are highly resistant to it. They are resistant to Phytophthora root rot, also. Therefore, many seeds and scions of Asiatic chestnut species have been brought into the United States. These have been tested to determine whether the Asiatic species are suitable for extensive planting in this country.

In Asia there are 3 principal species of chestnut and 1 of chinkapin: The Chinese chestnut, the Japanese chestnut, the Seguin chestnut, and the Henry chinkapin.

The Chinese chestnut is more resistant than any other chestnut species to the blight fungus. Its nuts (fig. 9, *A*) are sweeter and finer textured than those of the Japanese chestnut and usually are larger than those of the American chestnut (fig. 9, *B*). The Chinese chestnut is the hardiest of the Asiatic chestnuts. Its natural range, extending from south China, at elevations as great as 7,000 feet, north beyond Peiping, includes areas with very severe climate. In the northern part of its range the tree thrives only on the better sites, particularly lower mountain slopes where it has some protection, good air drainage, good soil, and the advantage of underground water from the slopes above.

Chinese chestnuts growing vigorously on good sites in the United States have seldom been injured by the blight. However, when trees of this species are in an unthrifty condition, owing to poor site, drought, or winter injury, they are sometimes severely attacked and may even be killed by the blight fungus.

Many selections of Chinese chestnut planted on favorable sites are growing well and producing good crops of nuts from southern New England to the Gulf States and from the Atlantic seaboard to just west of the Mississippi River. They have shown great differences in hardiness. In New York, for example, some of the trees have been damaged by a temperature of −20° F., but others have survived temperatures much lower than this without damage. The condition of the trees at the time of freezing, rather than the severity of the freezing temperature, is often the important factor. Trees that are cultivated or fertilized in the fall may harden off slowly and be severely damaged by sudden freezes. Unusually low temperatures in late winter or early spring may kill trees, especially young ones. Late spring frosts may kill Chinese chestnut buds, some of which may contain undeveloped flower parts, or kill back the young shoots for some distance. Trees with bark and cambium killed by low temperatures may leaf out in the spring and then die a month or so later. In the meantime the chestnut blight fungus may develop in the bark of such dying trees.

The Japanese chestnut grows wild in the mountains and hilly parts of Japan. The tree is not so tall as the American chestnut; the nuts range in size from that of the American to that of the European chestnut. Most Japanese selections have large nuts (fig. 9, *C*), but usually the kernels are coarse in texture and poor in flavor.

Reports from Asia and preliminary tests in this country indicate

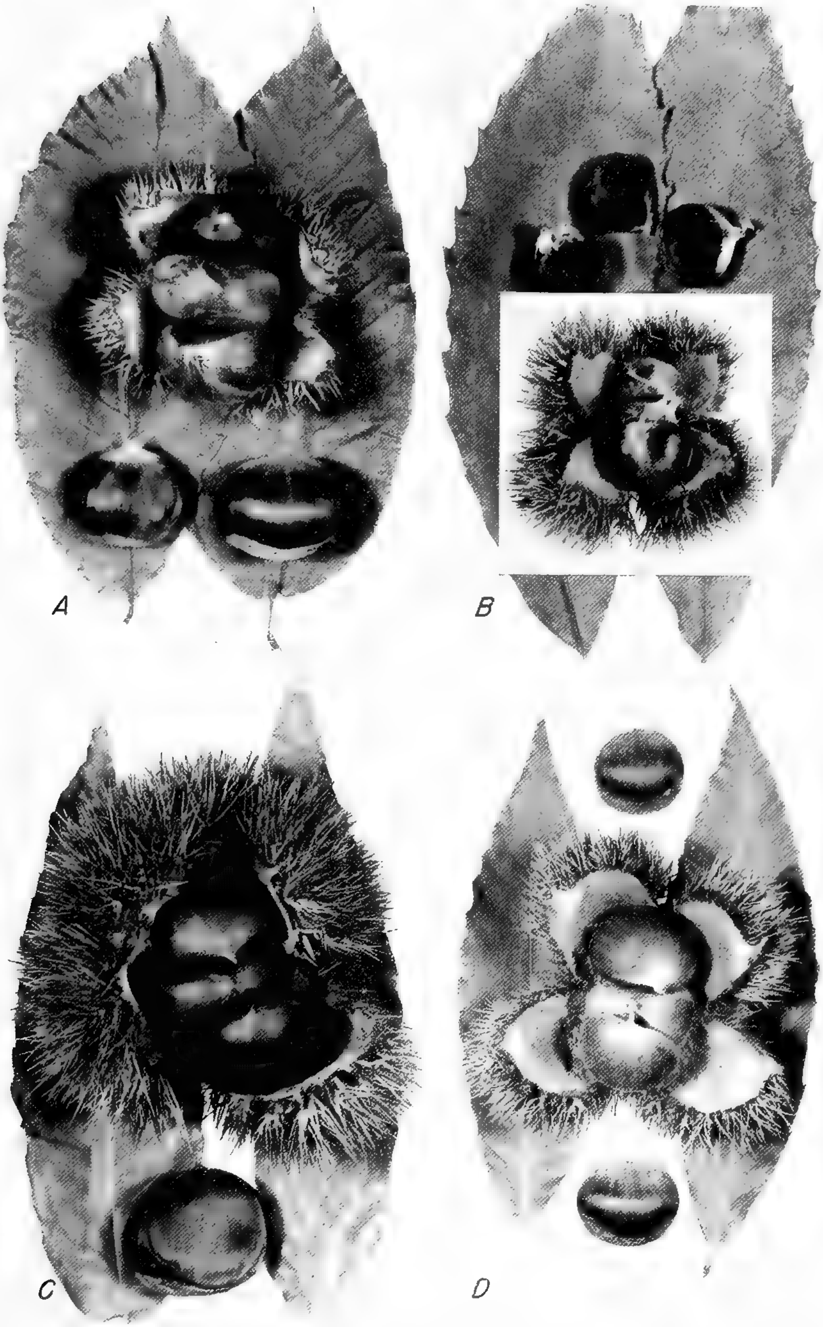

FIGURE 9.—Leaves, nuts, and bur of (*A*) the Chinese chestnut, (*B*) the American chestnut, (*C*) the Japanese chestnut, and (*D*) a first-generation hybrid between the Chinese and the American chestnut. (About half natural size.)

that the Chinese and the Japanese chestnut produce durable wood.

The Seguin chestnut usually does not attain a height greater than 25 or 30 feet. It grows in a rather warm climate in central and southern China. The nuts are very small but may have value as food for wildlife. A few trees of this species are growing well in the Southeast.

FIGURE 10.—Fifteen-year-old first-generation hybrids of Chinese and American chestnuts. They look like American chestnut trees and are just as vigorous, but they are more blight resistant.

Seguin chestnuts planted in other parts of the United States have not thrived.

The Henry chinkapin is a native of middle China, ranging from near the coast to the far west. In China it grows to a height of 75 or 90 feet and has a straight, symmetrical trunk. In this country the Henry chinkapin appears to be more susceptible than the Asiatic chestnut species to freezing temperatures and the blight fungus.

The blight resistance of chestnut species depends upon what type of tannin the bark contains and how soluble this tannin is. The tannins in the Chinese and the Japanese chestnut are more soluble than those in our native chestnut; it is for this reason that these two Asiatic species are the more blight resistant. The Chinese chestnut is more blight resistant than the Japanese because its tannin is more toxic to the blight fungus.

Owners of Chinese chestnut trees should make systematic observations on them, to locate the best ones for propagation as horticultural varieties or for use as parent trees for stock to be used in forest, wildlife, and ornamental plantings.

The United States Department of Agriculture has distributed more than half a million blight-resistant Asiatic chestnut trees, for testing, to foresters, soil conservationists, wildlife technicians, horticulturists, and private cooperators. **The Department of Agriculture does not now distribute blight-resistant chestnuts to the general public.** Such trees can be obtained from private nurseries and from some State forest and wildlife agencies.

BREEDING BLIGHT-RESISTANT CHESTNUTS

For many years the United States Department of Agriculture has been crossing the principal chestnut and chinkapin species on a large scale, in an effort to produce fast growing, blight-resistant hybrids to replace the American chestnut as a timber tree. In general, American chestnut trees that give evidence of having some blight resistance are crossed with Asiatic chestnut trees that have forest-tree form. Most of the first-generation hybrids from such crosses are vigorous and upright growing but too susceptible to the blight for practical use. Hybrids that show marked resistance to infection are used further in the breeding work.

One selection of Chinese chestnut, when crossed with American chestnut, produced fast growing, upright trees fairly resistant to the blight. A number of hybrids of this type were produced in 1932, and additional ones in 1935 and later. These first-generation hybrids resemble the American chestnut in such characteristics as rate of growth, form, and leaf shape (fig. 9, *D*). Their blight resistance is less than that of the Chinese parent but greater than that of the American. For the first 15 years, the progeny of the cross made in 1935 increased in height at a rate of almost 2½ feet per year, and in diameter at a rate of almost ½ inch per year (fig. 10). When these first-generation hybrids are backcrossed to the Chinese chestnut parent tree, the progeny is practically as resistant to the blight as the Chinese chestnut and has good forest-tree form. These first-generation hybrids are being backcrossed also to other selections of the Chinese chestnut in an effort to obtain better forest-tree form and a growth rate more like that of the American chestnut.

Special attention is being given to development of blight-resistant chestnut and chinkapin hybrids suitable for wildlife plantings on some of the poorer soils and in various climates not well suited to the Chinese chestnut.

Chestnut breeding in Connecticut was begun in 1930 under the sponsorship of the Brooklyn Botanic Garden, with the cooperation of the United States Department of Agriculture. Since 1947 the Connecticut Agricultural Experiment Station has sponsored this work. At first, crosses of the American and Japanese species were made; in 1934 the American and the Chinese species were crossed; and in 1937 a Japanese × American hybrid was crossed with the Chinese chestnut. Among the progenies produced thus far, the Chinese × (Japanese × American) hybrids have the best forest-tree form and are the most blight resistant, with some Chinese × American hybrids a close second. They are being crossed with American chestnuts to obtain a better forest tree.

At the Connecticut Agricultural Experiment Station a method of grafting known as inarching has been practiced, to save for further breeding work those blighted hybrids having valuable characteristics such as erect habit and rapid growth.

BLIGHT-RESISTANT CHESTNUTS ON THE FARM

The Chinese chestnut has proved to be superior to the other Asiatic chestnuts for use on farms in the United States, because of its blight resistance and hardiness and the quality of the nuts. The Japanese chestnut should not be planted for nut production; its nuts are usually coarse in texture and poor in flavor.

Chinese chestnut seedlings are now offered for sale by a large number of nurseries. A partial list of these nurseries may be obtained from the Agricultural Research Service, United States Department of Agriculture, Washington 25, D. C. A few nurseries sell grafted varieties of Chinese chestnut. The grafted trees are more expensive than the seedlings. Some State forest and game agencies are growing and distributing Chinese chestnut seedlings. **The Department of Agriculture does not now distribute chestnut seedlings to the general public.**

Chestnut trees for planting in States west of the Great Plains should not be ordered from eastern nurseries. Quarantine laws of some of these States prohibit the filling of such orders, to prevent chestnut blight infection from being carried into new territory.

A chestnut tree is largely incapable of pollinating its own blossoms. To provide for cross-pollination and good crops of nuts, it is necessary to plant two or more seedling trees, or trees of two or more grafted varieties. For cross-pollination, trees should be planted not more than 60 feet apart.

Forest and Woodland Plantings

Efforts have been made to establish forest plantings of Chinese chestnut on abandoned rundown agricultural land and on grassy sites, but nearly all these have failed. The most successful plantings were made on sites having deep, fertile soil and good drainage. Cool sites with north or east exposures are best. The Chinese chestnut can endure shade for 1 or 2 years after planting, but it is not so tolerant of shade as shellbark and pignut hickory, white ash, sugar maple, or beech. To produce clear, straight stems, Chinese chestnuts must be spaced not more than 10 x 10 feet apart and must have a good supply of moisture the year around. Successful plantings of Chinese chestnut have been made immediately after cutting of timber stands on sites on which yellow-poplar, northern red oak, and white ash grow well. On cut-over areas competing sprout and seedling growth of other tree species should be eliminated, preferably by poisoning, until the chestnut trees overtop surrounding growth. Chinese chestnut can well be planted on high-quality forest sites that have been poorly managed and as a result now support low-quality stands.

Good results have been obtained by girdling pole-size stands of yellow-poplar, northern red oak, white ash, and other species on high-quality sites and underplanting 1- or 2-year-old Chinese chestnut (fig. 11).[4] With this method of establishment, there is less competition from sprouts and seedlings of other species than if the trees had been clear cut. However, since this method sacrifices 15 or more years' growth of prime timber species it is not justified except where only a small planting of Chinese chestnut is desired for production of nuts as well as of other forest products.

Although farmland on which Chinese chestnut can be grown successfully is too valuable to be used extensively for this purpose, most farm woodlands can accommodate a block planting of 25 to 100 trees spaced about 10 x 10 feet. Such a planting (fig. 12) will provide decay-resistant posts and poles, nuts for wildlife and for human consumption, and a source from which chestnut can be seeded naturally in other parts of the woodland.

While the planted trees are becoming established, they need to be protected from various hazards. Where rabbits are numerous, a cylinder of woven wire should be placed around each young tree to keep rabbits from cutting off the stem. The wire should remain in place for at least 2 or 3 years after planting. Browsing and trampling by livestock or deer will cause the trees to become crooked, branchy, and dwarfed, and may eventually kill them. Fire is very destructive to chestnuts—although the Chinese chestnut, like the American, produces sprouts when the main stem is injured or destroyed.

Wildlife Plantings

Blight-resistant chestnuts could become an important source of food for wildlife in the Eastern States, because the nuts remain sound through the winter under a layer of fallen leaves. Before the blight epidemic, our native chestnut and chinkapins provided abundant food for squirrels, wild turkeys, bears, and deer.

Plantings such as those discussed under the heading "Forest and Woodland Plantings" provide food and shelter for wildlife. Other wildlife plantings may be made by similar methods in rough, hilly places where the soil quality and drainage are good, in fence corners, along fence rows and trails, and on the edges of forests and woodlands. It is usually necessary to cut out or poison competing vegetation each year until the chestnut trees are established.

Chestnuts planted in the pasture provide food for wildlife and shade and food for livestock. The young trees should be protected from live-

[4] DILLER, J. D. THE PLANTING AND CARE OF BLIGHT-RESISTANT CHESTNUTS FOR FOREST TREES. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Forest Path. Spec. Release No. 15, 7 pp., illus. 1950. (Revised.)

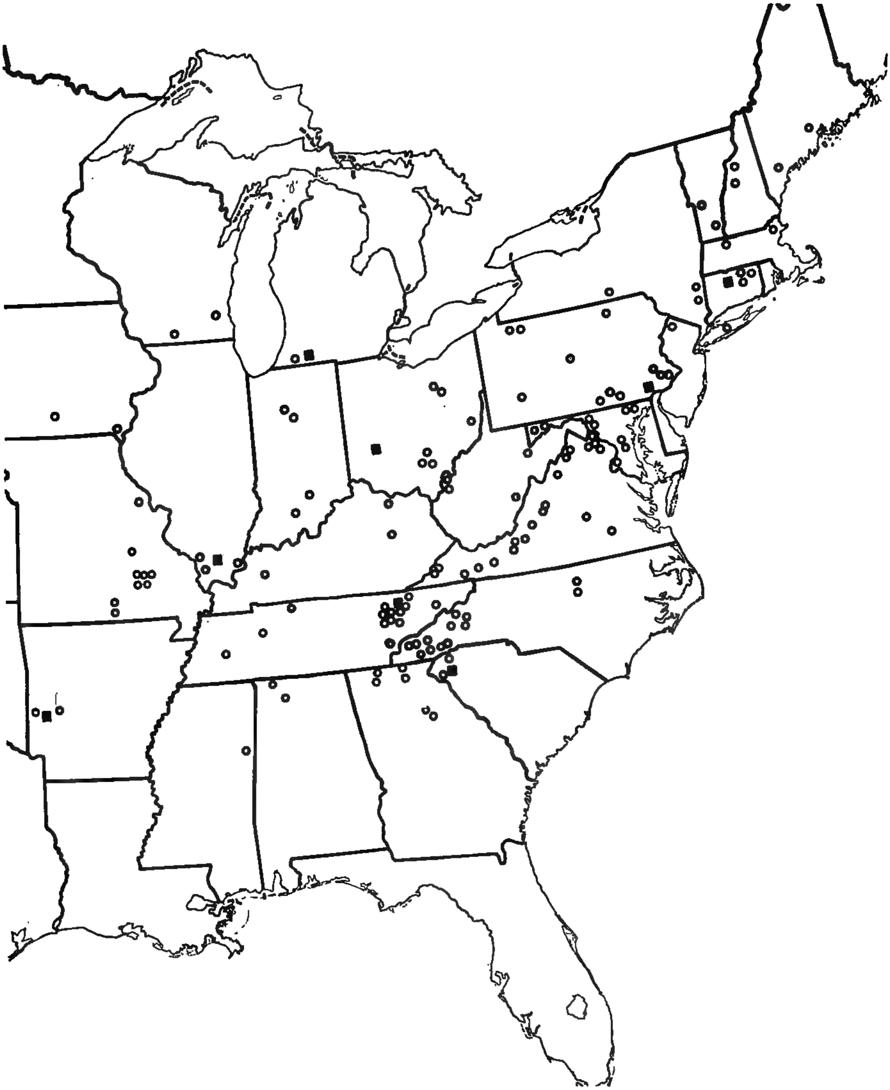

FIGURE 11.—Locations of quarter-acre demonstration plots of Chinese and hybrid chestnuts. (A circle signifies Chinese chestnut; a square, hybrid chestnut.) All the plots were established by girdling and underplanting. Usually the plots have required little maintenance.

stock with fencing until they become established. An area 6 feet in diameter around each young tree should be kept clear of grass and weeds for several years.

An important point to remember about wildlife plantings of chestnut is that only trees or parts of trees receiving full sunlight produce heavy yields of nuts.

Direct seeding is unsatisfactory as a method of planting blight-resistant chestnuts for wildlife purposes. Unprotected planted nuts are eaten by squirrels, chipmunks, field mice, moles, and woodchucks. In tests, survival of planted chestnut seed was greatly increased by this method: Remove one end of a No. 2 tin can, cut a cross in the other end, turn out slightly the four corners at the center of the cross, then force the can into the ground over the planted seed. The can rusts away in 2 or 3 years and does not interfere with seedling development. Even with this method, however, direct seeding is less effective than planting 1- or 2-year-old seedlings.

Orchard Plantings

Orchards of Chinese chestnut can be grown on a wide variety of soils if the drainage is good. They do best on light, fertile sandy or gravelly loam that is well drained. The soil should be deep and the subsoil friable enough for the roots to penetrate to a depth of at least 4 feet. Heavy silt or clay soils should be avoided. Chestnut trees will not grow on low ground that is poorly drained. The soil should be moderately to slightly acid, although in a few instances well fertilized and well-cared-for trees are known to be making satisfactory growth on slightly alkaline soil. The trees will withstand some drought after they become well established, but they will not bear heavy nut crops without ample rainfall.

Orchard Chinese chestnuts should be planted on high, sloping ground having good air drainage, which tends to prevent damage from late spring frosts. The Chinese chestnut starts growing early in the spring, and is subject to frost injury. Trees located on low ground or in frost pockets are usually injured by late spring freezes. In some cases such freezes kill whole limbs or even entire trees.

The Chinese chestnut as an orchard tree seems to be well suited to conditions in the southeastern part of the United States. It has not yet been grown extensively enough in the North to demonstrate its suitability for large orchard

FIGURE 12.—A 16-year-old plantation of Chinese chestnut on the George Washington National Forest, Amherst County, Va. The planting was done after clear cutting of hardwood growth.

plantings there. It probably can be grown successfully in northern parts of the eastern United States if planted on appropriate sites. In general, orchard chestnuts are likely to grow well on areas and under conditions that are suitable for peaches.

There is a great deal of variation in the time required for seedling trees to come into bearing. Seedlings sometimes begin to bear nuts 4 to 5 years after the seeds are planted, but usually they require 7 or 8 years or more. Nut yield varies among trees grown from seed of different seedling trees and also among trees grown from seed of the same seedling tree. The nuts vary in size, shape, and color. Some trees mature crops early, others in midseason, and others late. Grafted trees sometimes bear nuts the second year after grafting. Recommended early bearing horticultural varieties of Chinese chestnut include the Kuling, Meiling, and Nanking, which the United States Department of Agriculture released to commercial nurserymen a few years ago. The Abundance variety, also, has done well in many plantings.

Management

On sloping land the trees should be planted on the contour, to prevent excessive erosion.

Chestnuts planted for nut production require maximum sunlight, since any tree or part of a tree not receiving full sunlight cannot bear a heavy yield of nuts. Spacing the trees 40 feet or farther apart permits them to develop into the spreading, rounded form needed for heavy nut production (fig. 13). Mature trees should be spaced at least 40 feet and preferably 50 or 60 feet apart.

Early spring planting is recommended. As a rule the trees should be planted when cold weather is no longer expected and as soon as the

FIGURE 13.—A 14-year-old Chinese chestnut orchard on the Eastern Shore of Maryland.

soil can be worked. Planting stock may be 1 to 3 years old. The trees should be planted at the same depth at which they grew in the nursery. In refilling the holes, it is important that the soil be worked in around the roots to avoid air pockets. Do not put any fertilizer in the tree hole.

Grass and weeds may kill transplanted chestnut trees before the trees are large enough to compete with them for soil moisture and minerals. Cultivate the trees often enough to keep grass and weeds from growing within 6 feet of any of them. Begin cultivation in early spring and continue into July or early August. Sow a winter cover crop in the fall if the entire orchard area is cultivated.

Row crops of various kinds, such as corn, cotton, and beans, can be grown in the orchard for the first few years.

On most soils Chinese chestnut trees respond to fertilizers. After the transplanted trees begin to grow, about 1 pound of 5–10–5 or 6–8–6 fertilizer should be applied around each tree and worked into the soil. The following year, at about the time growth starts, 2 pounds of the same fertilizer should be applied in the same way. Thereafter, the quantity of fertilizer applied per tree should be increased each year by about 2 pounds until it reaches 20 pounds.

Young orchard chestnut trees should be pruned to a single trunk. Chinese chestnuts tend to branch low on the trunk, and in many cases they develop a bushy form if not pruned. Such form makes it difficult to work around the trees and to harvest the nuts. Pruning sufficient to train the tree to the desired form is all that is required. Additional pruning reduces the size of the tree and delays nut production.

Harvesting and Storing Nuts

Nuts on Chinese chestnut trees usually begin to mature about the first of September in the Southern States and in late September or early October in the Northern States. At maturity, the burs usually open and release the nuts. Harvesting should begin as soon as the first nuts drop to the ground. Fallen nuts should be gathered at least every other day. Chestnuts are a perishable crop. If not properly harvested and stored, they decay or dry out quickly and become hard and bony.

Chestnuts may be kept for several months by storing them in metal cans at low temperatures with protection against drying out. The nuts remain in good condition if kept at a temperature of 32° F. and a relative humidity of about 70 percent. For ventilation each can should have several holes about 1/16 inch in diameter. Small lots of nuts can be kept in the home refrigerator for several months if stored in cans or jars with loose fitting lids. When cold storage is not available the nuts may be stratified, that is, stored in layers alternating with layers of moist sand, or buried in the ground in a well drained location protected from rodents.

Insects and Diseases

Two species of weevil often attack the nuts, causing them to become wormy. These weevils can be controlled by spraying the trees with DDT 3 times at intervals of about 12 days. The best date to begin spraying varies from place to place and from season to season. In the vicinity of Washington, D. C., it is usually about August 15. To prepare the DDT spraying material, add 4 pounds of a 50-percent or 8 pounds of a 25-percent DDT wettable powder to 100 gallons of water. For small quantities, add 2/3 ounce (approximately 16 level tablespoonfuls) of a 50-percent powder or 1 1/3 ounces (about 32 level tablespoonfuls) of a 25-percent powder to 5 gallons of water. Mix the DDT powder thoroughly with the water. **DDT is a poison and should be handled carefully in accordance with manufacturer's directions.** If harvested nuts are found to be infested with weevil eggs or larvae, these should be killed by immersing the nuts in water held at a constant temperature of 120° F. for 30 to 45 minutes, depending on the size of the nuts.

Japanese beetles feed on the flowers and leaves and often cause serious injury to the trees. These beetles can be controlled by spraying with a mixture of 2 pounds of a 50-percent or 4 pounds of a 25-percent DDT wettable powder to 100 gallons of water.

Certain bacteria and fungi may attack the nuts, causing them to spoil or decay. Spoilage is more common in the Southeast than elsewhere, perhaps partly because of the higher temperatures and humidity that usually prevail there when the nuts are maturing. Nuts of the Kuling, Meiling, and Nanking varieties of the Chinese chestnut have good keeping qualities, and these varieties are recommended for orchard planting in the South, where nut decay is a serious problem.

Ornamentals

Blight-resistant chestnut trees make beautiful shade trees for the lawn or farmyard. They have attractive form and foliage. Most people enjoy the sight of a chestnut tree full of catkins in the spring and early summer or loaded with nuts in the fall. Chestnuts should not be planted where the branches would eventually overhang a roof from which water is collected for a cistern; the flowers and leaves have a disagreeable effect on the taste, odor, and color of water. A few trees, in full sunlight, will produce an abundant supply of nuts for family use, and, if properly stored, these can be enjoyed throughout the winter.

SCIENTIFIC NAMES OF TREES AND FUNGI MENTIONED

TREES

Common name	*Scientific name*
Chestnuts and chinkapins:	
American chestnut	*Castanea dentata*
Chinese chestnut	*Castanea mollissima*
European chestnut	*Castanea sativa*
Golden chinkapin	*Castanopsis chrysophylla*
Henry chinkapin	*Castanea henryi*
Japanese chestnut	*Castanea crenata*
Seguin chestnut	*Castanea seguinii*
Oaks:	
Chestnut oak	*Quercus prinus*
Northern red oak	*Quercus rubra*
Post oak	*Quercus stellata*
Other species:	
Beech	*Fagus grandifolia*
Pignut hickory	*Carya glabra*
Red maple	*Acer rubrum*
Shagbark hickory	*Carya ovata*
Shellbark hickory	*Carya laciniosa*
Staghorn sumac	*Rhus typhina*

TREES—Continued

Common name	*Scientific name*
Other species—Continued	
Sugar maple	*Acer saccharum*
White ash	*Fraxinus americana*
Yellow-poplar	*Liriodendron tulipifera*

FUNGI

Common name of disease	*Scientific name of causal fungus*
Chestnut blight	*Endothia parasitica*
Phytophthora root rot	*Phytophthora cinnamomi*

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PREVENT FARM FIRES

Fires kill more than 3,000 farm people each year, and cause painful injury to many thousands more.

In farm homes fire is the main cause of death and injury among younger people.

Each year fires destroy $133,000,000 worth of farm property.

Much of this loss and suffering can be avoided by taking precautions to prevent fires or by being prepared to control those that do get started. In making a fire-safety check on your own farm, keep in mind that the primary causes of farm fires are—

- Lightning
- Sparks on the roof
- Defective chimneys or heating systems
- Faulty electric wiring or appliances
- Careless smokers
- Careless use or storage of gasoline, kerosene, oily rags, and such
- Children playing with matches

Don't start any fire unless you know you can stop it.

Keep a fire extinguisher handy and make sure every member of the family knows how to use it.

For details, see U. S. Department of Agriculture Farmers' Bulletin No. 1643, Fire Safeguards for the Farm.

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Bulletin 137 March, 1912

West Virginia University
Agricultural Experiment Station

MORGANTOWN, W. VA.

DEPARTMENT OF PLANT PATHOLOGY

The Chestnut Bark Disease

N. J. GIDDINGS

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THE CHESTNUT BARK DISEASE

A DANGEROUS ENEMY OF WEST VIRGINIA'S CHESTNUT TREES.

The blight or bark disease of chestnut seems to be, in many respects, the worst pest that has appeared in the forests of this country. It is unusual for a disease to destroy the entire growth of a plant in any section, but this blight has been found to attack practically every chestnut tree in its line of advance, leaving in its wake only dead and dying trees of that species. We should be thankful indeed that it has not been found to attack other species of our forest trees since that would seriously complicate matters.

The chestnut timber is of very great value and importance in this state and it would seem well for us to take any reasonable and necessary steps for the prevention or control of the disease in West Virginia. The average annual cut during the past few years is about 118 million feet, and this figure does not include poles, cross ties, or posts.

The value of the nuts is also great, as food for man, or for fattening hogs. Shipments from one railroad station last fall aggregated 155,092 pounds.

We have secured estimates from several lumbermen as to the present standing chestnut timber of the state. These estimates range from *more than* one billion feet to ten billion feet. Taking five billion feet as a reasonable average, and $3.00 per

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In publishing this bulletin on the Chestnut Bark Disease we have drawn freely from all available publications on the subject. We are especially indebted to Dr. Haven Metcalf of the U. S. Department of Agriculture, Mr. A. B. Brooks, former State Forester of West Virginia, and Mr. S. B. Detweiler of the Pennsylvania Chestnut Blight Commission.

thousand as stumpage value, we have a total valuation of $15,-000,000. These figures do not mean a great deal as there are many things to be considered aside from the simple lumber value of the chestnut.

Our West Virginia forests deserve far more attention than they have thus far received, and it is hoped that the publication of this Bulletin will help to bring about some definite action both in regard to the Chestnut Bark Disease and general forestry work in this State.

FIG. 1.—A fine old tree, but dying from the bark disease.

HISTORY.

Attention was first called to this disease by Dr. H. W. Merkle, of the New York Botanical Gardens. During the summer of 1904-5 he noticed that a few of the chestnut trees in the parks appeared to be dying in a peculiar manner, and he brought the matter to the attention of Dr. W. A. Murrill, the Mycologist. In a paper on the subject given in the 1905 report of the Zoological Society Merkel says, "It has spread to such an extent that today it is no exaggeration to say that 98 per cent of all the chestnut trees in the parks of this borough are infected. The spread of this disease is so sudden that unless some radical measures are taken or a natural enemy of this fungus develops, it is safe to predict that not a live specimen of the American chestnut (*Castanea dentata*) will be found two years hence in the neighborhood of the Zoo-

FIG. 2.—A beautiful grove a few years ago, but all chestnut dead now.

logical Park". Valiant efforts were made to save trees which were not yet diseased by spraying them thoroughly with Bordeaux mixture, while many which were only slightly diseased were pruned and repruned, but all of their endeavors availed nothing, and today those great parks are destitute of the chestnut trees.

During the years 1905-6 Dr. Murrill studied the disease in laboratory, greenhouse and park. As a result of his studies he found it to be new and undescribed, tho a fungus similar to the one which causes this disease is known to occur in Europe. He published a careful description of the disease and its behavoir in 1906.

His work was followed by a great deal of discussion as to the cause and importance of the disease, and meanwhile the chestnut trees were dying by thousands and tens of thousands.

The Office of Forest Pathology at Washington, D. C., has devoted considerable time to the study of this disease, especially as to its manner of spreading, distribution, and methods of control.

Pennsylvania was the first state to give the matter serious consideration and more will be said of their work under another heading.

DESCRIPTION.

The disease may attack a tree of any age, and any part of the tree. It is caused by a fungus, and this seems able to start its growth only in wounds of some sort, but when we consider the squirrels, insects, and birds which may make small wounds through the bark it is easy to see that there are numerous points of entrance.

It finds conditions most favorable for its growth just between the bark and the wood. Once started, it spreads rapidly and soon girdles the part upon which it is growing. It is this characteristic of girdling which makes it especially destructive. Only a small amount of tissue is actually invaded by the fungus, but the entire tree, limb, or twig is killed beyond that point. When a twig or limb is diseased, the spores or fruiting bodies of the fungus are washed down toward the trunk, which soon becomes infected and girdled.

The disease is most noticeable during late spring and summer. During this period, the recently killed or dying limbs are easily detected from some distance, on account of their discolored foliage. The leaves on a diseased branch turn to a reddish brown color, and finally wither, but they have a ten-

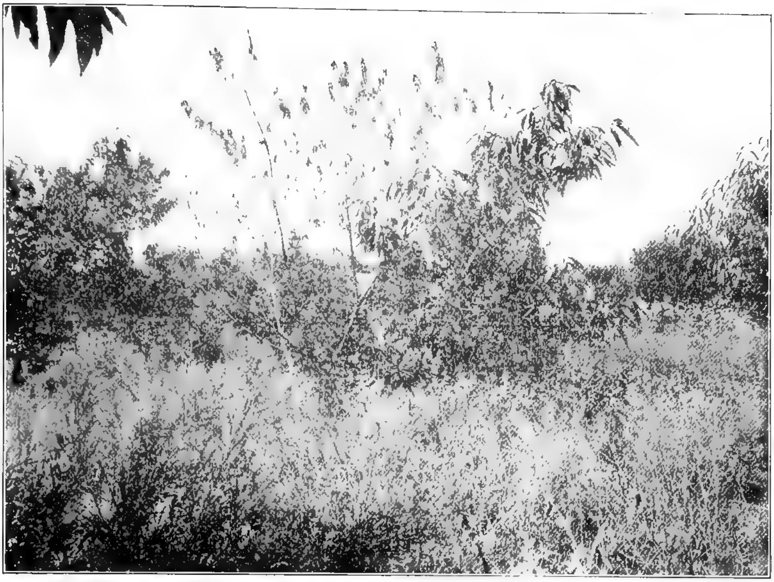


FIG. 3.—A diseased tree in young chestnut orchard. Note dead leaves clinging to branches.

FIG. 4.—An old tree making its final efforts to live. Girdling at a lower point will soon complete its death.

dency to remain on the tree for some time. The burs on infected branches usually remain on the tree during the winter following its girdling.

Diseased trees very frequently produce sprouts or "suckers" in considerable numbers. These may appear on the trunk or near the base of the tree. Such sprouts soon become infected, however, and very few survive more than two or three years.

FIG. 5.—Young tree showing postules on smooth bark, and sprouts. (See also Fig. 11, page 221.)

A closer examination reveals the diseased band near the base of the affected portion. It is especially conspicuous on smooth bark, causing a reddish brown discoloration and producing numerous little pustules which break through the bark and set free vast numbers of spores. These spore masses are orange colored but vary considerably in appearance according to climatic conditions. During warm, moist weather they are especially prominent and sometimes may be seen as long, curly, yellow threads issuing from the pustule (figure 6).

Fig. 6.—A very close view of a diseased portion. Note the summer spores issuing in long twisted strings from some of the pustules.

Such threads are composed of countless numbers of spores held together by some sticky material. Rains dissolve this adhesive material and carry the spores to lower portions of the same tree or to others standing close by.

When a branch is girdled by cutting around it, there is apt to be an enlargement produced just above the wound, and a similar effect is often noted in limbs attacked by this disease. In fact many of the gross symptoms are exactly similar to those which would be produced by mechanical or insect girdling.

If older portions are attacked, the discoloration and pustule formation are not so evident, as most of the pustules are produced in the fissures of the bark. Such bark, when cut through, is found to be discolored and breaks up easily like punk. Tapping upon this bark will usually produce a peculiar dull sound.

The fungus may continue to grow in the dead bark for some time. It was not generally thought to be capable of growth in the wood, but three investigators, Dr. Caroline Rumbold, W. H. Rankin, and J. Franklin Collins, in different sections of the country have reported finding it upon the wood during the past season. (1)

Besides the common so called summer spores mentioned above, the fungus produces another kind known as the perfect or winter spores. These are darker in color and the pustules are less conspicuous. They are most frequently produced during the late fall, and help the fungus to survive any unfavorable weather conditions.

DISTRIBUTION.

As previously stated, this disease threatens the destruciton of all chestnut timber in the Eastern States. At the present time it is known to be present in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsyl-

(1) This statement is taken from unpublished data furnished by the parties mentioned. Rankin gives a detailed description of the fungus growth on wood and reports finding fruiting pustules on wood entirely stripped of its bark and exposed to weathering.

Fig. 7.—A view to show how bark is rotting and cracking.

Fig. 8.—A more advanced stage than fig. 7. Bark peeling off.

vania, Deleware, Maryland, Virginia, West Virginia, and the District of Columbia.

A glance at the map, figure 10, will show how general has been the spread from New York City as a center. In considering this map one should remember that a diseased tree is practically doomed to die. There are numerous diseased areas, especially in Pennsylvania, which have been found since this map was plotted.

FIG. 9.—A view showing complete destruction on young chestnut stand in forest area.

E. R. Hodson, of the U. S. Forest Service, writing of this disease in 1908, says, "In Pennsylvania it is no where abundant yet, although it exists at Easton, South Bethlehem, and Morrisville, and is reported as far north as Pocono Mountains, and as far south now as Philadelphia." In recent correspondence with the Pennsylvania Commission for the investigation and control of this disease, they have sent us a map showing that the area of *general infection* now includes nearly one-half of the state. A similar rapid spread has been recorded in other states and a great united effort should be made to prevent its further progress.

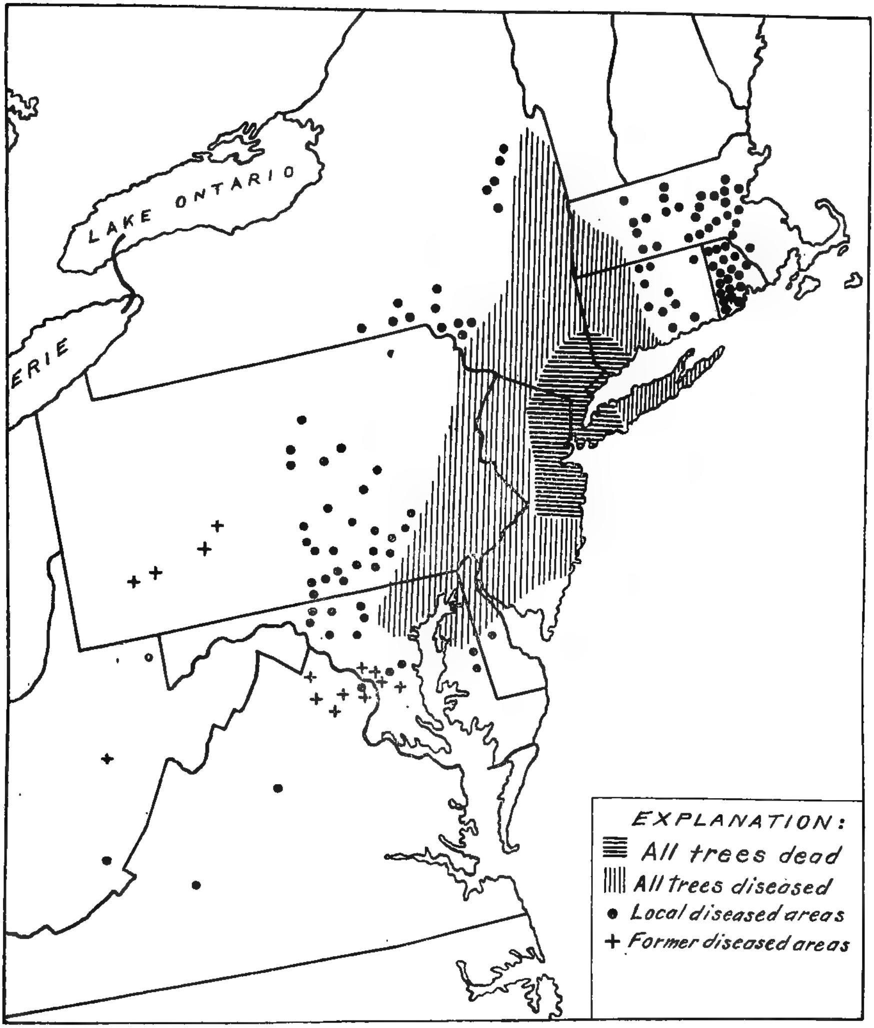


FIG. 10.—Map showing distribution of diseased chestnut. The area of general infection in Pennsylvania is much greater than would be indicated by this map.

Dr. Spaulding, of the U. S. Department of Agriculture, has made careful notes on this disease in the Connecticut Valley during the past three years. In summing up his observations there he states, "There can be no shadow of doubt that in the three years, 1909 to 1911, inclusive, the disease has spread so seriously as to now be beyond hopes of control in the lower Connecticut Valley." (1)

In the case of New Jersey infection is already so general that there is very little hope of saving any chestnut in that state.

Europe is fearful of the disease and Italy has already taken steps to prevent its introduction there.

PREVENTIVE MEASURES.

Numerous experiments have been conducted in the hope of finding some practical method of controlling the chestnut bark disease and some good results have been secured. Those most actively engaged in work along this line at present are the Pennsylvania Chestnut Tree Blight Commission and the Office of Forest Pathology in the U. S. Department of Agriculture.

Spraying appears to be of little value, and, of course, is entirely impractical in forest areas. The method which has finally been adopted aims to prevent the further spread of the disease from the area of general infection and to destroy all diseased trees outside this area. To accomplish the first point, it is essential to establish a line beyond which it will be extremely difficult for the disease to progress. The main, advancing front of the diseased section must come to a point where there are no more chestnut trees within easy range of infection. Large unwooded areas and forest tracts free from chestnut should form as large a part of this boundary line as

(1) From unpublished data furnished by Dr. Spaulding.

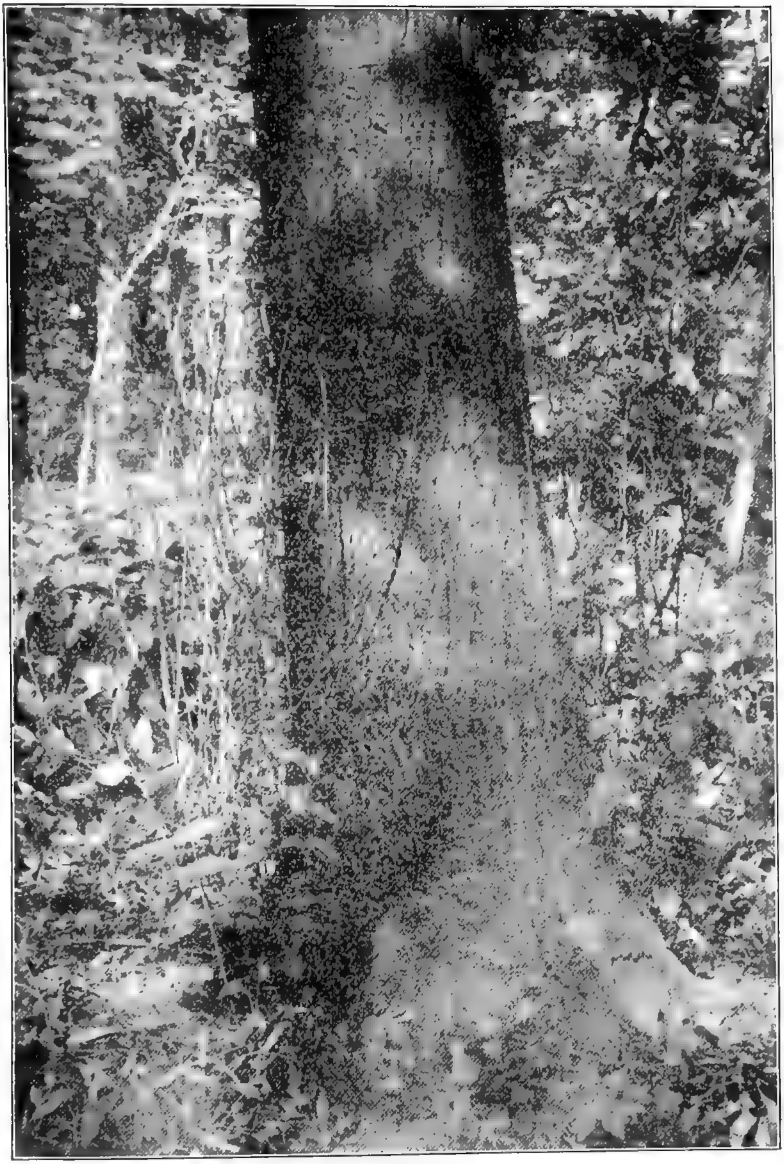


FIG. 11.—Note sprout production around base of this diseased tree.

practicable. In other portions it may be necessary to cut all chestnut trees both healthy and diseased, in a belt some miles wide along the line. The disease is left largely to itself in the area enclosed by this line while careful search is made for all diseased trees outside that area and they are destroyed when found. All chestnut timber in the generally diseased area should be cut and utilized as rapidly as possible but the disease will find itself checked upon reaching a boundry destitute of chestnut,—the same as a forest fire when it comes to a broad river.

In the case of individual trees which are quite valuable it is often possible to prolong their lives or even to save them by careful tree surgery. Diseased twigs and small limbs should be removed. The larger limbs and trunk may be treated by carefully cutting away all diseased bark and into the healthy bark around the edges. A layer of wood should also be removed from beneath this bark and the entire wound painted over with coal tar. The tools used for removing bark and wood should be very sharp, so as to make clean, smooth cuts, and the work must be done with great care and thoroughness, if good results are to be expected.

LEGISLATION.

The control of this disease is a matter which requires prompt action on the part of every state where it has been found. These states are all awakening to a realization of the danger from the Chestnut Bark Disease and Pennsylvania, Virginia, and New York have already taken steps to prevent its further spread. Pennsylvania was the first state to make a definite move along this line. Her legislature passed a bill carrying appropriations of $275,000. for use in investigating and controlling this specific disease. The full title of that act is as follows:

"An act to provide efficient and practical means for the prevention, control and eradication of a disease affecting the chestnut trees, commonly called the chestnut tree blight;

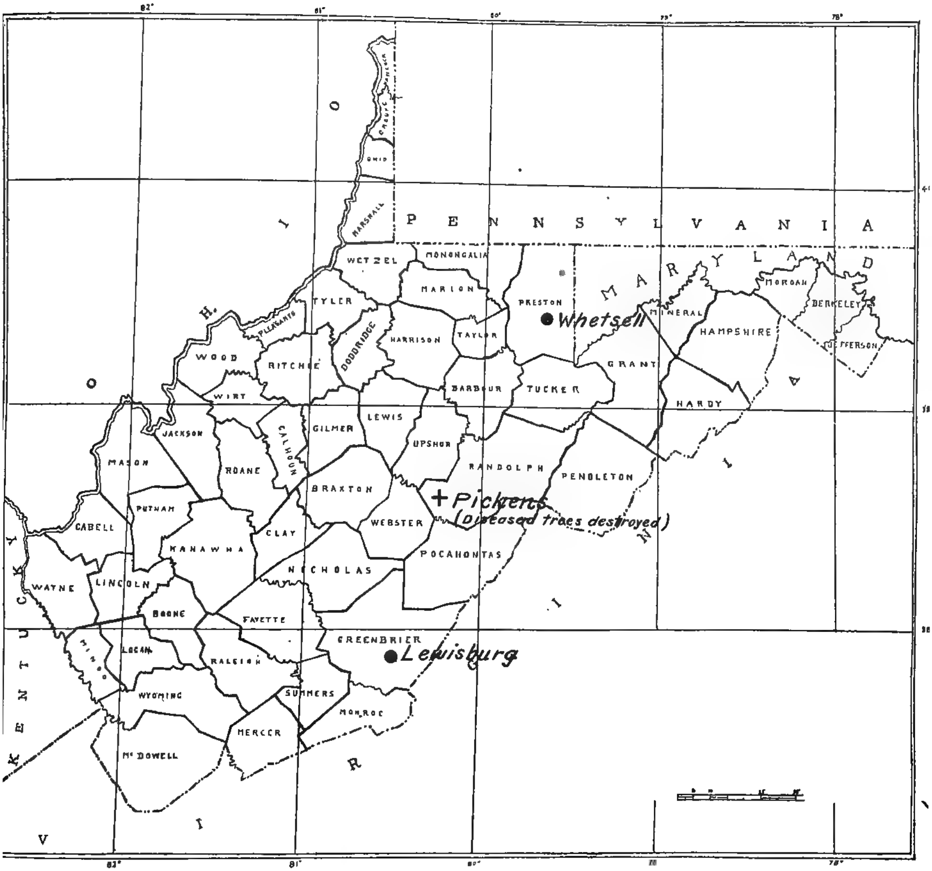


FIG. 12.—Map showing where the disease has been found in West Virginia. The specimen from Whetsell was picked up by a tourist and the one from Lewisburg by a summer visitor. The disease at Pickens was looked up by Mr. A. B. Brooks and the infected tree, which came from a nursery, was destroyed.

providing for the destruction of trees so affected; creating a commission to carry out the purpose of this act; fixing penalties for the violation of the provisions hereof; and making an appropriation therefor".

Soon after the passage of the bill, in June 1911, a commission was appointed. At present they have a well organized staff and are preparing for a tremendous campaign against the disease this coming season. They have accomplished much work of value already, and have had a considerable number of trained men in the field all the time. Space will not permit a detailed discussion of their methods, but they would surely serve as a safe model for any other state.

RECOMMENDATIONS.

Since the disease is known to be present in West Virginia, we owe it to ourselves and to neighboring states to take definite and immediate steps for preventing its further spread.

The disease has been found in a number of chestnut nurseries and in several cases local areas of infection have been directly traced to such diseased stock. Any one contemplating the purchase of chestnut trees from nurseries would do well to correspond with the Agricultural Experiment Station at Morgantown, before securing them. Any such trees should be inspected by competent authorities in this state before being accepted or paid for.

Some careful inspection work should be done in the vicinities of the three local infections already reported for this state and in the northern and north eastern portions of the state during the next season.

The control of this disease is a matter of great economic importance to the State of West Virginia, and deserves the serious consideration and hearty co-operation of every citizen. We would urge that everyone make it a point to take careful note of the condition of any chestnut trees which may come under their observation, especially during the season of 1912. Specimens may be compared with the pictures and descriptions given in this bulletin.

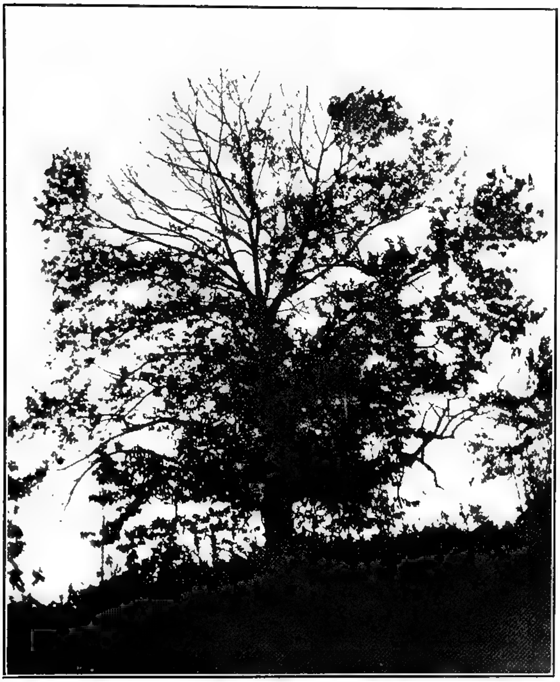
In case there is the least suspicion that a tree is diseased, samples of bark and wood from the girdled portion should be sent to this Station.

We would also be pleased to have correspondence from any one who has made observations which might be of general interest or value, concerning the chestnut or other forest trees of this State.

CONNECTICUT
AGRICULTURAL EXPERIMENT STATION
NEW HAVEN, CONN.

BULLETIN 178, SEPTEMBER, 1913.

THE CHESTNUT BARK DISEASE



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GENERAL DESTRUCTION OF CHESTNUT BY BLIGHT.

THE CHESTNUT BARK DISEASE.

Endothia gyrosa var. *parasitica* (MURR.) CLINT.

By E. M. STODDARD, *Asst. Botanist,*
and A. E. MOSS, *Asst. Forester.*

To the owner of chestnut woodland the vital questions are; What is killing the chestnuts? and, What are the prospects of maintaining the chestnut as a forest tree?

FIG. I. TREES KILLED BY CHESTNUT BLIGHT.

It is the purpose of this bulletin to answer the first question and to give such other information that the reader may have a clearer understanding of the problem and judge for himself what is the best course to pursue under the particular conditions in which his woodlot is situated.

CAUSE OF DISEASE.

First of all, let it be clearly understood that the chestnut blight is caused by a *fungus* and *not* by an *insect*, as is often erroneously supposed. The fact that insects of various kinds are found in the dead bark of an affected tree has often led to the conclusion that the trouble is of insect origin, but such is not the case and insects have no part in causing chestnut blight.

DESCRIPTION.

The chestnut disease is caused by the fungus technically known as *Endothia gyrosa* var. *parasitica*. This fungous parasite pene-

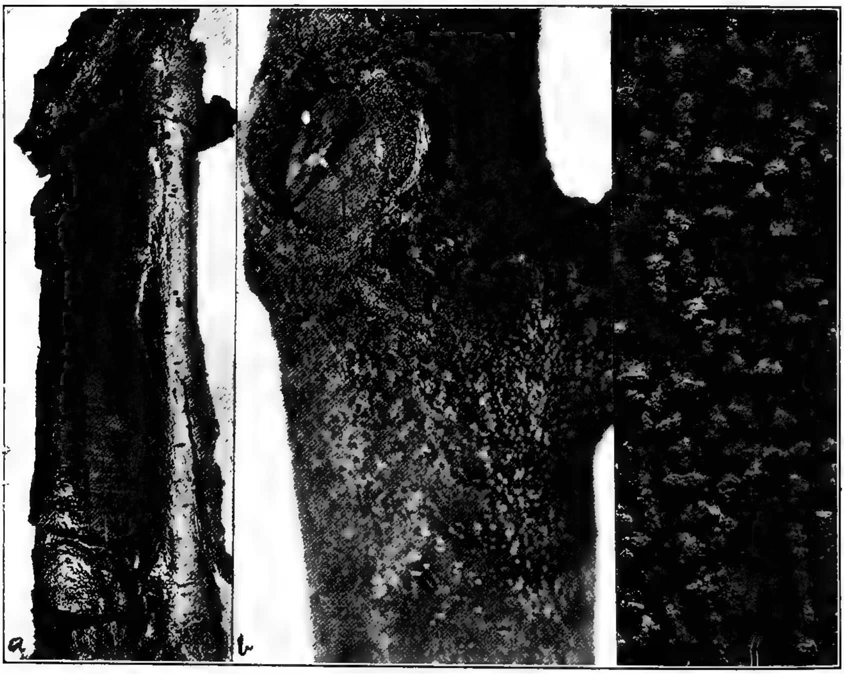

FIG. II. BLIGHT STARTED THROUGH INSECT INJURY (A), AND PRUNED BRANCH (B); C. MATURE FRUITING PUSTULES ON SMOOTH BARK.

trates the bark to the wood of the chestnut tree, killing the invaded tissues, but does not enter into the wood to any appreciable extent nor does it affect directly any part of the tree other than that with which it comes in contact. The tree or branch is killed only when the disease goes completely around it, thus girdling it and stopping the flow of sap to the parts above the infected area.

The mycelium or vegetative part of the fungous plant grows, as has been stated before, in and beneath the bark and the spores are borne in characteristic red-brown or orange-colored pustules. These are seen dotting the surface of the cankers on smooth bark and thickly clustered in the crevices of rough bark. The spores are the bodies by which the organism perpetuates itself and are borne on the fruiting pustules in countless numbers. There are two forms of these spores, one of which is borne in the summer and the other in late fall and winter, both being capable of infecting chestnut trees under the proper condition. So small are the summer spores that 8,000 of them placed end to end equal an inch in length. The chestnut blight fungus does not so far as known injure any other kind of tree nor does it usually attack a tree unless the bark has been injured or the tree is in a weakened condition. It has, however, been found to a very limited extent on a few oaks, but never doing any appreciable injury.

REMEDIES TRIED.

At present there are no sure remedies known for this disease, because the fungus grows wholly within the tree, only its fruiting pustules appearing on the surface, thus making it very difficult to control the disease by spraying even if it were practicable to do spraying in a chestnut forest. Other methods of control have also proved unsuccessful.

Spraying. It has been claimed that spraying with Bordeaux mixture will prevent trees from becoming infected, which it doubtless would if the tree had no wounds in the bark and could be covered completely with the mixture at all seasons of the year. But this is nearly impossible and surely impracticable except perhaps on single trees used for ornamental purposes.

Medication. Injecting various substances into the tree has been tried but with no success, as any substance sufficiently poisonous to kill the blight is injurious to the tree, and furthermore it is difficult to make a tree absorb any very great amount of material injected into it.

Cutting Infected Trees. The removing of all infected trees has been tried but as with the other remedies its success has been only indifferent at the best, as it is hard to find all infected trees when scouting for the disease, and the few not found are sources of new infections. The expense and trouble of destroying infected portions of the tree after cutting makes this method of control out of the question for treating chestnut woodland.

Thus at present we are without any effective method of combating this trouble in the forest and at best are only partly successful with single specimens in a yard or park.

DISSEMINATION OF SPORES.

There are several ways in which the blight may be spread, but from our own observations it would seem that the wind and possibly birds, especially those which hunt for larvæ of insects in the bark, are chiefly responsible. It can be readily seen that when an affected tree is producing countless millions of such minute spores the wind will easily blow them to a considerable distance. This is especially true of the winter spores, which are forcibly ejected from the sacs in which they are borne. These spores lodging in a wound in the bark of a chestnut tree or being washed there by the rain would start a new infection of the disease. As the summer spores are produced in sticky masses, birds may pick them up on their beaks and feet and thus carry them to new localities. Other ways of dissemination are insects and transportation of diseased chestnut wood from one place to another. The fungus often produces spores for one or two years on cut wood especially when the bark has been left, so that diseased wood can be a source of infection for some little time. Rains are very effective in washing spores to various parts of the tree below the infected portion.

PROGRESS OF DISEASE.

While we have not much definite data at hand to show just how fast the disease progresses after attacking a large tree, we have found by inoculating small seedlings and sprouts that these may be entirely girdled in one season, and from general observations on marked trees at Stamford and Middlebury it takes at least two years to kill the tree and probably three or four. Of course how long it takes the blight to kill a tree

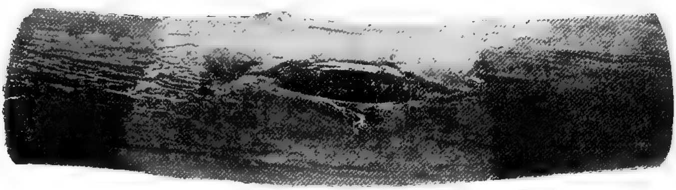

FIG. III. SPROUT WITH DEAD BARK AROUND INOCULATION POINT.

depends on where the tree is attacked. If it is attacked on the small branches these will be killed but the rest of the tree will remain healthy and in a growing condition for a considerable time. On the other hand if the infection is on the main trunk this will be girdled and the entire tree killed in a much shorter time. Certain weather conditions also apparently affect the rate of development of the fungus.

DISTRIBUTION IN CONNECTICUT.

At the present time the chestnut blight is distributed entirely over Connecticut. The accompanying maps show its spread from 1908 to 1912 and also show approximately the varying degrees of damage done in various parts of the state. The trouble is more serious in the southwestern part of the state and west of the Connecticut River. This is probably due to the fact that there is more chestnut in the western half. It was reported

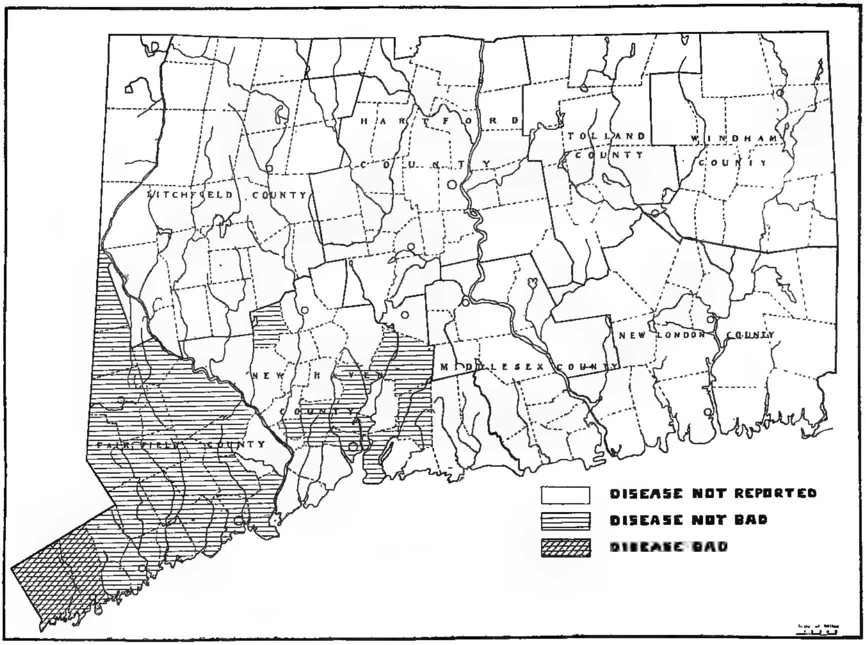

FIG. IV. KNOWN DISTRIBUTION OF CHESTNUT BLIGHT IN 1908.

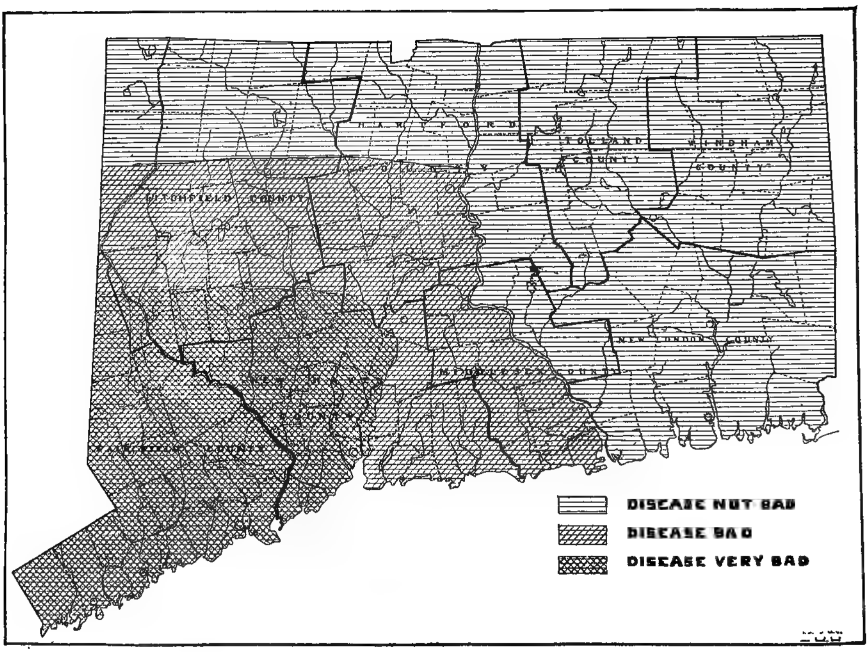

FIG. V. KNOWN DISTRIBUTION OF CHESTNUT BLIGHT IN 1912.

DISTRIBUTION OF CHESTNUT BLIGHT IN CONNECTICUT.

first in the southwestern towns of the state but recent studies of the disease prove that it was present to a greater or less degree in scattered localities throughout the state as early as in these reported towns.

DISTRIBUTION IN THE UNITED STATES.

Chestnut blight is present in Massachusetts along and west of the Connecticut River, in Rhode Island it is scattered and seri-

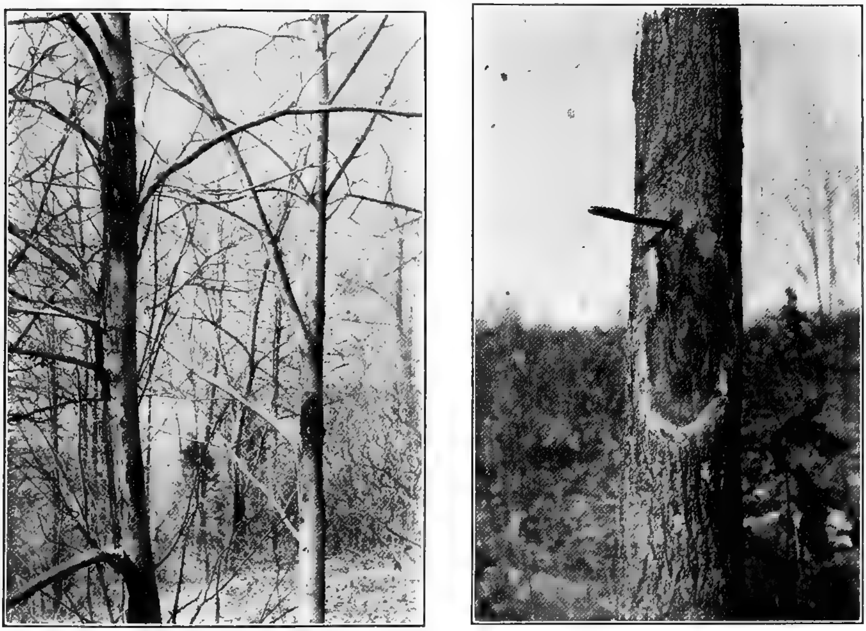

FIG. VI: A–B: CANKERS ON SMOOTH (A) AND ROUGH (B) BARKED TREES.

ous in certain localities, and it has also been reported from Vermont and New Hampshire. In New York it is progressing north along the Hudson River and is present in western Long Island. In New Jersey the chestnut has suffered over the entire state and in Pennsylvania the trouble is serious in the eastern and bad in the southeastern part. The disease occurs generally in Delaware, while Maryland, Virginia and West Virginia have it scatteringly, the points of infection being few and inconspicuous in the latter state. Thus we see that the disease is spread in varying degrees of seriousness over nearly the entire northern territory where chestnut grows.

RELATION TO HOST CONDITIONS.

From our own observation and from the opinions of woodland owners who have watched the spread of the disease it would seem that the dry seasons, which are unfavorable for the growth of the chestnut, have been an important factor in the spread of the disease. It has been found that chestnut growing on dry hill-tops is generally more seriously affected with the blight than that in lower land where there is more moisture. Chestnut growing on dry hillsides has been evidently killed entirely by dry conditions, as no blight could be found on it. Chestnut injured by fire or in other ways is invariably more quickly attacked by this disease and often it is the trunks of these trees which are infected, thus causing the death of the tree much quicker than if the twigs and small branches were attacked.

Instead of the chestnut bark disease being an introduced disease as is thought by some, it seems more probable that it was present in this country, growing inconspicuously on dead and dying trees, and that after the chestnut was weakened by a succession of dry seasons it became an active parasite and attacked and killed living trees.

PRESENT SITUATION AND FUTURE PROSPECTS IN CONNECTICUT.

The present situation in Connecticut is that the disease is still spreading and unless its progress is checked by some natural causes the future prospects are not bright for chestnut in this state. However, instances have been noted where trees were overcoming the disease and blight cankers which had attained a diameter of eighteen inches were healing over, this healing process having been begun in 1911. This condition is not general, but if it is possible for some trees which have had favorable growing conditions to overcome the disease we may expect that if the seasons are such that the trees are able to make a more vigorous growth the disease will decrease in virulence considerably. Of course, predictions as to the final outcome are at best rather uncertain and evidence at hand furnishes arguments for both the optimist and the pessimist, but until the chestnut is nearer extinction than at present, a prediction of ultimate destruction does not seem warranted.

WORK DONE IN CONNECTICUT.

The work done on the chestnut blight in Connecticut by the Experiment Station consists of a survey of the state to determine the extent and seriousness of the disease, and of a thorough inspection of a tract on the state forest in Portland for the purpose of locating and cutting out diseased trees and also a plot where affected trees were located, counted but not cut out. Besides this a large amount of laboratory work has been done to determine various points of scientific interest in regard to the life history and cultural characteristics of the blight fungus.

The survey of the state was made by members of the Botanical and Forestry Departments visiting and locating the disease in all towns from which specimens had not already been received. In this survey no attempt was made to locate definitely all the points of infection in every town, but each town was inspected in a very general way to locate the disease and get an approximate idea of the amount of chestnut.

The work in the Portland forest consists of a thorough inspection of a definite tract in which all infected trees are located, cut out, the brush burned and the infected timber removed and peeled. Such as is not large enough for timber is burned for charcoal nearby. As a check on the results obtained on this tract an adjacent tract is inspected, the trees counted and not cut out, thus showing whether the cutting out has any control on the disease. This has been done for two years and, while the results have so far been negative, this experiment must be carried on for a series of years to arrive at definite conclusions. Besides this inspection a small amount of work has been done in the way of peeling or burning the infected stumps to determine the effect of such treatment on the sprouting of the stumps and on the destruction of the disease. At this writing it is too early to say what the results of this experiment will be. Judging from the time taken to do a small amount of such work it would prove too expensive for the owner of timber land to undertake cutting diseased trees and burning the stumps.

WORK DONE BY OTHER STATES.

The work of studying and combating chestnut blight has been taken up by the various states in various ways and on a larger or smaller scale according to the views of the investigators and

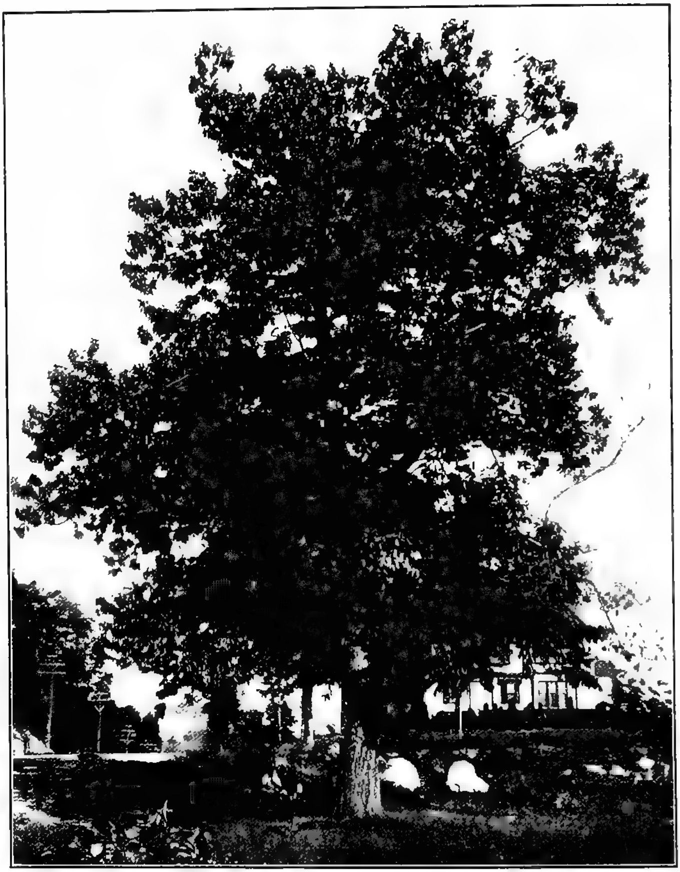

FIG. VII. SMALL BRANCHES ON OPEN GROWN TREE KILLED BY BLIGHT.

to the amounts of money appropriated for the work. Massachusetts has done some work in locating the diseased areas, but nothing in the way of control measures, the same course being followed by Rhode Island. Pennsylvania has expended $275,000 on the study and work of combating the blight. Spraying, cutting out infected trees, medication and tree surgery were tried, and while many experiments of interest have been performed no very definite progress, in our opinion, has been made in discovering successful and practical measures of control.

Maryland, Virginia and West Virginia are expending small sums on locating points of infection with an idea of possibly removing the scattered areas of infection at a later date if the success of such treatment shall seem to warrant it. The chestnut in New Jersey and Delaware has been so nearly destroyed that little work of any kind has been undertaken.

HISTORICAL CONSIDERATION.

The chestnut blight was first noticed in the New York Zoological Park by H. W. Merkel in the summer of 1904. In 1905 it was so serious that measures were taken to control it, and the first description of the trouble was published in the report of the New York Zoological Society for that year. From a botanical standpoint the first work was done by W. A. Murrill of the New York Botanical Garden in 1906. Shortly after Murrill's work the study of the blight was taken up by Clinton of this Station and by Metcalf and Collins of the United States Department of Agriculture. Since then many investigators have become interested in the study of this disease and the opinions and discoveries have been nearly as numerous as the investigators.

RANGE AND CONDITIONS OF GROWTH.

Chestnut ranges from southern New Hampshire south to Georgia and Alabama. Connecticut is near the northern limit of its range, which accounts for the decrease in per cent. of this species toward the northern part of the state and on the cool northern slopes.

It occurs nearly pure on medium to deep well-drained sites, but on the drier ridges and in the swamps it is crowded out of the stand by species better adapted to the conditions. This tree requires direct light and forms a wide spreading tree in the open, while in the forest the demand for light causes increased height growth, forming a clear full-boled tree. Chestnut sprouts very abundantly, even when the tree cut is 100 years or more in age. The nuts are largely eaten, but a few are scattered by the birds and animals which accounts for the numerous seedling trees to be seen in abandoned fields. The sprout tree grows much more rapidly in youth but the seed tree will often overtake and pass it in forty-five or fifty years.

Chestnut forms the larger part of the stand in the southern counties of the state but decreases in the northern portion, where white pine is more abundant. East of the Connecticut River it does not form as large a percentage of the stand as in the

FIG. VIII. PURE STAND OF CHESTNUT.

western part of the state. It usually occurs in pure stands or mixed with oak, tulip, and other hardwoods.

CHARACTER OF WOOD AND UTILIZATION.

Its wood is durable in contact with the soil and has been largely used in the form of posts, ties, and other products which are exposed to the weather. The stands in the northern portion of the state have been coaled a number of times to furnish charcoal for the iron mines which have been in operation there since colonial days. The wood is soft and easy to cut, and when dry burns with a steady heat leaving little ash, which fact has resulted in the use of this species to the almost total exclusion of the hard woods in the brass industry. The brickyards and the lime kilns also use it when it can be obtained. These numerous uses for the smaller products, such as cordwood, have resulted in large areas of sprout forests under 30 years of age, in which the percentage of chestnut has been on the increase, due to the great vigor with which the stumps sprout. In those sections of the state where the market for cordwood is not as good, the stands are usually left until pole or tie size. Here the percentage of seedling trees is slightly greater, due to the increased seed production of the more mature trees. These stands, as a whole, are mixed with a greater variety of species and are in a better condition to withstand the spread of the chestnut blight, as there are in many cases enough trees of other species to continue the stand even if the chestnut is entirely removed. There are very few stands in the state in which the trees are of a size to make lumber. This is largely due to the ready market for ties and poles, but it is also due to the fact that in a sprout stand the trees begin to deteriorate after it reaches the age of fifty to sixty years.

Native chestnut is the wood most used in this section for ties and poles. Chestnut and red cedar are most commonly used for posts. Chestnut is used for timbers in the construction of a large number of buildings, especially on the farm where the owner has his own wood lot. When the tree is large enough to saw, the planks are commonly used in the wooden bridges to be found throughout the state. The boards are used as rough siding and to a limited extent in the manufacture of boxes, but this use is limited by the weight of the lumber. As an interior finish, this wood is coming into favor, but up to the present time the southern lumber is preferred because of better milling and closer grading. Chestnut is used in furniture as the core for veneering.

MILL PRACTICE.

The chestnut of this state is milled by small portable outfits which have a daily capacity of five to fifteen thousand feet per day. The timber holdings are small and a mill has to make frequent moves which tends to make the owner careless in setting up, with the result that there is a tendency to produce lumber of varying thickness. The mills have circular, inserted tooth saws which cut out a 9-32 inch kerf, which means a loss of one board in four. This is probably unavoidable as the stands of timber are so small that any other form of mill is out of the question, but the unnecessary loss due to the saw not lining up or the teeth not being in good shape is avoidable. Where the stand is being cut for ties the felling crews cut the logs into tie lengths, and the sawyer does not save the boards that the cut may contain above the tie contents, as there is little demand for eight-foot boards. If the logs were cut in two tie lengths, this question of the short board would be avoided and a merchantable product obtained in place of a thick slab.

The sale of a stand by the thousand feet is undesirable since there is then a tendency on the part of the operator to cut as rapidly as possible, and not to get the maximum amount out of each log. There is a lack of appreciation of the loss from the cutting of high stumps and leaving merchantable material in the tops. If the stump is six inches too high, the loss in the average tree is from one to two per cent. and it is the best timber in the tree which is wasted.

RECOMMENDATIONS.

Cutting a stand of chestnut simply because there are a few diseased trees scattered through it is to be avoided if possible. The stand should be watched and when the loss from the disease is greater than the increase by growth the stand should be cut. The value of the timber is steadily increasing so long as it is growing thriftily, and it is good policy to hold a stand as long as possible, to get the greatest possible growth and this increase in value. A tree killed by the blight is still merchantable, as the timber is not affected so far as can be determined by test.

The owner of a timber lot should cut out the diseased trees, not so much to prevent the spread of the infection as to save the material already grown. In cutting a stand it is advisable to leave species other than chestnut so that there may be some reproduction by seed to take the place of the chestnut if it does not recover sufficiently to sprout.

In a pure chestnut stand where the infection is bad, clearing of brush and planting with pine is the best method for keeping the area in forest.

SUMMARY.

1. The chestnut blight is caused by the parasitic fungus Endothia gyrosa var. parasitica and not by an insect.

2. The chestnut bark disease is slowly and surely killing the chestnut in Connecticut, and will continue to do so unless stopped by natural causes or some effective remedy can be found.

3. All methods of control that have been tried have proven only partially successful and are not practical for use in woodland.

4. It is believed that dry weather conditions have weakened the tree and enabled a native fungus to become an active parasite and that the disease has not been introduced from a foreign country.

5. If individual infected trees are cut and the bark and brush burned on the stumps, the spread of the disease may be checked, but experiments show that in most cases the surrounding trees are already infected, and the disease is only temporarily checked.

6. The presence of the disease in the stand in itself is not sufficient reason for cutting. Unless the trees are mature and the market condition is good, it is better to give the uninfected trees a chance to get all the growth possible, especially where the presence of the blight has only just become apparent.

For a more detailed report on this subject the reader is referred to the Report of the Botanist, Connecticut Agricultural Experiment Station, 1911-1912.

State of Connecticut

REPORT

OF

The Connecticut Agricultural Experiment Station

NEW HAVEN, CONN.

REPORT OF THE STATION BOTANIST, 1911-1912

G. P. CLINTON, Sc.D.

BEING PART V OF THE ANNUAL REPORT OF 1912

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CONNECTICUT AGRICULTURAL EXPERIMENT STATION

REPORT OF THE BOTANIST

1911 and 1912

G. P. CLINTON, Sc.D.

ISSUED MAY, 1913

PART V.

REPORT OF THE BOTANIST FOR 1911 AND 1912.

G. P. CLINTON.

I. NOTES ON PLANT DISEASES OF CONNECTICUT.

A. DISEASES PREVALENT IN 1911 AND 1912.

Weather Conditions in 1911. The winter of 1910-11 was rather open, with very little extremely cold weather. Snow was not abundant, and the little that fell did not cover the ground long. During January and February there were a number of rainy days. As this moist, warm weather was not followed by a sudden cold snap, comparatively little winter injury resulted.

There were two late frosts during the first week of May that injured some of the fruit blossoms, especially cherry and certain varieties of apple, also tomatoes that had been set out early, but on the whole the injury was not extensive. In case of the apples, the pistils were frequently the only part of the blossoms hurt. Some of the very young leaves were also injured, causing them to have a stunted appearance, with the epidermis loosened, in a wrinkled irregular fashion, from the apparently thickened tissues beneath. The spring, on the whole, was rather dry and warm.

June and July were extremely dry, with very hot periods in the latter month, causing an unusual scald of apples and, to a less extent, of peaches. Gooseberries were even baked on the bushes. This drought, perhaps the worst of those that have occurred during the last five years, was extremely hard on vegetation in general, and especially so on certain market garden crops and on trees that had suffered previously from drought and winter injury. Hail during the summer caused some damage to tobacco and apples in certain restricted localities. From the middle of August on, the moisture was sufficient for most plants, though it could not overcome the previous ill effects of the drought on some crops. An early frost, coming about September 13, cut the season rather short, and caused considerable injury to corn and late tobacco.

Diseases Prevalent in 1911. On account of the comparatively dry spring and very dry early summer, fungous diseases were not prominent, especially those that get their start in the spring. Among the more prominent may be mentioned the following: Sun Scorch, Sooty Blotch and Speck Rots (due chiefly to Black Rot and Fruit Speck) of apple; Scab of beets, prominent in the vicinity of Norfolk; Leaf Spot of celery; Black Knot of cherry and plum; Bark Disease of chestnuts, especially bad, apparently because of drought injury to the trees; Anthracnose of cucumber and muskmelon, and also Leaf Mold of the latter host; Leaf Scorch of hemlock, etc.; Bacterial Blight of pear; Tip Burn of potatoes; Mildew of rose; Calico and Pole Burn of tobacco.

On the other hand, certain diseases were less conspicuous than usual, and in some cases not seen at all. Among these were: Rust and Scab of apple, less prominent than usual because of the comparatively dry spring; Rust of asparagus, not uncommon at the end of the season, but late in starting, and so not especially injurious; Anthracnose of string beans, apparently quite inconspicuous; Mildew of Lima beans, not found at all; Brown Rot, causing little injury to cherry and plum, and not so much as usual to peaches; Leaf Curl of peach, comparatively inconspicuous; Scab of pear, very much less than usual, even on susceptible varieties; Late Blight of potatoes, entirely absent except in the northwestern part of the State, where it caused a little rot of the tubers; Rust of quince, less prominent than usual.

Weather Conditions in 1912. The year 1912 presented weather conditions rather different from those of the preceding year. In the first place, the winter was unusually severe, some of the coldest weather for years being recorded during January. As this followed much warm weather in December, it killed a good many fruit buds, particularly peaches, so that this crop was quite light, especially inland. This cold also produced some injury to the wood of peach trees, but not nearly so much as in some of the preceding severe winters.

The spring was very wet in April and May, and as considerable rain had soaked into the ground during the winter, this largely replenished the supply greatly depleted by the drought of 1911. This wet spring put back the earlier crops considerably, and late frosts about the middle of June added further to their troubles. These frosts injured garden crops considerably, and even killed the leaves of certain trees in the northern part of the State. The wet spring, however, favored forage crops as a whole.

June and July (to the middle), however, showed another long drought period, but this was not so hot as that of the preceding year, and because of the supply of water in the ground, the deep-rooted crops did not suffer much. From the middle of July on, while some localities suffered from lack of rain, most of them had enough scattered rains to mature the crops in good shape, except potatoes, and, in some cases, onions.

Another factor that made the season a favorable one for vegetation in general was the very late appearance of the fall frosts. While very slight frosts occurred the last of September and the first of October, these only partially killed the most tender plants, as melons, etc. The first heavy frost did not occur until November 2, thus giving in the end an unusually long growing season despite the late spring. On the whole, the season was much more favorable to vegetation than the preceding one. Peach trees showed the best foliage conditions for some years.

Diseases Prevalent in 1912. Fungous diseases were more prominent this year than the preceding, especially those that developed into prominence because of the wet spring. Among those occurring abundantly may be mentioned the following: Black Rot of apple, on the foliage, and Rust and Scab on the same host, especially the former, were abundant. The Cedar Apple, *Gymnosporangium macropus,* Plate XVIII c, which is the III stage from which the apple rust develops, was also unusually common in the spring, thus accounting for the abundance of the apple rust which followed later.

Rust of white ash, *Æcidium Fraxini,* was also very common, being sent in for identification from a number of localities, especially along the shore. It was prominent there because the III, or mature stage, of this rust occurs on marsh grass, Spartina sps., which is common along the shore. The appearance of the I stage on the ash is shown in Plate XVII a.

Orange Rust of blackberry, etc., was more common than usual, as was also the Anthracnose of cherry. Sun Scorch and Black Spot of maple were not uncommon. The Bark Disease of chestnut, on the other hand, seems to have been set back somewhat by the moisture conditions more favorable to its host, since a number of observers reported fewer infections, and old cankers with less vigorous development than in the preceding year. Bacterial Rot of cabbage did some damage in certain fields, and will be described later in this report. Anthracnose of currants caused considerable harm by premature defoliation.

Leaf Spots of horse-chestnut and Boston ivy were more conspicuous than usual. Leaf Mold of melons caused considerable injury, so that the sprayed vines did much better than those unsprayed. Leaf Curl of peach was more conspicuous by far than we have ever seen it, due to the favorable wet spring; and Scab was also conspicuous. Brown Rot, on the other hand, did comparatively little harm except to certain early varieties like the Champion. This was due in part to the light crop, and in part to the rather dry weather at harvest time. The Bacterial Blight of pear and quince and the Rust of the latter host were more prevalent than usual, though not very serious. Early Blight of potatoes developed somewhat, and there was considerable Tip Burn, but little or no Late Blight. There were a few complaints of Yellows of raspberry and Mildew of rose.

Beside the preceding, there were reported during the two years a number of new or unusual troubles which we shall describe more in detail under the following heads:

B. DISEASES OR HOSTS NOT PREVIOUSLY REPORTED.

APPLE, *Pyrus Malus.*

RUST, ORANGE, *Rœstelia aurantiaca* Pk. We have already reported two other species of rusts on the leaves and fruit of apple, but this is the first species we have seen occurring on the stems. This, however, is rather characteristic of the present species, as we have found it on other hosts, the quince and Cratægus, not uncommon on the twigs. It was sent to the Station from two different localities during the past season, but evidently is not very common on the apple, as we have never collected it ourselves on this host. It forms fusiform swellings on the twigs, and in these the fragile, white peridia, or fruiting cups, develop, and upon opening disclose a mass of bright orange-colored spores that by their color and microscopic characters are easily distinguished from the other two species previously reported. One of the specimens sent in the late fall showed the young twig swollen and still alive, while the fruiting pustules had not yet developed. This indicated that the twig might live over the winter and develop this stage the following spring. Ordinarily these swellings develop their fruiting bodies, and then are gradually killed by the fungus, so that the next season no further development occurs on them or on the uninjured portion of the twig below, thus showing that the fungus is not perennial on the host. The III, or Gymnosporangium, stage of the fungus occurs on both the red cedar and the common juniper in spring, and is spread from these to its alternate rosaceous hosts, among which, besides those already mentioned, is the Juneberry.

BANANA, *Musa sapientum.*

ANTHRACNOSE, *Glœosporium musarum* Cke. & Mass. This fungus is not uncommonly found on bananas in our markets. It causes a blackening and dry decay of the skin. Eventually the fruiting stage shows as small, pinkish, more or less numerous exudations. If kept in a moist chamber, these become much more prominent. Cultures are easily obtained, and these produce only the conidial stage. As these cultures differ somewhat in appearance from those of the bitter rot of apple, and never with us have developed any asco-stage, we believe Shear is correct in considering it a distinct species. It is doubtful if *Myxosporium Musae* B. & C. (Grev. 3: 13), later issued by Ellis and Everhart (N. A. F. n. 2672) as *Glœosporium Musae,* is different, if we judge by the Ellis specimen, though the original description gives the spores as somewhat smaller than in the species under consideration here.

CABBAGE, *Brassica oleracea.*

BLACK BACTERIAL ROT, *Pseudomonas campestris* (Pamm.) Smith. Pl. XX a-b. This disease occurs on a number of related cruciferous plants, but we have reported it from this state before only on cauliflower. While we did not see it on cabbage until last season, it seems quite probable that it has caused more or less harm to this host before, since it has been reported as quite injurious in several other Eastern states in times past. The trouble was called to our attention last year by a request, late in September, from H. B. Cornwall of Meriden to visit his farm and see what was the matter with his cabbages. Inspection showed that the trouble, which was quite serious, was this bacterial disease. Although Mr. Cornwall had grown cabbage for some years, this was the first time that he had noticed trouble of this sort.

From what we could learn from Mr. Cornwall, the disease apparently started in his cabbage from the seed of Danish Bald Head, which was imported. This variety was by far the most infected, and in looking over the old seedbed, we found several stunted seedlings of this variety that showed the disease. Mr. Cornwall also gave some of the young plants to several of his neighbors, and an examination of their fields showed the disease on this variety, but not usually on the others.

Mr. Cornwall did not notice the trouble until about the middle of September, when, following a spell of muggy weather, this variety began to go down rapidly. Several other varieties, such as Copenhagen Market, Flat Dutch, and Savoy, showed little or none of the disease, although close to the Danish Bald Head. This probably means that the disease was not present in their seedlings, and that it spread to them later from the infected Danish Bald Head when the latter became badly infected. But of course it might also mean that these varieties were not so susceptible to the disease. The cabbage was on new land, and the plants were all from new seed beds. Part of the land had manure on it, and part had not, but this did not seem to make any difference. The Danish Bald Head first set out showed the trouble worse than those planted later.

This disease is recognized by the blackened veins of the leaves, Plate XX b, where the bacteria develop chiefly, and in time extend down into the head. The leaf tissues finally turn yellow, and the leaves are easily pulled off. Soft rot, caused in part by other organisms, often loosens them at the base, and develops an ill-smelling internal decay, XX a. The bacteria gain entrance through drops of water at the water pores on the margins of the leaves.

As the germs of this disease can be carried on the seed, as determined by Harding and Stewart, it is wise to see that the seed used does not come from a diseased crop. If doubt exists, it is well to treat the seed with formalin, 1-240, or corrosive sublimate, 1-1000, for fifteen minutes, as recommended by the investigators just mentioned. Likewise, if the disease shows up in a seedbed, this should be changed the next year. If bad in the field, this land should not be used for cruciferous crops for several seasons, and even if the disease is not present, yearly rotation is desirable where it can be carried on without especial difficulty. Refuse from diseased cabbages should never find its way to the manure pile.

CURRANT, BLACK, *Ribes nigrum*.

PINE-CURRANT RUST, *Cronartium ribicola* Waldh. Plate XVII b-c. In our last report, 1909-10, p. 730, we noted the finding of a few specimens of the peridial stage of this fungus, known as *Peridermium Strobi* Kleb., on recently imported white pine seedlings in several plantations in the state. These pines all came from one firm in Germany. In April, 1912, Mr. Walden, while inspecting imported nursery stock in one of the nurseries of the state, found in a shipment of three-year-old white pine seedlings, purchased from Schaum and Van Tol of Oudenbosch, Holland, at least 185 that showed the characteristic swellings or fruiting stage of this blister rust (see illustrations). The whole shipment was destroyed in consequence of this finding. Since then the United States Government has placed a quarantine on the importation of white pines into this country from any of the European countries where this disease is known to exist. Since our inspection of the plantations previously mentioned, no other examples of this rust have come to our attention, and, so far as we know, it does not exist to-day in this state.

The II and III stages of this rust occur on species of the genus Ribes, which includes our currants and gooseberries. Although occasional outbreaks of the rust on currant had been reported at Geneva, N. Y., we had never found it in this state. In 1912 Stewart, of the Geneva, N. Y., Station, reported another of these outbreaks, and later Stone, of the Amherst Station, found the disease in Massachusetts. The black currant seems to be by far the most susceptible of any of the varieties to this disease. On learning of the outbreak at Geneva, we kept watch for this rust in Connecticut, and early in October received leaves of black currants from H. B. Birdsey of Meriden which showed the III stage of the fungus. These currants, originally obtained from outside the state, had been planted in his garden about eight years, but he had not noticed this trouble before, though it may have escaped his attention. This year he noticed it because of the premature defoliation of the currants.

After locating this rust at Meriden, we visited several nurseries, and inspected their currants to see if it occurred there. We also wrote to all the nurseries in the state handling black currants, and requested them to look for the disease on the fallen leaves, as it was then late in the season, and to send us any suspicious ones. We were not able, however, to locate the rust in any of these nurseries. As black currants are not handled to any extent by our nurserymen, it is not likely that the disease occurs with them.

There are no white pines in the immediate vicinity of the rusted currants in Meriden, and Stewart has never found the peridial stage on the white pine at Geneva. This makes it look as if the rust might carry over on the currants in some way without the aid of this stage for reïnfection in the spring. In connection with Stewart and Stone, we have started, in the greenhouse, black currants that were last year badly infected, to see if the rust will again appear on them without the aid of the peridial stage. These plants were brought into the greenhouse in February, 1913, and at this writing, April 15th, although in full leaf, they had as yet shown no signs of the rust. From this it appears as if the fungus did not (at least commonly) carry over on the currants. Possibly we have not learned all about the life history of this fungus.

EVERGREENS, *Various Species.*

DAMPENING-OFF, *Rhizoctonia* sp. During the past year complaints were received of dampening-off in coniferous seed-beds. At the Station trouble of this kind was also noticed, especially among the white pines. A superficial examination of these plants, which lop over on the ground and finally rot off at the surface, showed no conspicuous growth of any fungus, but upon microscopic examination, especially after keeping the plants in a moist chamber, the characteristic mycelium of this fungus could be found in more or less abundance. Cultures were readily obtained, and while these looked very similar to those of the potato Rhizoctonia, we are not sure whether they are identical. It seems, however, to be the same thing that causes dampening-off of a variety of plants in seed-beds and greenhouses.

This same fungus was also found dampening off coniferous seedlings in the Elm City Nursery, especially those of the yew, *Taxus cuspidata.* Those in charge stated that it was almost impossible to grow seedlings of this species, as it seems to be particularly subject to this injury. They found that if, as soon as the trouble appeared, they sprayed the ground around the affected plants with Bordeaux mixture, and repeated the spraying when necessary, they could save a fair percentage of the seedlings.

Sun Scorch. This may perhaps be considered a combination of winter injury and sun scorch. Various evergreens, especially hemlock, suffered severely from this widespread trouble in the early spring of 1911. While in most cases merely the leaves were killed in greater or less numbers, yet when this injury was severe enough the plants themselves died as a result of the severe defoliation that followed. Often only the outer ends of the leaves were killed, turning a reddish-brown in contrast with the green of the uninjured portion.

The trouble was probably due to unusually warm weather in March and April, starting evaporation from the leaves while the roots were still frozen in the ground and unable to readily replace this loss. Possibly part of the trouble may have been caused by the warm, moist weather in January and February and the subsequent colder weather. Plants recently re-planted suffered more than those well rooted.

HOPS, *Humulus japonicus.*

Powdery Mildew, *Sphærotheca Humuli* (DC.) Burr. This fungus forms a whitish, powdery growth on the leaves and stems with a mature fruiting stage showing as very small, blackish, crowded specks, chiefly on the under side of the leaves. It was found rather conspicuously in the fall on the variegated variety of the Japanese hop, cultivated for ornament in the writer's yard, and caused premature death of the foliage. While this mildew has been responsible for considerable damage in the hop districts of Europe in times past, it has only recently been complained of in the hop districts of New York State. Blodgett reports that dusting the plants with sulphur is a rather satisfactory method of controlling the trouble there.

JUNIPER, CHINESE, *Juniperus chinensis.*

RUST, *Gymnosporangium japonicum* Syd. Plate XVIII d. The last of March, 1911, Mr. Walden, while inspecting importations from Japan at the Elm City Nursery, found on the above host, specially on the form known as *compacta,* an unusual rust on both stems and leaves. On a seedling of this same species, called *J. virginalis,* this same rust was also found, but only on the leaves. Altogether, 55 plants were found that had the outbreaks on the stems, and these were all destroyed. Those showing the rust only on the leaves were ordered planted in an isolated place, and an examination of them the next spring revealed no signs of the fungus. A few days after Mr. Walden found these infected specimens, he discovered others in an importation, also from Japan, of the Stephen Hoyt's Sons Nursery Company. In this case 49 plants showing the rust on the stems were destroyed. The writer determined both these collections to be the telial, or III, stage of *Gymnosporangium japonicum* Syd., which until this time had not been reported in America.

An examination of Plate XVIII c-d shows that this rust is quite different from our common red cedar rust, though apparently it is not so different from some of the other species reported from this country, especially *G. effusum.* This fungus has been well described by Shirai in Zeitschr. für Pflanzenk. 10, pp. 1-5, and he determined that the I stage is *Ræstelia koreænsis,* which is more or less injurious to the foliage of pears; and can also infect apples and quinces, in Japan.

The gelatinous swellings of the fungus evidently developed on the infected trees in transit, though they appear in Japan a little earlier than in this country. These are the fruiting bodies, or sori, and are 3-5 mm. high, more or less flattened or tongue-shaped, and run together on the stems, as shown in the illustration. On the leaves they are smaller, more isolated, more nearly conical, with one to three on a leaf. An examination of the sori showed that they contained two types of spores,—one type long, pointed, thin-walled, chiefly in the interior of the sorus, and the other smaller, thicker-walled, with round apices, less abundant, and chiefly on the exterior. Those on the leaves are as a rule smaller than those on the stem. Shirai found that insects, especially bees, were important factors in carrying the sporidia of the germinating teleutospores in these sori to the alternate rosaceous hosts.

This rust is probably perennial in the stems of the juniper, or else it takes two years for the sori to develop after infection. A juniper, which was badly rusted at the time of their discovery, was potted and placed in our greenhouse, where it has remained for two years. After the disappearance of the sori in the spring, the plant showed no signs of the rust that year or the next, but the spring following it again broke out in a different part of the stem, but not so conspicuously. Just how serious this rust might prove in its I stage on our pomaceous fruits, if it got started here, we do not know, but they certainly already have enough similar troubles.

KAFFIR CORN, *Sorghum vulgare* var.

Grain Smut, *Sphacelotheca Sorghi* (Lk.) Clint. We have reported this smut before on sorghum and broom corn. In September, 1911, we found it not only on these hosts, but also on Red Kaffir corn grown at the Experiment Station farm for experimental purposes. None of these hosts are of commercial importance in this state, so the smut is not of economic importance here, though often serious elsewhere. It changes the seeds into kernels filled with a dusty mass of brownish-black spores.

PEACH, *Prunus Persica.*

Stem Canker, *Phoma Persicæ* Sacc. This fungus has been reported previously in this country by Selby of Ohio (Ohio Exp. Stat. Bull. 92: 233. 1898. *Ibid.* 214: 423. 1910), who called it Constriction Disease of Stem, or Stem Blight. He reported it doing considerable injury in one lot of heeled-in nursery stock, and he also found occasional specimens in orchards. Selby has not since found that this was a serious trouble in his state, and apparently the pruning off of the diseased branches is the only treatment necessary. From what we have seen of it in Connecticut we do not consider it a disease likely to prove troublesome here. Apparently it develops best on trees in a weakened condition.

It was first found in Connecticut in October, 1911, by Dr. Britton, while inspecting one-year-old seedlings in one of the nurseries, and later the same nursery company sent the writer specimens, writing as follows: "We are sending you under separate cover some samples of peach twigs. These were sent us by a customer of ours in New York State. We think he planted these trees last spring, and he says that he has quite a few where the wood is black in the center and the foliage is turning yellow and the edges of the leaves have been looking bad since July 15th."

An examination of both sets of specimens showed the fruiting stage of the Phoma fungus present. The twigs were partially or completely encircled by a depressed band of dead bark of varying width. This injury does not immediately kill the parts above, as the wood there often forms a greater growth than that below the cankers, giving rise to a slight swelling, though eventually the parts above are killed. The leaves turn yellow, and finally drop off. Cutting through the wood, we found a dark streak next the cambium, below the canker, but above it this was covered by the subsequent growth of the wood which formed the swelling. The stems were brittle and easily broken off at these areas. The fruiting pustules of the fungus show as small, more or less abundant, black specks. From these there ooze out the hyaline, oblong to broadly oval spores, which are round at the ends, sometimes slightly curved, and 7-10 μ long by 3-3.5 μ wide.

PINES, *Pinus* sps.

PINE-? SOLIDAGO RUST, *Peridermium delicatulum* A. & K. Plate XVIII a-b. Late in June, 1912, while examining the leaves of *Pinus rigida* at Granby for *Peridermium acicolum,* we not only found specimens of that rust, but also ran across specimens of another leaf rust on the same host, which was entirely different and had never been collected before in the state. This rust we determined to be *Peridermium delicatulum,* and Kern, to whom we sent specimens, verified our determination, and kindly sent specimens of the type for comparison. This rust was originally described in 1906 by Arthur and Kern (Bull. Torr. Bot. Club 33: 412) from Florida on leaves of Pinus sp., and apparently had not been collected since.

The illustration shows very well some of the macroscopic differences between this species and our more common *Peridermium acicolum.* These differences are as follows: (1) The peridia of *P. delicatulum* are very inconspicuous, being deeply embedded in, and standing very slightly above, the leaf tissues, and open by a long slit; while those of *P. acicolum* stand up prominently, 1-3 mm. above the surface of the leaf, and frequently remain as white, tongue-shaped elevations after the spores are shed. (2) The fresh spore-masses of the first species are less dusty, and are crimson, as compared with the orange-colored sori of the other species. (3) Microscopically the spores are smaller (18-29μ x 17-21μ, subspherical or cuboidal to ovoid), and with minute verruculations, while the spores of *P. acicolum* are covered with coarse, scale-like tubercles.

From observations made at the time, though not proved by inoculation experiments, it seems very probable that *P. delicatulum* has, like *P. acicolum,* its III stage as a Coleosporium on Solidago. Immediately under and close to the branch of *Pinus rigida* bearing the *P. delicatulum* was found a specimen of *Solidago graminifolia* var. *Nuttallii* containing the II stage of an undetermined Coleosporium. The spores of this were very similar in color and in fine verruculations to those of *Peridermium delicatulum* on the pine, just as are those of the II stage of *Coleosporium Solidaginis* on *Solidago rugosa* similar in color and coarse tubercles to those of its peridial stage, *P. acicolum.* We have reported before that the spores of all the specimens on Solidago, etc., of the II stage of so-called *Coleosporium Solidaginis* were not alike, and an examination of specimens on *Solidago graminifolia* var. *Nuttallii* already in the herbarium showed that these had the fine verruculations of this new species. It is hoped that we shall be able later by inoculation experiments to fully determine this species on the goldenrod and connect it with the suspected stage on pine.

Pine-Sweet Fern Rust, *Peridermium pyriforme* Pk. We have already reported this fungus (which has its II and III stages on sweet fern, known as *Cronartium Comptoniae* Arth.) on *Pinus sylvestris, P. rigida, P. austriaca,* and *P. maritima,* from the Station forestry plantation at Rainbow. In May, 1911, Forester Spring found it there on *P. ponderosa,* and in May, 1912, Forester Filley and the writer found it on this host and *P. montana,* both hosts new, at least to this state. This makes six different species of pine on which we have now found this Peridermium.

Stem Canker, ? *Phoma* sp. Plate XIX a. Several times we have had young specimens of white pine brought to us by foresters showing the base encircled by a dead sunken area, as shown in the illustration. Occasionally we have found the Phoma fruiting slightly on these dead areas, and at least in one case, we obtained this fungus in cultures from the specimens. We are not sure as yet whether this fungus is responsible for the trouble or whether it merely follows winter and drought injury. Some of the specimens have the aspect of being quite parasitic.

We have seen no notice of a Phoma canker of white pine in this country, but Tubeuf, in his Diseases of Plants, mentions two species of Phoma in Europe that attack the branches of various coniferous plants. One of these is *Phoma pithya* Sacc., and Saccardo, in his Host Index, gives the white pine as one of the hosts of this fungus. On the leaves of certain species of pine, including *Pinus montana,* we have seen *Phoma acicola* (Lev.) Sacc. It is a question with this species also whether it is parasitic or is merely following other injury where the leaves have been killed part way from the apex inward.

QUINCE, *Cydonia* sps.

Fruit Spot, *Cylindrosporium Pomi* Brooks. In our 1909-10 Report, page 723, we described the appearance of this fungus on the apple, and also reported finding it rarely on the common quince, *Cydonia vulgaris.* In October, 1912, the writer also found it on fruit of the Japan quince, *Cydonia japonica.* While the fruit of this was abundantly covered with small purplish discolorations, none of these showed the fruiting stage of the fungus. Cultures from the tissue, however, showed that they were caused by this fungus. Of course the fruit of this ornamental plant is of no economic importance.

ROSE, *Rosa* sp.

CROWN GALL, *Bacterium tumefaciens* Sm. & Towns. Plate XIX b. We have reported previously this bacterial disease on the following hosts: apple, bittersweet (Japanese), blackberry, peach, plum, and raspberry. Besides these, we have reported a somewhat similar trouble on the branches of oak trees, and a trouble of grapes which we have considered a winter injury, but which some others attribute to the crown gall organism. While the rose has been reported elsewhere as a host, it had not been found infected in Connecticut until Walden, in December, 1911, while inspecting Manetti stock recently imported from England by A. N. Pierson of Cromwell, discovered a few plants showing the galls conspicuously on the roots. Specimens of these have been planted in our greenhouse for over a year, and the disease does not seem to have as yet very seriously affected the plants, or to have spread to any extent to the new roots.

TURNIP, SWEDE, *Brassica campestris.*

PHOMA ROT, *Phoma Napobrassicæ* Rost. Plate XX c-d. In December, 1912, Mr. W. N. Durgy of Danbury noticed a rot trouble in his Swede turnips, and later sent specimens to the Station for information. Concerning this he wrote: "As I have a trouble with my Rock turnips this year that I never had before, I thought I would send you a sample. They were nice and solid when I put them in the cellar, and now nearly half of them are like the sample. Will you kindly report what is the cause of the trouble." Later, in answer to inquiries, he furnished the following information: "The turnips did not show any spots when they were dug. The only thing we saw when we dug them was a decay on a very few around the top, so that when we pulled them, the top would come off, but I thought nothing of this. I have not heard of any similar trouble around here. I have made a specialty of raising turnips for a good many years, and have always stored them in the same place, i. e., the cellar bottom. My cellar is warm, but not very damp. I have had the farm for sixteen years, and never raised but one crop of turnips before on the same ground, which was in 1911, but I manured it heavily with horse and cow manure, and used fertilizer besides."

An examination of the turnips sent showed that they had a dry rot, appearing as sunken, subcircular areas scattered over the roots, especially above, as in illustration c. These areas usually had a darker border, but on the samples we received we did not notice that this was purplish or that the spots were finally cracked, as described for the trouble on Swedish turnips elsewhere. A microscopic examination showed the mycelium of the fungus abundant in these spots, and apparently the cause of the decay. No fruiting bodies showed, but after placing the turnip for a few days in a moist chamber, these became abundant, as shown in illustration d. Cultures of the fungus were easily obtained, and these produced a black growth in the medium with a scanty, superficial, whitish or slightly pinkish tinted growth above. The spores exuded more or less abundantly in rose-colored, viscid masses. Mr. Stoddard readily produced the disease in healthy tubers, kept fairly moist and warm, on inoculation with spores from the cultures.

The writer is indebted to Stewart of Geneva, N. Y., for several references to this disease in other countries, but neither Stewart, Selby, nor anyone else apparently, has reported a similar trouble in the United States. So far as the writer can judge from the meager description, our disease appears to be the same as that reported by Rostrup (5-6) from Denmark in 1893. He found it on Swéde turnips, and describes as its cause a new fungus which he called *Phoma Napobrassicæ*. The trouble was next reported from the north of England, by Potter (4), who first noticed it in the winter of 1896-7. He also found it on the roots in the field. Potter merely identified the disease as caused by a species of Phoma, though he noted the possibility of its being the same species described by Rostrup. Carruthers (1) also reported this trouble from Lincolnshire, England, in 1903, and he had no doubt but that the disease reported by Potter and himself was the same as that described by Rostrup.

In 1905, Kirk (3) reported the disease from New Zealand as new in that region. He gives the following description of the injury: "Below the crown, and forming a kind of irregular ring around the upper third of the turnip, are numerous more or less circular depressed areas of decaying tissue, varying considerably in size. They are light brown and corky, and are generally surrounded by a well-defined purple margin. As the disease advances, these patches crack and form deep fissures, which spread deeply into the interior of the turnip, ruining it. Numerous black dots (pycnidia) now appear on the diseased patches; these dots are cone-shaped, and contain immense numbers of minute spores, which emerge from the apices of the fructification in small, globular, rose-colored masses. The spores then soon separate, and are disseminated by various agencies, especially wind."

In 1912, Güssow (2) reported the disease from Prince Edward Island, Canada, and this seems to be the first report of the disease from North America. While we have accepted Rostrup's name for the fungus, we are not sure whether it is distinct from a cabbage fungus (*Phoma Brassicæ*, or *P. oleracea*) that has caused more or less damage in Europe and was reported in 1911 by Manns (Ohio Agr. Exp. Stat. Bull. 228: 276-89) as causing serious injury in Ohio, especially through cankers on the stems. The cabbage and turnip both belong to the same genus, and so are closely related, and the Phoma fungi found on each cause cankers, and have spores about the same size. (Manns reports the spores of the cabbage Phoma as 4.5-5μ x 1.7-2μ, while those of our turnip Phoma are chiefly 3.6-4.5μ x 1.8μ). But we do not know whether the spore masses of the cabbage Phoma are rose-colored, as are those of the turnip Phoma. Manns reports the fungus as occurring on the leaves somewhat, and McAlpine reports it on the leaves of cabbage, turnip and rape. Johnson has reported a Phoma disease on the leaves of Swede turnip in Ireland, and this may be the same as our Phoma. The other writers do not distinctly mention the Phoma as occurring on the leaves of turnips, though from the spraying treatment recommended, it is at least suggested that it may occur there.

While the different investigators have suggested various preventive treatments, it is not known yet whether all of these are practical, especially the spraying of the foliage in the field. Certainly, however, rotation should be practiced where the disease has appeared in a field. It is also quite likely that the kind and amount of manure used in the field may have some influence.

This is especially true if diseased turnips have been fed to the stock. Storage in a dry, cool place, with piles not too large, may also help to keep down the trouble. No doubt the character of the season is a factor in the development of the disease.

1. **Carruthers, W.** Diseases of the turnip bulb. Journ. Roy. Agr. Soc. Eng. 64: 297-300. 1903. [Illust.]

2. **Güssow, H. T.** Phoma rot of turnip. Exp. Farms Ottawa Rept. 1912: 202-4. 1912.

3. **Kirk, T. W.** Diseases of Swede turnip. New Zealand Dept. Agr. Div. Biol. Hort. Bull. 14: 1-4. 1905. [Illust.]

4. **Potter, M. C.** A new Phoma disease of the Swede. Journ. Bd. Agr. 6: (1-11 Reprint). [Illust.]

5. **Rostrup, E.** Oversigt over Sygdomme hos Kulturplanter. Tidsskr. Landökonom. 11: 330. 1893.

6. **Rostrup, E.** Phoma-Angriff bei Wurzelgewächsen. Zeitschr. Pflanzenkr. 4: 322-3. 1894.

WISTARIA, CHINESE, *Wistaria chinensis.*

CROWN GALL, *Bacterium tumefaciens* Sm. & Towns. Although we do not find the above host among those mentioned by Smith as infected by the crown gall, yet so far as one can judge from macroscopic examination, it is occasionally infected in this state. Mr. Walden collected specimens in March, 1912, on plants imported from Japan in one of the nurseries, and Dr. Britton later brought us specimens from a plant grown in his yard. In the latter case the galls were associated with an elongated, sunken area of dead bark, and on this we found the fruiting pustules of a fungus that agrees fairly well with *Phoma seposita* Sacc. Whether the latter was present as a saprophyte or a parasite was not determined, but probably it was the former, since we have seen no references to it as causing injury.

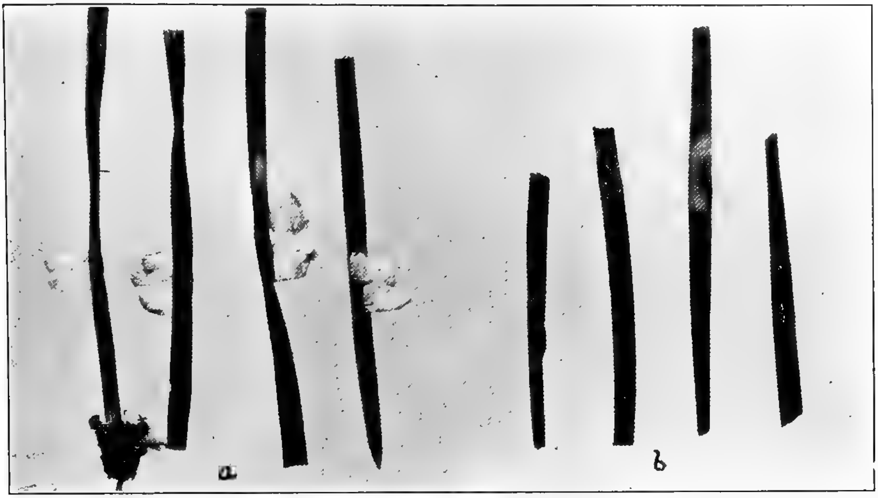
a. Ash Rust, p. 343.

b. White Pine Rust, x 2, p. 347.

c. White Pine Rust, nat. size, p. 347.

SOME TREE RUSTS.

PLATE XVIII.



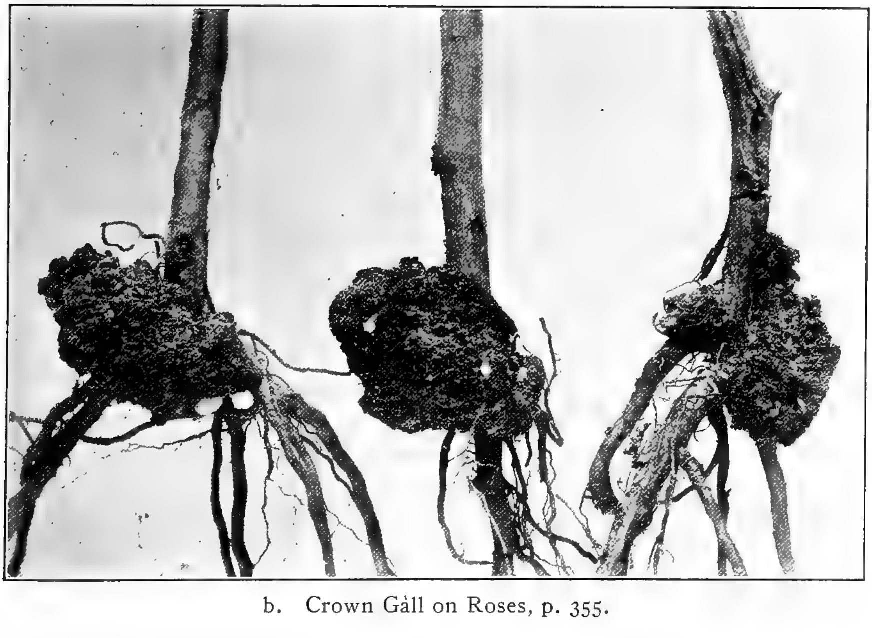
a–b. Two species of Pine leaf Rusts, x 2–3, p. 352.

c. Common Cedar Rust, p. 343.

d. Japanese Juniper Rust, p. 350.

SOME TREE RUSTS.

a. Canker of White Pine, p. 354.



b. Crown Gall on Roses, p. 355.

DISEASES OF WHITE PINE AND ROSE.

a–b. Black Bacterial Rot of Cabbage, b. Showing blackened veins, p. 345.

c–d. Phoma Rot of Swede Turnip, d, x 2, with fruiting pustules, p. 355.

DISEASES OF CABBAGE AND TURNIP.

CHESTNUT BARK DISEASE,

Endothia gyrosa var. *parasitica* (Murr.) Clint.

HISTORICAL CONSIDERATION.

Introduction. It is now over eight years since the chestnut blight was first found in New York, and nearly six years since it was reported to this Station as occurring in Connecticut. The writer became acquainted with the trouble in 1905 through Murrill's work and specimens sent by him, and has been actively engaged in a special study of it ever since its discovery in Connecticut. Articles (5-12) concerning these studies have appeared from time to time in the Station Reports and elsewhere. Since our views have been, in part, at variance with those held by certain other investigators, we propose to give here more in detail the information we have gained during these investigations, and our conclusions therefrom.

We wish to acknowledge especial indebtedness to our assistant, Mr. Stoddard, who during the last three years has greatly aided in the work with artificial cultures, inoculation experiments, etc. Mr. Spring, the former, and Mr. Filley, the present, forester of this Station, have coöperated with the botanical department in determining the conditions in our forests and the possible remedial treatments. American and European botanists have aided with specimens and information; and we are especially indebted to Professor Farlow, of Harvard, in our systematic study of the blight fungus and its allies. We are also indebted to numerous persons interested in forestry in Connecticut for much local information.

Discovery of Disease. The chestnut blight was first noticed by H. W. Merkel, in charge of the trees of the New York Zoological Park, in the summer of 1904, as injuring scattered trees in that park. In 1905 it was so bad that he took active measures to bring it under control, and published (32) the first general description of the trouble in the Report of the New York Zoological Society for that year. The attention of Murrill, of the New York Botanical Garden, was called to the disease, which had now become quite conspicuous in the parks and woods in the vicinity of New York City, and he began a botanical study of it to determine the exact cause.

After a preliminary paper in the Journal of the New York Botanical Garden (45), published in June, 1906, he described in Torreya (47), in September of the same year, the specific fungus responsible for the trouble, a species new to science which he called *Diaporthe parasitica.*

Previous to this outbreak there is no record, so far as the writer knows, of a disease of chestnuts in this country, or elsewhere, that can be surely attributed to the same cause, though there have been troubles of chestnuts in the Southern States that may or may not have been due to it. These will be discussed more fully later. Since the disease has been called to the attention of the public, however, there are a number of persons who have reported that they believe that they have seen this or a very similar trouble previous to 1904.

For example, Metcalf and Collins (36, p. 45) say: "No earlier observation than this is recorded, but it is evident that the disease, which would of necessity have made slow advance at first, must have been in this general locality for a number of years in order to have gained such a foothold by 1904." And further on (p. 46) they add: "Observations by the junior writer indicate that this disease may have been present in an orchard in Bedford County, Va., as early as 1903, and that in Lancaster County, Pa., it was probably present as early as 1905."

Dr. Britton of this Station informs the writer that as far back as 1889 he knew of a seedling chestnut tree on a farm near Keene, N. H., that suddenly, during the summer, developed a progressive canker trouble that now seems to him to have been the chestnut blight.

Professor Davis, in the discussion at the Pennsylvania Chestnut Blight Conference at Harrisburg (54, p. 102), said: "I will say that I think I saw the blight on Long Island in 1897 or 1898. * * * That was in Cold Spring Harbor, in Huntington, especially back of Huntington, through the hills around there. So I think it was in 1898 well established in those localities." Mr. Child, of Putnam, Conn., at this same conference (54, p. 107) also said: "I know two men about sixty years of age who state that they are positive that they saw this blight twenty years ago, or something that looked the same as is shown in the blight to-day."

Early Investigations. We are indebted largely to Murrill (45-51) for our knowledge of the life history of the chestnut blight fungus. He not only gave a careful scientific description of its different spore stages, but by inoculation experiments proved that it could produce the disease in healthy seedlings. He also tried various methods of control.

The United States Department of Agriculture soon became interested in the disease, and through the efforts of Metcalf (33-39) and later of Collins (13-16) and others, facts concerning the distribution, hosts, and control of the fungus were made known. Metcalf (33) was the first to note the relative immunity of the Japanese varieties to the disease, and to suggest that the fungus was originally brought into this country from Japan. He is also, more than anyone else, to be credited for what good, if any, may arise from the attempted control of the fungus by the cutting-out quarantine method, since it is through his advocacy that this method has been undertaken in Pennsylvania and perhaps elsewhere.

The writer apparently was the next after Murrill and Metcalf to take up the special study of the disease. He was the first to try to prove that weather had some connection with the trouble, and through his investigations, in connection with Farlow, to show the relationship of the fungus to two other species found in this country, all of which are now considered species of the genus Endothia.

Recent Investigations. With the spread of the blight to new localities, and the appropriation of large sums of money by the National Government and the State of Pennsylvania for its special study and control, popular and scientific interest in this disease was greatly augmented. The more recent investigations have had to do largely with the detailed study of field conditions in the different states, especially in the State of Pennsylvania, where the force of scientific and general workers is larger than on any other special botanical investigation ever carried on in this country. This control work has been largely devised by Foresters Williams and Detwiler (19, p. 129), based on the cutting-out experiments of Metcalf at Washington (38). Recently Carleton, of the United States Department of Agriculture, has been given general control of all the work in

Pennsylvania, with Heald, formerly of Texas, in charge of the laboratory investigations.

Collins (16) has contributed to our knowledge of the treatment of individual trees. Rankin (59, 60), of New York, has reported on results of inoculation tests as to time of year, water content of trees, etc. Fulton (24), of Pennsylvania, has made a variety of field observations as to distribution of spores, conditions of infection, etc. The Andersons (1, 2) have reported on the character of the fungus in cultures, inoculation tests, etc. Craighead (17) and others have studied its relation to insects. Miss Rumbold (62, 63) has experimented with chemicals to determine their effect on the trees as regards blight resistance, etc.

Farlow (20, 21), Shear (64, 65), the Andersons (1, 2) and the writer (8-10) have studied the nomenclature and systematic relationships of the fungus. Stewart (70), Murrill (51, p. 194) and the writer have regarded unfavorably extensive control by cutting-out methods. Mickleborough (40, 41), Smith (67, 68) and others have contributed articles of interest to the general public. In Europe, von Höhnel (29), Rehm (61), and Pantanelli (52, 53) have published notes or papers on the subject.

Identity. In the study of a disease it is always very desirable to know exactly the fungus that causes it. While Murrill proved conclusively that his *Diaporthe parasitica* was the immediate cause of the chestnut blight, this did not necessarily prove, as he claimed, that it was a species new to science. The question naturally arises, has this fungus been previously known under some other name? As a vigorous parasite, killing off chestnut trees, there is certainly no record of any fungus that can be definitely identified with it. The writer from the first was skeptical about the fungus having entirely escaped previous observation by botanists, especially if it might under certain conditions exist as a weak parasite or a saprophyte. One of the first things we set about to learn, therefore, was whether or not this fungus had had a previous botanical record.

Schweinitz, a Bavarian minister, who lived at Salem, N. C., and Bethlehem, Pa., and made his botanical studies from about 1812 to 1834, was one of the first and most extensive collectors of fungi in this country. He described many species new to science. It was among the species described by him, since the relationships of many of them are now somewhat obscure, that we made a search for some fungus that might throw additional light on *Diaporthe parasitica.* In this search we asked the aid of Professor Farlow, whose knowledge of American fungi is unsurpassed, and who has some of the Schweinitzian specimens in his herbarium, and from him we first learned of the close relationship of the chestnut blight to *Endothia gyrosa* (Schw.) Fr. This fungus was first described by Schweinitz as *Sphaeria gyrosa,* from North Carolina on Fagus and Juglans. He sent specimens to Fries, a famous authority on fungi in Europe, who later recognized it as a European species, and finally placed it under a new genus, Endothia. This possible relationship of the blight was brought out for the first time in the writer's Report (6) for 1908. Neither Farlow nor the writer had at that time examined the ascospore stage of the true *Endothia gyrosa,* so the exact relationship of our blight fungus to this species was not positively determined, though the writer called attention to the fact that, so far as one could tell from the Cytospora stage, it was impossible to distinguish between *Diaporthe parasitica* collected on chestnut in America and *Endothia gyrosa* found on the same host in Italy.

Previous to this, however, Rehm (61) had decided that Diaporthe was not the proper genus for our chestnut blight, and had placed it under the genus Valsonectria, but had not questioned its identity as a new species or its relationship to Endothia.

Von Höhnel (29) seems to have been the first to definitely state that *Diaporthe parasitica* was not distinct morphologically from *Endothia gyrosa,* for in the latter part of 1909 he wrote: "Diese Pilz ist in Rehm Ascomyc., No. 1710, ausgegeben unter dem Nahmen *Valsonectria parasitica* (Murr.) Rehm. Es ist aber nicht anders als *E. gyrosa* mit schwach entwickelten Stroma." Since then Farlow (20), Shear (65), Saccardo, and Rehm, the last two in letters to the writer, have also decided that the chestnut blight fungus is not distinct morphologically from *Endothia gyrosa* (sometimes called *E. radicalis*) of Europe.

The Andersons (1) were among the last to study the relationship of *Diaporthe parasitica* to the genus Endothia. Their studies having led them to believe that the blight fungus, though related, was entirely distinct from *Endothia gyrosa,* they have placed it under Endothia as *E. parasitica* (Murr.) Anders.

Although the writer started out to prove the identity of the chestnut blight with the *Endothia gyrosa* of Europe, he has been forced to conclude from his microscopical, cultural and inoculation studies that it is not exactly identical with that species, as is held by von Höhnel and others. The relationship, however, is so close that he cannot, on the other hand, agree with the Andersons in considering it an entirely distinct species. Hence he (9) has placed it as a variety under that species, calling it *Endothia gyrosa* var. *parasitica* (Murr.) Clint.

The preponderance of opinion of those who have made a critical study of the fungus, therefore, is that it is not an entirely new species, but that it is merely a strain, or at most, a variety of a previously described saprophytic or semi-parasitic species, that for certain reasons has now attained unusual virulence in the northeastern United States.

CHARACTERISTICS OF THE DISEASE.

As to the Host. It is easy enough to distinguish this disease on the smooth bark of sprouts or young trees, Plate XXIII a, since it forms definite cankers by killing the infected bark, and these usually increase in size until the entire stem or limb is girdled. These cankered spots are slightly sunken, and distinguished from the healthy bark by a chestnut-brown color, whereas the normal bark is more of a greenish-brown. Often the bark on these cankered spots is more or less cracked, and in time the fruiting pustules show as numerous minute cushions projecting through lenticel-like openings.

On the rough bark of the older trees the cankers do not show very distinctly, though when cut out, as shown in Plate XXIII b, they give a cankered effect. Frequently with these the whole bark becomes infested, and the presence of the fungus is shown by the fruiting pustules breaking out from the deep cracks of the bark. Often when these do not develop, the bark may look healthy, but when hit by a hammer, it gives a hollow sound and is easily separated from the wood, showing the cambium entirely dead. After the tissues are killed, one is apt to find the larvae of beetles, etc., at work between the bark and the wood, and their presence has led some to think that they were the real cause of the trouble.

The first appearance of the disease on the smooth bark frequently seems to be due to the injuries caused by bark miners, Plate XXIV a. The most frequent starting points, however, are through cracks, wounds or where a branch has been pruned, XXIV b, or killed from some cause, as winter injury. Very frequently the fungus gets a start from a crack in the crotch of the limbs.

In summer time the disease is recognized in the top of the trees, even at some distance, by the dead leaves on certain branches, which have been girdled, but whose girdled area is not easily seen from the ground, Plate XXII a. These dead leaves adhere for a long time to the branches. They first begin to show about the latter part of June or the first of July, when the previous year's canker has finally succeeded in girdling the branch. In the winter these dead branches sometimes retain their dead foliage and burs long after those from healthy branches have fallen. This is true, however, of a branch killed prematurely from any cause.

The cankers on the main trunk, as they become serious, cause the latent or adventitious buds in the healthy tissues beneath to develop, so that in time there are produced a number of slender sprouts, and one can detect the presence of a canker high up in the tree by these.

The fungus, while it kills the bark and cambium, and thus eventually the tree, is not a true wood-destroying species. When the trunk of a living, but cankered, tree is cut and barked, the cankered spot, Plate XXIII d, is usually visible as a darker area in the wood corresponding to the cankered spot in the bark, the mycelium of the fungus having injured the woody tissues for a short distance inward. Such cankered spots can sometimes be seen on telephone poles used along the highway. This injury in itself, however, is negligible so far as it affects the value of the pole.

Often, after trees are cut, the stumps of those infected at the base develop a vigorous growth of the fruiting stage on the three or four outer rings of wood. This probably means that the mycelium can penetrate thus far into the wood from the canker, or possibly it may mean that fresh infection takes place from spores developing in the nutrient material furnished by the exposed sapwood.

After an infected tree has been killed, or has been cut before death, there may be a further development of the fruiting stage of the fungus. We doubt, however, if disease-free trees often develop prominent infection after cutting. In other words, the fungus is parasitic or semi-parasitic, but does not develop in its prime as a saprophyte. Even on trees killed suddenly and left standing, Plate XXII b, we have often failed to notice a general spread of the fungus through the bark. In the wood pile, too, while the fruiting stage no doubt shows some increase, a general subsequent infection of the disease-free bark does not seem to take place.

As to the Fungus. The mycelium of the fungus ramifies through the bark, beneath it, and often into the wood for a short distance. When the epidermis of a young, smooth, cankered branch is carefully peeled off, it often shows the mycelium as a whitish or yellowish coating just beneath, and below this is the reddish-brown diseased bark sharply marked off at its edges from the healthy white tissues. In the older infected bark, the mycelium is sometimes seen as fan-shaped areas between the tissues or on the wood. The mycelium often gives a mottled effect to the bark as seen when cut through. In time, with the aid of insects, it produces soft, semi-dusty spots in the firmer, less affected tissues.

The infected tissues do not show external signs of the fungus itself at first (with artificially inoculated cankers, not for two months or more after inoculation, Plate XXV b), but in the smooth bark in time numerous fruiting pustules are gradually protruded through small, lenticel-like openings. These at first are quite small, but in time show as subspherical to irregularly oblong cushions one-eighth of an inch or less in length and about that in height, XXIV c. In the rough bark they break out more irregularly from the crevices, and are more run together into compound groups, XXIV d. They vary in color with age from light-orange through almost crimson- to dark chestnut-brown. The interior of the pustules is usually lighter colored, and more uniformly remains of a yellow tint. When fully matured, the fruiting pustules show small black dots on the surface or in cross-section, which are the ducts through which the matured spores escape.

On the wood, the fruiting pustules are usually simple, smaller, conical in shape, and apparently do not produce the mature stage of the fungus. They have an appearance to the eye quite different from those on the bark, and for this reason Saccardo formed a distinct genus, Endothiella, for them.

The pustules, within inconspicuous cavities, soon begin to form a summer, or conidial, stage. This, if it were the only stage produced, would place the fungus in the imperfect genus Cytospora, so this is sometimes known as the Cytospora stage of the fungus. The spores are produced apically in great numbers from slender fruiting threads. When filling the cavities and swollen by moisture, they ooze out over the surface of the pustules as drops, or more frequently, slender yellowish tendrils. These tendrils are most conspicuous in summer just after rainy weather. Soon, however, they become worn or washed away by rains, and, if carried to cracks in the bark, they cause new infection.

As the spore masses are viscid and moist, they easily adhere to insects, especially when crawling over them in the larval stage, and to the feet and beaks of birds, and these are considered means of spreading infection, not only in the neighborhood, but also to distant points. These spores, Plate XXVIII i, are very minute, in fact, so small that it would take two or three hundred million to cover an area an inch square. They are hyaline, oblong, unicellular with rounded ends, and about $2.5\text{-}4 \times 0.75\ \mu$ in size.

In the same fruiting pustules that produce the Cytospora stage there appears, after some time, the mature spore stage, often called the winter stage, because it occurs most commonly from late fall to late spring. However, like the summer stage, this winter stage can be found more or less abundant at any time of the year, its appearance depending in part on the age of the fruiting pustules. With the beginning of this stage, the fruiting pustules have reached their maximum growth and the production of the summer spores is practically over. It is quite unlike the Cytospora stage in that the spores are borne in sacs, or asci, situated in special receptacles called perithecia.

The mature perithecia, Plate XXVIII k, are minute, light to dark-colored spherical bodies, situated within, but generally beneath and around, the edge of the pustules. By means of long black necks these perithecia open on the exposed surface of the fruiting pustules, where they show as minute black specks called ostioles. With the later growth and wearing away of the fruiting pustules these ostioles sometimes project as short spines. Each perithecium contains numerous, hyaline, oblong, asci, Plate XXVIII f, tapering somewhat at their base, within which are eight ascospores arranged one above another in one or two rows. In size the asci usually vary from 40 to 45 μ in length by 7 to 9 μ wide, though some vary from 37 to 50 μ in length.

The ascospores, Plate XXVIII c, are hyaline, oblong to broadly oval, with a central septum, at which they are often slightly constricted. These spores are usually rounded at the ends, though sometimes somewhat pointed at one or both ends. They vary from 6 to 10 μ in length by 2.75 to 5 μ in width. While the chief time of germination of the ascospores is undoubtedly in the spring, their production and germination seems to be more or less distributed throughout the year. After rainy weather they are shot through the ostioles of the perithecia with some little force, and no doubt may be carried much further by the wind. By this means their distribution is greatly facilitated, and, because of their greater vigor, some experimenters believe they are more important in producing infection than the conidial spores.

Progress of Disease. From our inoculation experiments it is evident that seedling trees one-half inch or less in diameter may be girdled, and in some cases their tops killed in one season, Plate XXV a. Sprouts an inch or more in diameter may likewise be entirely girdled for a distance of six or more inches, so that the death of the parts may be expected at least by the following spring. We have not inoculated the large limbs of trees, neither have we measured the rate of growth of cankers on the same, but we have had under general observation, for several seasons, marked trees at both Stamford and Middlebury.

From the results of these observations, it seems to take at least two, and more frequently three, four or more years, to entirely kill the larger trees.

The trees at Stamford were on the farm of Mr. F. V. Stevens, and we are indebted to him and his son for aid in the experiments there. The trees were first marked by the writer and Mr. Filley in April, 1909. At that time many of them were in bad condition, as they were in the region where the blight first made its appearance in this state. All of the trees and sprouts in a certain area were numbered, and their condition as regards blight recorded. They varied in size from sprouts 2 to 8 inches in diameter to large trees two feet in diameter. The following table shows their condition when first examined, and after two growing seasons. They were not examined in 1911. In 1912, according to Mr. Stevens, Jr., all of the infected trees were dead; some of the sprouts, especially those developed since the marking, however, were alive. In 1910 some of the dead sprouts did not show any, and others but little signs of the fungus, and their death may have been partly due to other causes, as drought and winter injury, though all are included in the following table.

	Sprouts, 2–8 in. diam.				Trees, 10–24 in. diam.			
	Apr. 1909.		Nov. 1910.		Apr. 1909.		Nov. 1910.	
	No.	%	No.	%	No.	%	No.	%
Free	26	25.7	7	6.9	7	29.2	0	0
Little diseased	28	27.7	10	9.9	8	33.3	1	4.2
Moderately diseased	14	13.9	4	4.0	2	8.3	3	12.5
Badly diseased	24	23.8	15	14.8	2	8.3	10	41.7
Dead	9	8.9	65	64.4	5	20.8	10	41.7
Totals	101		101		24		24	

The trees at Middlebury, all above six inches in diameter, were in a grove belonging to the Whittemore estate. For their experimental use the Station is indebted to the farm superintendent, Mr. W. M. Shepardson. The trees were on a hillside having a southern exposure, and had recently been thinned, by taking out those most diseased. They no doubt suffered from blight more severely because of winter and drought injury, due in part to their exposure and the thinning. The trees were first examined in February, 1910, and marked, but not numbered, with a sign indicating their condition as to the disease at that time. They were examined again and re-marked at the end of that season, and examinations were made again at the end of the seasons in 1911 and 1912. In these later examinations data were not taken from all of the marked trees, but the condition of each tree examined was compared with its condition in the fall of 1910. The badly diseased and dead trees increased from 5.7 per cent. in the spring to 35 per cent. in the fall of 1910, to 58 per cent. in 1911, and to 69 per cent. in 1912. The following table shows the conditions at the different times of examination:

	Feb. 1910.		Nov. 1910.		Fall, 1910.		Fall, 1911.		Fall, 1910.		Fall, 1912	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Not diseased	67	42.7	0	0	24	20.5	0	0	12	21.8	0	0
Little diseased	67	42.7	68	43.3	40	34.2	25	21.4	25	45.5	8	14.5
Medium diseased	14	8.9	34	21.7	22	18.8	24	20.5	9	16.4	9	16.4
Badly diseased	9	5.7	55	35.0	31	26.5	44	37.6	9	16.4	21	38.2
Dead	0	0	0	0	0	0	24	20.5	0	0	17	30.9
Totals	157		157		117		117		55		55	

DISTRIBUTION AND HOSTS.

In the United States. The blight, first noticed in the late summer of 1904 at Bronx Park, New York, was said by Merkel to have spread by the end of 1905 so that 98 per cent. of the trees in this borough were infected. Murrill (45), in June, 1906, reported the disease from New York, New Jersey, Maryland and Virginia, and in September also from the District of Columbia. In February, 1908, he (48) gave Connecticut and Massachusetts as additional states. Metcalf and Collins (36). showed the distribution by August, 1909, to include Rhode Island, Pennsylvania and Delaware. Except in the vicinity of New York City, including adjacent parts of New York, Connecticut, Long Island and New Jersey, the points of infection at this time, so far as known, were scattered rather than general. In May, 1910, Metcalf and Collins (37) included West Virginia among the infected states. The past year the disease has been reported also from New Hampshire and Vermont.

At the present time the most damage caused by this disease in Massachusetts and Connecticut has been along and west of the Connecticut river. In New York it is conspicuous along the Hudson River up to Albany, and in western Long Island.

In New Jersey the chestnuts of the whole state have suffered. In Pennsylvania the trouble is serious in the eastern half, and quite bad in the southeastern part. The disease occurs generally in Delaware, but is especially bad in the northern counties, where the chestnuts are most abundant. Maryland and Rhode Island have the disease scattered, and serious in certain localities. In Virginia and West Virginia the infections are apparently few and inconspicuous.

In Connecticut. The first specimens from Connecticut were sent to the Experiment Station in November, 1907, by F. V. Stevens, Jr., of Stamford, who found the disease doing considerable damage in this region during the summer. He also mentioned that he thought he had seen it in one or two other towns in the state. Since that report others have stated to us that they had seen the disease earlier, but had not known its nature at the time. For example, Mr. G. H. Hollister, of Keney Park, Hartford, said that in the summer of 1905 he found a tree on the Edgewood Park estate at Greenwich that he is now sure had the blight. Forester Spring reported that a farmer in the town of Easton noticed the disease as early as 1905. These three towns are all in Fairfield County, near the first reported outbreak in New York.

Hodson (28) reported the blight in New London County as early as 1908. Mr. N. J. Peck brought us a specimen from Woodbridge, New Haven County, in the winter of 1909, and reported that he had seen it in his woods for four or five years. The first fruiting specimen collected by the writer outside of Stamford was found at Morris Cove, New Haven County, in September, 1908, though immature specimens were seen that spring in Westville.

By the end of 1908 the disease had been reported in all but one of the twenty-three towns of Fairfield County, in eight towns of New Haven County, and in one town of New London County. By March, 1911, the writer (7, p. 716) had reports of it in all of the twenty-three towns of Fairfield County, twenty-one in New Haven, fourteen in Litchfield, seven in Hartford, two in Middlesex, three in Tolland, and one each in Windham and New London counties. Out of these seventy-two towns all but seven were west of the Connecticut River. In November, 1911 (11), it was reported in 121 towns of the state, and in February, 1912 (12), it had been found in 164 out of 168 towns of the state. Since that time it has been reported in the remaining four.

We have no doubt that a careful examination would have revealed the blight's presence in many of these towns much earlier than it was first reported. There is no question, however, that it was much more conspicuous in Fairfield and New Haven counties at first than elsewhere, and that to-day it is much more prevalent west than east of the Connecticut River. This is probably due to the fact that in the western part of the state chestnut is more abundant than in the eastern half, and also to the fact that the disease started earliest in the southeastern part of the state. We doubt very much, however, if it has spread from a single infected locality in Fairfield County through all the rest of the state, but hold rather to the idea that it was present in a very inconspicuous way in a number of localities scattered over the state, and has spread from these. See Plate XXI.

Manner of Distribution. Many persons believe that the chestnut blight started at some one locality in the region of New York City and from there spread to all of the localities where it is now known to occur. Maps issued from time to time by Metcalf and Collins are based on this idea. Williams (54, p. 198) has rather positively stated this in the following quotation: "I would like to ask the gentlemen from around the neighborhood of New York City whether if they had been really active and alert and on the firing line when this thing was discovered in 1904, might they not have accomplished some real thing which would have redounded to the benefit of the other states, as Massachusetts has done in her gypsy moth fight? If instead of sitting down and nursing their hands in idleness, and allowing the scourge to go on, simply because they could not originate sufficient interest in their state, they had gone out and done what they could, this thing would probably not have come upon us."

This view almost of necessity carries with it the additional belief that the chestnut blight is of foreign origin, since if of native origin there is little likelihood that the fungus would have been limited to one locality; whereas if imported, it could have spread from one center or even from a single tree. On the other hand, the writer holds the view, at least tentatively, that the chestnut blight has not spread from a single central locality in New York City, but that at the time of its discovery there in 1904 it occurred in an inconspicuous way in widely scattered spots in several states, and that it has been in these localities for years.

The reasons for this belief are as follows: (1) While originally reported from the New York Zoological Park in 1904, subsequent information has shown that at about that time, or even earlier, in several cases already cited, the disease was present in such widely separated places as Woodbridge, Stamford and Greenwich, Conn.; Huntington, L. I.; Bronx Park, N. Y.; Bergen County, N. J.; Lancaster County, Pa., and Bedford County, Va. (2) Its sudden appearance and quick destruction of the trees where first found (98 per cent. infected by end of 1905, as reported by Merkel) indicate that there was some other factor involved than the spread of a virulent parasitic fungus, since such quick work is without parallel in the history of other fungous diseases of trees, or even with this one in its later history. (3) Recent investigations have shown that the fungus is more likely native than imported, and if native, there is no good reason why it should have been limited to the immediate vicinity of New York City. (4) Our investigations in Connecticut have shown it present in some localities in an inconspicuous way at the base of the trees, as if it were a native instead of an introduced fungus, just as its nearest relative is found to-day in the South. This latter fungus, *Endothia gyrosa,* is so generally distributed in the South that there is no doubt that it has occurred there since Schweinitz's time, and yet no one had, previous to our investigations, reported it on chestnut in that region.

We believe that the chestnut blight fungus existed in the North previous to its outbreak in 1904 as a weak parasite in a number of scattered localities. From these centers it spread with greater or less rapidity according to local conditions. This belief does not in any way contradict the possibility of the disease being carried longer or shorter distances by such agencies as infected nursery stock, birds, etc. Perhaps the strongest evidence against this belief is the fact that the greatest damage has occurred in the vicinity of New York City, and apparently has spread outward with the development of seemingly new infections. This apparent wave of progress, however, is in part due to a corresponding wave of interest on the part of the people to locate a disease so generally discussed. It is quite doubtful whether the disease was observed in most of the localities as soon as it made its appearance there, but rather our experience has been that it was usually discovered in a place when someone became interested enough to search for it.

Hosts, Resistance, etc. While the blight was first found on our native chestnut, *Castanea dentata,* and most of the damage has been done to this species, it was soon determined that other species of Castanea were more or less susceptible to the disease. Murrill (48, p. 27) in 1908 called attention to these hosts, as follows: "It is now certain that the chestnut disease attacks all species of Castanea, both native and cultivated, that occur in this region, namely, *Castanea dentata,* the common native chestnut, *C. crenata,* the Japanese chestnut, and *C. pumila,* the chinquapin, found native from New Jersey to Florida." The European chestnut, *Castanea sativa,* though not mentioned by Murrill, is now known to be about as susceptible to the disease as our native species. At first certain varieties of this, as the Paragon, were thought to be more or less immune, but subsequent observation has not shown any that possessed marked resistance.

Concerning the infection of the Japanese chestnut, Murrill said: "This discovery is especially timely because of the fact that the Japanese chestnut has been under observation elsewhere in the vicinity of affected native trees, and has been considered immune, so that it has been mentioned as a desirable substitute for the native tree in some of our parks." Metcalf also had noticed this apparent resistance of the Japanese chestnut, and published a short bulletin (33) in February, 1908, in which he says: "Observations made by the writer the past year indicate that all varieties and species of the genus Castanea are subject to the disease except the Japanese varieties (*Castanea crenata* Sieb. & Zucc.). All of the latter that have been observed in the field or tested by inoculation have been found immune. This fact can hardly fail to be of fundamental importance to the future of chestnut culture. Although the nuts are distinctly inferior in flavor to the European varieties, such as Paragon, the Japanese is already grown on a large scale as a nut-producing tree. There are, however, many trade varieties of dubious origin. Some of these may prove later to be subject to the disease."

So far as the writer has observed in Connecticut, the Japanese varieties seem to have more or less resistance to the disease, but our experience has not been very extended. We have seen two cases, one in a nursery and another in a private yard, where the Japanese species was directly attacked by the blight, but have examined it in nurseries several times without finding any sign of the disease. We also failed to produce the disease in a Japanese variety in the Station yard, although the bark was inoculated in sixteen different places.

In April, 1910, with the aid of the State Forester, we had set on the hillside, beside a badly diseased patch of chestnut timber on the Whittemore estate in Middlebury, six young trees each of the following varieties: Paragon, Reliance, Early Bon, Japan Mammoth, Late Tamba and Alpha, mostly Japanese varieties. These were planted to see if any would escape the blight. Unfortunately, many of them were killed back to the ground the first summer by drought. On the stems of some there appeared on the exposed southern side sun-scald cankers similar to those described by Powell, but no sign of the blight fungus showed that year. Since then a number of the trees have died from drought, but none have been killed or seriously injured by the blight fungus, though in 1911 a little of the fungus was found on two of the badly injured Japanese Mammoth, and in 1912 on two of the languishing Paragon trees cankers had started. The Paragon, of all the varieties, stood the transplanting and drought conditions the best.

Some years ago, through the work of the late Judge Coe of Meriden, Mr. Hale of Glastonbury, and Dr. Britton of this Station, considerable interest was aroused in the cultivation of chestnuts, especially the large fruiting varieties. While we know of no cultivated orchards that were set out, a number of men grafted these varieties onto the native sprouts and trees. Among these were W. O. Corning of Marbledale, and Mr. John Dickerman of Mount Carmel. Both these gentlemen say their grafted trees have been badly injured by the blight. Mr. Corning writes: "Of my Japanese trees a great many will have to be cut down. At the same ratio of progress, none will be left in three years." And in another letter he states further, in answer to our inquiry: "I bought in New Jersey cions for four kinds, namely, Japanese, Numbo, Ridgely and Paragon, all on chestnut sprouts. I bought at the same time trees from seedlings, but they all died before the blight struck us. I find the Japanese stand so far the best. The Paragon are the poorest, although they have made the best growth and produced the most chestnuts. I find the infection commences about at the juncture of the grafts on the sprouts, and runs up and down, faster up than down."

Dr. Robert T. Morris, of Stamford, has experimented more with different varieties than anyone else in the state, so his statement, following a discussion of a paper by Collins (13, p. 43), is of special interest: "In my own orchards I have twenty-six kinds of chestnuts, and have followed them along for the purpose of determining which ones would resist the blight best. I cut out last year [1910] five thousand old American chestnut trees on my property. There is not a tree in all that part of Connecticut, the vicinity of Stamford, that is not blighted, and very few that are not dead. Now, in the midst of this disaster, what was the behavior of my experimental chestnuts of various kinds? It was this. I had about one thousand Coreans that lived up to five years of age, growing in the midst of blighted chestnuts, and none of these blighted. It occurred to me that it might be well to graft these on the stumps of American chestnuts, because these Coreans resisted the blight. But when I grafted them on the sprouts of American stumps, at least 50 per cent. of the Coreans blighted, showing that the pabulum wanted by the Diaporthe seemed to be furnished by the American chestnut. I had some chestnuts from North Japan that resisted the blight, and yet these grafted on sprouts from American chestnuts blighted. I had some Chinese chestnuts, and none of those have blighted as yet; and in grafting them, two or three have not been blighted. I have perhaps twenty-four chinquapins, both the Western form and the Eastern, and only one branch of one tree has blighted. Of the Southern Japanese chestnuts, very many are blighted. They are not as resistant as the Northern. I have a good many chestnuts of European descent, and among these some resist the blight pretty well; and some of the American progeny, like the Hannum and Ridgely, seem to resist well enough, so that I am grafting these upon many different sprouts."

As interest became aroused, inquiries have been frequently made if other trees than the chestnut, especially oaks, were not attacked by this fungus. For a long time its occurrence was not reported on any other host than Castanea. Even as late as April, 1912, Metcalf (35, p. 223) published the following: "So far as is now known, the bark disease is limited to the members of the genus Castanea. The American chestnut, the chinquapin, and the cultivated varieties of the European chestnut, are all readily subject to the disease. Only the Japanese and some other East Asian varieties appear to have any resistance."

Fulton seems to have been the first to report the chestnut blight on oak, having exhibited cultures in December, 1911, at the Washington meeting of the American Phytopathological Society. In his Harrisburg paper (24, p. 53) he reports finding a fungus on white and black oak in Pennsylvania, and says concerning it: "While it is desirable to carry on further cross inoculation experiments, it seems reasonable to suppose in the light of present evidence that *Diaporthe parasitica* may, under unusual circumstances, establish itself saprophytically on portions of trees outside the genus Castanea, if these portions are already dead. We have found no evidence that the fungus produces in any sense a disease of such trees as the oak."

The writer and Mr. Filley first found the chestnut blight on oak in October, 1912, at Middlebury, Conn., in a badly diseased chestnut grove on the Whittemore estate. Previous search for several years had failed to show it on any of the various species of oak examined. At this place the fungus occurred rather inconspicuously, as follows: (1) On an exposed living root of *Quercus alba* that had been injured in some way; (2) On cut surface of wood of a live stump of *Q. rubra* from which young sprouts were growing; (3) On the dead bark and dead stub of a twig on a recently cut stump of *Q. rubra*. Also, in November of the same year, Mr. Walden, of the entomological department, brought to the writer specimens of white oak from Greenwich, Conn., that had been killed by drought, on which this fungus occurred.

Cultures have been made from all these specimens and from a specimen of black oak, *Quercus velutina,* sent by Detwiler from Pennsylvania, and all have shown the characteristic growth of the blight fungus as distinguished from *Endothia gyrosa,* which also grows on oak in the South. However, in none of the cases so far reported does the fungus seem to have been an aggressive parasite on oak. We doubt very much if it ever will produce any serious trouble, since the oaks are hardier than the chestnuts, and have not been deteriorated through sprout renewal.

DAMAGE AND LOSS ALREADY CAUSED.

Character of Damage. The injury caused by the blight fungus to the wood of the chestnut tree is not considered to be very important. Lumber, poles or ties cut from recently killed trees are not distinguished, as a rule, from those taken from perfectly healthy trees, and no data have yet been produced to show that they are in any way inferior. This is because the fungus limits its attack to the bark, and the superficial layers of sapwood. After the death of the tree, the mycelium does not, apparently, form any progressive decay or deterioration of the wood.

If the blight killed only the old trees ready for marketing the damage would not be very great. Loss arises in part from the irregularity of its attack. Each season some trees die, thereby making cutting and marketing inconvenient. The market is often glutted so that they cannot be disposed of to advantage. Further loss may arise in the deterioration of the dead trees if they are not cut soon after death, through decay started by other fungi and by insect depredations.

The situation in Stamford, Conn., was shown in 1909 by Morris (42), as follows: "Millions of feet of fine chestnut timber, valuable for planking, piles, telegraph poles and cordwood, will be lost within the next two years. Right now the blighted trees are still good for cutting purposes. I tried to dispose of about one thousand chestnut trees, but could not find a purchaser. All my neighbors are in the same predicament. 'No market,' is the regular reply to all my letters asking dealers if they handle wood of any sort. Forty or fifty cords of hard wood were rotting on the ground last autumn because I could not find any one that wanted cordwood that had been split and stacked while clearing part of the property three years ago."

The type of damage so far mentioned, however, is inconspicuous in this state as compared with the loss that occurs through the death of trees which are not yet fit for commercial purposes and can be used only for cordwood. The market for the latter in certain districts is easily satisfied. This means low prices or long storage. The greatest loss is caused where future profits are entirely cut out by the death of half grown trees and sprout growth too small for present use. If the disease progresses in the future as actively as in the past, the prospects of our chestnut forests are very poor indeed. This means serious loss, for the chestnut is one of the most useful forest trees in all parts of the country where it occurs.

Besides the loss from a commercial point of view, there is the damage caused to the shade and ornamental trees, and to groves kept on estates, parks, etc., for aesthetic rather than practical purposes. To estimate the damage here is impossible.

In the United States. Certain writers have attempted to estimate in money value the loss caused by the blight. Just how this loss is estimated is not made very clear. To the writer it seems to be largely guess work. However, it is interesting to note these figures in order to compare them with losses given for other fungous diseases and insects. Murrill (49) in 1908 estimated the damage in and about New York City between five and ten million dollars. Mickleborough (40) about the same time estimated the damage through the country at not less than ten million dollars, while in 1909 he (41, p. 14) wrote: "The damage already done in the states of New York, Pennsylvania and New Jersey, would not be less than twelve million dollars." Metcalf and Collins (38) gave twenty-five million dollars as a conservative estimate of the financial loss to the country up to 1911. Detwiler (19, p. 130) estimates the loss in Pennsylvania alone as ten million dollars, allowing seven million for forest and three million for ornamental trees. The largest estimate that we have seen is that given by Marlatt (31, p. 345), who said in 1911: "It is estimated that the loss in and about the City of New York is now between five and ten million dollars, and the loss throughout the area now infested is fully one hundred million dollars."

In Connecticut. We shall not attempt to give any figures for the loss in Connecticut. To do this, one would have to determine the future value of sprout growth, and with more mature timber, to determine the difference between what one really got out of it and what he would have received if there had been no blight. Some idea of the loss, however, can be gained by an estimate of the chestnut in our forests and the percentage already injured by the blight.

Hawes and Hawley, in their forest survey of Litchfield and New Haven counties, estimate the forest land in Litchfield as 55 per cent., and that in New Haven as 46 per cent., of their area. This gives a total of something over five hundred thousand acres of forest for these two counties. While considerable of this is in brush and some in white pine, by far the most of it is mixed hardwoods, with chestnut forming about 60 per cent. of these in Litchfield and 70 per cent. in New Haven County. Counting in all the forest land, Litchfield probably would run over 45 per cent. chestnut and New Haven over 50 per cent., according to these authors. Probably no other county of the state has proportionately so large a part of its area in forest as Litchfield, according to State Forester Filley, but on the other hand, New London is probably the only one that has a less proportion than New Haven County.

On the whole, it is perhaps safe to estimate 40 per cent. of all the forest land of the state as being chestnut. The census for 1910 gives the lumber cut of chestnut in this state for that year as 58,810,000 feet B. M., or nearly equal to that cut from all other trees. These statements show how extensive the tree is in our forests, and how useful. When we consider that from 5 to 90 per cent. of the chestnuts in different parts of the state have already been attacked by the blight, a clearer idea of the great loss already caused may be gained, especially in Fairfield County, where over large areas there is scarcely a chestnut tree to be found that is not either killed or infected by the blight.

PRESENT SITUATION AND FUTURE PROSPECTS IN CONNECTICUT.

In order to give some idea of the damage already done in different parts of the state, the botanical and forestry departments of the Station, after consideration of all the data available, have made approximate estimates of the percentage of chestnut trees attacked in each of the counties. To gain more immediate information as to the condition in the different counties, the writer recently sent the following letter to about seventy-five men scattered over the state who have been especially interested in the blight and have had a chance to watch local conditions: "In 1911 the blight was more widely reported to us and was apparently more generally conspicuous than in any previous year. What we wish to learn from you is whether it was, where you observed it in 1912, more prominent, less prominent, or just about the same, as in 1911." Information gained by this and other means is given by counties as follows:

Fairfield County. The blight was first found by Mr. Stevens, Jr., of Stamford in the summer of 1907, and reported soon afterward to the Station. From Mr. Hollister's observations at Greenwich, the disease no doubt occurred in the county at least as early as 1905. The injury has been greater here than in any other county, and is apparently now on the decline, since most of the trees have been attacked or killed. The Station estimates 75 to 85 per cent. of the trees already dead or infected. In answer to our letter, three report the blight worse, and four about the same or less conspicuous in 1912 than in 1911.

Mr. F. A. Bartlett of Stamford writes: "The chestnut is practically extinct in Fairfield County." Mr. Joseph Cornwell of Norwalk says: "From my observations the chestnut blight was far more conspicuous in 1912 than in 1911. In 1912 I made a special trip into the woods for the purpose of examining the undergrowth, and found it more affected by the disease than at any earlier period. My observations were made in Wilton, Norwalk, Westport, Ridgefield and Redding."

Dr. R. T. Morris, who owns a farm near Stamford, says: "In the different years since the blight appeared some of my neighbors in the country have stated that they have observed more rapid progress than before, and others have expressed the opinion that we had less blight than before. As a matter of fact, so far as I can judge, there has been pretty steady progress of the blight from the first, and at the present time I do not know of a single unblighted tree in the vicinity of Stamford, Conn., although my men and I have taken long walks for the purpose of finding a resistant tree in order to propagate this tree because of its individual characteristics. A great many thousand trees were examined."

On the other hand, Mr. F. V. Stevens, Jr., of Stamford, writes: "I have found that in this section of the state the blight has been far less prominent than in any year since 1908 on the young sprouts, which are practically the only chestnuts we have." Mr. J. H. Treadwell of Danbury also says: "I would say that in this section dead trees caused by the attack of previous years were more in evidence in 1912 than in 1911. However, it does not appear to me that attacks on healthy trees are quite as prominent in 1912 as in 1911."

New Haven County. This was the second county in the state in which the disease was reported. It was found by the writer in Westville in the spring of 1908. From the observations of Mr. Peck of Woodbridge, already alluded to, there is little doubt that it occurred in places here as early as 1905 or 1906. The damage has been second only to that in Fairfield County. Quite a little of the timber has been cut in recent years for use in brick kilns and brass foundries. This has resulted in considerable young growth, which is always likely to show the disease badly. In most of the forests many of the large trees have also been badly infected or entirely killed. We estimate that 55 to 65 per cent. of the chestnut has already been infected or killed. In answer to our letter, nine stated that they believed the blight was worse in 1912 than in 1911, while seven thought it about the same or even less conspicuous.

Professor R. C. Hawley of the Yale Forest School, who has charge of the New Haven Water Company's forests, writes: "My observations have been principally confined to timber merchantable for cordwood or larger products. On such trees I think the chestnut blight has spread steadily in 1912 both in number of trees which it has attacked and, of course, in progress on trees already attacked. From a practical standpoint I anticipate cutting out all the chestnut now merchantable in the vicinity of New Haven. My general impressions are that the disease is slowly spreading among the trees below cordwood size, although I have not devoted so much time to observing these trees."

Mr. W. M. Shepardson, of Middlebury, who has had considerable experience in cutting out diseased trees on the Whittemore estate, says: "The blight was much worse in 1912 here than in any other year, and, as near as I can estimate, spread as much last year as in all previous years put together, so that in badly infested areas few or no trees are left without disease. In the home woods, round the fireplace and on the hill, where all trees were taken out last winter that we could discern, we found in September 845 trees over one foot in diameter that were much diseased and a great many smaller ones."

Mr. G. H. Bartlett of North Guilford writes: "In the vicinity of North Guilford and North Madison the chestnut blight increased very rapidly in 1912. Young trees seemed to be less able to resist the attack than old and large ones. Present indications are that all chestnut sprouts will soon die. Some old trees seem likely to survive for a time."

Mr. E. C. Warner, of North Haven, says, however: "In regard to the chestnut blight I would say it was very much more prominent in 1911 than in 1912. I think it spread very fast in 1910 and 1911, and not very much in 1912. In some places where we cut the diseased trees, blight did not increase very much, and one piece of sprouts I was through the other day did not seem any worse than last year."

Mr. C. A. Metzger, of Mount Carmel, also writes: "As a whole, the blight seems about the same as last year. It does not seem to have advanced as fast as it has hitherto. On our Mount Carmel farm the number of trees infected this year seems less than the number last year."

Litchfield County. Our first knowledge of the occurrence of the disease in this county was due to specimens sent by W. E. Frost from Bridgewater in January, 1909. The next August Mr. F. V. Stevens, Jr., sent specimens from Harwinton and also reported the disease from near Winsted; and Spaulding (69) found specimens at Bantam in September. In January, 1910, E. M. Stoddard collected specimens at Litchfield, and in March W. O. Corning sent others from Marbledale. So by the beginning of 1910 the disease was certainly well established throughout this county. So far the blight has not caused so much damage as in New Haven County, though in some places it has been very severe. Several of the best observers here seem to have noticed an apparent halt in the progress of the disease the past year, which, if continued for another year, will give hope that the chestnuts may escape the severe injury caused in Fairfield County. We estimate the infected chestnuts to be from 40 to 50 per cent. in this county. Of the reports received, seven indicate an increase of the trouble over 1911, while six say the disease was about the same, or less conspicuous.

J. H. Putnam, of Litchfield, writes: "I do not think that the chestnut blight has spread any worse the past season. Its ravages are more noticeable, as many trees previously attacked but not noticed, are now dead. The pieces where I cleaned it out two years ago do not show much spread since." In a later letter he adds this interesting statement: "We have no large trees killed, but have just cut a large tree seriously injured. The cankers on this showed that the disease had gained two to three inches in 1911, but only one-half to one inch in 1912, and in some places the new bark had held its own. Looking over a block of sprouts some ten years old, I found that where two years ago I had considered them doomed, they were making a splendid fight, and in some cases had apparently entirely overcome the disease."

Donald J. Warner, of Salisbury, takes a similar favorable view, as follows: "I do not think that there were as many trees attacked by the blight in 1912 as in 1911 in this vicinity. On our own property in 1911 we cut several infected patches, and around these patches there were quite a number of trees which died in 1912. Of course it is quite possible that these trees had the disease in 1911 and were missed by the choppers. I did not notice nearly as many new cases as in the previous year."

C. L. Gold, of West Cornwall, expresses the same view: "I have been cutting quite a lot of chestnut timber this last fall and winter, and find considerable evidence of the disease, which did not show much or at all before the tree was cut. However, the general appearance of our forests as we look at them from a distance showed but little signs of it the past season, nothing near as much as in the summer of 1911. It would seem as if the trees already infected would surely die, but from the results of the past season I am not so sure of it."

W. O. Corning, of Marbledale, however, reports a worse condition, as follows: "I sent two men this morning to cut out my next winter's wood, and I found a very bad condition, nine out of ten young trees about thirteen years old infected. I was on the same ground last winter, but I found only half as many diseased as to-day. Of my Japanese trees, a great many of them will have to be cut down, and with the same ratio of progress none will be left in three years."

Ellicott D. Curtis, of Bantam, likewise sees no improvement, as he writes: "In our own woods the blight is much more conspicuous than last year, and is doing much greater damage. Some of the infested woods were thinned last winter, and the diseased wood taken out. This winter the disease is very prominent in these, and it looks as if the chestnut would have to be cut clean. It looks to me as if our chestnuts were completely doomed, although I have not so far been able to find the disease in a small stand of trees about sixty years old."

F. V. Stevens also takes a similar view: "At Torrington the outlook is about as bad as it was here [Stamford] three years ago, i. e., it promises to cause a total loss of all the chestnuts in that vicinity."

Middlesex County. Forester Moss found a single infected tree in the state forest at Portland in March, 1910, and this is the earliest date we have for the disease in this county. Later examination, however, showed this infection to have occurred probably as early as 1906. The disease was seen by the writer at Middlefield and Middletown in March, and at Chatham and East Haddam in July, 1911. The blight as a whole is probably somewhat worse here than in Hartford County, but not so bad as in Litchfield. We estimate 30 to 40 per cent. of the chestnuts infected. Three persons report the disease worse, and three no worse, in 1912 than in 1911.

Mr. J. E. Doane, of Centerbrook, writes: "I find plenty of blight in the chestnuts, more in the young than in the older growth. I find about one-half of the twenty-year-old trees in a tract that I have are either dead or diseased. I do not believe that there is any chestnut about here that has escaped from the blight, and think it has spread more in the last year than any time before." D. Herdman, of the Wadsworth estate of Middletown, also thinks the trouble on the increase, as he says: "There is no doubt in my mind but what the blight is more prominent on this estate in 1912 than it was in 1911."

W. S. Hungerford, of East Haddam, reports an improvement: "I noticed the chestnut blight as being more conspicuous in 1911 with a slight decrease in 1912." Mr. J. C. Reeves, of Portland, says: "I think it showed up more prominently in 1912 in some localities, and not so much in others. On my land it was decidedly worse. Not so much new disease, but the trees showed it more. I think there is a change on the state land where we have cut it out. In some places where we would get a load last year, we did not find a tree with the disease."

Hartford County. The first reports we had of the disease in this county were in the fall of 1910, Forester Filley having collected specimens at Hartland in September, and Spaulding (69) at Windsor, and L. H. Goodrich at Hartford, in October. In March, 1911, the writer found the disease at Granby. At present the disease is perhaps not as bad as in Middlesex County, though in some regions considerable damage has been caused. We estimate 25 to 35 per cent. of the chestnuts infected. Of the letters received from this county, three writers think the disease worse in 1912 than in 1911, and three think it was no worse.

Mr. G. H. Hollister, superintendent of Keney Park, Hartford, writes: "As we made a pretty thorough cutting of the diseased chestnut trees last winter, I have not found the tops of the larger trees so badly infected as last year. I have found a great many trees with one or more branches infected, and more young trees than ever before. Probably many of the older trees have the blight, but it is not easily seen at present. On the whole, I consider the disease more prominent in 1912 than in 1911."

S. W. Eddy, of Avon, says: "I looked over the woods yesterday, and would state that there is much more chestnut blight than last year. It showed up more in the young growth and small trees in the open. In fact, the woods and trees there show many leaves still holding on, and on looking them over, one can find the yellow or orange fruiting pustules."

R. S. Tryon, of Glastonbury, writes: "The blight is generally prevalent here, I should say more prominent in 1912 than in 1911, but growth and spread appears not to have been so rapid.

Have noticed two or three instances where healthy growth appears to be overcoming diseased portions."

F. H. Stadtmueller, of Newington, says: "We have as yet escaped any perceptible invasion of the chestnut blight in this immediate vicinity, consequently can make no comparative statements. Lumbermen of this neighborhood have reported it less prevalent in 1912 than in 1911."

New London County. Hodson (28) in 1908 reported the blight along the Connecticut coast to New London, and about that time or a year later Hazard, a Yale forestry student, reported it present in North Stonington. The first specimens we received from this county were sent from Gales' Ferry by Dr. C. B. Graves in May, and from Lebanon by T. E. Clark, in October, 1911. The disease does not seem so bad in this county as in the preceding, and yet is worse than in the two following counties. We estimate the number of infected trees as between 15 and 25 per cent. Only three answers to our letters were received, of which two said the disease was worse in 1912 than in 1911, and one reported it about the same.

Dr. C. B. Graves, of New London, writes: "I should say the blight was just about the same as to general prevalence, but it is my impression that the proportion of badly infected and dead trees may be somewhat greater." Walter C. Tanner, of Voluntown, says: "Where I noticed this blight in 1912, it was much more conspicuous than in 1911."

Tolland County. The writer saw specimens of the blight at Mansfield in July, 1910; Filley collected specimens at Bolton in November of the same year; and H. Wood sent specimens from Tolland in April, 1911. As yet the blight has done comparatively little harm in this county, less than in any other except perhaps Windham. We estimate the percentage of infected trees to be between 10 and 15 per cent. Of the replies received to our letter four place the disease as more, and three as the same, or less conspicuous in 1912 than in 1911.

E. G. Walker, of Union, writes: "There is very little chestnut blight in Union, and I do not think there was any increase over 1911." George Towne, also of Union, says, however: "More cases of the chestnut blight were observed by me in 1912 than in 1911. There is little doubt that it is spreading in this locality." Harry Wood, of Rockville, also thinks it on the increase: "In answer to your question it is my opinion that the disease around here has steadily increased in the past two years."

George V. Smith, of Willington, says: "The blight is increasing quite rapidly in this town. In 1911 I did not observe more than a few cases. In 1912 I found it in colonies of infection. Some men tell me they are finding it everywhere in chestnut cuttings. Two years ago I did not find a tree on my farms. Now there are many." Professor C. D. Jarvis, of Storrs, writes, however: "Replying to your letter, I would say that in my opinion the chestnut bark disease has not been so conspicuous during the past year. Fewer new infections were discovered, and the spread of the disease seems to have been much slower in the sections where it was present."

Windham County. Former Forester Spring collected the first specimens we had from this county at Windham in September, 1910, while Filley and Stoddard reported it from several towns in the fall of 1911. The last two towns in the state in which we found the blight were in this county. The situation here is about the same as in Tolland County, or perhaps somewhat better, as we estimate only 5 to 10 per cent. of the trees infected. Two reported the disease worse, and four as the same or better in 1912 than in 1911.

Mr. W. H. Hammond, of Hampton, writes: "So far as my observation went on my own farm, I was of the opinion that the blight did not spread last year as much as I expected, but there were many reports of it in new sections of the surrounding towns." C. S. Hyde, of Canterbury, says: "I should say the blight was about the same as in 1911, but if anything not quite so prominent in this section." C. E. Child, of Putnam, says: "Less prominent in 1912." On the other hand, C. A. Tillinghast, of Danielson, writes: "I have found the chestnut blight spreading quite rapidly in this section, much more in 1912 than in 1911."

Future Outlook in the State. If we judge from what the blight has already accomplished in Fairfield and New Haven counties, and what it is now doing in certain parts of Litchfield, Middlesex and Hartford counties, there does not seem to be much hope for those regions where the blight has become firmly established. There are those who believe that the blight is bound to go on in the future just as it has in the past, which means the death of all the chestnuts in the infected regions. On the other hand, there are others, like the writer, who believe that there have been unusual conditions that have favored the rise and spread of the disease so far, and that the crest of this wave of infection is bound to be reached, and a gradual decrease to follow when these conditions are changed.

The blight has become far too prevalent and widespread to show sudden improvement in a single year, yet we believe that a let-up in its destructive spread was shown in the year 1912. In 1911, according to all our information, blight was by far more conspicuous and became more widely distributed than in any previous year. This was a year of serious drought, following several dry years. In the winter and spring of 1912 numerous rains replenished very largely the depleted supply of water in the soil, so that even trees in general that had not suffered seriously from any particular trouble showed decided improvement in foliage and growth. This was especially true of the peach, which is a very good indicator of weather conditions. True, there was a drought period in midsummer in 1912, but this did not affect trees so much as it did the superficially rooted crops.

Now, if weather conditions have had nothing whatever to do with the spread of blight, so far as increased or decreased vigor of the chestnut trees is concerned, then the blight in 1912 should have been far more prominent, destructive, and widespread than in any previous year. Yet, thirty-one out of sixty-four persons answering our letter stated that the blight was no worse, or even apparently better, in 1912 than in 1911. If our observations and those of the persons who corroborate them are true, then there is certainly some hope for the future of the chestnut in Connecticut. Just what percentage of the trees will survive the blight we do not aim to predict, but we certainly do not believe they are all to be exterminated.

RELATION TO CONDITION OF HOST.

General Statement. Some writers believe that the condition of the host has had no influence whatever on the rise and spread of this disease. For instance, Metcalf and Collins (37) in 1910 said: "A debilitated tree is no more subject to attack than a healthy one. * * * Dry weather checks the disease by suppressing spore production. * * * Winter injury is not common over the whole range of the bark disease, but may be locally important in producing lesions through which the parasite enters. Winter injury bears no other relation to the bark disease." Metcalf (35, p. 225) in 1912 said again: "No definite evidence, experimental or otherwise, has been adduced to show that a tree with reduced vitality is more susceptible to infection, or that the disease spreads more rapidly in such a tree than in a perfectly healthy and well nourished tree of either seedling or coppice growth, provided that such reduced vitality does not result in or is not accompanied by bark injury by which spores may gain entrance."

Now, if the condition of the host bears no relation to the rise and spread of the disease, the writer knows of no satisfactory explanation for its sudden and destructive appearance in this country except its importation from some foreign country. The evidence to date, however, is very strongly against the idea that it is an imported pest, as we shall show later. Among the farmers in Connecticut who have been able to watch this disease rather closely there are many who believe that the weakened vitality of the chestnuts has had considerable to do with its development and spread in this state. The writer more than anyone else has advocated this view, and we propose to give here the reasons we have for holding it. Briefly expressed, they are as follows:

The chestnut blight was brought to sudden prominence just after the severe winter of 1903-04, which injured and killed fruit and forest trees in general along the coast and water-courses, of which New York City was the central point. The resulting enfeebled condition of the chestnut enabled the blight, a previously inconspicuous parasite, to spring into sudden prominence on these trees and to gain credit for the death of others which had been largely or entirely due to winter injury. Since then we have had one or two severe winters, and more especially several dry summers, that have injured not only the chestnut, but other forest trees over an extended area. Due to its successful attack on the weakened trees, the blight fungus has perhaps acquired an added virulence that has enabled it to attack apparently healthy trees, especially those of sprout renewal. The enfeebled condition of the chestnut trees and their consequent susceptibility to the blight may possibly be related to some lessened chemical activity in the bark and newly-formed wood, such as the production of tannic acid, for instance. If so, then when this has returned to its normal production through favorable weather conditions, the blight should gradually become correspondingly less aggressive. Under the following heads we shall take up more in detail our ideas of the relationship between weakened vitality of the chestnut and consequent susceptibility to the blight.

Winter Injury. We have in a previous Station Report (6) called attention to the results of winter injury on fruit and other trees in Connecticut. We shall attempt here to show also that these conditions were not confined to this state. In December, 1902, following a very open fall, the temperature suddenly fell below zero, with the result that many trees, especially young fruit trees which had not properly matured their wood, were severely injured or killed outright. The following winter of 1903-04 was so unusually severe that thousands of fruit trees in Connecticut, especially those situated in the valleys and on the lower slopes, were killed, and others so severely injured as to develop physiological troubles for some time afterward. The injuries caused by these two winters were most noticeable in the region along the Sound, in the valleys or on the lower hill slopes, and along the river courses, regions in which the chestnut blight afterward first appeared, and in which it has caused the most damage. The winters of 1906-07 and 1907-08 also caused considerable winter injury.

Although we did not at the time directly study the effect on the forest trees of these winters, especially that of 1903-04, which was the most severe, we do know from subsequent observations that many trees were injured. In the summer of 1904 we examined a young fruit orchard, at Stamford, whose wood had been largely killed by winter injury; and two or three years later in examining chestnuts from this region, where the blight has been the most severe, we could see indications of winter injury to the wood of the chestnut sprouts dating back to the winter of 1903-04. In the winter of 1910, in examining chestnut at Middlebury, where the blight was just coming into prominence, we found quite a number of injured and dead trees with no sign of the blight on them. There were others with the bark killed on the south or southwest exposures, and sound on the northern, as shown in Plate XXIII c by the dark and white wood; and on many of these there were no signs of the blight fungus as yet. There is no doubt that these trees had been injured by an attack of sun-scorch winter-injury, complicated probably by summer droughts. That we are not alone in believing that these winters did not confine their injurious effects to Connecticut or to fruit trees, that they may have had some connection with the chestnut blight, and that some persons have attributed their effects to fungous and bacterial troubles in certain cases, we shall attempt to show by the following quotations.

Concerning the injury to fruit trees caused by the severe winter of 1903-04, Waite, of the United States Bureau of Plant Industry (Bull. 51), writes: "The severe cold weather of the past winter, especially the intense cold of January 4th and 5th, resulted in very severe damage by freezing to orchards in New York and New England, especially in the Hudson and Connecticut valleys. The damage was found to be mainly to peach, Japanese plums and pear trees, and the most serious harm was largely confined to the lower levels and pockets."

Eustace, of the Geneva, N. Y., Station (Bull. 269), in his discussion of this winter injury, says: "The winter of 1903-04 was an unusually severe one throughout New York state. In many places the temperature was the lowest on record, and the periods of extreme cold were protracted. As a result the end of the winter found many of the orchards, especially those of peaches and pears, extensively and seriously injured. * * * The damage was greatest in the Hudson River valley, where the cold was most severe, more than forty degrees below zero being reported. * * * At the end of the winter the external appearance of the trees was entirely normal, the bark of the trunk was smooth and of normal color, and the twigs on all parts of the tree were plump and bright. Nothing about the trees looked unusual or wrong, but upon cutting into the trunk anywhere above the snow line, it was found that both bark and wood were discolored for some depth into the trunk. * * * Altitude, air drainage, and condition of the soil had a very important bearing upon the severity of the injury. The advantages of a high altitude were best shown in some of the peach orchards in the Hudson Valley. * * * The dying of the trees (afterwards) at such unusual and irregular times gave rise to much alarm among the fruit growers in some localities. It was feared that a virulent attack of the yellows had broken out, or some new and serious disease had become prevalent."

Whetzel, of the Cornell, N. Y., Station (Bull. 236, p. 133), says concerning a supposed outbreak of the bacterial blight of apple in that state: "Anything that reduces the general vitality of the tree tends to render it more susceptible to attack of the bacteria. I have already referred to the apparent effect of low temperature in relation to this disease in the Hudson River region. A long growing season during 1902, with excessive rain, followed by a sudden and extreme fall of temperature early in December, is referred to by growers in that section as the beginning of the injury to their orchards. The winter that followed was a severe one, with sudden and severe changes of temperature during the early days of the spring of 1903. Many trees failed to leaf out, and large cankers were now observed on limbs and bodies of dead and dying trees. The general conclusion at once prevailed that these dead spots were the direct results of these weather conditions. * * * I am therefore of the opinion that many of the trees in the Hudson River Valley and about Kirkville were cankered prior to the winter of 1902-03. The severe weather no doubt weakened the trees yet free from the disease, thus rendering them more susceptible to attack during the summer of 1903. * * * The winter of 1903-04 was also a severe one, and no doubt added to the sum of the injury already produced. To just what extent the winter injury in this section is responsible for the death of the trees is a question. In certain cases it was very evident that the trees had died from this cause." This statement shows that Whetzel recognized the importance of these winter injuries, though apparently he made a mistake in considering blight the major cause of the trouble.

Stone, of the Massachusetts Station (Report 20, p. 123), also says: "In previous reports attention has been called to some of these troubles, more particularly to the extensive winter killing which caused so much injury during the winter of 1903-04, at which time thousands of trees and shrubs were severely affected, many having been dying slowly ever since. Besides the trees which are dying, there are many others which are in a very much weakened condition. Numerous oaks which were injured four years ago have died during the past three years, and some of these not yet dead are gradually becoming weaker. * * * Mention has previously been made in our reports of the condition of the red maples, many of which are now gradually dying, and the white and rock maples are suffering to a limited extent from the same cause." And in a later Report (23, p. 66) he adds: "The severe winter of 1903-04 was not confined to our state, as its work may be seen throughout the whole northeastern section of the United States, and in many instances large orchards were wiped out entirely."

The so-called pine blight was a trouble very prominent in New England a few years ago, culminating in its damage in 1907. At first some investigators, as well as growers, tried to show that this was a fungous trouble, but the investigations of Stone of Massachusetts, Morse of Maine, and of the writer, proved that it was entirely due to unusual seasonal conditions, prominent among which was winter injury. Concerning this trouble, Stone (Report 22, p. 65) writes: "The present pine blight dates back to the winter of 1902-03, when the conditions were such as to cause much injury to vegetation in general. The following winter, 1903-04, was even more severe in its effects on vegetation, and caused extensive root killing of many trees and shrubs. Pine, as well as other trees, in many cases was killed outright, but the injury to the pine was largely confined to the small roots or those less than three-sixteenths of an inch in diameter." Morse (Forester's Seventh Rept., Me., p. 24) also says: "Practically all of the so-called pine blight in Maine appeared in 1907 and 1908, and was coincident with the most destructive winter injury to fruit trees known in the state in the last hundred years."

In the spring of 1907 a late frost killed the immature leaves of the sycamore over a considerable area, as shown by von Schrenk and the writer. It is at this time of the year that the anthracnose fungus begins to be prominent, and the action of the frost was so similar to that of the fungus that several investigators, who apparently were not acquainted with the result of this frost, later laid the trouble entirely to the fungus.

And this has been the case with a number of investigators who have laid winter-injury troubles largely or entirely to the fungi which later became prominent on the winter-injured tissues. One of the first problems the writer had in Connecticut was to connect, as the cause, a Cytospora fungus found on cankered bark of apple trees. We did not know as much about winter injury then as now, and were using the agent that was most evident at the time of the investigation, which occurred some time after the winter-injured cankers were produced.

As to the relationship of winter injury to the chestnuts themselves, we have this statement by Murrill (45, p. 153), when he first began his investigations: "It is possible that the conspicuous ravages of the disease about New York City are largely due to the severe and prolonged winter of 1903-04, in which many trees of various kinds were killed or injured." Later, Murrill seemed to have given up this idea. Stone (Report 23, p. 57) also writes on this point: "The writer has been informed by one who has had some opportunity to observe this disease, that it appears to be less prevalent on high elevations than in the valleys. * * * It is, however, quite significant that the Connecticut Valley region should possess such a large amount of infection as compared with other sections. We have noticed for some time that there is a difference in the degree of winter killing occurring in valleys and high elevations in this state. By far a greater amount of winter killing of trees occurred in river valleys and on the lower elevations, the Connecticut Valley being especially notable in this respect. It is, moreover, a significant coincidence that the chestnut disease should make its appearance at about the same time that vegetation was so severely injured by the severe cold which occurred during the winter of 1903-04 all over the northeastern part of the United States."

From the preceding discussion we have made it evident that there was a general and severe injury of trees of various kinds, resulting especially from the winters of 1902-03 and 1903-04 in New England and New York. We believe that the same conditions would have been found true for at least New Jersey and eastern Pennsylvania, had observations been made there at that time. This winter injury took severest effect along the

Sound* and its contributory rivers, and was soon followed in all these regions by the outbreak of chestnut blight.

Merkel (32), just about a year after the blight was first noticed by him, states that 98 per cent. of the trees were then affected, and adds: "The disease was noticed with equal frequency upon young specimens in the nursery, upon sprouts that had sprung from stumps of trees cut down the previous year, on young vigorous trees thirty to forty feet high standing in deep, rich soil, and also upon the few survivors of the primeval forest with trunks twelve to fourteen feet in circumference." Such a destructive and indiscriminate attack in a single year is not the history of the blight in the later infected regions. To the writer it leads to but one conclusion, namely, that in those regions where the blight first appeared and was most severe the trees had suffered severely from winter injury, as this is the only agent we know of that acts in such a quick and thorough manner.

Drought Injury. There are a number of observers, like Metcalf and Collins, who claim that lack of moisture as affecting the vigor of the chestnut has nothing whatever to do with the spread of the blight, but that, on the other hand, it should show greater progress in moist seasons, since these favor spore development and infection. This idea is also expressed in the following statement by Murrill (46): "Dry summers and otherwise unfavorable conditions may delay the progress of the disease a few years, but not very long." If the fungus were a strictly parasitic species, the condition of whose host made no difference in its virulence, this would be true. The writer, however, holds that the reverse is really the truth, namely, that drought, by weakening the trees, has greatly increased the spread of the disease, and that moist years, while favoring spore production, increase the resistance of the trees, and thereby really lessen infection.

From 1907 to 1911 Connecticut, at least, had an unusual series of summers, with drought periods that caused serious damage to cultivated crops and forest trees in general. For trees alone, that of 1911 caused the most injury, since it was not only severe

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* Hodson (28) wrote in 1908:—"A favorable feature in the situation is that so far the disease has done most damage in the vicinity of the sea."

in itself, but was a culmination of a period of dry summers. During this dry period blight has been most conspicuous in its development and spread in Connecticut, culminating in 1911 with by far the most frequent complaints of damage and spread to new localities. Its unusual prominence in 1911 was not confined to Connecticut, for according to Rane (57, p. 49), Metcalf wrote him: "During the past summer the disease has spread more than in all its previous history." As we have already stated, the winter and spring of 1912 were so wet that much of the depleted moisture was restored to the soil. As the result, the general aspect of fruit and forest trees, including chestnut, showed great improvement over 1911, and along with this came a more or less apparent let-up in the spread and severity of the blight.

The particular situation of the trees, according to our observations, often makes a big difference in the development of this disease. Those on the edge of the forest, specially on the southern exposure, have often showed the disease first and most severely. Isolated clumps of sprouts in the open are very susceptible. Forests that have been opened up by removal of trees, especially if on hillsides with southern exposure, are where we find the blight most prominent. Also we have sometimes found it bad in the lowlands. All these represent conditions where the trees suffer most from lack of moisture under continued severe drought.

We have especially in mind a forest in Middlebury on a hillside with southern exposure where the blight became very prevalent. There the trees unquestionably suffered severely from lack of moisture due to the droughts and the opening up of the forest by the removal of diseased trees. Many of those left finally showed sun-scald cankers with accompanying development of blight, at their base on the southern exposure, while the protected northern sides did not. Young nursery trees on this hillside also developed similar sun-scald cankers the first summer they were set out. While this part of the forest was being severely injured, trees on the northern exposure showed very little of the blight.

This observation agrees with the statement of Ashe (Tenn. Geol. Surv., 10 B, p. 11), who writes: "For many years the chestnut on the lower mountains in the southeastern portion of the state has been dying out a few trees at a time. * * * Trees in the hollows and on cool north slopes and on land where a moderately dense shade and soil cover exist have not been affected. * * * The dying off of the trees is certainly not due to the chestnut bark disease." Local conditions such as outcrop of rocks, depth and character of soil, water table, presence of streams, exposure, etc., are all factors in the regulation of soil moisture,* and are not always easily determined by superficial examination. We do know that the blight often acts quite differently with these conditions varying in the same vicinity.

It is often hard to distinguish drought injury from winter injury, as trees that have suffered from severe droughts without much outward evidence of the trouble often succumb during the following winter, and winter injury is given the entire blame. This was well illustrated after the drought of 1911, by a number of fine large chestnut trees on the Experiment Station grounds. The drought of 1911, following the preceding dry years, was very hard on certain of these trees, as the rock in spots comes very close to the surface. The result was that, following the winter of 1911-12 they were seen to be very badly injured at their base, the dead bark in some cases almost entirely encircling the trees. On one tree this dead bark ran up the side for a considerable distance. A little of the blight fungus showed on these injured areas shortly afterward, but it was entirely a secondary factor.

There can be no question whatever that these droughts have injured various trees; and there is no getting around the fact that the blight has been more prevalent because of these droughts, and seems to have gotten the credit for injury to the chestnuts that is in part due to the droughts. Most persons admit that drought has injured and killed many trees other than the chestnut, yet are reluctant to concede that anything but the blight is responsible for the death of the latter. The injury by drought is well illustrated by the death of trees in

* We understand that, due to the installation of a large water reservoir in the southwestern part of Long Island, the water table of the surrounding region has been lowered considerably. This in turn has severely affected the forest trees, among which are many chestnuts. The blight is quite bad in this region.

East Rock Park, New Haven. This rock rises to a considerable height above the surrounding country, and the soil in many places is quite shallow, so that the trees have suffered severely from lack of moisture during the dry years. The chestnut has suffered with the other trees, and the blight has developed conspicuously, killing many of them. Superintendent Amrhyn furnishes us with the following list of dead and dying trees that were found in this park in 1910.

"I herewith enclose a list of dead trees found in the East Rock Park forests in an inspection made during the month of August, 1910. You will find the largest percentage of them to be chestnut and hemlock. The first were not all dead, but were severely affected by the blight. The hemlocks are all dead, but a few of them have been in that state for two or three years, while all affected or dead chestnuts were cut down last winter.

Chestnut	1,362	Hickory	75	Beech	15
Hemlock	494	Maples	48	Elm	10
Oaks	271	Walnut	44	Linden	7
Birch	101	Wild cherry	24	Locust	4
Cedar	101	Ash	23	Sassafras	3
Carpinus	84	Pines	17	Apple	2

"I think that a very large percentage of these trees, 2,685, have died on account of the great dryness which has existed for about three years, changing conditions ever so much for the root systems of the trees."

Other investigators have admitted the connection between drought injury and blight infection, or at least the possibility of such connection, as shown by the following quotations:

Stone (Rept. 23, p. 57) says: "Our observations on the effects of meteorological conditions on vegetation, and the unusual opportunities we have had to study shade tree conditions for some years, have brought to our attention the unusually large amount of dead wood found on chestnut trees the past four or five years. From what we have seen of the chestnut during this period, we are of the opinion that it has not been in the best condition during late years, and that the chestnut, like the native white and black oaks, elms, red and rock maples, ash, etc., has been more or less affected by the severe cold and droughts of late years." A year later he writes further (Rept.

24, p. 78): "Like the preceding one, the past summer [1911] has been exceptionally dry, and the heat has been intense at times. This drought, coming as it did after three or four previous dry seasons, has affected vegetation to a considerable extent, and will result in later injury, especially to trees."

Rane (54, p. 152) said: "The disease was worse where thinnings had been made and a few trees allowed to stand because they were not large enough to cut into ties. These forests were unbalanced, and the air and sun allowed to get in. The blight was on the southern side; the cankers showed up largely there, but in the stands where we had normal conditions we found only a diseased tree once in a while."

Rankin (60, p. 47), in speaking of the relation of chestnut blight to drought, says: "Preliminary investigations carried on by the speaker seem to point to the fact that the susceptibility of the chestnut tree to this fungus depends upon drought conditions; that is, a low water content in the tree. * * * If the results of Doctor Moench on the cause of susceptibility and immunity of forest trees to disease should prove true in the case of this disease also, we may hope to be able to control the bark disease in shade, lawn and park trees by keeping up the water content of the tree."

Dr. Caroline Rumbold (63, p. 57) states: "As for water, there is the question, as to whether or not droughts of recent years are partially responsible for the spread of the disease in the chestnut tree. I am now conducting experiments in which chestnut trees are being exposed to infection under varying conditions, from dryness to excessive moisture, both atmospheric and soil. These experiments may also throw some light on the report that the blight spreads rapidly where trees are in a crowded coppice, while trees growing on the ridge of a hill are unaffected."

Fire Injury. Not only the writer, but other members of the Station staff, have repeatedly noticed the blight on trees injured by forest fires. Examination of the region has usually shown that the blight was much worse on the trees within the fire area than on those beyond it. This fungus, in the writer's opinion, has not developed merely because of mechanical injury to the tissues, but rather because of lowered vitality of the inner bark and cambium. S. W. Eddy of Avon, in March, 1912, sent us specimens of the blight, and wrote: "We are enclosing you sample of what we think is the chestnut blight. As about 50 per cent. of the trees that were burned by forest fires last spring are covered with this growth, we desire very much to learn whether or not this is the blight." Mr. Eddy, in February of the following year, reported that he found the fungus abundant on the cut wood and fire-injured trees, but scarce on the perfectly healthy ones.

Others have noticed this relationship of blight to fire injury, as shown by the following quotations. Rane (54, p. 152) says: "There is an unbalanced condition again where forest fires have run through the state year after year, and the trees are abnormal, and only half alive anyway. There you find the disease seems to travel more rapidly than it does where the trees are under normal conditions, and have a forest floor where there is plenty of moisture and the conditions are more favorable." Buttrick, in a paper on the effects of forest fires on the trees (Forestry Quarterly, Vol. 10, No. 2), also remarks: "*Diaporthe parasitica,* chestnut bark fungus, seems to be more abundant and severe on fire-injured trees."

Sprouts versus Seedlings. Much of the chestnut of Connecticut has been cut over two or three times, being renewed by sprout growth. This repeated cutting has occurred not only in Connecticut, and in the greater part of New England, but in the chestnut forests of New Jersey, Delaware, and the eastern parts of New York, Pennsylvania and Maryland. It is generally admitted that this treatment has reduced the vitality of the coppice growth, as shown by the following quotation from R. Zon on the chestnut in southern Maryland (U. S. Dept. Agr. Bur. For. Bull. 53, p. 29): "It must not be forgotten, however, that a chestnut stump cannot go on coppicing forever. With each new generation of sprouts, the stump becomes more and more weakened, and hence gradually loses its capacity to produce healthy and vigorous sprouts. Although it is impossible to state with certainty how many generations of chestnut can be raised from the same stock without impairing the vitality of the sprouts, the effects of repeated and bad coppicing manifest themselves in the increasing number of dying chestnuts all over Maryland. The immediate cause of their death can nearly always be traced to attacks of either insects or fungi, yet the prime reason is their decreased vitality, which makes them easy prey to their natural enemies."

If the chestnut blight has no relation to the age or vigor of the tree, it is certainly a curious coincidence that the blight makes its first appearance and causes its greatest damage in the regions where the chestnut has suffered most from repeated cutting over. This is indicated by the two following statements.

Nellis, of the United States Forest Service, in an unpublished working plan on "Utilization of Blight-killed Chestnut," writes: "It is expected that this study will show that the present range of the chestnut bark disease is in a region of entirely second-growth chestnut, which has been culled of its most valuable timber, where only rough products are now being produced."

Barrus, of New York (54, p. 160), says: "In those sections of New York state where the chestnut disease is present most of the marketable timber has been cut out. Fire has gone through the remainder, and as a result, there is a great majority of the chestnut which is sprout growth of small dimensions. I should estimate that one-fifth of the chestnut is of merchantable size, and perhaps in the districts where the disease is, more than four-fifths is under merchantable size."

It has been our experience that young, especially isolated coppice growth, has suffered first and most severely in Connecticut. We believe that these sprouts are naturally weak and easily killed by drought, etc. On the other hand, very large seedling trees have been the last to go with the blight. We noticed also, in our inoculation work, that it was somewhat easier to infect sprout growth than young seedling trees, and that the cankers on sprouts developed more rapidly.

In June, 1912, we examined a field where the Ansonia Water Company had planted about seven bushels of chestnuts in 1908, in 1909 had set out 6,900 one-year seedlings, and in 1910, 9,875 two-year seedlings. While many of these seedlings had been killed by drought soon after they were set out, as shown by the vacant places, we were able to find only two seedlings that showed any signs of the blight fungus. Yet the woods surrounding these trees were quite badly infected with the blight.

At one of the Connecticut nurseries, however, in September, 1911, we inspected about three hundred five-year-old American seedling chestnuts which had been transplanted when one year old, and found 46 per cent. infected with the blight, which had been present there at least two years, and probably started at the time of transplanting. The roots of these plants, when examined, were in good condition. We had the superintendent cut off all the diseased trees in one row (sixty-nine), and in February, 1913, the sprouts that had come from these showed only one that was plainly infected with blight, although they were exposed to the blight from infected seedlings that had not been removed. The first-year sprouts from old stumps also rarely show infection. According to our infection experiments, it usually takes only a month for the canker to show after inoculation, so these one-year-old sprouts had time to show the disease if they were infected. We believe the old, well-established roots produced unusually vigorous sprouts, which for the time being, at least, escaped infection.

Vitality versus Chemical Activity. We believe that favorable or unfavorable climatic conditions for a plant are recorded through chemical activities concerned with its growth and vigor, and that a lessening of this chemical activity might with some plants be shown by lessened resistance to fungous attack. The following few references show the relationship of environment on chemical activities of certain plants.

Hasselbring (Bot. Gaz. 53, p. 120) says: "It is true, of course, that plants are modified in their fluctuating characteristics by changes in the environment, but so far as experimental evidence shows, such modifications persist only as long as the environment inducing them persists. LeClerc and Leavitt, in their work with wheat, showed that this influence of the environment is exerted also on the chemical composition of plants. When wheat of one variety from one locality was grown in other localities with a widely different environment, the chemical composition of the grain was different in each locality. These differences persisted as long as the wheat was grown in the particular locality, but if at any time seed from one locality was grown in any of the others, the grain took on the composition of the wheat constantly grown in those localities.

Vasey (U. S. Dept. Agr. Rept. 1872, p. 171) mentions a case where the alkaloids of cinchona bark were decreased by unfavorable climatic conditions in the case of plants grown in England as compared with plants grown in Peru. Yet when plants from England were sent to India, their vigor was restored, and an increase of the alkaloids was shown by chemical analysis, especially in the descendants of plants sent there.

McKenney (Science 31, p. 750) writes concerning the blight of Central American bananas: "The juice of diseased plants contains much less tannin than that of the normal plants. * * * It has been proved that the disease is not due to local conditions, such as too wet or too dry soil, etc. Yet some of these conditions may predispose the plants to the disease." He does not say whether the lessened tannic acid is the result of the disease or vice versa.

Tannic Acid and its Relationship to Chestnut Blight. The chestnut as a source of tannin is one of our most important trees. However, it seems that most of this tannin is made from the chestnuts in the South, although they are utilized as far north as Pennsylvania. The reason for this is that the chestnuts in the South furnish a greater percentage of tannin than those in the North. At least one cause for this seems to be that the older the trees the greater the percentage of tannic acid, since the tannin is made from the ground wood and apparently comes largely from the older wood. As a rule, the chestnuts of the South are much older than those of the North, and are more likely to be seedlings. As yet the chestnut blight has not caused much harm in the South. Whether or not the present of more tannic acid in the trees there has any relationship to the absence of the blight is as yet uncertain, but there is a possibility of its having a direct bearing.

In answer to a question regarding variation of tannic acid in chestnut trees, Mr. F. Veitch, of the Leather and Paper Laboratory of the United States Department of Agriculture, writes me as follows: "I have your letter of the 11th inst. asking for the tannin content of chestnut wood. This differs all the way from 2 per cent. to as high as 10 or 12 per cent. in very old, dry chestnut. The chestnut wood used by extract makers probably averages around 6 per cent. of tannin. I can make no more definite statement regarding the tannin content of any particular chestnut than to say that young chestnut as a rule contains the least, while the old chestnut contains the highest percentage of tannin. Only the body and large limbs of the tree without the bark are used in the making of tannin extracts."

W. M. Benson (54, p. 229) makes a statement regarding chestnut trees grown on different soils which, if true, possibly explains why, in very dry years, the trees suffer more from the blight than in wet ones, since there may be some relation between the amount of moisture and lime taken in by the roots and tannin produced in the tree. He says: "The chestnut wood received at the extract factories was at first supposed to be all alike in tannin strength, but costly experience proved that wood from good strong lime shale or limestone lands is far richer in tannin than wood from soils that are rocky, sterile, and contain little lime. The difference is so marked that even the workmen in the leach house at extract plants can tell when wood from a lime shale or limestone region is being leached simply by the unusual increase in the strength of the liquid obtained from such wood. Chemical analyses proved the same thing beyond all question, that in order for chestnut timber to attain its full tannin strength it must grow on limestone or lime shale soil."

The part that tannin plays in the economy of plants is not very definitely known. It has generally been supposed to be largely a waste product, which serves more or less as a protective agent against animal and fungus attack. Some few writers have raised the question whether or not it might serve some use in the physiological activities of the plant, possibly in the way of food.

For instance, Pfeffer (Physiol. of Plants, 1, p. 491-3) says: "Fungi can assimilate many aromatic bodies such as tannin, resorcin, hydroquinone, phloroglucin, etc., but except in the case of quinic acid most of these afford very poor food materials. * * * Tannins, phloroglucin, and apparently all aromatic substances which accumulate to any extent, are contained in solution in the cell sap, so that their presence does not injuriously affect the protoplast. * * * Tannins and glucosides are undoubtedly produced for definite purposes, and are not mere by-products produced under all circumstances. * * * In spite of numerous recent researches, but little is known as to the function of tannin."

Barnes (Textbook of Botany, 1, p. 414) says concerning this subject: "Some substances, including the loose term tannin, are glucosides, and such as can be made to yield glucose by digestion may be considered as plastic substances rather than wastes." Stevens (Plant Anat., p. 205) also states: "Tannins seem to be by-products, set aside in the tannin cells from the general circulation. It is uncertain whether the tannins are ever used to an appreciable extent in nutrition. They seem to be of service, however, in warding off parasites by their aseptic qualities and astringent taste."

Cook (Delaware Agr. Exp. Sta. Bull. 91, p. 59), who studied the effect of tannic acid on different species of fungi in artificial cultures, says in his general summary: "It appears that tannin is an important factor, and that its importance varies in accordance with the other substances with which it is associated in the cells of the host plant. While tannin no doubt serves as a protective agent, its efficiency in this direction will vary somewhat with the character of the other substances within the cell. This may account for the variation in power of resistance between species, varieties, and individual plants. The fact that plants which produce large quantities of tannin are subject to disease is no argument against the preceding. The organism may live in tissues which bear little or no tannin, or which contain other substances that in a measure counteract the influence of the tannin. Furthermore, some species of fungi are much more resistant to tannin than are others, and the species which attack these high tannin-bearing plants no doubt possess this quality."

To the writer it has occurred that possibly tannin may serve as an unusual source of food for certain trees rich in this product under unfavorable conditions for active formation of their normal food supply, such as drought years, and that such a use would lessen the supply of tannin laid down in the annual growth of wood formed in these years. Or possibly if not used for food, these unusual conditions do not favor its normal production. In any case, if tannin content bears a relation to the blight disease, it is not the tannin of the whole tree that counts so much as the tannin of the bark and wood of that year's growth. If it bears any relation to the chemical activity of the tree, we can readily see that it could easily vary from year to year according to external conditions more or less favorable for its production.

In our tannic acid culture work with the true chestnut blight and its close ally, *Endothia gyrosa,* reported in detail later on, we found: (1) Both fungi can use tannic acid, at least in small amounts, as food,—shown by the blackening of media through oxidation, loss of acidity, more luxuriant growth, with a low per cent. of the acid added, than without it, and a slight growth on agar-agar with tannic acid as the available source of food. (2) Higher percentages of tannic acid (four per cent. and above) are detrimental to a vigorous growth of either of these fungi, and finally (10 to 14 per cent.) entirely inhibit their growth. But with the true blight the tolerance is apparently greater by 2 to 4 per cent. than that of the saprophytic *E. gyrosa.* (3) Long-continued cultivation of the parasitic variety in artificial cultures without tannic acid probably lowers its tolerance to the higher percentages of tannic acid. (4) Gradually passing these fungi in cultures from the lower to the higher percentages of tannic acid apparently raises their tolerance to it.

From the results of these cultural experiments and what we have been able to learn about tannic acid in the chestnut, we reason that the true chestnut blight is better able to become an active parasite on chestnut trees than the *Endothia gyrosa.* Any cause that would lower the tannic acid, etc., content of the trees would allow it to develop into a more vigorous parasite, and its gradual tolerance to this higher percentage of tannic acid would give it an added virulence up to a certain extent. With the return of the tannic acid, etc., content of the tree above this limit of tolerance, the fungus would gradually revert to a less virulent and finally to even an inconspicuous parasite.

PREVIOUS CHESTNUT TROUBLES.

Nature of the Troubles. It is well known that in times past the chestnut trees in this country have suffered severely in certain districts, particularly in the South, in some cases being practically exterminated, so that their range is now considerably lessened from what it was originally. Strangely enough, no one has surely accounted for any of these devastations.

Personally we believe that this tree is extremely susceptible to changes in the natural environment, and that such changes, with water playing an important part, have been the chief factors back of the gradual decline of this important forest tree. Other factors, such as forest fires, deterioration through repeated cuttings, insect and fungus attacks, are contributing causes varying in different localities.

The question naturally arises, has the blight fungus had anything to do with these previous troubles of the chestnut? As no one ever made a careful study of them at the time, it is impossible to state whether or not the blight was connected with them. One thing is certain, and that is that the saprophytic *Endothia gyrosa* is so generally scattered over the South to-day that there is no doubt it occurred in the regions where these chestnut troubles existed. It seems almost equally certain that the real chestnut blight does not to-day occur in those regions, or if it does, it is very inconspicuous. This would seem to indicate that if the blight had anything to do with these troubles in the past it was not able afterwards to exist there, but gradually extended northward. When one reads the accounts of the outbreaks, he can easily imagine that the trouble might be due to the blight fungus. We give here, arranged according to the time of their occurrence, some references to these troubles.

1825-45. We quote the following from an article by Mr. Jones of Georgia, which appeared in the American Journal of Science, Vol. 1, p. 450, in 1846: "The present remarks are particularly directed to the death and disappearance of some of our trees and shrubs. The first that I will mention is the *Castanea pumila,* which is a tree from ten to thirty feet in height. In the year 1825, during the months from June to September, I observed this tree dying when in full leaf, and with fruit half matured. I examined numerous individuals, and could find no internal cause for their dying. I at first attributed it to the great fall of rain which took place in the year 1823. During the month of July of that year a considerable quantity of land not subject to overflow was covered with water for some time, and the highest lands were completely saturated. The latter part of 1824 was also very rainy. Knowing that this tree belongs in our highest and dryest soils, I concluded it was owing to a too moist state of the ground, but since that time I am convinced that there must be some other cause, for the tree continues still to die up to the year 1845, and if the disease is not arrested, in a few years I fear it will be entirely exterminated."

1856. Following is a letter from Professor G. W. Hilgard, received October 25, 1909 (similar observations by him have been recorded by Dr. Rumbold in Science, Vol. 34, p. 917): "Your paper on the chestnut disease in New England reminds me of some old observations of mine made in the state of Mississippi in 1856. Traveling in the pine hills of northeastern Mississippi, I noted that of the small percentage of chestnut trees among the pines only a few were living, the great majority, mostly very large, tall trees, dead and decaying. On inquiry of the inhabitants, I found that this deadening had occurred lately, and they were at a loss to account for it. To my question why so many were charred at the base, the reply was that when the boys wanted to make a fire for nooning, they made it against these trees because they burned easily. The trees had not been killed in that way, but had died 'of their own account.' No other kind of trees seemed to be diseased. It was distinctly a dying off of the chestnut alone, and it extended far into Alabama. It would be interesting to know whether the results of that epidemic have been permanent, or whether a new growth has come since the time I saw it. If the Diaporthe disease existed in Mississippi, the presumption is that it extends or extended all along the western Alleghany slopes, and has perhaps reached the Atlantic Coast only recently."

1856. This note was found in The Horticulturist, 1856, p. 97: "All the chestnut trees throughout Rockingham County, North Carolina, and the surrounding counties have died this season."

1855-75. The following references are taken from an article on Statistics of Forestry in the U. S. Dept. Agr., 1875, p. 262, and are concerning chestnuts in the southern belt: "In several localities chestnut for some undiscovered reason appears to be dying out." Under notes on forestry conditions in Henry County, Va., is the following statement: "Chestnut has been dying out for years, and there are fears that it will become extinct." Concerning Elbert County, Ga., is the following: "The forests are a mixture of almost all kinds, but chestnut during the last twenty years has nearly died out." Under

Carroll County, the same state, is the statement: "The forests contained a large quantity of chestnut, which began to die about ten years ago, and now scarcely a tree is left. Even the bushes are nearly all dead, though no insect or worm or other cause affecting them has been discovered." From Hall County also it is said: "Until within a few years chestnut abounded, but now nearly every tree is dead or dying." And from Walton County: "The chestnut has all died."

1847-77. Under Diseases of Chestnut, p. 116, A. S. Fuller, in The Nut Culturist, published in 1896, writes: "I have never noticed any special disease among chestnuts, neither do I find any mentioned in European books on forestry. The nearest approach to any such malady being recorded as having appeared in this country, is found in a paragraph in Hough's Report on Forestry, 1877, page 470, where the author copies from Professor W. C. Kerr, state geologist of North Carolina, as follows: 'The chestnut was formerly abundant in the Piedmont region down to the country between the Catawba and Yadkin rivers, but within the last thirty years they have mostly perished. They are now found east of the Blue Ridge only, on higher ridges and spurs of the mountains. They have suffered injury here, and are dying out both here and beyond the Blue Ridge. They are much less fruitful than they were a generation ago, and the crop is much more uncertain.' While there is nothing said about chestnut disease in the paragraph quoted, we only infer that the author intended to convey the idea that the trees were suffering from some endemic malady, although it may have been due to long droughts, insect depredators, or other causes. A few years later Mr. Hough, in his Elements of Forestry, refers to the subject again, and admits that 'the cause of the malady is unknown.' But as the chestnuts continue to come to our market in vast quantities from the Piedmont regions, there must be a goodly number of healthy trees remaining."

1889. On this date, P. H. Mell, in the Ala. Exp. Stat. Bull. 3, p. 16, says: "The trees [chestnut] of this state seem to be subject to a blight, or some destructive disease that is rapidly destroying them. This is particularly true when other trees are cut around them. This subject is worthy of careful investigation, and will be a problem for the experiment station to solve in the future." Recently writing to Professor Mell regarding this trouble, he replied: "In reference to Bulletin 3 of the Alabama Experiment Station in regard to the disease which attacked the chestnut trees in Alabama during 1889, I do not think investigation was ever carefully carried out." Atkinson, former, and Wolf, present botanist, at the Auburn Station are unable to throw any additional light on this trouble.

1894. G. McCarthy, in N. Car. Exp. Stat. Bull. 105, p. 267, says concerning chestnut in this state: "The woodman's axe, casual fires, and the ravages of the root disease, have wrought much havoc with these grand forests."

—*1896.* W. P. Corsa, in Nut Culture in the United States, a special report of the U. S. Dept. Agr., Div. Pom., published in 1896, p. 78, writes: "From causes not well understood, there is a marked decline in the vigor of the chestnut throughout the broad area of territory in the Southern States where the white man found this tree among the most thrifty of the original forests. Down to the first quarter of the present century there seems to have been no mention of a trouble in the chestnuts of that section. Within the memory of residents of the Gulf States the chestnut flourished in all their higher lands. In point of time the trouble seems to have begun in the most southern limit of chestnut growth, and there the destruction has been most complete. It has pushed its encroachments throughout Mississippi, Alabama, Georgia, and South Carolina, and is now reported in the strongholds of chestnut growth in North Carolina, Tennessee and Virginia. Observation of the native chestnut growth of Maryland and Virginia discloses the fact that many trees are dying without apparent cause. In some sections this is attributed to the ravages of insects. In others, to an unknown disease resembling blight. There is need for a more thorough investigation of this subject than has yet been made. No injury to the Japanese or European chestnut planted in this country is yet reported."

—*1901.* Dr. Mohr, in Plant Life of Alabama, published by the U. S. Dept. of Agr., Div. Bot., in 1901, page 61, states: "The chestnut, usually one of the most frequent trees of these forests, is at present rarely found in perfection. The older trees mostly show signs of decay, and the seedlings, as well as the coppice growth proceeding from the stumps, are more or less stunted. It is asserted by the old settlers that this tree is dying out all over the mountainous regions, where at the beginning of the second half of the century it was still abundant and in perfection."

—*1911.* W. W. Ashe, in Chestnut in Tennessee, Tenn. Geol. Surv. Bull. 10 B, p. 11, remarks: "For many years the chestnut in lower mountains in the southeastern portion of the state has been dying out a few trees at a time. * * * The dying off of the trees is certainly not due to the chestnut bark disease, a very destructive malady from Virginia to southern New England, no evidence of which was seen in Tennessee."

—*1912.* Dr. Hopkins (54, p. 180), of the United States Dept. of Agriculture, who has recently been making a study of the relationship of insects to the death of chestnut trees in the South, states: "When we review the history of the extensive dying of chestnut during the past half century in Mississippi, Tennessee, Georgia, South Carolina, North Carolina, and Virginia, it is surprising that there are any living trees left. In fact, there are not many left in some sections of these states, where the tree was abundant and healthy fifty years ago. It appears that there are a number of agencies of destruction other than the new chestnut blight disease, and that these agencies have been in operation in the area affected by the disease as well as in areas where this disease is not known to occur. Therefore, they must be taken into consideration and investigated before the problem of protecting the chestnuts can be solved. There appear to be other diseases, and we know that there are insects which have been directly or indirectly the cause of the death of a large percentage of the chestnuts over extensive areas."

—*1913.* Professor H. R. Fulton, of the Agricultural Experiment Station, West Raleigh, N. C., under date of January 29, 1913, writes: "Throughout the whole Piedmont section of this state, just as in the corresponding section of Virginia and further south, the chestnut trees are in an unthrifty condition. This is probably due to a combination of factors. Changes in soil conditions due to a clearing up of extensive areas probably play a part. Trees are evidently attacked to a considerable extent by borers and other insects. Fire injury has in many instances had something to do with the situation. Our preliminary survey of the field has not disclosed any fungous disease that seems to be importantly connected with the condition of the trees."

NATIVE HOME OF THE FUNGUS.

General Considerations. Previous to the work of Merkel and Murrill, no one had ever, so far as known, collected or described the true chestnut blight fungus. Its sudden and destructive appearance naturally leads to the question,—Where did it come from? Murrill has not tried to solve this problem, although we understand he at first believed it to be a native species. The writer is the only one who, claiming it a native species, has attempted to give definite reasons for the belief, and an explanation of its sudden and aggressive development. Others have come forward with the suggestion that it is an introduced parasite, brought in accidentally, either from Japan or Europe. They have been led to their belief apparently largely because the blight was reported at first from a restricted region around New York City, and has apparently since then spread from this center into the regions in which it is now known. We shall consider in the following paragraphs each of these possible habitats for this fungus.

Japan. Metcalf has suggested most definitely that the fungus originally came from Japan, and Marlatt (31), following this suggestion, gives the blight as one of the most striking examples of "why we need a national law to prevent the importation of insect-infested and diseased plants." Metcalf's (33, p. 4) first statement concerning the native home of this fungus is as follows: "The immunity of the Japanese chestnut, together with the fact that it was first introduced and cultivated on Long Island and in the very locality from which the disease appears to have spread, suggests the interesting hypothesis that the disease was introduced from Japan.' So far, however, no facts have been adduced to substantiate this view." Later, Metcalf and Collins (36, p. 46) say: "Investigations are in progress to determine the origin of the bark disease in America, and the details regarding its spread. The theory advanced in the previous publication of this Bureau that the Japanese chestnuts were the original source of infection has been strengthened by many facts. It lacks much of demonstration, however, and is still advanced only tentatively. * * * Chester's Cytospora on a Japanese chestnut noted at Newark, Del., in 1902, may have been the bark disease."

Recently Metcalf (35, p. 222) remarks: "Its origin is unknown, but there is some evidence that it was imported from the Orient." Later, in answer to a direct question as to its origin, he adds (p. 227): "That is exactly what we would like to know more about. The fact that the disease has obviously spread from a center leads me to believe that it is an importation rather than a disease which has developed here. The fact that the locality from which it has spread is the same locality into which the Japanese chestnut was first extensively introduced, that the Japanese and Corean chestnuts are highly resistant, and are the only varieties that are at all resistant, all suggest the hypothesis that the fungus parasite may have come from the Orient. However, the origin of the parasite is not a matter of practical importance, unless it could be shown that the fungus parasite is developing spontaneously in many localities from some native saprophytic form, in which case the difficulties of control would be greatly increased."

In the preceding, Metcalf brings out four points in favor of the Japanese origin of the fungus, as follows: (1) Immunity of Japanese and Corean chestnuts; (2) Outbreak of disease originally in Long Island, where Japanese chestnuts were first imported; (3) Spread of the disease from a single center; (4) Possibility of Chester's Cytospora on Japanese chestnut being the blight fungus. Let us take up these four points for further consideration.

(1) The immunity of Japanese chestnut does not necessarily mean that this fungus occurred on it in Japan, and when brought to America spread to the American chestnut, and, finding it a more favorable host, caused the serious outbreak here, as Metcalf suggests. It may merely mean that the Japanese is a more hardy species. From the statements of Morris (13, p. 43) we take it that this is the case, since it is only the Japanese or Corean varieties from the more northern regions that show this resistance. Recently it has been found that the Japanese chestnut is highly resistant to the black canker, a serious chestnut disease now causing trouble in France. Arguing along Metcalf's theory, one could say that this French fungus was of probable Japanese

origin, which no one claims, so far as we know. Again, neither the chestnut blight fungus nor the closely related *Endothia gyrosa* has ever been reported from Japan, so far as the writer has been able to learn. In order to look into this matter a little more thoroughly, we wrote to three of the leading Japanese mycologists on this point. None of them could give us any information of the occurrence of these fungi there, or of any serious chestnut trouble that could be attributed to them. One of them naïvely answered: "Some botanists in your country seem to entertain the opinion that this chestnut blight fungus is of Japanese origin,—an apparently plausible opinion in accordance with a popular belief in certain quarters of your country that things obnoxious come from the other side of the Pacific. Let us see whether the words of these chestnut prophets prove to be the fact or not."

(2, 3) We have attempted, under the head "Manner of Distribution," to show that this disease did not originate in one locality, where first reported, and that its spread has not been from a single, but from many centers.

(4) Regarding Chester's Cytospora on Japanese chestnut, we can say definitely that this was not the blight fungus. We are indebted to the Delaware Experiment Station for the opportunity of examining the herbarium specimen of this, and we find that it is an entirely different fungus, being similar to a Phoma-like fungus not uncommon on dead and dying chestnut sprouts.

Europe. While Farlow (20, p. 70) was one of the first to call attention to the very close relationship, if not exact identity, of our chestnut blight with *Endothia gyrosa* as found in Europe, he has made no claim that the disease was introduced into this country from Europe. He merely asks, "Is *Diaporthe parasitica,* as at first supposed, really a species new to science? If so, is it a native species which has hitherto escaped the notice of all mycologists, or has it been introduced from some other country?" One can infer from his article, however, that if the fungus was proved to be an imported one he would favor Europe rather than Japan as being its native home.

Shear (65, p. 212), however, comes out with a more definite statement as regards the European origin of the fungus, as follows: "As a result of our studies to date, we are of the opinion that *Diaporthe parasitica* Murr. is the same as *Endothia* *radicalis of* European authors, but not of Schweinitz, and that it was probably introduced into this country from Europe, and has gradually spread from the original points of introduction, its spread being facilitated chiefly by borers or other animal agencies which produced wounds favorable for infection by the fungus."

Shear's reason for supposing that the chestnut blight was imported from Europe was that *Endothia gyrosa* occurred on chestnut there, and he could not distinguish the American chestnut blight from this fungus. He, however, apparently did not know that *E. gyrosa* (*E. radicalis* of some European authors) also occurred on chestnut in this country. Further, he (66) was misled by an incorrectly named culture received from Pantanelli (supposed to be of European origin but later turning out to be the real blight from America) with which he produced the disease in chestnuts.

Pantanelli (53) of Italy, who has recently made a study of the European *Endothia gyrosa* and the American chestnut blight, finds (1) that they are different in many small microscopic characters; (2) that, while *E. gyrosa* varies somewhat in character in Europe, there are no variations that correspond to the chestnut blight type; (3) that the native *E. gyrosa* causes no serious disease in Europe; (4) that the American chestnut blight, when inoculated into chestnut in Italy, produces the disease. Naturally he concludes that our chestnut blight cannot be of European origin.

To the above we might add the fact that European chestnut grown in this country is quite susceptible to the blight, and it would be rather difficult to explain its susceptibility in this country and its immunity to the native fungus there, unless environment really did bear some relationship to susceptibility and immunity of the host, which is denied by Metcalf.

United States. The writer's reasons for believing the chestnut blight is native to this country may be summarized as follows: (1) It has never been found in any other country. (2) It is very closely related to *Endothia gyrosa,* apparently developing from it as a distinct variety, and this species is a native fungus in this country as well as in Europe. (3) The limits of distribution of *E. gyrosa* and the chestnut blight overlap at least in the region covered by Washington, D. C., to southern Pennsylvania, while *E. gyrosa* occurs south of this common area and the chestnut blight north of it. (4) We have previously had serious troubles of chestnut trees in this country, and there seems to have been a continued northward movement of these, culminating in the recent trouble in the northern limit. While the chestnut blight has been definitely connected only with this last trouble, the previous ones have never been really explained. (5) The suddenness, etc., of the recent blight outbreak has been adequately explained by the writer through the unusual environmental conditions that have weakened the chestnuts in the general regions where the outbreak has occurred. (6) The fact that the chestnut blight fungus was never reported before this outbreak is no more difficult to explain than the fact that *E. gyrosa* had never been reported on chestnut in this country until by the writer a year ago, and yet this is a native fungus widely distributed on chestnut in the South, and has been known there on other hosts since 1822, when described by Schweinitz. They both were, in fact, merely overlooked on the chestnut. (7) Our cultures of *E. gyrosa* vary more from their normal type than do those of the variety *parasitica,* and some of these have varied somewhat toward the variety *parasitica* type. This, however, may have been due in part to bacterial contamination, etc.

AMERICAN SPECIES OF ENDOTHIA.

Various Species. It has been agreed among those who have recently studied the blight fungus from a systematic standpoint that it belongs under the genus Endothia rather than under Diaporthe, and is at least very closely related to the American-European species *Endothia gyrosa.* So far there have been described under the genus Endothia comparatively few species. Fries, who founded this genus, apparently considered *Sphaeria gyrosa* as the type, but did not give a very complete generic description. As understood to-day, however, Endothia has quite distinct generic characters. Of the species other than *Endothia gyrosa* and the chestnut blight, there have been found in North America *Endothia Parryi* (Farl.) Cke., on Agave sp., *Endothia longirostrata* Earle, on the bark of fallen trees from Porto Rico, and *Endothia radicalis* (Schw.) Farl., on Quercus, etc., chiefly from the Southern states.

Besides these, there is a somewhat similar appearing fungus recently described, by H. & P. Sydow (Ann. Myc. 10, p. 82) on Quercus from Colorado, as *Calopactis singularis.* It is a semi-parasitic species, apparently, whose generic position is somewhat doubtful, as the asco-stage has not been found. It has been known in this country for some time, and by some botanists has been placed under *Endothia gyrosa,* since the fruiting pustules and the Cytospora spores of the two are very similar. However, the fruiting pustules are larger, deeper crimson in color, and in maturity more powdery. We have it in culture from a specimen recently sent by Bethel from Colorado, and while it grows something like *E. gyrosa,* it does not form any distinct conidial fruiting pustules on media tried so far, and in manner of growth and color of mycelium resembles more nearly the cultures of *E. radicalis.*

Of the species mentioned, we need to consider in connection with the blight fungus only *Endothia gyrosa,* already discussed somewhat, and *Endothia radicalis,* since these three in their Cytospora stage are so similar in appearance that they cannot be distinguished by the naked eye, and all have at least the oak as a common host. As *E. radicalis* is most sharply set off from the other two, we will discuss it first.

Endothia radicalis. While the fruiting pustules of this species are not different from the other two, when we examine the asco-stage under the microscope it is very easily distinguished by the much narrower spores. These ascospores vary from linear to linear-oblong, are occasionally slightly curved, are apparently single-celled, though possibly they may in some cases develop an indistinct septum, and are 6-10 μ, rarely 12 μ, long by 1-2 μ wide. We have never seen spores which grade into those of the other two species described here, so it is apparently quite a distinct species. See Plate XXVIII a, d.

It seems to be largely southern, having been found in its asco-stage in Louisiana, Mississippi, Georgia, Alabama, Florida and North and South Carolina. However, there are specimens in various herbaria from much further north, showing only the conidial stage, that apparently belong to this species. One specimen found in Connecticut has been under observation on roots of an oak tree for over a year, and though in a vigorous growing condition, has made no attempt to form the asco-stage.

Artificial cultures, however, show that it is this species. This means, apparently, that the species does not form its asco-stage readily in the North. It has not been reported as yet from Europe or elsewhere. While it seems to be largely saprophytic, we recently received from Wolf, of Auburn, Ala., an elegant specimen on the live trunk of water oak, that shows it possesses parasitic tendencies. Plate XXIV e.

So far this fungus has been reported on several species of Quercus and on *Liquidambar Styraciflua.* Earle and Underwood collected what may be this species on Vitis. Schweinitz described his *Sphaeria radicalis* as rare on roots of Fagus, though on the envelope containing the original specimen he states it is on the roots of Quercus, which seems more likely. However, we have recently received ample specimens collected by Hall, at Clemson College, S. C., on the roots and bark of Fagus, which proves that this is to-day a host of the fungus further south, and so it may have been at Salem, N. C., as stated by Schweinitz.

In cultures it forms a rather abundant aerial mycelium, something like *Endothia gyrosa,* but differs in that this is much more fluffy in character, and does not usually form fruiting pustules on the surface of the agar, Plate XXVI 7596. The conidial spores are produced in rather indefinite spots on the mycelium, and are very similar in appearance to those of the other two species, Plate XXVIII g-i. The mycelium lacks the *bright* orange color that is characteristic of *Endothia gyrosa* on most media. At first it is white, and often remains partly uncolored, but finally has considerable *brownish* orange color, especially next the glass on the surface of the agar. In Petrie dishes the mycelium often forms a somewhat annulated development by the newer growth being less elevated than the older. We have cultures of it from *Liquidambar Stryraciflua* and *Quercus nigra,* from Alabama; *Fagus ferruginea, Quercus coccinea,* and Quercus sp., from South Carolina; *Quercus falcata,* from North Carolina; and *Quercus rubra,* from Connecticut.

There is considerable doubt as to who first described this species, since it has usually been confused with the next. Shear (64) speaks of it as *Endothia radicalis* (Schw.), thus identifying it with *Sphaeria radicalis* of Schweinitz; and the Andersons seem to think that Shear definitely proved it to be identical with that species. No Schweinitzian specimens of *Sphaeria radicalis* in this country, however, have yet been found which have ascospores, though there is no doubt from the specimen in the conidial stage in the Schweinitzian collection in the Philadelphia Academy of Science that *S. radicalis* refers either to this species or to *E. gyrosa.* As Shear had opportunity to see certain specimens of *S. radicalis* and *S. gyrosa* sent by Schweinitz to European botanists, the writer thought he had found the ascospores of *S. radicalis* to be linear. Recently writing Shear on this point, we received the following letter:

"The specimens on oak roots collected by Hall in South Carolina which I identified as the typical *S. radicalis* of Schweinitz were, according to my recollection, compared with authentic specimens of Schweinitz from either Schweinitz's herbarium or Curtis' herbarium at Harvard. This identification was made last winter before my trip to Europe. I have been going over carefully all our slides and specimens to locate the material on which this identification was based. I regret to say that thus far I have been unable to find it. In this same connection I have examined very carefully the material from the Kew herbarium, which consists of an autograph specimen collected by Schweinitz, presumably at Salem, N. C., and sent by him to Hooker. I am surprised to find, on examination, that this specimen, though it shows considerable variation in ascospore measurements, does not appear to agree with the long, slender form of ascospores found in the specimen on oak roots which I sent you from Hall's collection at Clemson College, S. C. The measurements, as they have just been made from a slide from the Kew specimen, range mostly from 6.3-8.6 by 2.8-3.6 μ. I think it is still possible that all sorts of intermediate forms and sizes of spores will be found in the South connecting the long and short-spored specimens."

Writing to the Kew herbarium for information concerning the specimen mentioned by Shear, which seems to be the only Schweinitzian ascospore specimen of *Sphaeria radicalis* yet reported, we received a letter from Assistant Director Hill, with the following notes made by E. M. Wakefield: "The specimen referred to by Shear appears to be one which bears simply a pasted-on rough paper label with the name '*Sphaeria radicalis*' in ink. On the authority of Mr. C. G. Lloyd, who is working here at present, the handwriting is that of Schwaegrichen, and the specimen is an authentic Schweinitzian one. It is probably one of a set sent to Hooker, though there is nothing on the label to indicate that this was the case. There is a pencil reference in another handwriting (apparently Berkeley's) to 'Fr El. 2 p. 73. Versatiles.' Some ascospores have been found in this specimen from which the accompanying drawing has been made. They measure 5-7.5 x 2-3 μ (average size about 7 x 2 μ). The spores are usually one-septate. The septa are indistinct unless stained."

From Shear's and Wakefield's measurements of the spores, one can readily see that the specimen in the Kew herbarium labeled *Sphaeria radicalis* is not the species we are considering here under that name, but really the next species, *Endothia gyrosa*. In a previous publication (9) we stated our belief that Schweinitz's *S. radicalis* and *S. gyrosa* represented either the two distinct species of Endothia that we now find in the southern United States or else the conidial and the asco-stage of only one of them, most likely *S. gyrosa*. This Kew specimen points to the latter of these two conclusions. It has also been the opinion of certain European botanists that these two species of Schweinitz were merely synonyms, and identical with the form found in Europe, which we call *Endothia gyrosa*.

Ellis (N. Am. Pyren. p. 552) in his description included both of these species (his spore measurements relating to one and his drawings to the other), though most of the specimens he referred to are those with linear spores. Farlow (20) was the first to really point out the two as distinct species, and because of this we (9) previously referred to the linear-spored form as *Endothia radicalis* (Schw.) Farl., though Farlow never definitely used this combination for the fungus. While at present it seems somewhat doubtful if Schweinitz's *Sphaeria radicalis* really relates to this fungus, we shall retain this combination, hoping for further light on the subject through future investigation. On the other hand, there is little if any doubt that Schweinitz's *Peziza cinnabarina* does relate to its conidial stage, since it is identical, and has Liquidambar for a host, a host upon which *E. gyrosa* has not yet been reported. The nomenclature already used for this fungus by different writers is as follows:

Endothia radicalis (Schw.?) Farl.

Peziza flammea Schw. (not Alb. & Schw.) in Fung. Car. Sup. n. 1193. 1822.

Peziza cinnabarina Schw. N. A. Fung. n. 840. 1831.

? Sphaeria radicalis Schw. N. A. Fung. n. 1269. 1831.

Sphaeria gyrosa Schw., Ravenel in Fung. Car. n. 49. 1852.

Lachnella cinnabarina Sacc. Syll. Fung. **8**: 399. 1889.

Endothia gyrosa (Schw.), Ell. & Ev. in N. A. Pyren.: 552. 1892. *p. p.*

Endothia radicalis (Schw.), Shear in Phytop. **2**: 88. Ap. 1912.

Endothia radicalis (Schw.) Fr., Andersons in Phytop. **2**: 210. O. 1912.

Endothia radicalis (Schw.) Farl., Clinton in Science **36**: 910. D. 1912.

Endothia gyrosa. We have examined ascospore specimens of this species on *Castanea dentata* from several southern states; on *Castanea sativa* from two sources in Italy; on *Quercus alba, Q. velutina,* Quercus sps. from several localities in America; on Quercus sp. from Italy; on *Carpinus Betulus* from Tiflis, Russia; on Carpinus sp. from Italy. So far as we can tell from a microscopic examination, these all belong to the same species, though there is some slight variation of the ascospores in the different specimens. These ascospores vary from elliptical oblong to narrowly oval, often tapering to one or both ends, have an evident septum, and are chiefly 6-9 μ long x 2-3.5 μ wide. They are therefore quite distinct from those of the preceding species (see Plate XXVIII b, e). Saccardo gives Aesculus, Alnus, Corylus, Fagus, Juglans and Ulmus as reported hosts for this species, with a distribution including North America, Europe, Ceylon, and New Zealand. But a careful comparative examination would be necessary to state positively that these all relate to the same fungus.

We have made cultures of this fungus from many different sources on chestnut and oak from the South, and on chestnut from Italy. See Plate XXVI 7590, 7584. While these show some slight variations, they have a general agreement, but differ decidedly from all cultures of the true chestnut blight. We have made inoculation tests, and have found the fungus to be a saprophyte, but with weak parasitic tendencies. Both the cultures and the inoculations we will discuss later in connection with those of the true chestnut blight.

From the name usually applied, *Endothia gyrosa* (Schw.) Fr., it is seen that Schweinitz's *Sphaeria gyrosa* is considered the original type of the species. Schweinitz, in his Fung. Car. Sup., 1822, described this from Salem, N. C., on decaying bark of knots and also living bark of Fagus and Juglans. There is to-day some doubt about his correct determination of these hosts. He sent specimens to Fries, who also described it in his Syst. Myc. 2, p. 419, in 1823; and in his Elench. Fung. 2, p. 84, in 1828, he compares it with specimens received from Southern Europe. In 1845, Fries, in Summ. Veg. Scand., created a new genus, Endothia, citing *S. gyrosa* of Schweinitz as the type, and ever since then European botanists have considered *Endothia gyrosa* of Europe to be the same fungus as *Sphaeria gyrosa,* described by Schweinitz from America. Some few have given Fuckel as a second authority for the name, *E. gyrosa* (Schw.) Fckl., since that author in his Sym. Myc. p. 226, in 1869, indicated that he was the first to place this species under this genus, evidently considering that Fries had not properly placed it there, since he did not really write the combination *Endothia gyrosa.*

From the descriptions of both Schweinitz and Fries, it looks as if Schweinitz collected only the Cytospora stage of this fungus. This is further borne out by the fact that Schweinitzian specimens examined by Farlow and Shear in this country and Europe show only that stage. The original specimen of Schweinitz at the Philadelphia Academy of Science has been lost or misplaced, and in the original envelope is an entirely different fungus, a Nectria sent by Torrey from New England, which Schweinitz years afterwards apparently mistook to be this species. The writer (10) found a misplaced specimen (in another collection made by Schweinitz, now at the Philadelphia Academy of Science), which probably is his original type, but this also shows only the conidial stage. In the Curtis collection at Harvard, however, there is a Schweinitzian specimen of *S. gyrosa* which, while in the conidial stage, has a drawing on the envelope by Curtis of ascospores which are like those of this species rather than linear, like those of *E. radicalis,* already discussed.

Both Schweinitz and Fries always considered *Sphaeria gyrosa* and *S. radicalis* as distinct species, but of very similar appearance, and Fries, when he formed the genus Endothia, did not include the latter under it. Botanists in their day, however, did not make very careful microscopic examinations. De Notaris, in Sfer. Ital. 1^1, p. 91, in 1863, seems to have been the first to place *S. radicalis* under the genus Endothia, and Tulasne, in Sel. Fung. Carp. 2, p. 87 and p. 298, the same year, was apparently the first to consider the *S. gyrosa* and *S. radicalis* as one species, which he called *Melogramma gyrosa.* Fuckel also, in 1869, treated them as one species, and since that time European botanists have generally considered them as a single species, using sometimes *E. gyrosa* and sometimes *E. radicalis* as a specific name. In view of the information already given in Shear's letter, we are inclined to believe that this interpretation is correct, and that *S. gyrosa* is merely the conidial stage, as first suggested by Winter in Rab. Krypt. Fl. 1^2, p. 804.

A considerable number of names have been applied in Europe to *Endothia gyrosa,* but it is rather difficult to determine whether all of these apply to the fungus under discussion. For instance, Streinz, in Nom. Fung., p. 545, in 1862, under *S. gyrosa,* gives *S. fluens* Sow. as a synonym, and under *S. radicalis,* p. 559, gives *S. tuberculariae* Rud. as another. Shear has examined the Sowerby specimen, and he says: "There is little doubt that *Sphaeria fluens* Sow., described and figured by Sowerby in the supplement of his English Fungi, 1814, Plate 420, published as part of Plate 438, from a collection by Charles Lyall, in the New Forest of southern England, is the pycnidial condition of *Endothia radicalis* De Not." If this is true, then it must be an extremely rare fungus in England, since in answer to a letter to the Kew herbarium we received the reply that "*Endothia gyrosa* is very rare in Britain, if it really occurs." From Sowerby's description, one cannot be sure if it relates to this or some other fungus. Mr. Wakefield of Kew writes concerning our inquiry as to the host: "It is not possible to say with certainty what is the host of Sowerby's *Sphaeria fluens.* The specimen is very small, and no note is attached to it." We do not believe that this English specimen has as yet been definitely identified as the same thing as *Endothia gyrosa.* We give below the nomenclature which probably applies to the fungus in question.

Endothia gyrosa (Schw.) Fr.

? Sphaeria fluens Sow. Eng. Fung. *t. 438* (with *t. 420*). 1809?

Sphaeria gyrosa Schw.* Fung. Car. Sup. n. 24. 1822.

Sphaeria Tuberculariae, Rudolphi in Linnaea 4: 393. 1829.

? Sphaeria radicalis Schw.† N. A. Fung. n. 1269. 1831.

Endothia gyrosa Fr. Summ. Veg. Scand.: 385. 1845.

Diatrype radicalis Mont. Ann. Sci. Nat. Bot. 3: 123. 1855.

Valsa radicalis Ces. & De Not. Schem. Sfer. Ital.: 33. 1863.

Endothia radicalis De Not. Sfer. Ital. 1^1: 9. 1863.

Melogramma gyrosum Tul. Sel. Fung. Carp. 2: 87. 1863.

Nectria gyrosa B. & Br.‡ Journ. Linn. Soc. Bot. 15: 86. 1877.

Chryphonectria gyrosa Sacc.‡ Syll. Fung. 17: 784. 1905.

Endothiella gyrosa Sacc. Ann. Myc. 4: 273. 1906.

Endothia virginiana Anders. Phytop. 2: 261. D. 1912.

Endothia gyrosa var. *parasitica.* We have previously spoken of the very close connection of *Endothia gyrosa* to the chestnut blight, and have shown that Farlow and Shear in this country, and von Höhnel, Saccardo and Rehm in Europe recognize them morphologically as a single species. Recently we sent ascospore specimens of the two on chestnuts from this country to these European botanists for further comparison, and their opinion as to the relationship. They still maintained that the American chestnut blight was not different specifically from *E. gyrosa* as found in Europe and America, but was merely a more luxuriant strain that had so developed through its parasitic habit. It is to be remembered, however, that all of the above investigators, except Shear, have based their conclusions merely on microscopic examination, since they have not had opportunity to study the situation in the field, and have not made cultures or inoculation experiments. On the other hand, it is to be taken

* The conidial stage of the fungus described.

† The asco-stage of the fungus described. Fries apparently published his description before Schweinitz.

‡ This fungus, according to von Höhnel (29).

into consideration that they are all botanists with a very extended experience in the systematic study of fungi.

The Andersons have taken the other extreme, namely, that the chestnut blight, which they call *Endothia parasitica,* is entirely a distinct species from *E. gyrosa,* which they call *E. virginiana.* Their conclusion is evidently based on the parasitic habit of the former as compared with the saprophytic habit of the latter, the difference between the two in artificial cultures, and the slight morphological differences in their ascospores. Pantanelli (53) in his recent article might be considered as agreeing with the Andersons in considering the two as distinct species, since in his conclusions he says: "The *Diaporthe parasitica* Murrill is an Endothia, closely related to, but not like, the *E. radicalis* (Schw.) Fr. Hence it is opportune to distinguish it as *E. parasitica* (Murr.) Anderson." However, Pantanelli was trying to show that these two were not entirely identical, and was not really concerned in their exact relationship, since he stated earlier in a footnote: "Recently, November 28, 1912, Professor P. A. Saccardo has communicated to me that he regards *E. parasitica* as a race of *E. radicalis* modified by parasitism. One may then consider whether it is a species or a distinct variety, but from the viewpoint of the pathologist it makes no difference."

The writer, after a careful study of the blight fungus and of *Endothia gyrosa,* microscopically, in cultures, and in inoculation experiments, with an opportunity to examine both in the field, and also specimens of *E. gyrosa* on several hosts from Europe, has come to the conclusion that these two forms are too closely related to be considered distinct species. On the other hand, they are certainly distinguished through slight morphological differences in their ascospores, marked and constant cultural differences, and the apparently great difference in their parasitic tendencies. These differences lead us to consider the blight fungus as a distinct variety of *E. gyrosa,* which is evidently the older form from which the blight fungus has been derived.

As previously stated, neither *Endothia radicalis* nor *E. gyrosa* and its variety *parasitica* differ enough in their fruiting pustules or conidial spores to present any very special distinguishing characters. The ascospores of *E. radicalis,* however, differ from both the latter by being decidedly narrower (see Plate XXVIII a-c). The ascospores of *E. gyrosa* are much nearer to the type of the true blight fungus than to *E. radicalis,* although they are somewhat intermediate. In general we can describe the ascospores of *E. radicalis* as linear, those of *E. gyrosa* as narrowly oval, and those of *E. gyrosa* var. *parasitica* as broadly oval. Usually one finds some spores of *E. gyrosa* and the variety *parasitica* that cannot be distinguished in size or shape. However, upon examining many from a specimen, one can tell which it is, as *E. gyrosa* has some spores that are narrower, and variety *parasitica* some that are broader, than any found in the other form.

Measurements were made of one hundred ascospores of *Endothia gyrosa* var. *parasitica* from ten different chestnut trees from various localities, and these varied from 6 to 10 μ long x 2.75 to 5 μ wide, while the average was 7.45 μ long x 3.2 μ wide. Similarly, one hundred ascospores of *E. gyrosa* from ten different chestnut trees from various localities, including one from Europe, varied from 6 to 9 μ long x 2 to 3.5 μ wide, the average being 7.205 μ long x 2.695 μ wide. To have maintained the same proportion in width as in length to var. *parasitica,* these spores should have been 3.095 μ wide. Likewise, sixty ascospores of *E. gyrosa* on six oak trees from different localities, one from Europe, showed a variation of 6-9 μ x 2-3.25 μ, averaging 7.099 μ x 2.733 μ. Also forty ascospores of *E. gyrosa* on Carpinus from two sources in Europe varied from 5 to 10 μ x 2.25-3.5 μ, averaging 7.58 μ x 2.8 μ.

These measurements show that there is a rather constant difference in the width of the ascospores of *Endothia gyrosa* and *E. gyrosa* var. *parasitica,* no matter what the host or the locality from which they came, and if we also take into consideration the differences in artificial cultures and in the parasitic habits of the two, there seems no reason for not considering the blight fungus at least a distinct variety. The nomenclature of this variety is as follows:

Endothia gyrosa var. **parasitica** (Murr.) Clint.
Diaporthe parasitica Murr. Torreya **6**: 189. 1906.
Valsonectria parasitica Rehm, Ann. Myc. **5**: 210. 1907.
Endothia parasitica Anders. Phytop. **2**: 262. D. 1912.
Endothia gyrosa var. *parasitica* Clint. Science **34**: 913. 27 D. 1912.

ARTIFICIAL CULTURES.

Source of Cultures, etc. We have had cultures of *Endothia gyrosa* under observation for more than a year, and of the variety *parasitica* for more than four years. These have been obtained from many different localities, and from both chestnut and oak in each case. For example, we now have eighteen different cultures of the chestnut blight obtained from localities in Massachusetts, Connecticut, New York, Pennsylvania, and the District of Columbia; and besides these we have had others from time to time. We have five cultures of the blight originally obtained from three different species of oak, from two regions in Connecticut and one in Pennsylvania. Of *E. gyrosa* on chestnut we have fifteen cultures from eight different regions in Pennsylvania, Virginia, Tennessee, and North Carolina, and one from Europe; and ten cultures from three species of oak from five different regions in the District of Columbia, Virginia, and North Carolina.

We have grown many hundreds of these cultures on a variety of media in test tubes and Petrie dishes, though for most purposes tubes of potato- or oat-juice agar have proved the most satisfactory. From this extended experience we have been able to judge accurately as to purity of the cultures, constancy of their cultural characteristics, and differences that distinguish the variety from the species. Ordinarily the conidial spores of each have regularly appeared in these cultures, but in varying degree. In no case has the asco-stage of either been produced. Its production has seemed more likely to occur in the case of *Endothia gyrosa,* since in some cultures the conidial fruiting stage appeared as rather large, distinct, elevated pustules; but these have never shown any signs of ascospore formation. We have made some attempts, by special media or treatment, to induce the asco-stage to appear in these pustules, but without success.

Endothia gyrosa versus var. parasitica. The following characteristic differences were noted in special test tube cultures made at the same time on potato-, Lima bean-, and oat-juice agar, from twenty-five sources of *Endothia gyrosa* and ten sources of var. *parasitica.* In general, it may be stated that the potato-juice agar favors spore production for both, while the oat-juice agar favors a vigorous aerial mycelial development, especially for *E. gyrosa.* The bean-juice agar is somewhat intermediate in both respects. On any of these media, *E. gyrosa* is much less likely to exude spore masses in abundance than the variety *parasitica.* Perhaps this accounts for the ease with which the variety propagates itself in nature. The chief cultural differences of the two are as follows:

(1) Var. *parasitica* fruits more abundantly, and exudes the sticky spore masses much more conspicuously, than does *Endothia gyrosa.* (2) The variety fruits earlier than the species, as determined by the exuding spore drops. (3) The variety has less evident, smaller, or more embedded fruiting bodies than the species, in which they are often elevated, distinct pustules, rarely hidden by the exuding spore mass. (4) The species develops a much more luxuriant aerial mycelium (except possibly on potato agar) than does the variety. (5) The species has its aerial mycelium more generally and more highly orange colored, especially on oat-juice agar, than does the variety.

The more minute and variable differences of the two on the three media are as follows: On the potato-juice agar var. *parasitica* forms chiefly an embedded growth, which, while white at first, soon becomes rather deeply colored, and produces numerous obscure or embedded fruiting bodies, which exude small, colored, sticky spore drops rather thickly over the surface of the agar. Finally, a slight surface growth of a flavus mycelium sometimes develops. The species differs in having at first a slightly more evident growth of mycelium, and finally having usually fewer, but larger, spore masses. The color of the embedded growth is variable, usually darker than in the variety, sometimes blackish, as if from bacterial contamination, but possibly due to variation in the composition of the medium.

On the Lima bean-juice agar var. *parasitica* produces fewer, but larger, fruiting bodies and spore drops than on the potato-juice agar, while its aerial mycelium is more evident, and varies from albus to sulphureus in color. The species makes a much more evident aerial growth than the variety, while its fruiting pustules are decidedly fewer, larger, more elevated and distinct, and exude spores less abundantly. The color is much more evident than in the variety, though variable even in the same tube, running from albus through sulphureus and flavus to even aurantiacus-miniatus on the edges where it is in contact with glass or medium.

On oat-juice agar the variety *parasitica* forms a somewhat more evident aerial mycelium, but has fewer pustules and less evident spore drops even than on the Lima bean-juice agar. It usually has a deeper color, which varies from albus to luteus. The species on oat-juice agar forms a very luxuriant growth, even more so than on Lima bean-juice agar, and though its fruiting bodies are not so numerous, they are often evident exposed pustules, only partially hidden by the spores mass, which exudes with difficulty. The color assumes its maximum development and is in strong contrast to that of the variety on the same medium. It is usually more uniform and intense in color than on the bean-juice agar, finally varying from luteus through aurantiacus to miniatus and even badius when in contact with the glass or medium. Part of the growth, especially on the upper edge, however, often remains albus.

The color of the spore masses of both forms varies in different cultures from sulphureus to nearly purpureus, depending apparently on age, variation of the medium, bacterial contamination, or other unknown factors. Likewise, a culture when renewed on the same medium sometimes acts somewhat differently for some unknown reason, as to luxuriance in mycelial growth or spore development, or color characters.

Tannic Acid in Cultures. Since tannin is found in such large quantities in the wood of chestnut, and since this varies according to the age of the tree, etc., it has been suggested previously in this paper that this variation may have some bearing upon the development of the chestnut blight. It was thought desirable, therefore, to study both the saprophytic *Endothia gyrosa* and the variety *parasitica* in artificial cultures containing different percentages of tannic acid (M. C. W. brand, U. S. P.) to determine how this affected their vigor, growth and spore production. These cultures have all been made by Mr. Stoddard under the writer's direction, and the data here given should be credited to both investigators. We have used mainly for this work two rather recent cultures of *E. gyrosa* on two species of oak from Washington, D. C., and four cultures of *E. gyrosa* var. *parasitica* on chestnut, two from Washington and two from

Per cent. of Tannin.	Result.	Endothia gyrosa Quercus sp.	Endothia gyrosa Quercus velutina.	E. gyrosa var. parasitica Castanea dentata.	E. gyrosa var. parasitica Castanea dentata.	E. gyrosa var. parasitica Castanea dentata.	E. gyrosa var. parasitica Castanea dentata.
4%	Grew...	5	8	8	8	7	5
	Failed..	3	0	0	0	1	3
4.8%	Grew...	6	6	7	8	7	7
	Failed..	2	2	1	0	1	1
6%	Grew...	7	5	5	7	8	7
	Failed..	1	3	3	1	0	1
8%	Grew...	4	4	6	4	4	4
	Failed..	4	4	2	4	4	4
10%	Grew...	0	2	3	3	4	6
	Failed..	8	6	5	5	4	2
10.5%	Grew...	1	0	6	4	5	5
	Failed..	7	8	2	4	3	3
11%	Grew...	2	1	8	4	5	3
	Failed..	6	7	0	4	3	5
11.5%	Grew...	1	1	5	5	4	5
	Failed..	7	7	3	3	4	3
12%	Grew...	2	2	5	6	5	5
	Failed..	6	6	3	2	3	3
14%	Grew...	0	0	1	0	0	0
	Failed..	8	8	7	8	8	8
Total No.	Grew...	28	29	56	49	49	48
	Failed..	52	51	24	31	31	32
Total %	Grew...	35%	36%	70%	61%	61%	60%
	Failed..	65%	64%	30%	39%	39%	40%

Connecticut. Of these four, three had been in culture only a few months, while one had been in culture over three years.

In each test we made three cultures of each of the above for duplication. We grew these on plain potato-juice agar, as checks for comparison, and also on this medium to which had been added the following percentages of tannic acid: 0.2, 0.4, 0.8, 1.2, 1.6, 2.4, 3.2, 4.0, 4.8, 6.0, 8.0, 10.0, 10.5, 11.0, 11.5, 12.0, 14.0; see Plate XXVII. These cultures were first made in 1912, and repeated in 1913 for confirmation, this time using five cultures of each in each test. The table shows the results of all these cultures in the tubes containing 4% or more of tannic acid. Those containing lower per cents. all grew, and so are omitted in the table. From the results of these investigations we obtained the following information:

(1) The growth of either fungus causes no darkening of the plain potato-juice agar, but when tannic acid is added, even as

low as 0.2 per cent. in case of var. *parasitica,* the growth of the fungus causes a darkening of the medium. This indicates an oxidation of the tannic acid by the fungus, since these tubes without the introduction of the fungus remain undarkened except with the higher percentages, when they color as soon as made, upon cooling. With *E. gyrosa,* this darkening scarcely takes place, and with var. *parasitica* is less evident in those tubes containing only 0.2 and 0.4 per cent. of tannic acid, but shows on all strengths above these with both fungi about the same, though appearing sooner with var. *parasitica.*

(2) The medium in the tannic acid tubes remains liquefied when 0.8 per cent. or more tannic acid is added. The acidity of potato-juice agar and, in the lower percentages, of tannic acid potato-juice agar, where darkening of the medium does not interfere, can be tested before and after growth of these fungi by titrating with $\frac{N}{20}$ Na O H, using phenolphthalein as an indicator. These tests show that after *E. gyrosa* or var. *parasitica* has fully developed in plain potato-juice agar the acidity is practically unchanged; but in tannic acid potato-juice agar both of these fungi cause a lowering in the acidity of the medium, and the higher the acidity usually the greater the loss, though not proportionately greater, as shown by the following tests:

Tannic Acid added (per cent.).	Acid Test before inoculation.	Acid Test after growth.	Loss in Acidity.
0.0	0.15 cc. $\frac{N}{20}$ Na O H	0.15 cc. $\frac{N}{20}$ Na O H	0.0
0.2	.9 " " " " "	0.4 " " " " "	0.5
0.4	1.2 " " " " "	0.85 " " " " "	0.35
0.8	1.8 " " " " "	... " " " " "	...
1.2	2.1 " " " " "	1.4 " " " " "	0.7
1.6	2.7 " " " " "	1.8 " " " " "	0.9

(3) Cultures of *E. gyrosa* var. *parasitica* containing 0.2, 0.4, 0.8 per cent. tannic acid show a more vigorous spore development than the check cultures of potato-juice agar without tannic acid. The same was true of *E. gyrosa* regarding mycelial development, but to a less extent, and possibly also as to spore development, though with this fungus the spores do not exude very abundantly in any case.

(4) At about 4 per cent. the loss in color, especially with *E. gyrosa,* becomes quite evident. In the liquefied tubes up to

4 per cent. tannic acid, the growth of the fungi tends to form a more or less firm coating over the surface, after the manner of growth on the solid medium. Above 4 per cent. the growth becomes gradually less evident, generally showing in floating patches, embedded masses, or lateral growths around the side of the glass. Finally, at the highest percentages, 10 to 14, growth entirely ceases, only one having been successful at the latter strength in any of the tubes.

(5) In the higher percentages of tannic acid *E. gyrosa* shows an enfeebled growth sooner than does var. *parasitica,* since at 6 to 8 per cent. it makes comparatively little growth, corresponding to that made by the variety at about 10 per cent. It generally fails entirely to make any growth at above 10 per cent., or only a poor growth above 8 per cent. in most of the tubes; while the variety in only one case made any growth above 12 per cent. and rarely any but a poor growth above 10 per cent.

(6) At the higher percentages the difference in the appearance of the two fungi is less marked than at the lower, so that from 4 per cent. up, where spore production of the variety is largely cut out, they are scarcely to be distinguished.

(7) There was some variation in development with the different cultures of the same fungus in the higher percentages of the tannic acid, as shown by one of the cultures of var. *parasitica* from Connecticut which had been in artificial culture for over three years failing to grow quite as well as the more recent cultures. These variations are perhaps not constant.

(8) All the preceding notes relate to cultures that were inoculated from plain potato-juice agar directly onto those containing various percentages of tannic acid. Another set of cultures was made in which each was brought up gradually through all the lower percentages of tannic acid. In these it was found that this gradual acclimatization to the tannic acid gave a somewhat more luxuriant growth of both fungi at the higher percentages than when transferred directly from the potato-juice agar to these.

Later experiments based on the preceding results were made with all our cultures of *E. gyrosa* (26 in number) and those of var. *parasitica* (22 in number), using two cultures of each and the following percentages of tannic acid: 4.0, 6.0, 8.0, 10.0. These cultures showed, as in the previous tests, that the variety *parasitica* will grow in higher per cents. of tannic acid and give a more evident development of mycelium than *E. gyrosa.* The details of this experiment are given in the appended table.

Per cent. of Tannin.	Name.	Grew. Good.	Fair.	Poor.	Slight.	Very Slight.	Total. No.	Per cent.	Failed. No.	Per cent.
4%	Endothia gyrosa.............	6	15	10	0	0	31	59.6	21	40.4
	E. gyrosa var. parasitica......	18	23	2	0	0	43	97.6	1	2.4
6%	Endothia gyrosa.............	1	15	9	2	4	31	59.6	21	40.4
	E. gyrosa var. parasitica......	29	13	3	0	0	44	100.0	0	0.0
8%	Endothia gyrosa.............	0	0	9	13	7	29	55.7	23	44.3
	E. gyrosa var. parasitica......	15	14	5	3	0	37	84.1	7	15.9
10%	Endothia gyrosa.............	0	0	0	20	6	26	50.0	26	50.0
	Endothia gyrosa var. parasitica	2	15	8	13	0	38	86.3	6	13.7

INOCULATION EXPERIMENTS.

General Conditions, etc. These experiments were undertaken primarily to determine the parasitic tendency of *Endothia gyrosa* as compared with that of the variety *parasitica.* That the latter could produce cankers when inoculated into chestnuts had been abundantly proved by the work of Murrill and others. With most of our inoculations both the species and the variety were used at the same time, and checks were also included. Nearly all these inoculations were made from artificial cultures, and usually only with conidial spores. Ordinarily a small slit in the bark was made with a sharp scalpel, spores from the cultures were introduced on a needle, the wound covered with moist cotton, and then bound with paraffine paper or bicycle tape. After several weeks the covering was removed. The checks were treated in the same way, except that no spores were introduced into the wound.

In this way there were inoculated two- to three-year-old seedling chestnuts, four- or five-year-old chestnut sprouts, and two-year seedling oak at the Station Farm at Mount Carmel; six- to eight-year-old slow-growing chestnut seedlings at the Station forestry plantation at Rainbow; and two- to four-year-old oak sprouts in a waste lot at Highwood. The tables which follow give the data for all inoculations, since there are factors that apparently enter into their success that we had not in mind when the experiments were undertaken, namely:—length of time the fungus has been in artificial cultivation, age of the particular spores used, and time of year of the inoculation. This makes it difficult to judge of the results of certain of these inoculations, since two or more of these factors may have been involved. The final results of our inoculations were determined about the second week in October. Of course this gave some of the earlier inoculations made in May a much longer time to develop than those made in July, although these latter had plenty of time to show whether or not they were successful. We will consider the results briefly under the following headings.

Endothia gyrosa versus var. parasitica. Ordinarily it takes about a month to determine whether or not an inoculation has taken, and even then it is sometimes doubtful, since the tissues around the wound often die back for a short distance as the result of the mechanical injury. The sum total of our experiments brings out quite clearly the difference in the parasitic nature of these two fungi. For instance, 151 out of all of our 324 inoculations with var. *parasitica,* from all sources on all hosts, produced more or less evident cankers, that is, 47 per cent. were successful; while of the 148 similar inoculations with *E. gyrosa* only 2 took, or about 1 per cent. Of these two, one showed only a comparatively small dead area, with fruiting pustules, around the point of inoculation, but did not seem to continue its growth, while the other was on a dead seedling whose roots had been cut off by mice, which no doubt weakened it, allowing the fungus to make an excellent growth, and even to produce its ascospores. If we take into consideration only our inoculations of var. *parasitica* originally obtained from chestnut and inoculated into chestnut sprouts and seedlings, we find that out of 232 inoculations 132, or 57 per cent., took, as compared with entire failure of *E. gyrosa* under the same conditions. None of the 228 check trees in all our experiments showed any signs of infection, thus proving that the wounding alone was not harmful when protected from infection.

With the check trees the cutting usually killed a little bark on either side, especially if the knife was run under between the bark and the wood. This never grew larger, and the callus of new tissue formed in the wound was always healthy. With the wounds inoculated with *E. gyrosa,* sometimes this injured bark was a little more extensive than with the checks, which indicated a slight but futile attempt at parasitism. Occasionally, on this dead bark and exposed wood, a slight fruiting growth of the fungus as a saprophyte was formed.

With var. *parasitica,* however, the bark was gradually killed in an increasing area surrounding the point of inoculation, and this had a more or less irregular outline, spreading faster in some directions than in others. Eventually the whole stem or limb was encircled, if the inoculation was made early in the season (see Plate XXV a). At the inoculation point a callus of young tissue often developed, and the vitality of this was greater than that of the older tissues, since it often remained healthy, until, being entirely surrounded by dead tissues, it died as much from adverse nutritive conditions as from the direct action of the fungus (Plate XXV b).

After the cankers attained some size, their reddish dead bark often became cracked, and the Cytospora fruiting stage appeared in more or less abundance. An examination of the inoculations as late as the last of December, however, failed to show that the asco-stage had developed on any of them. Whether this means that ordinarily the mature fruiting stage does not appear until the second season, we do not know, but it shows that sometimes this is the case. The inoculations made early in May on the chestnut sprouts one to two inches in diameter entirely girdled these for six to eight inches, forming very evident cankers, but not always with a conspicuous development of conidial spores.

Hosts Inoculated. In the inoculation tests we used seedlings and sprouts of both chestnuts and oaks. Considering first only the chestnut hosts, we found that, as a rule, the variety *parasitica* could be more easily inoculated into the sprouts than into the seedlings, and that on the sprouts the blight made a larger growth in the same length of time. This greater development might in part be due to the larger size of the sprouts, which varied from about one-half to one and one-half inches in diameter, while the seedlings were only about one-quarter to three-quarters of an inch in diameter. Out of a total of 177 inoculations with cultures originally from chestnut made on chestnut seedlings, 91, or 51 per cent., took, as compared with

41 successful out of a total of 55, or 75 per cent., on the sprouts. An attempt to inoculate a young Japanese chestnut six inches in diameter failed entirely, although sixteen inoculations were made at two different periods. This seems to show that the tree had great resistance, if not immunity, to the disease.

As regards inoculation of chestnut, versus oaks, it was found that the former were much more readily infected than the latter, which showed only 12 successful infections out of 51, or 23 per cent. All of these were confined to the sprouts, and did not make nearly so vigorous growth as did the inoculations on chestnut sprouts. The oak seedlings used were rather small, and the inoculations were made comparatively late, using cultures obtained originally from both oak and chestnut.

Source of Cultures. Most of our inoculations were made with cultures obtained from chestnut, as at the time we had only one culture of var. *parasitica* from oak, namely *Quercus velutina* from Woodmont, Pa. This was inoculated into both chestnut and oak seedlings and sprouts. The inoculations into chestnut seedlings showed 4 successful out of 25, or about 15 per cent., while the 16 made on the chestnut sprouts all apparently failed, for some not very evident reason, possibly because made in July with old spores. Of the 20 inoculations on oak seedlings, all failed, while of the 12 on oak sprouts, 5, or 42 per cent., took more or less vigorously. From the results of the inoculations with this single culture, it would seem that the strain from oak at least was not quite so active a parasite as that from the chestnut itself.

Whether or not cultures from chestnuts from different regions, or from living as compared with dead trees, show any difference in virulence, we are not certain. In our experiments we did not get any conclusive results along this line. To determine these points accurately, however, one would need cultures that had only recently been obtained from their hosts, and whose spores when used were comparatively young and of the same age.

Age of Cultures. It seems quite probable that the longer the variety *parasitica* is kept in culture the more likely it is to lose, at least in part, its virulence. While no direct experiments were made to determine this point, it is possibly shown by the cultures obtained originally from a Japanese chestnut in Westville

RESULTS OF INOCULATIONS WITH ARTIFICIAL CULTURES OF *Endothia gyrosa* AND *E. gyrosa* VAR. *parasitica*. 1912

Fungus.	From Host.	Locality.	Culture obtained.	Age of Spores.	Cult. No.	Date Inoc.	Place.	Host Inoc.	Protection.	No. of Inoc.	Failed. %	Failed. No.	Very doubtful.	Took slightly.	Took well.
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	43	7004[1]	June 4	Greenh.	C. dent. sdl.[1]	Paper	6	33	2	0	0	4
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	43	7004[1]	June 4	Greenh.	C. dent. sdl.[2]	Paper	6	33	2	0	0	4
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	43	7004[1]	June 4	Greenh.	Q. alba 2[8]	Paper	2	100	2	0	0	0
Check	....	....	....	..	......	June 4	Greenh.	C. dent. sdl. 2[8]	Paper	2	100	2	0	0	0
E. gy. par.	C. dent.	Wash'n, D. C.	2 Ja., '12	55	6758a[2]	May 9	Rainb.	C. dent. sdl.[3]	Paper	10	40	4	0	2	4
E. gy. par.	C. dent.	Wash'n, D. C.	2 Ja., '12	55	6757a[3]	May 9	Rainb.	C. dent. sdl.[4]	Tape	10	0	0	0	0	10
E. gy. par.	C. dent.	N. Lond., Ct.	4 O., '11	55	6527a[2]	May 9	Rainb.	C. dent. sdl.	Paper	10	50	5	0	1	4
E. gy. par.	C. cren.	Westv., Ct.	4 Au., '09	55	6594a[1]	May 9	Rainb.	C. dent. sdl.	Tape	10	50	5	0	0	5
E. gyrosa	Q. alba	Wash'n, D. C.	2 Ja., '12	64	6891	May 9	Rainb.	C. dent. sdl.	Paper	8	100?	5	3	0	0
E. gyrosa	Quer. sp.	Wash'n, D. C.	2 Ja., '12	55	6753a[1]	May 9	Rainb.	C. dent. sdl.[4]	Paper	8	100	8	0	0	0
E. gyrosa	Quer. sp.	Wash'n, D. C.	2 Ja., '12	64	6899	May 9	Rainb.	C. dent. sdl.[4]	Tape	8	100	8	0	0	0
E. gyrosa	Quer. sp.	Wash'n, D. C.	2 Ja., '12	55	6753a[2]	May 9	Rainb.	C. dent. sdl.	Tape	8	100	8	0	0	0
Checks	....	....	....	..	......	May 9	Rainb.	C. dent. sdl.	Paper	16	100	16	0	0	0
Checks	....	....	....	..	......	May 9	Rainb.	C. dent. sdl.	Tape	16	100	16	0	0	0
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	31	7004[2]	May 23	Station	C. cren.	Uncov.	8	100	8	0	0	0
E. gy. par.	C. dent.	Merid., Ct.	22 Jl., '12	19	7284[3]	Aug. 13	Station	C. cren.[4]	Tape	8	100	8	0	0	0
E. gy. par.	C. dent.	Wash'n, D. C.	2 Ja.. '12	28	7092[2]	June 25	Mt. Car.	C. dent. sdl.[5]	Paper	25	24	6	0	0	19
E. gyrosa	Q. velut.	Wash n, D. C.	2 Ja., '12	102	6756a[2]	June 25	Mt. Car.	C. dent. sdl.[5]	Paper	20	95	19	0	0	1
Checks	....	....	....	..	......	June 25	Mt. Car.	C. dent. sdl.[5]	Paper	10	100	10	0	0	0
E. gy. par.	C. dent.	Wash'n, D. C.	2 Ja., '12	28	7092[1]	June 25	Mt. Car.	C. dent. sdl.[6]	Paper	25	4	1	0	3	21
E. gyrosa	Quer. sp.	Wash'n, D. C.	2 Ja., '12	102	6753a[8]	June 25	Mt. Car.	C. dent. sdl.[6]	Paper	15	100	15	0	0	0
Checks	....	....	....	..	......	June 25	Mt. Car.	C. dent. sdl.[6]	Paper	10	100	10	0	0	0
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	79	7002[1]	July 10	Mt. Car.	C. dent. sdl.	Tape	15	87?	12	1	2	0
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	79	7002[1]	July 10	Mt. Car.	C. dent. sdl.[7]	Tape	10	80	8	0	1	1
Checks	....	....	....	..	......	July 10	Mt. Car.	C. dent. sdl.	Tape	5	100	5	0	0	0
Checks	....	....	....	..	......	July 10	Mt. Car.	C. dent. sdl.[8]	Tape	10	100	10	0	0	0
E. gy. par.	C. dent.	Wash'n, D. C.	2 Ja., '12	84	6985[1]	July 10	Mt. Car.	C. dent. sdl.[4]	Tape	10	70	7	0	1	2
E. gy. par.	C. dent.	Wash'n, D. C.	2 Ja., '12	84	6985[1]	July 10	Mt. Car.	C. dent. sdl.[7]	Tape	10	100	10	0	0	0
Checks	....	....	....	..	......	July 10	Mt. Car.	C. dent. sdl.	Tape	10	100	10	0	0	0
E. gy. par.	C. dent.	Brist., Ct.	24 Fe., '11	250	6598[3]	July 10	Mt. Car.	C. dent. sdl.	Tape	10	90	9	0	0	1
E. gy. par.	C. dent.	Brist., Ct.	24 Fe., '11	250	6598[3]	July 10	Mt. Car.	C. dent. sdl.[7]	Tape	10	100?	9	1	0	0
Checks	....	....	....	..	......	July 10	Mt. Car.	C. dent. sdl.	Tape	10	100	10	0	0	0
E. gyrosa	Quer. sp.	Tryon, N. C.	24 Ap., '12	81	7016[2]	July 10	Mt. Car.	C. dent. sdl.	Tape	5	100	5	0	0	0
E. gyrosa	Quer. sp.	Tryon, N. C.	24 Ap., '12	81	7016[2]	July 10	Mt. Car.	C. dent. sdl.[7]	Tape	10	100	10	0	0	0
Checks	....	....	....	..	......	July 10	Mt. Car.	C. dent. sdl.[8]	Tape	10	100	10	0	0	0

E. gyrosa	C. dent.	Con'lsv., Pa.	18 Ap., '12	79	7003[2]	July 10	Mt. Car.	C. dent. sdl.[8]	Tape	5	100	5	0	0	0
E. gyrosa	C. dent.	Con'lsv., Pa.	18 Ap., '12	79	7003[2]	July 10	Mt. Car.	C. dent. sdl.[7]	Tape	10	100	10	0	0	0
E. gy. par.	C. dent.	Wash'n, D. C.	2 Ja., '12	84	6985[1]	July 10	Mt. Car.	C. dent. sdl.[4]	Uncov.	10	100	10	0	0	0
Checks	....	....	....	..	......	July 10	Mt. Car.	C. dent. sdl.	Uncov.	10	100	10	0	0	0
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	84	7004[1]	July 15	Mt. Car.	C. dent. sdl.	Tape	5	100	5	0	0	0
E. gy. par.	C. dent.	Mt. Car., Ct.	Fresh Cytospora	spores	......	July 15	Mt. Car.	C. dent. sdl.	Tape	10	60	6	0	2	2
E. gy. par.	C. dent.	Mt. Car., Ct.	Fresh ascospore	s	......	July 15	Mt. Car.	C. dent. sdl.	Tape	10	40	4	0	1	5
E. gy. par.	C. dent.	Woodbr., Ct.	3 Fe., '11	28	7090[1]	June 25	Mt. Car.	C. dent. spr.	Paper	8	0	0	0	0	8
E. gyrosa	Q. velut.	Wash'n, D. C.	2 Ja., '12	84	6756f[3]	June 25	Mt. Car.	C. dent. spr.	Paper	4	75?	1	2	1	0
Checks	....	....	....	..	......	June 25	Mt. Car.	C. dent. spr.	Paper	4	100	4	0	0	0
E. gy. par.	C. dent.	Woodbr., Ct.	3 Fe., '11	251	6599[3]	July 11	Mt. Car.	C. dent. spr.	Tape	4	50	2	0	0	2
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	80	7002[1]	July 11	Mt. Car.	C. dent. spr.[7]	Tape	16	100?	15?	1	0	0
E. gyrosa	C. dent.	Con'lsv., Pa.	18 Ap., '12	80	7003[2]	July 11	Mt. Car.	C. dent. spr.	Tape	14	100?	12	2	0	0
E. gyrosa	C. dent.	Blcks'g, Va.	27 Fe., '12	85	6979[2]	July 11	Mt. Car.	C. dent. spr.	Tape	4	100	4	0	0	0
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	84	7004[1]	July 15	Mt. Car.	C. dent. spr.	Tape	5	40?	1	1	0	3
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	84	7004[1]	July 15	Mt. Car.	C. dent. spr.[7]	Tape	10	80	8	0	0	2
E. gy. par.	C. dent.	Mt. Car., Ct.	Fresh Cytospora	spores	......	July 15	Mt. Car.	C. dent. spr.	Tape	10	20	2	0	1	7
E. gy. par.	C. dent.	Mt. Car., Ct.	Fresh Cytospora	spores	......	July 15	Mt. Car.	C. dent. spr.[7]	Tape	18	0	0	0	0	18
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	81	7002[1]	July 12	Mt. Car.	Q. rubra sdl.	Tape	10	100	10	0	0	0
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	81	7002[1]	July 12	Mt. Car.	Q. rubra sdl.[9]	Uncov.	10	100	10	0	0	0
Checks	....	....	....	..	......	July 12	Mt. Car.	Q. rubra sdl.	Tape	5	100	5	0	0	0
Checks	....	....	....	..	......	July 12	Mt. Car.	Q. rubra sdl.[10]	Uncov.	5	100	5	0	0	0
E. gy. par.	C. dent.	Phila., Pa.	18 Ap., '12	81	7004[1]	July 12	Mt. Car.	Q. rubra sdl.	Tape	10	100	10	0	0	0
E. gyrosa	C. dent.	Blcks'g, Va.	27 Fe., '12	86	6979[2]	July 12	Mt. Car.	Q. rubra sdl.	Tape	5	100	5	0	0	0
E. gyrosa	Quer. sp.	Tryon, N. C.	24 Ap., '12	74	7016[2]	July 12	Mt. Car.	Q. rubra sdl.	Tape	5	100	5	0	0	0
Checks	....	....	....	..	......	July 12	Mt. Car.	Q. rubra sdl.	Tape	5	100	5	0	0	0
E. gy. par.	C. dent.	Westv., Ct.	23 My., '12	33	7103[2]	July 3	Highw.	Q. alba spr.	Tape	2	0	0	0	0	2
E. gy. par.	C. dent.	Westv., Ct.	23 My., '12	33	7103[2]	July 3	Highw.	Q. alba spr.[7]	Tape	2	0	0	0	0	2
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	44	7066	July 3	Highw.	Q. alba spr.	Tape	4	50	2	0	2	0
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	44	7066	July 3	Highw.	Q. alba spr.[7]	Tape	4	75	3	0	0	1
E. gyrosa	Q. alba.	Wash'n, D. C.	2 Ja., '12	76	6992[1]	July 3	Highw.	Q. alba spr.	Tape	2	100	2	0	0	0
E. gyrosa	Q. alba.	Wash'n, D. C.	2 Ja., '12	76	6992[1]	July 3	Highw.	Q. alba spr.[7]	Tape	2	100	2	0	0	0
E. gyrosa	Quer. sp.	Tryon, N. C.	24 Ap., '12	65	7016[1]	July 3	Highw.	Q. alba spr.	Tape	4	100	4	0	0	0
E. gyrosa	Quer. sp.	Tryon, N. C.	24 Ap., '12	65	7016[1]	July 3	Highw.	Q. alba spr.[7]	Tape	4	100	4	0	0	0
E. gy. par.	C. dent.	Westv., Ct.	23 My., '12	33	7103[2]	July 3	Highw.	Quer. sp. spr.	Tape	1	0	0	0	1	0
E. gy. par.	C. dent.	Westv., Ct.	23 My., '12	33	7103[2]	July 3	Highw.	Quer. sp. spr.[7]	Tape	2	0	0	0	2	0
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	44	7066	July 3	Highw.	Quer. sp. spr.	Tape	2	50	1	0	0	1
E. gy. par.	Q. velut.	Woodm., Pa.	18 Ap., '12	44	7066	July 3	Highw.	Quer. sp. spr.[7]	Tape	2	50	1	0	1	0
E. gyrosa	Q. alba.	Wash'n, D. C.	2 Ja., '12	76	6992[1]	July 3	Highw.	Quer. sp. spr.	Tape	1	100	1	0	0	0
E. gyrosa	Q. alba.	Wash'n, D. C.	2 Ja., '12	76	6992[1]	July 3	Highw.	Quer. sp. spr.[7]	Tape	2	100?	1	1	0	0
E. gyrosa	Quer. sp.	Tryon, N. C.	24 Ap., '12	65	7016[1]	July 3	Highw.	Quer. sp. spr.	Tape	2	100?	0	2	0	0
E. gyrosa	Quer. sp.	Tryon, N. C.	24 Ap., '12	65	7016[1]	July 3	Highw.	Quer. sp. spr.[7]	Tape	2	100?	0	2	0	0

CONDENSED RESULTS OF INOCULATIONS WITH ENDOTHIA GYROSA AND ENDOTHIA GYROSA PARASITICA.

	Inoc. (No.)	Failed (No.)	Took (No.)	Took %
E. g. parasitica from Cast. on Cast. dent. seedl. ..	177	86	91	51
" " " " " " " " sprts. ..	55	14	41	75
" " " " " " Quer. sp. seedl. ..	12	12	0	0
" " " " " " " " sprts. ..	7	0	7	100
" " " " Querc. on Cast. dent. seedl. ..	25	21	4	16
" " " " " " " " sprts. ..	16	16[11]	0	0
" " " " " " Quer. sps. seedl. ..	20	20	0	0
" " " " " " " " sprts. ..	12	7	5	42
E. gyrosa " Cast. on Cast. dent. seedl. ..	15	15	0	0
" " " " " " " sprts. ..	18	18	0	0
" " " " " Quer. sps. seedl. ..	5	5	0	0
" " " " " " " sprts. ..	0	0	0	0
" " " Querc. on Cast. dent. seedl. ..	82	81	1	1
" " " " " " " sprts. ..	4	3	1	25
" " " " " Quer. sp. seedl. ..	5	5	0	0
" " " " " " " sprts. ..	19	19	0	0
Checks........................ on all Castanea..	113	113	0	0
Checks........................ on all Quercus ..	15	15	0	0

[1] Kept moist. [2] Kept dry. [2-8] One dry, one moist. [3] Culture originally from conidial spores. [4] Culture from ascospores. [5] Trees ridged to produce drought conditions. [6] Trees unridged. [7] Inoculated above and below knife girdle. [8] Cut above and below knife girdle, but not inoculated. [9] Stem inoculated underground. [10] Stem cut underground, but not inoculated. [11] If done earlier in the season, possibly some would have taken. These footnotes apply chiefly to large table; see column "Host Inoc." for numbers.

on August 4, 1909, which produced only 50 per cent. infection as against 100 per cent. produced by a culture over two years younger obtained from Washington, D. C., on January, 2, 1912. Both of these were of the same spore age, and inoculated into chestnut seedlings at the same time and place.

That the age of the spores used affects their virulence is apparently shown in a number of our inoculations. We used spores from cultures that had been made all the way from 20 to 100 days, in a few cases even 250 days. These spores were always somewhat moist when used, and though possibly some of them were too old to germinate, there must have been others that were not, since we have renewed cultures not infrequently that were 100 days old, and in one case a culture that was 399 days old. Our inoculation tests apparently indicate that the younger the spores the higher the percentage of infection. For instance, on chestnut seedlings, cultures varying from 28 to 55 days old gave successful inoculations varying from 100 to 50 per cent.; while those 79 to 250 days old gave from 30 to 0 per cent. However, with the latter the time of inoculation may have entered into the problem, since in no case did we try to inoculate on the same date with spores of greatly different ages.

Time of Inoculation. Inoculations made in the spring are more successful than those made in midsummer, at least those we made in the spring were, as a rule, much more successful than those we made in July. However, as just stated, those made in the spring were made with younger spores than those made later, and just how much of the failure of the latter was due to the time of inoculation and how much to the age of the spores could not be determined. We have also tried inoculations on dormant seedlings in the greenhouse, and these have either failed to take or took only after the trees began to grow. The length of time the fungus has been in culture, age of the spores used, time of year the inoculation is made, are all points that need further investigation to bring out their bearings more clearly.

Condition of Host. We tried several experiments to determine what effect the condition of the host had on the success of the infection. These experiments included a few plants kept unusually wet and others very dry, in the greenhouse; others severely ridged outdoors to aid in drought conditions, compared with plants not ridged; and plants with knife cuts encircling the bark (in some cases with a band of bark removed) which were inoculated above and below these injured places. The results were rather conflicting, so that we could not tell whether or not these treatments made any special difference. Inasmuch as they did not show more striking evidence in favor of increased blight development under unfavorable conditions of the host, perhaps they may be interpreted as rather against, than in favor of, our theory that the condition of the host affects the prominence of the fungus as a parasite. However, such experiments need to be made in greater number and during several seasons in order to judge accurately as to results.

PREVENTIVE EXPERIMENTS.

Earlier Experiments. Murrill tried to control the chestnut disease, when it was first discovered at the New York Botanical Garden, by cutting down and destroying the badly infected trees and by cutting out cankers on those less seriously injured. He found this did not prevent its further spread. Writing in 1908, he (48) says: "Preventive measures have apparently not affected it in the slightest degree. Pruning of diseased branches has evidently failed to check it even in the case of very young trees. Branches have been carefully removed, and wounds covered, leaving trees apparently entirely sound, but upon inspection a few weeks or a few months later, they would be found badly diseased at other points." Merkel, at the New York Zoological Park, also tried to control the trouble by cutting down the badly infected trees and by spraying with Bordeaux mixture, but little or no benefit resulted from his efforts.

Metcalf undertook experiments to control the trouble on Long Island in a region where it was very bad. In 1909 he and Collins (36) say: "At present it is impossible definitely to record general beneficial results from any of the sprayings which have been undertaken or have been under observation. This may in part be due to the fact that it is yet too early to judge satisfactorily of the results, and in part perhaps to the infrequency of sprayings. * * * Almost the only treatment that can at present be safely recommended as surely retarding the spread of the disease, to a greater or less extent, is one which will never be of practical use except in the case of orchard trees or certain valuable ornamental trees. It consists essentially in cutting out the infected branches or areas of bark and carefully protecting the cut surfaces from outside infection by means of a coat of paint or tar. This cutting must be thoroughly done and the bark of every infected place entirely removed for a distance of at least an inch (when the size of the branch permits) beyond the characteristic, often fan-shaped, discolored area produced by the growing fungus in the inner bark." In a later report, they also advocate that when the inner bark is badly infected "at least two or three annual layers of wood beneath the diseased bark must also be gouged out."

Later Experiments. In a bulletin published in October, 1911, Metcalf and Collins (38, p. 10) advocate fighting the chestnut bark disease, in those regions or states where it has not yet obtained a serious foothold, by means of quarantine and cutting out all diseased trees. This recommendation was based on the results of some experiments carried on in the vicinity of Washington, D. C., concerning which they write as follows:

"Fortunately, however, there is a method of dealing with the situation which is applicable to the country as a whole and which, so far as tested, is practicable. Early in the course of the writers' investigations it became evident that the disease advances but slowly in a solid line, but instead spreads from isolated centers of infection often many miles in advance of the main line of disease. * * * It therefore seems probable that if these advance infections could be located at a reasonably early stage, they could be eliminated at relatively little expense, thus preventing further spread from these points, at least. Accordingly the country within approximately thirty-five miles of Washington, D. C., was chosen in the fall of 1908 as preliminary territory in which to test this method of control. This section has been gone over fairly thoroughly once a year. As will be shown by Figure 1, fourteen points of infection were located and the infected trees destroyed. Most of this work was done by the senior writer. The largest infection was a group of nursery trees that had been imported from New Jersey; the smallest, a simple lesion on a small branch of a large forest tree. In one case eleven forest trees in a group were infected, the original infection having been on two trees dating apparently from as early as 1907. Up to the present time (June, 1911) the disease has not reappeared at any point where eliminated, and the country within a radius of approximately thirty-five miles from Washington is apparently free from the bark disease, although new infections must be looked for as long as the disease remains elsewhere unchecked. It is therefore believed that this method of attack will prove equally practicable in other localities, and if carried out on a large scale, will result ultimately in the control of the bark disease."

Stewart, of the Geneva, N. Y., Station, and the writer, through the kindness of Metcalf, had the opportunity of examining, in January, 1912, part of the region where this work was carried on. Stewart (70) in his paper at Harrisburg said: "I hold that no definite conclusions can be drawn from that test." The writer also believes that the apparent results would not justify the application of the method on a wholesale scale in other regions, for the following reasons: (1) Apparently neither the chestnut tree nor the blight disease was very common in the region under experimentation; hence the greater difficulty of the disease starting there, and also the greater ease with which it could be controlled. (2) Although those in control evidently made a careful survey of the region for the blight, they overlooked infected trees. In a region with the chestnut tree and the disease more abundant, it would be impossible to locate all the diseased trees. (3) Where infected trees were cut down, the disease appeared on the bark of the stumps in some cases. To destroy the bark on the infected stumps as well is too great a task to be successfully accomplished without great expense. (4) No check areas, apparently, were reserved with which to compare the results of the treatment.

Yet, based on this experiment apparently, local advocates of such measures succeeded in having the State of Pennsylvania establish a chestnut blight commission to fight the disease in that state along these lines. To aid in the further study of the disease in all its aspects and in the control work, a grant of $275,000 was made by their Legislature. Shortly afterward, the United States Government also appropriated $80,000 for further work by Metcalf's department. With the aid of the government, and with more or less state aid, several of the states south of Pennsylvania have taken up this work, chiefly along the lines advocated by Metcalf and Collins, though apparently so far most of this work has been in the nature of preliminary surveys for locating the disease.

In order to have a clearer idea of what has been accomplished in a practical way in Pennsylvania by this commission, we recently wrote Carleton, who is now general manager, the following letter: "I understand from newspaper reports that the chestnut blight commission of Pennsylvania has found that spraying with Bordeaux mixture is effective in controlling the disease. I wish to ask for a statement from you concerning this report. Also, I should like very much to know what has been the outcome of your quarantine and cutting out work as carried on so far. Have you seen any conclusive evidence that this has been successful in checking the blight? Lastly, I should like to know if the blight on the whole, without regard to treatment in checking it, has spread as seriously in Pennsylvania during the past year as it did in 1911. So far as Connecticut is concerned, there seems to be a decided improvement, if we can judge by the reports that we have received."

In answer to this letter, under date of March 1, 1913, Carleton wrote as follows: "I have your letter of February 28th, and in reply will say first, that the reports in the papers about the spraying with Bordeaux mixture in connection with chestnut blight were, as usual, much exaggerated, and in some respects quite erroneous. The use of Bordeaux mixture is, at most, only a preventive, though the papers reported it to be a cure. Of course, as you know, nothing will cure the disease after it is in the tree. The Bordeaux was used on the estate of Pierre DuPont near Kennett Square. In connection with tree surgery methods, and by spraying about every two weeks during the summer, these two methods taken together appear to have controlled the blight. It is believed that the Bordeaux mixture was of great use in preventing the germination of spores on healthy trees, and on healthy portions of trees that were being treated. I believe the spraying with Bordeaux is of sufficient importance in chestnut orchards to recommend its practice in all cases of chestnut blight. It might be used, also, on unusually valuable lawn trees, but of course, it would be impracticable in forest tracts, chiefly on account of the cost, and for other reasons.

"As to the spread of the blight in Pennsylvania, I regret to say that over a large portion of the state it has apparently spread more rapidly than the year before, so that the conditions appear, therefore, to be different from those in Connecticut, according to your statement. Because of the condition last stated, of the serious increase of the disease in this state, and particularly in those portions west of the Susquehanna, where we are endeavoring to check its progress, you can see that our work has been unusually difficult. Answering your question, however, as to our success in actually checking the blight, so far as we can get evidence one way or the other at all in the short time that I have been in the state, I believe we have accomplished a great deal in that line. We can only actually know next summer, when we re-scout the areas over which cutting was done this summer. So far, in the areas of removal which have been re-inspected, the evidence is that our work has been very good. There was some return of the disease, of course, as was to be expected, but a rather small percentage."

Experiments in Connecticut. In Connecticut there has been no appropriation of money by the state to investigate the chestnut blight, and none has been asked for. Such work as has been done has been carried on by the botanical and forestry departments of this Station with funds at hand, and in connection with their other duties. There has been no attempt to enforce state control of the disease, or to eliminate it by the cutting out and quarantine method. There has been no demand for such treatment on the part of those interested. Preliminary surveys have shown that the disease now exists in all the towns, and in some of them to such an extent that any attempt to gain control of the fungus by the cutting out method, even if successful, could only be made at a cost disproportionate to the good that would be accomplished. Add to this the constant watch that would have to be maintained against re-infection, the opposition that would be aroused among some property owners by the enforced cutting, and we have sufficient reason for not attempting such a program in this state. Then, too, none of the surrounding states, Rhode Island, Massachusetts, or New York, is attempting such control.

In order, however, to gain some idea of the value of the cutting out method, two experiments, in coöperation with the forestry department, have been conducted in this state. The first was at the Whittemore estate in Middlebury, and was largely preliminary in nature, being carried out by Mr. Shepardson, manager of the estate, at our suggestion, but not immediately under our control. The disease was rather bad in certain of the woods on this large estate, and in a special effort to protect those nearest the residence, the removal of all infected trees was started in 1910. These woods have now been gone over four different years, each time removing all trees of whatever size showing cankers. Apparently this removal has had little effect in decreasing the disease in these particular woods. A count was not made of the number removed each year, except that Mr. Shepardson states that more were removed in the winter of 1913 than in all previous years. In these woods, something over one hundred acres, forty or fifty of which contained trees over one foot in diameter, 845 trees over one foot in diameter were marked for removal in the winter of 1912-13, besides numerous trees and sprouts of less diameter. This same winter, in all the woods on the estate, there were 2,200 trees over one foot in diameter that were marked for removal. In this experiment it was not attempted to remove the bark from the stumps. In certain badly diseased spots where the stumps were examined, it was found that perhaps 30 per cent. of them showed some signs of the fruiting stage of the fungus the following summer.

The second experiment was started in the fall of 1911, at the Portland state forest. Here certain designated wood lots, eight in number, were gone over, and all trees and sprouts showing cankers were noted and marked for removal. These were removed during the following winter, and the wood and bark disposed of. A partial reëxamination was made the next spring, to determine how effectively the work was done. In spite of the fact that the preliminary examination had been carefully made by two well-trained scientific men, and the ground had again been gone over by a practical man who removed the marked trees and any others he saw to be infected, it was found that some of the diseased trees had been overlooked. Six other lots in these woods were also examined, and the blighted trees counted, but not removed, these serving as a check to determine the benefit of removal in the other lots.

All of these lots were reëxamined in the fall of 1912, and the trees removed that winter, as before, from those lots reserved for removal. It is expected to keep up this experiment for several years, if warranted by the results or the prevalence of the blight. As yet it is too early to determine the effect of the removal of the trees on the spread of the blight by comparison with the check lots. So far as the second year's results go, however, there were proportionately just as many newly blighted trees found in lots where all had been removed the year before as in the lots where all diseased trees had been left.

RECOMMENDATIONS FOR CONNECTICUT.

We are not advocating concerted action throughout the state to attempt control of the disease by the cutting out method. We are only rarely advising this method, in certain districts where probable results might seem to warrant it, such as isolated woods recently and slightly infected, and of sufficient value to warrant the expense. Where a wood lot as a whole is merchantable, and the disease is present, we advocate that, if market conditions are favorable, it be cut and disposed of in the ordinary way. Where the trees are not as a whole of marketable size, and the disease is present, we advocate the removal of the dead and badly diseased trees and their disposal as lumber, poles, ties or cordwood, as their size will permit.

We have no uniform recommendations for treatment of sprout growth too small for market purposes, but as a usual thing no treatment is recommended. Where trees have been cut, and numerous sprouts are developing, it is perhaps advisable at the end of the second or third year to go over these and cut off all the diseased and weak ones, leaving only four to six vigorous ones, to renew the stand if possible.

We are trying to prevent a glut of the market by discouraging wholesale cutting of the forests, especially where there is little need of it. As yet there has been no general glut and drop of prices except on cordwood in certain towns, and 7 x 9 ties, for which the demand on the part of the railroad has evidently fallen off. On the whole, however, there has been considerable more timber cut than usual.

There are no small factories for the utilization of waste products such as tannin, etc., and the establishment of such here is not likely or advisable. In the recent investigations of the wood-using industries of Connecticut, by Pierson of the United States Department of Agriculture, published as Bulletin 174 of this Station, it is stated that the chestnut is used by nineteen different industries in wood manufacture, of which 50 per cent. of the supply used is for musical instruments. Of all the chestnut timber used, however, only 35 per cent. was Connecticut-grown.

Whether the consumption of the home-grown product can be profitably increased is a question we cannot answer here, but is worthy of the attention of the timber growers and buyers. The largest use made of the chestnut trees is for building timber, telephone poles, railroad ties, and cordwood. The latter, besides its extensive family use, is consumed in brick kilns, brass foundries and charcoal pits. Its consumption by brass factories, however, is on the decrease, due to the substitution of crude petroleum.

LITERATURE.

Although chestnut blight is a comparatively new disease, the literature on the subject has already become rather extended, because of the popular interest aroused. We do not aim to include all of the popular articles, but do include all articles, so far as we know, that relate to any special study of the disease. These are arranged alphabetically according to their authors, and for convenience in the preceding discussion have been referred to by the appended numbers.

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2. **Anderson, P. J. and H. W.** *Endothia virginiana.* Phytop. **2**: 261-2. D. 1912.
3. **Baker, H. P.** The chestnut blight and the practice of forestry in Pennsylvania. Penn. Chest. Blight Confer.: 137-43. 1912.
4. **Benson, W. M.** Chestnut blight and its possible remedy. Penn. Chest. Blight Confer.: 229-33. 1912.
5. **Clinton, G. P.** Chestnut bark disease, *Diaporthe parasitica* Murr. Conn. Agr. Exp. Stat. Rept. **1907-8**: 345-6. My. 1908.
6. **Clinton, G. P.** Chestnut bark disease, *Diaporthe parasitica* Murr. Conn. Agr. Exp. Stat. Rept. **1907-8**: 879-90. Jl. 1909. [Illust.]
7. **Clinton, G. P.** Chestnut bark disease. Conn. Agr. Exp. Stat. Rept. **1909-10**: 716-17, 725. Je. 1911.
8. **Clinton, G. P.** Some facts and theories concerning chestnut blight. Penn. Chest. Blight Confer.: 75-83. 1912.
9. **Clinton, G. P.** The relationships of the chestnut blight fungus. Science **36**: 907-14. 27 D. 1912.
10. **Clinton, G. P.** Chestnut blight fungus and its allies. Phytop. **2**: 265-9. D. 1912.
11. **Clinton, G. P., and Spring, S. N.** Chestnut blight conference. Conn. Farmer **41**[47]: 7. 25 N. 1911.
12. **Clinton, G. P., and Spring, S. N.** Chestnut blight situation in Connecticut. Penn. Chest. Blight Confer.: 154-7. 1912.
13. **Collins, J. F.** Chestnut bark disease. North. Nut Grow. Rept. **1911**: 37-49. 1912.
14. **Collins, J. F.** Some observations on experiments with the chestnut bark disease. Phytop. **2**: 97. Ap. 1912.
15. **Collins, J. F.** Historical review and pathological aspects of the chestnut bark disease. Penn. Chest. Blight Confer.: 28-39. 1912. [Illust.]
16. **Collins, J. F.** Treatment of orchard and ornamental trees. Penn. Chest. Blight Confer.: 59-69. 1912.
17. **Craighead, F. C.** Insects contributing to the control of the chestnut blight disease. Science **36**: 825. 13 D. 1912.
18. **Detwiler, S. B.** Chestnut blight in various stages. Penn. Chest. Blight Confer. Circ. Let.: 1. 18 O. 1911. [Illust.]

19. **Detwiler, S. B.** The Pennsylvania program. Penn. Chest. Blight Confer.: 129-36. 1912.
20. **Farlow, W. G.** Fungus of the chestnut tree blight. Penn. Chest. Blight Confer.: 70-5. 1912.
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GENERAL SUMMARY.

(1) Chestnut blight was first noticed in this country by Merkel, of the New York Zoological Park in 1904, and in 1906 was attributed by Murrill, of the New York Botanical Garden, to a fungus which he described as new to science, and called Diaporthe parasitica.

(2) The chestnut blight fungus has now been found in twelve states, from New Hampshire and Vermont on the north to Virginia and West Virginia on the south, and the damage that it has caused has been variously estimated from twenty-five to one hundred million dollars.

(3) The fungus consists of a conidial, or Cytospora stage, and a mature, or asco-stage, produced one after the other in the orange- to chestnut-colored fruiting bodies, which break out of the bark as small, more or less clustered pustules. The fungus has also rarely been found on oaks, where as yet it causes no particular damage. In artificial cultures only the conidial stage occurs, whose spores exude in viscid drops, or rarely in tendrils as in nature. Artificial inoculation of chestnut sprouts or seedlings produces the characteristic cankers in the bark, and these can be produced somewhat in oak sprouts.

(4) This fungus has been found by Farlow, the writer, and others, to come more properly under the genus Endothia

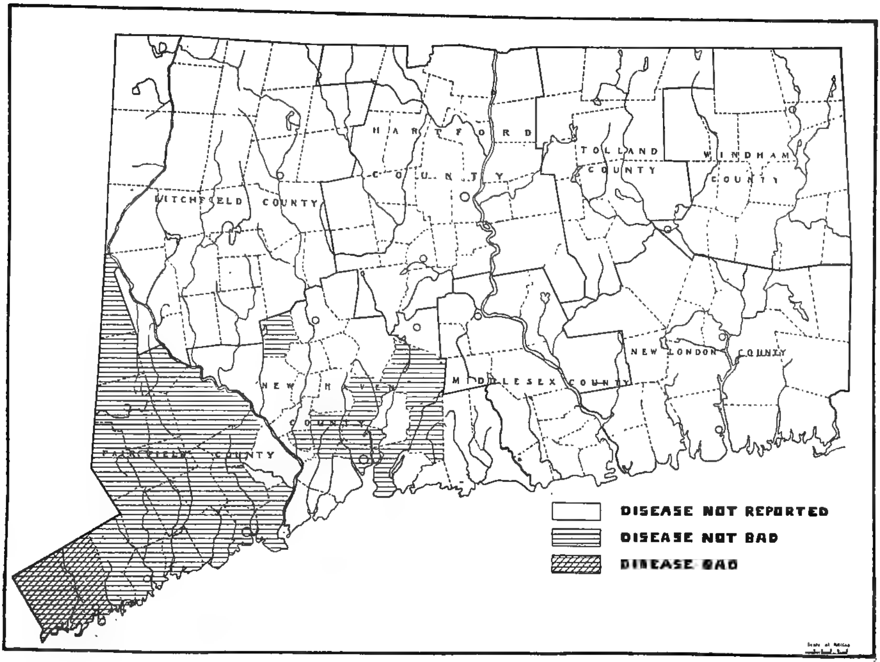
than Diaporthe. It has two saprophytic or semi-parasitic relatives in this country, known as Endothia radicalis and Endothia gyrosa. The latter also occurs on chestnut, and the chestnut blight, being very similar morphologically, has been referred to it by the writer as a parasitic variety called Endothia gyrosa var. parasitica. Others have considered the two as entirely distinct species, and still others as forms so closely related as to be identical morphologically.

(5) While no record, either here or abroad, has been found of any previous outbreak of the blight fungus, there have been reported at different times in the past century unknown chestnut troubles in the southeastern United States that possibly may have been due to it.

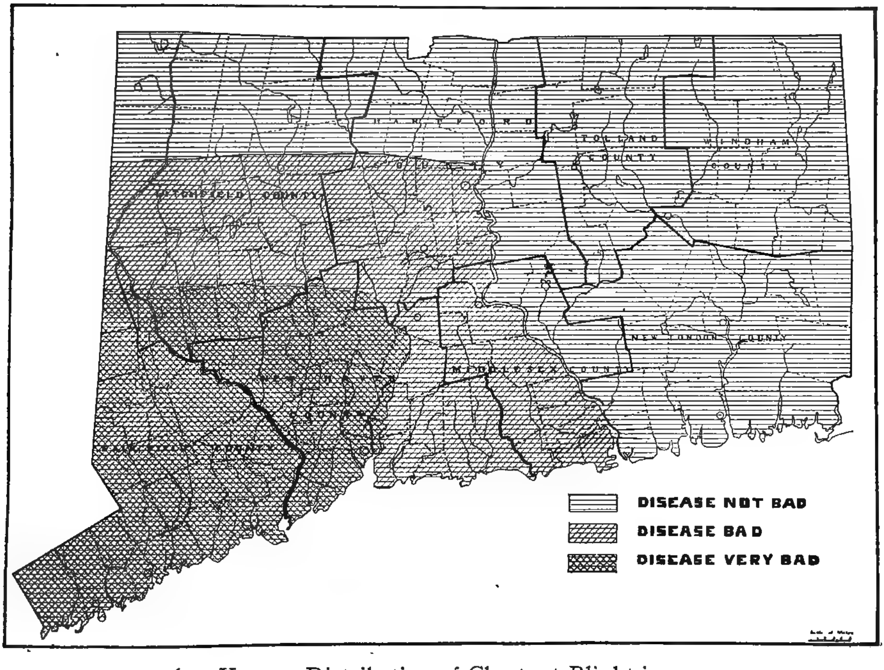
(6) The blight fungus has been considered by Metcalf as an importation from Japan, and by Shear as introduced from Europe, while the writer maintains that it is a native fungus, which, because of peculiar conditions detrimental to the host, has assumed unusual virulence and widespread prominence.

(7) These conditions unfavorable to the host were in part the unusually severe winter of 1903-04, which injured trees in general in the northeastern United States, and after which the blight suddenly made its appearance, and in part the subsequent unfavorable seasons for trees, especially the last four or five years, when summer droughts were unusually severe.

(8) If the writer's conclusions are correct, then it is useless to try to make a widespread fight against the fungus, since it will, under conditions favorable to the host, return in time to its former inconspicuous parasitism. If they are incorrect, it is still a question whether or not the cutting out and quarantine method is effective and can be carried on so economically and extensively as to be of practical value.



a. Known Distribution of Chestnut Blight in 1908.



b. Known Distribution of Chestnut Blight in 1912.

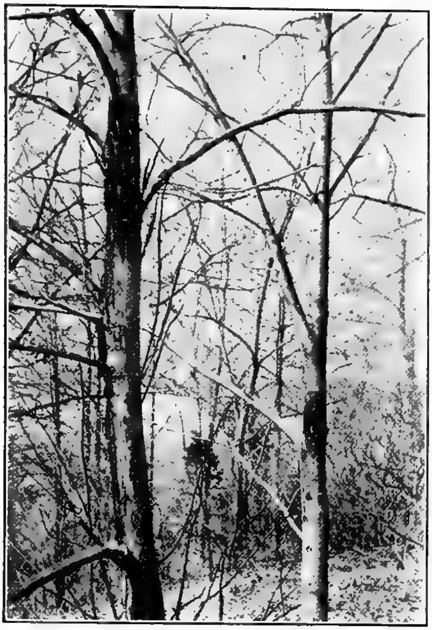
DISTRIBUTION OF CHESTNUT BLIGHT IN CONNECTICUT, p. 371.

a. Tree with single branch killed, p. 365.

b. Trees killed by Chestnut Blight.

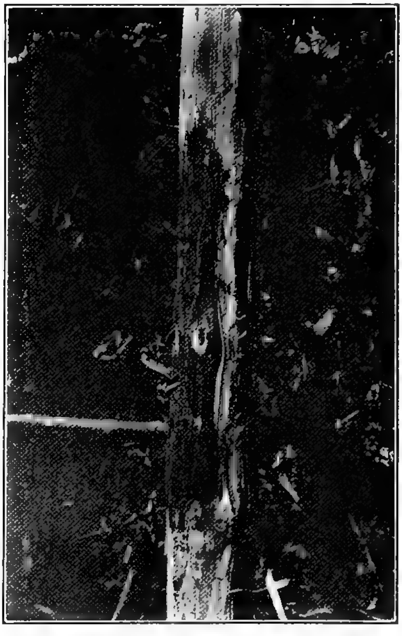
CHESTNUT TREES INJURED BY BLIGHT.

PLATE XXIII.



a–b. Cankers on smooth (a) and rough (b) barked trees, p. 364.

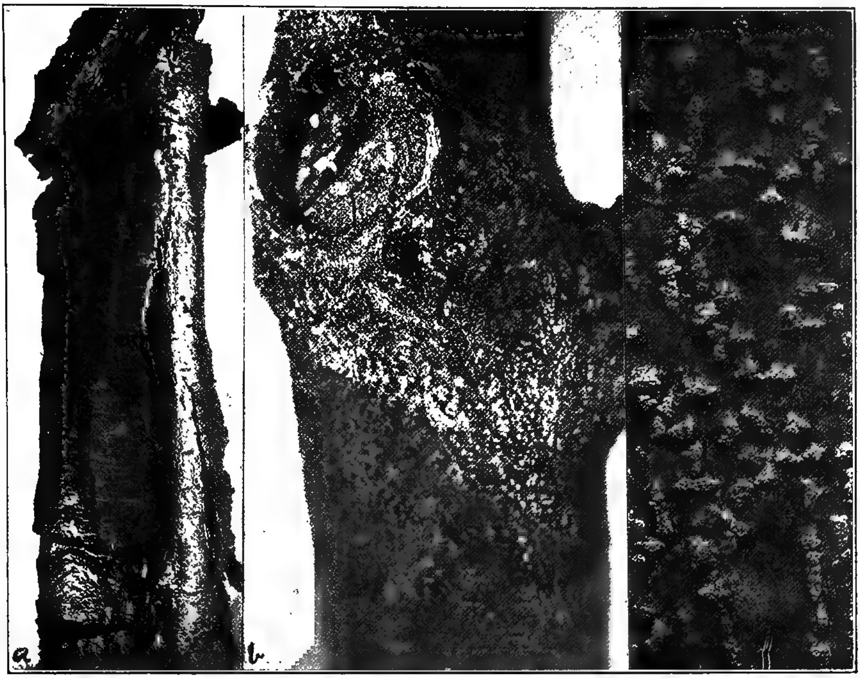
c. Winter-injured tree, p. 392.



d. Injury showing on pole, p. 365.

CHESTNUT BLIGHT INJURY, ETC.

PLATE XXIV.

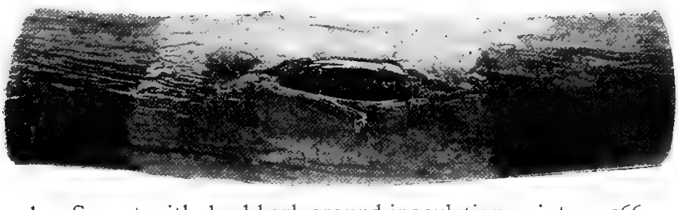


a–b. Blight started through insect injury (a), and pruned branch (b);
c. Mature fruiting pustules on smooth bark, p. 366.

d. Blight on rough bark. e. Fruiting pustules of *E. radicalis*, p. 419

FRUITING PUSTULES OF BLIGHT AND ENDOTHIA RADICALIS.

a. Tree killed above inoculation point ; canker shown by the enlarged stem, p. 436.

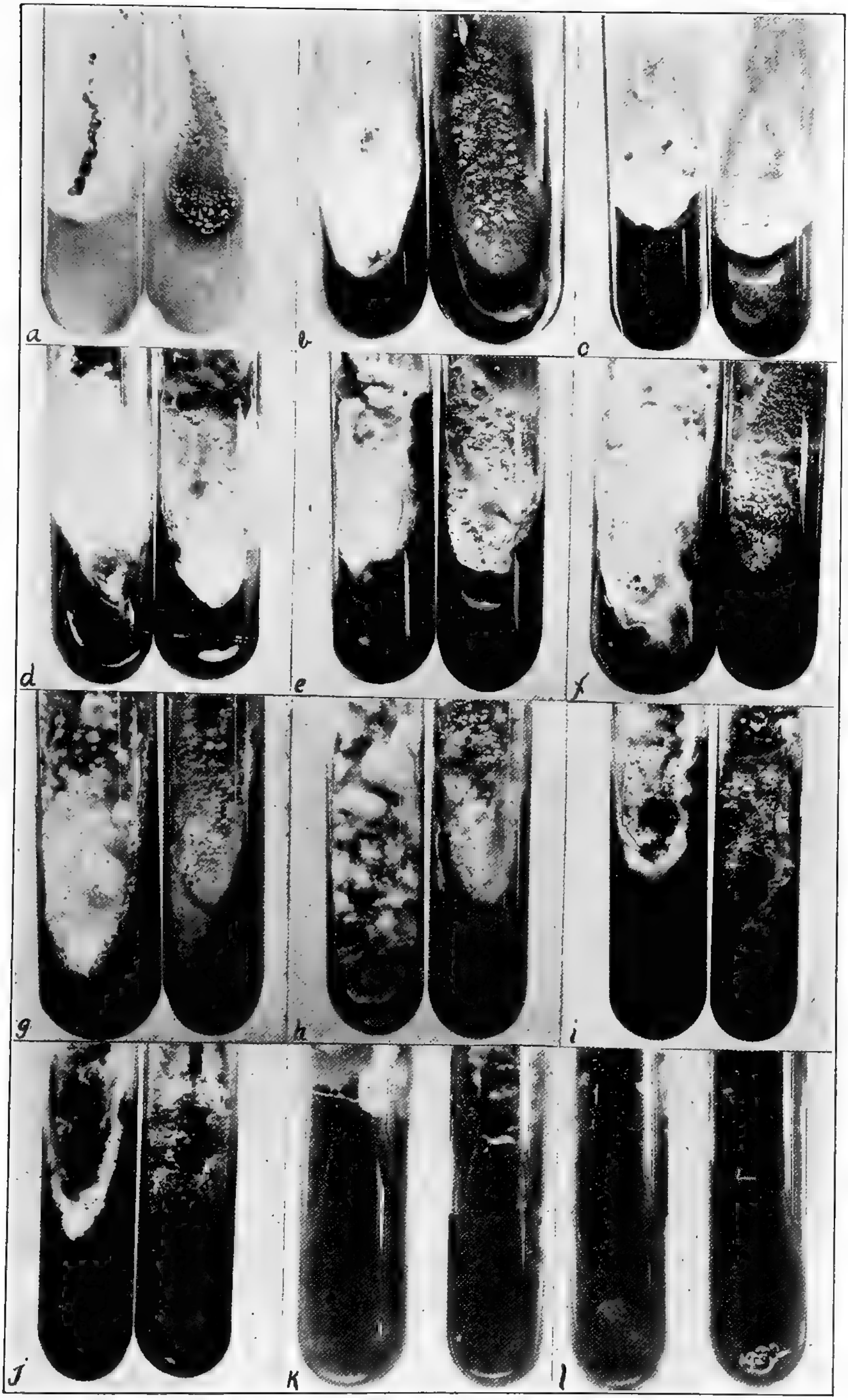


b. Sprout with dead bark around inoculation point, p. 366.

ARTIFICIAL INOCULATIONS OF BLIGHT.

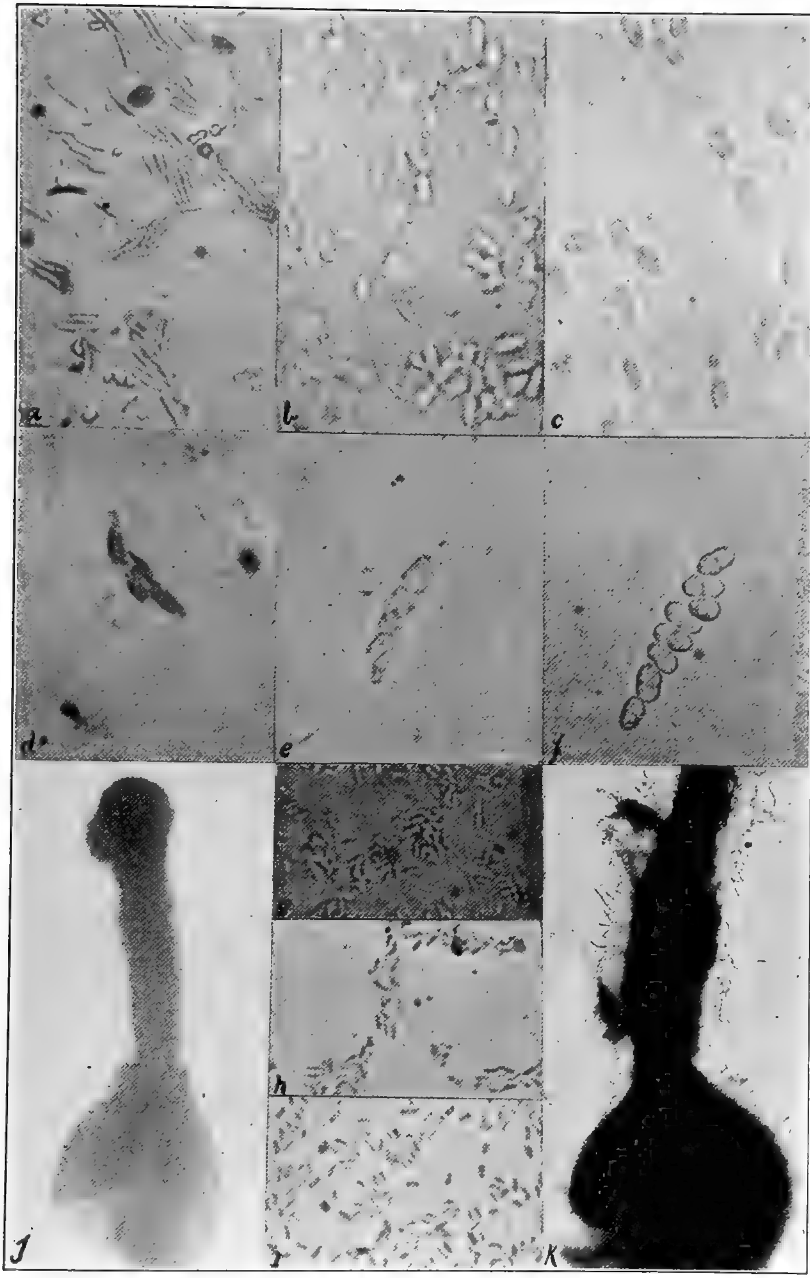
7596. *E. radicalis.* 7590, 7584. *E. gyrosa.* 7582, 7581. *E. gyrosa* var. *parasitica.*

PETRIE DISH CULTURES OF THREE AMERICAN ENDOTHIAS.



a–l. *E. gyrosa* first in each case, on following per cents.: a, 0; b, .2; c, .4; d, .8; e, 1.2; f, 1.6; g, 2.4; h, 3.2; i, 4.; j, 4.8; k, 6.; l, 10.

TANNIC ACID CULTURES OF ENDOTHIA GYROSA AND VAR. PARASITICA, p. 430.



a, d, g. *E. radicalis.* b, e, h, j. *E. gyrosa.* c, f, i, k. *E. gyrosa* var. *parasitica*, p. 367. a–c. ascospores; d–f. spores in ascus; g–i. conidial spores; j–k. isolated perithecia, k. showing mycelium from germinating ascospores within.

SPORE STAGES OF THREE AMERICAN ENDOTHIAS.

JUNE, 1914 BULLETIN 347

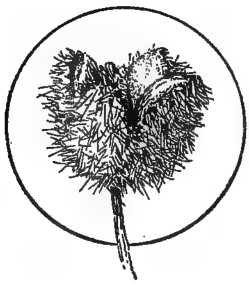
CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Plant Pathology

ENDOTHIA CANKER OF CHESTNUT



By P. J. ANDERSON AND W. H. RANKIN

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COURTESY OF THE NEW YORK STATE CONSERVATION COMMISSION

CANKER ON TRUNK OF CASTANEA DENTATA CAUSED BY THE FUNGUS ENDOTHIA PARASITICA. YELLOW TENDRILS OF PYCNOSPORES SHOWN AROUND MARGIN

CONTENTS

ENDOTHIA CANKER OF CHESTNUT

P. J. Anderson and W. H. Rankin [1]

(*Received for publication March 27, 1914*)

HOSTS

The Endothia canker was first discovered by Merkel (1906), on the American chestnut (*Castanea dentata*), in the New York Zoological Park during the summer of 1904. Metcalf (1908 a) states: "Observations made by the writer during the past year indicate that all varieties and species of the genus Castanea are subject to the disease except the Japanese varieties (*Castanea crenata* Sieb. and Zucc.)." In the same year Metcalf (1908 b) states that the Japanese varieties are in general resistant, and Murrill (1908 a: 27) reports having found the canker on a Japanese chestnut and on the chinquapin (*Castanea pumila*) in the New York Botanical Gardens. Pantanelli (1911), Metcalf (1912 b: 76), and Morris (Clinton 1911: 725) give evidence that varieties of the European chestnut (*Castanea sativa*) are also subject to this disease. Morris (Clinton 1913: 376) gives his observations on orchard varieties as follows: Corean, Chinese, and northern Japanese varieties were not attacked, although they had grown for five years alongside diseased trees, while southern Japanese varieties were attacked; but the Corean, Chinese, and northern Japanese varieties were attacked after having been grafted on American stocks. A small number of the eastern and the western chinquapins were unaffected except for one branch of a single tree. Many points that are essential for determining the real value of these observations as establishing the immunity or the susceptibility of these varieties are unfortunately not given. Fairchild (1913) reports having found the disease in northern China on a species of Castanea, probably *C. mollissima*.

Van Fleet (1914) records many observations concerning the spread of the canker in the breeding-plots at Washington, D. C., where he has been breeding chestnuts experimentally since 1894. Nearly all the trees having *C. americana* in any combination have disappeared. Recently Van Fleet has worked with selections made from self- and chance-pollinated individuals of the chinquapin and Asiatic types. He has obtained many precocious hybrids from these crosses. He reports his observations on the resistance to the canker shown by these hybrids as follows:

"Seedlings of Paragon chestnut, the best variety of the European type, pollinated with our native species, attained an average height of

[1] Names of authors arranged alphabetically.

twenty-five feet and were bearing excellent nuts when attacked in 1910, but all have succumbed. The crosses of Asiatic and native, fewer in number, showed greater resistance but all have been seriously affected. The chinquapin-European hybrids are readily affected but have great recuperative powers, bearing nuts the second year on suckers springing from the bases of diseased stems. Chinquapin-native crosses with the exception of the Rush chinquapin — a probable natural hybrid found wild in Pennsylvania — appear very susceptible and do not as readily recover. The wild chinquapin itself appears measurably resistant, several individuals, including two Rush chinquapins, thriving for years with no signs of disease though constantly surrounded by infection.

"The Asiatic chestnuts, and the chinquapin-Asiatic hybrids, are plainly highly resistant. Few have shown any appearance of infection and when noticeable the injury is quite local in character. Second generation seedlings of chinquapin-crenata crosses show no disease at all though always exposed to infection."

Morris (1914) reports that five trees of the species *C. mollissima* have not been affected, although American trees have died all around them. Specimens of *C. alnifolia* also have remained free from the disease.

In brief, it may be said that there is no species of Castanea which is wholly immune. Some varieties show marked resistance, especially Asiatic varieties, and Metcalf (1914) claims apparent immunity for certain strains. On the other hand, no species outside the genus Castanea is known to be seriously affected.

The species of Castanea are confined to the northern hemisphere and are widely distributed through their range. Schneider[2] states that there are five species which are very closely related one to the other, in part probably representing only geographical varieties. The following species are recognized: *C. crenata*, of Japan and Central China; *C. sativa*, of southern Europe and northern Africa, and eastward to Persia; *C. dentata* and *C. pumila*, of eastern and southern United States. A species *C. mollissima*, of which little is known, has been described from China.

Many varieties from Europe, Japan, and China have been introduced into the United States for orchard culture. Taylor[3] states that the European chestnut was introduced into this country in 1803 and the Japanese chestnut in 1876. Corsa,[4] speaking of the European and the Japanese species, states: "Both species can be grown in portions of this country, either as seedlings or as grafted trees on American stock. . . The majority of imported trees and seedlings raised in this country from

[2] Schneider, C. K. Handbuch der laubholzkunde 1: 156. 1906.
[3] Taylor, W. A. Bailey's Encyclopedia of American horticulture 1: 294.
[4] Corsa, W. P. Nut culture in the United States. U. S. Agr. Dept., Pomol. Div. 1896. (Unnumbered bulletin.)

imported nuts are injured or killed entirely by our severe winters. It is doubtful whether five per cent of the imported European chestnuts live long enough to come into bearing, but stocks raised from seed of the few exceptional hardy trees which do flourish here are generally hardy, and in this way a strain of European chestnuts has been secured that is well adapted to the climate of the Eastern States. . . . Trees from nuts imported from France and Spain have been fruiting for at least a half century near Philadelphia, Pennsylvania, and Wilmington, Delaware." These cultivated varieties are now being grown throughout the eastern and southern States, although the greater part of the chestnut-growing industry is confined to the States of Delaware, Maryland, Pennsylvania, New Jersey, New York, and Connecticut.

There are two native American species of Castanea, *C. dentata* and *C. pumila*. Sargent [5] gives the distribution of the forest species (*C. dentata*) as from " southern Maine to the valley of the Winooski River, Vermont, and southern Ontario, along the southern shores of Lake Ontario to southern Michigan, southward to Delaware and southeastern Indiana, and along the Alleghany Mountains to central Alabama and Mississippi, and to central Kentucky and Tennessee . . . . attaining its greatest size in western North Carolina and eastern Tennessee " (Fig. 77, page 542). *C. pumila*, as described by Sargent,[5] is found from southern Pennsylvania to northern Florida and west to Arkansas and Texas, is usually shrubby in the region east of the Allegheny Mountains and arborescent west of the Mississippi River, and is most abundant and reaches its largest size in southern Arkansas and eastern Texas.

ECONOMIC VALUE OF CHESTNUT

From an economic standpoint the American chestnut is by far the most important species. It is one of the main forest trees of New York, Connecticut, Pennsylvania, and the Allegheny Mountain region southward to Alabama. The cut of chestnut comprised about seven per cent of the total amount of hardwood timber cut in the United States in 1910. In 1907 the United States Bureau of the Census [6] reports: " Chestnut is a wood whose use for lumber has increased remarkably within the last few years. The total cut in 1907 was over three times as large and its total value over four and one half times as great as in 1900 . . . having a value of $11,130,547 . . . . nearly one half of the total cut was reported by Pennsylvania, West Virginia, and Tennessee. . . . In addition to being largely used for lumber, much chestnut is also cut into posts, poles, rails, and cross-ties, and used in the manufacture of

[5] Sargent, C. S. Manual of the trees of North America, pp. 220–222. 1905.
[6] The lumber cut of the United States, 1907. U. S. Census Bureau. Forest Products, No. 2:1–53. 1908.

tanning extract." For 1907 the value of the chestnut used in the latter products amounted to $1,619,785 for poles, about $3,500,000 for ties, $2,560,007 for tanning extract, and $377,880 for slack-cooperage. The total value for all chestnut used in the products reported amounted to $19,188,219 in 1907. The later reports show but little variation from these figures for the yearly consumption. Unfortunately value computations are omitted in the reports for 1910 and 1911. For 1909 the total value of the chestnut cut, according to the reports, amounted to $19,098,581.

Besides its commercial value the chestnut has been utilized in its natural range as a much-favored ornamental. Many large estates in New York, Pennsylvania, New Jersey, and Connecticut valued their chestnut trees very highly. As an orchard tree the varieties of the American and the foreign species are of relatively less economic importance. The chinquapin, except as a variety for nut production, is of little commercial value.

The chestnut tree is our most important source of tanning extract. We know of no rapidly growing species that could be economically substituted in case of its extinction. The result of this would inevitably be a material increase in the cost of tanning leather.

SOIL REQUIREMENTS

Concerning the soil requirements of the chestnut, Zon [7] states:

"Chestnut is not very exacting in its demands upon the nutritive substances of the soil, but requires that it be deep, fresh, loose, and moderately fertile. The development of chestnut seems to depend more on the situation and the physical conditions of the soil than on its chemical composition. A moderate amount of clay, though not enough to interfere with the looseness of the soil, together with some potassium and lime, suits the species best. . . .

"Chestnut is a deep-rooted species, which derives its nutrition from the lower layers of earth — a fact explaining its vigorous growth on exposures with poor surface soil."

NATURAL REPRODUCTION

Quoting further from Zon: "The conditions for the reproduction of chestnut from seed are very unfavorable. The presence of man, who has made a business of gathering and selling chestnuts, of hogs, which seek them greedily, and of coppice chestnut and other hardwoods, under whose dense shade the chestnut seedlings must come up, renders reproduction from seed almost impossible."

[7] Zon, Raphael. Chestnut in southern Maryland. U. S. Forestry Bur. Bul. 53 : 1–31. 1904.

The chestnut is noted for its ability to sprout from the collar after the tree is cut, forming a dense growth of coppice. Practically all the second and successive growths of chestnut in the Eastern States have come about in this way. This coppicing method of reproduction is followed in forestry practice to great advantage. The influence of different factors on the thriftiness of coppice growth are discussed by Zon.[8] Many persons have contended that this practice has devitalized the chestnut, making it more susceptible to diseases; however, as Metcalf (1912 b:81–82) says, there seems to be no substantiating evidence for such an assertion. The marked abundance of dead branches on slow-growing chestnuts has been taken as a sign of their debility.

The opinion that the chestnut has not always been thrifty throughout its range is based on observations of various writers. Clinton (1913: 407–408) discusses this subject, quoting extensively from many sources. He states: "It is well known that in times past the chestnut trees in this country have suffered severely in certain districts, particularly in the South, in some cases being practically exterminated, so that their range is now considerably lessened from what it was originally. Strangely enough, no one has surely accounted for any of these devastations. Personally we believe that this tree is extremely susceptible to changes in the natural environment, and that such changes, with water playing an important part, have been the chief factors back of the gradual decline of this important forest tree. Other factors, such as forest fires, deterioration through repeated cuttings, insect and fungus attacks, are contributing causes varying in different localities."

THE DISEASE

NAME

The present epiphytotic disease of the chestnut has become known by several common names. Metcalf (1908 a) applied the name "bark disease," and since that time this name, as well as the name "blight," has been used by most writers. Murrill (1908 b) used the name "canker," but unfortunately this name has found preference with but few writers.

There are arbitrary rules, at least, for the naming of types of diseases. The term "canker" has come to mean, both to the pathologist and to the layman in this country, a disease which causes the death of definite areas of the bark of the limbs or the trunks of trees. The various apple-tree cankers are well known. There is no conflict in meaning, therefore, between the names "bark disease" and "canker," for they are synonymous; but, since we already have in common use the name "canker,"

[8] Zon, Raphael. Chestnut in southern Maryland. U. S. Forestry Bur. Bul. 53: 1–31. 1904.

there is no logical reason why we should not use it for this disease. Pantanelli (1911) says this name does not seem very exact, as very different alterations of a tree are understood by the word "canker." In a later article, however, Pantanelli (1912:869) used the name "canker."

It is true that European writers attach to the name "canker" the additional significance of a callus formation around the diseased area. Thus they retain the original Greek neaning of the root of the word, which meant an excrescence on the limbs of trees.

The name "blight" has been more generally applied to rapidly spreading and destructive diseases of herbaceous plants or the herbaceous parts of woody plants. As the term "blight" in the case of this disease signifies only a symptom of the disease, not the lesion, it is evidently not so appropriate as either of the other two names. The authors of this bulletin prefer to use the name "canker," and in order that the name may be entirely specific it should be called the Endothia canker of the chestnut.

HISTORY

In the first published account of the Endothia canker, Merkel (1906:97) says: "This disease was first noticed in the New York Zoological Park, in a few scattered cases which occurred during the summer of 1904." In a letter to the writers Mr. Merkel adds: "No indication of the chestnut-tree disease was noticed by me previous to the year 1904. In 1904, however, toward the latter part of the season, I noticed that certain very old chestnut trees were suffering in certain portions of their tops from some trouble or other, but no investigation was made of the cause. . . . Early during the following year, in fact on June 17, I became thoroughly alarmed and sent to the Bureau of Forestry a specimen of the disease on a young tree and a letter asking for information."

Metcalf and Collins (1909:45) state: "Even at that time [referring to the discovery of Merkel in 1904] it is certain that it had spread over Nassau county and Greater New York, and had found lodgment in the adjacent counties of Connecticut and New Jersey. No earlier observation than this [1904 by Merkel] is recorded, but it is evident that the disease, which would of necessity have made slow advance at first, must have been in this general locality for a number of years in order to have gained such a foothold by 1904. Conspicuous as it is, it is strange that the fungus causing this disease was not observed or collected by any mycologist until May, 1905, when specimens were received from New Jersey by Mrs. F. W. Patterson, the Mycologist of the Bureau of Plant Industry."

This was the starting-point of the numerous investigations conducted by a large number of workers. Metcalf and Collins (1911:5) state:

"There is reliable evidence, however, that it was present on Long Island at least as early as 1893." This statement was based entirely on the recollections of certain observant nurserymen.

ORIGIN OF THE EPIPHYTOTIC

In his first publication Murrill (1906 a: 153) advances the theory that "it is possible that the conspicuous ravages of the disease about New York City are largely due to the severe and prolonged winter of 1903–04, during which many trees of various kinds were killed or injured." Metcalf (1908 a: 56) believed it possible that the Japanese chestnut had been the means of introducing a new fungous disease to this country. Clinton (1909: 887), after discussing observations that he had made, states: "From the preceding account one can readily see that the writer believes that the fungus alone is not entirely responsible for the havoc. . . . . Winter injury in 1903–04, aggravated by the droughts, especially that of 1907, we believe to have been important factors in handicapping the trees so that the way was opened for further serious injury by the fungus."

From these statements and the evidence cited for upholding this view, it is seen that Clinton did not believe a new and dangerous pathogen was being dealt with; but, as he states later, he believed that a native obscure fungous disease had suddenly sprung into prominence, due more to the condition of the host than to the potentialities of the organism. These two quite divergent opinions were each based on circumstantial evidence which will be more fully treated under etiology and ecologic relations. As a solution of the problem pathologists welcomed the finding of the disease in China in 1913, for this furnished a satisfactory basis for explaining many factors concerning the epiphytotic.

It therefore seems certain that Metcalf's assumption as to the origin of the outbreak has been proved correct. The opposing views of others, which no longer have any significance in accounting for the origin of the disease, are nevertheless important points to be considered under the influence of ecologic factors on the fungus, the susceptibility of the host, and the possible augmentation of the epiphytotic.

SPREAD IN THE UNITED STATES

The rapidity of spread has been phenomenal, and the completeness of destruction is without parallel in the annals of plant pathology. Merkel (1906) wrote in November, 1905: "Since that time [1904], however, it has spread to such an extent that to-day it is no exaggeration to say that ninety-eight per cent of all the chestnut trees in the parks of this borough [Bronx] are infected." Metcalf and Collins (1909: 45) state that specimens were received from New Jersey in May, 1905. Murrill (1906 a:

143) states in June, 1906: " The same disease has been found to exist among the chestnuts of New Jersey, Maryland, and Virginia." As to the authenticity of the records in Maryland and Virginia at this date the writers of this bulletin are in doubt.

Murrill (1906 b: 203, 207) states in September, 1906: " I now know of very few chestnut trees in this portion [Bronx] of the city that appear to be worth trying to save and I do not consider any immune "; and further: " Mr. Levison reports all the chestnut trees of Forest Park, Brooklyn, to be either dead or dying, and many in Prospect Park to be seriously affected. Wherever he has found the chestnut tree in Brooklyn, he has found the disease."

Metcalf (1908 a: 55) states in February, 1908: " The bark disease.... is now reported from Connecticut, Massachusetts, Vermont, New York as far north as Poughkeepsie, New Jersey, Pennsylvania, and possibly Delaware." In the same month Murrill (1908 a: 26) reports approximately the same distribution, and adds Maryland to the list. Clinton (1908: 345) reports that the disease has become common in the neighborhood of Stamford, Connecticut. Hodson (1908: 4–5), after giving more nearly exactly the location of diseased areas in each State, sums up the situation thus: " The range at present, then, includes eight states, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and Massachusetts." Mickleborough (1909) reports the presence of the disease in six counties in eastern Pennsylvania, and Clinton (1909: 881–885; 1911: 716–717; 1913: 371–372) gives the data regarding the spread of the disease in Connecticut.

Metcalf and Collins (1909: 46) present a map showing the distribution at that time in so far as it was known. By this map it was shown that the disease was found in Rhode Island and southern Connecticut, in New York, New Jersey, and Delaware, and in eastern Pennsylvania, Maryland, and Virginia. They add: " It can be quite confidently stated that the bark disease does not yet occur south of Virginia and at only a few points in that State." Metcalf (1910) states: " At the present time it has spread from Saratoga county, New York, and Suffolk county, Massachusetts, on the north and east, to Bedford county, Virginia, on the south, and Greenbriar and Preston counties, West Virginia, and Westmoreland county, Pennsylvania, on the west."

Metcalf and Collins (1912) publish a detailed map which shows the results of more nearly accurate surveys of the territory along the border line of the spread of the disease. No new States were added to the distribution as already given above, although spot infections were found in many places in Massachusetts, western Pennsylvania, Maryland, and northern Virginia.

The latest published information is given by Metcalf (1914:8), who reports: "The disease is now generally distributed in native chestnuts from Merrimack county, New Hampshire, and Warren county, New York, on the north, to Albemarle county, Virginia, on the south. In New York the western border of distribution is sharply delimited by an area without chestnut trees—a natural 'immune zone'—which extends southward along the eastern borders of Fulton, Montgomery, and Schoharie counties nearly to the Pennsylvania line in Delaware county. Consequently, in New York the range of the disease is at present practically limited to the valley of the Hudson. In Pennsylvania the western limit of general infection is roughly along a curved line extending from the northwest corner of Susquehanna county to the eastern border of Clearfield county and on to the southwest corner of Fulton county. West of this line the advance infections were cut out by the Pennsylvania Chestnut Tree Blight Commission. The disease has not yet been found in Ohio or Indiana. In general it appears to spread northeastward and southwestward, following the direction of the ridges of the Appalachians, much more rapidly than westward, across the ridges and valleys.

"Scattering infections occur outside of this area. Of these, the outposts are two infections on planted chestnuts in Franklin and Androscoggin counties, Maine, and one infection in a nursery in North Carolina. There is reason to suppose that the North Carolina infection, and an orchard infection in British Columbia, owe their origin to trees imported directly from the Orient."

The data for the map, Fig. 77, were furnished by Dr. Haven Metcalf, and represent the distribution known to him on March 1, 1914.

One might infer from the above that the disease has been spreading in ever-widening circles from the region about New York City. However, Clinton (1913:374) remarks: "This apparent wave of progress, however, is in part due to a corresponding wave of interest on the part of the people to locate a disease so generally discussed." He, as well as many others, believes that the disease has not started from a single center, but that other affected localities, such as those in Warren county, New York, Bedford county, Virgina, and Lancaster and York counties, Pennsylvania, are nearly as old as that about New York City. Even though the disease was imported from the Orient, as now seems certain to have been the case, it is reasonable to suppose that there were centers of infection started at distant places by the shipment of nursery stock. None of these outlying centers, however, have developed areas of total destruction such as that around New York City; so that it is still reasonable to suppose, from the evidence at hand, that this was the original center and that all other centers were early spot infections originating from it or from later direct importations.

DISTRIBUTION IN NEW YORK STATE

One of the writers of this bulletin (Rankin, 1914) reports the results of the surveys conducted in New York State as follows:

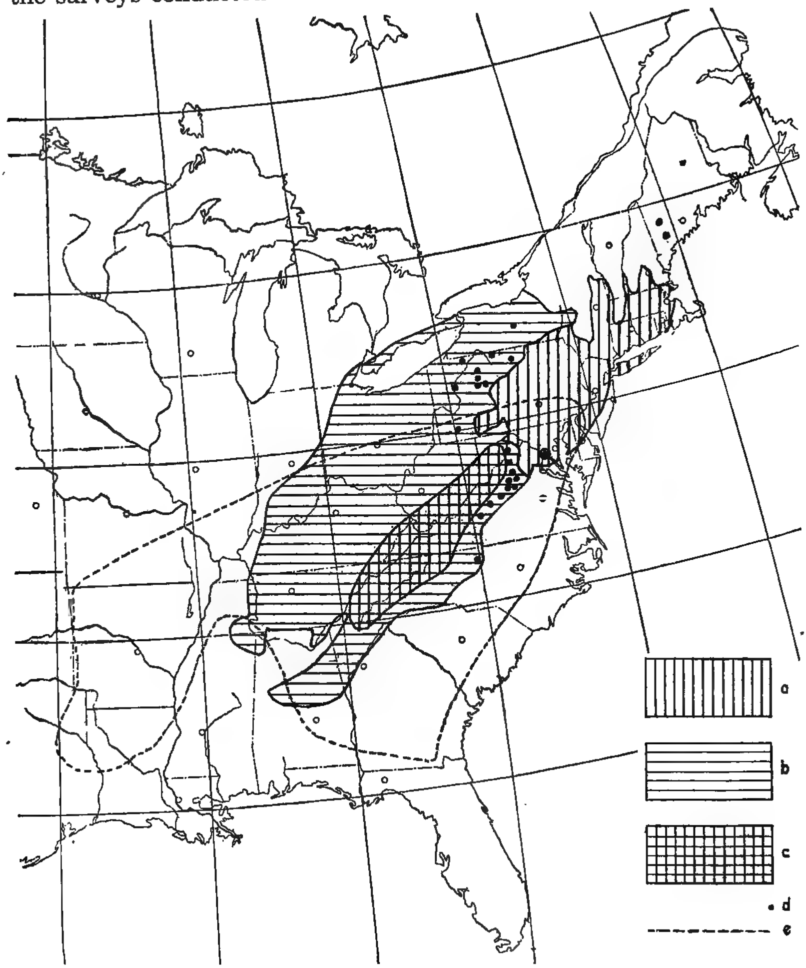


FIG. 77.— *Map showing present distribution of the chestnut canker in the United States. Furnished by Dr. Haven Metcalf*

a, Area over which the chestnut canker is abundantly present

b, Area of natural range of Castanea dentata as yet unaffected except for a few spot infections

c, Area of heaviest stands of chestnut

d, Location of known spot infections

e, Limit of natural range of the chinquapin, Castanea pumila

" At the outset of this investigation [May, 1911] the information available concerning the distribution of the disease attributed the northern limit of its range to southern Dutchess and central Orange counties.

It was known to be generally established in the western part of Long Island, Staten Island, and the counties of New York, Westchester, and Rockland. It was also expected that Orange county had been invaded to some extent."

Range of the chestnut in New York State

Reference to the accompanying map (Fig. 78) shows that the chestnut region of the State lies in two almost separated areas — the Hudson Valley, and the central and western parts of the State — and the two areas are connected by a narrow band of chestnut skirting the Delaware

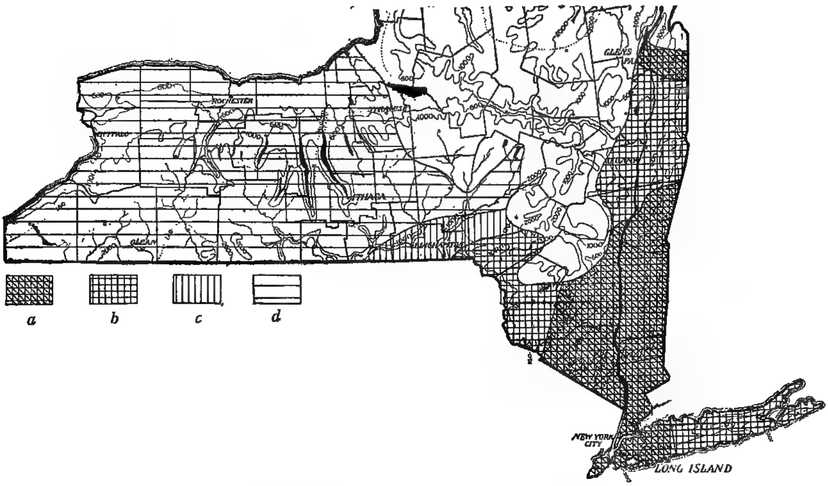


FIG. 78.— *Map showing distribution of the chestnut canker in New York State*
a, Canker abundantly present in 1911
b, Spot infections numerous in 1911
c, Spot infections numerous in 1913
d, Area containing more or less chestnut that is healthy

River in Sullivan and Delaware counties. There is no chestnut to be found in the Adirondack Mountains, and but little in the Catskill Mountains and the Highlands in Ulster, Sullivan, and Delaware counties. The extreme northeastern corner of the State contains but a few scattering chestnut trees.

Conditions in 1911

The accompanying map (Fig. 78) shows the results of the survey in fixing the limits of spread of the disease at that time. East of the Hudson River the disease was found abundantly as far north as Albany. The chestnut is most abundant along the state line between New York and Connecticut and Massachusetts, in the range of mountains making up the Berkshires. Along the Hudson River the chestnut is plentiful, but not so abundant as in the hills. It was along the state line, in these heavy stands of chestnut, that the disease had made the greatest ravages. It was present, however, in every locality where there was any quantity of chestnut. Practically every town east of the Hudson River is represented in the list of those in which the disease was found. In those towns in this region from which the disease was not reported, the stand of chestnut was slight. In the central part of Rensselaer county there is little chestnut, and especially is this true of the part near the Hudson River. Along the state line separating New York from Massachusetts and Vermont, in the continuation of the Berkshires northward, there is considerable chestnut, but no disease was found there.

The natural northern limit of the chestnut, as is seen by the map, is in the towns of Fort Ann and Granville, in Washington county. The disease was found very abundant throughout Washington county. Many lumbermen were cutting chestnut as rapidly as possible in the towns of Hartford, Argyle, and Hebron, in order to keep ahead of the disease.

West of the Hudson River the disease had not advanced so far north. Practically the entire stand of chestnut in Orange county and in southern Ulster county was diseased. In the Catskill Mountains proper there is much chestnut in the valleys opening into the Hudson River Valley. In the southernmost of these valleys the disease had spread as far as chestnut is to be found, but in the Esopus Valley and in the valleys north of it the disease had spread for only a little distance. In Albany county the chestnut is scattering, except in the Helderberg Mountains, and it is very scarce in the western part of the county. A complete survey of Albany county was not made, owing to the unimportance of this information; however, the disease was found general in the southern part of the county along the Hudson River.

The connecting link between the chestnut region of the Hudson River Valley and that of the central and western part of the State is the strip in Sullivan county along the Delaware River. Chestnut is abundant here for fifteen to twenty miles away from the river. Many isolated spot infections were found here. The general spread extended about as far up the Delaware River as Port Jervis. A few spot infections were found in southern Delaware county along the Delaware and Susquehanna rivers. One spot infection was found at Masonville, Delaware county, and was destroyed. No infections were known west of this region in 1911. A special investigation of the cause of the dying of the chestnut near Cooperstown was made, but it was found not to be due to the canker disease.

Conditions in 1913

A hasty resurvey of the territory bordering on the line of advance determined in 1911 was made in September, 1913, for Doctor Metcalf. The area just west of the chestnut-free belt was covered, and the line as drawn on the map (Fig. 78) was fixed as representing approximately the limit of spot infections at that time. The strip along the Delaware River where isolated spots were found in 1911, was found at this time to be abundantly affected. The disease seems not to be spreading so rapidly north as west, and no infections were found in Otsego county just west of the chestnut-free belt in the Catskills. The width of this belt varies from thirty to forty miles, and it is interesting to note that apparently this distance has furnished a natural barrier which has so far impeded the dissemination of the fungus westward from the diseased areas along the west bank of the Hudson River.

ECONOMIC IMPORTANCE

Several writers have attempted to estimate in pecuniary value the losses due to the Endothia canker. The disease not only kills the merchantable trees on which a pecuniary value can be placed, but also destroys the young growth which would have been cut in the future, the value of which cannot be determined accurately. Aside from this, the æsthetic loss from the destruction of thousands of shade and ornamental trees cannot be computed in dollars.

Great as the damage has been, it seems that estimates are worth but little because of the lack of accurate data. Clinton (1913:379) tersely sums up the situation: "Just how this loss is estimated is not made very clear. To the writer it seems to be largely guess work. However, it is interesting to note these figures in order to compare them with losses given for other fungous diseases and insects." Murrill (1908 b:111) states: "The amount of damage done by it, in and about New York City, where it has been most carefully observed, probably reaches a total of between five and ten million dollars." Metcalf and Collins (1911:5) regard $25,000,000 as a conservative estimate of the financial loss from this disease up to 1911. Metcalf (1913:364) states: "The estimate of $25,000,000 made in 1911 as representing the loss up to that time was probably much too conservative. But the total loss to date is insignificant compared with the loss which will ensue if the disease once attacks the fine chestnut timber of the South Appalachians."

SYMPTOMS

With few exceptions every writer on the subject has described the symptoms of the disease, and many writers have published excellent illustrations. The effects of the disease on the general appearance of the tree are most noticeable during the summer, when the trees are in leaf. In regions where the disease is common, the newly affected limbs and twigs are girdled in large numbers during the summer, and the brown, shriveled leaves are readily seen even at a distance. This most striking symptom is common during July and August, while the healthy parts of the tree are still green. The dead leaves also remain clinging to the limbs during the winter (Fig. 79). If the girdling of a limb is completed during the time when the burs are maturing, the latter often remain on the branches over winter. If, however, the girdling takes place after leaves and burs are shed and before the leaves come out in the spring, the leaves do not attain their full size and are pale and distorted. This is a common symptom in May and June (Fig. 80). Dead limbs without attached leaves or burs are often indications of the presence of the canker disease (Fig. 81). Water sprouts or suckers are commonly developed just below the cankers. Thick clumps of suckers on the trunk (Fig. 82), on the branches, or at the base of the tree, are often the only telltale evidence of a developing canker. Such growths

FIG. 79.— *Tree during winter, showing the leaves still clinging to the branches, which have been killed by girdling cankers*

are very conspicuous the year round. In time they are killed either by the canker's invading the area from which they grow or by the infection of the suckers themselves.

FIG. 80.— *A diseased and a healthy tree in midsummer. Notice the poorly developed leaves on the diseased tree (at the left)*

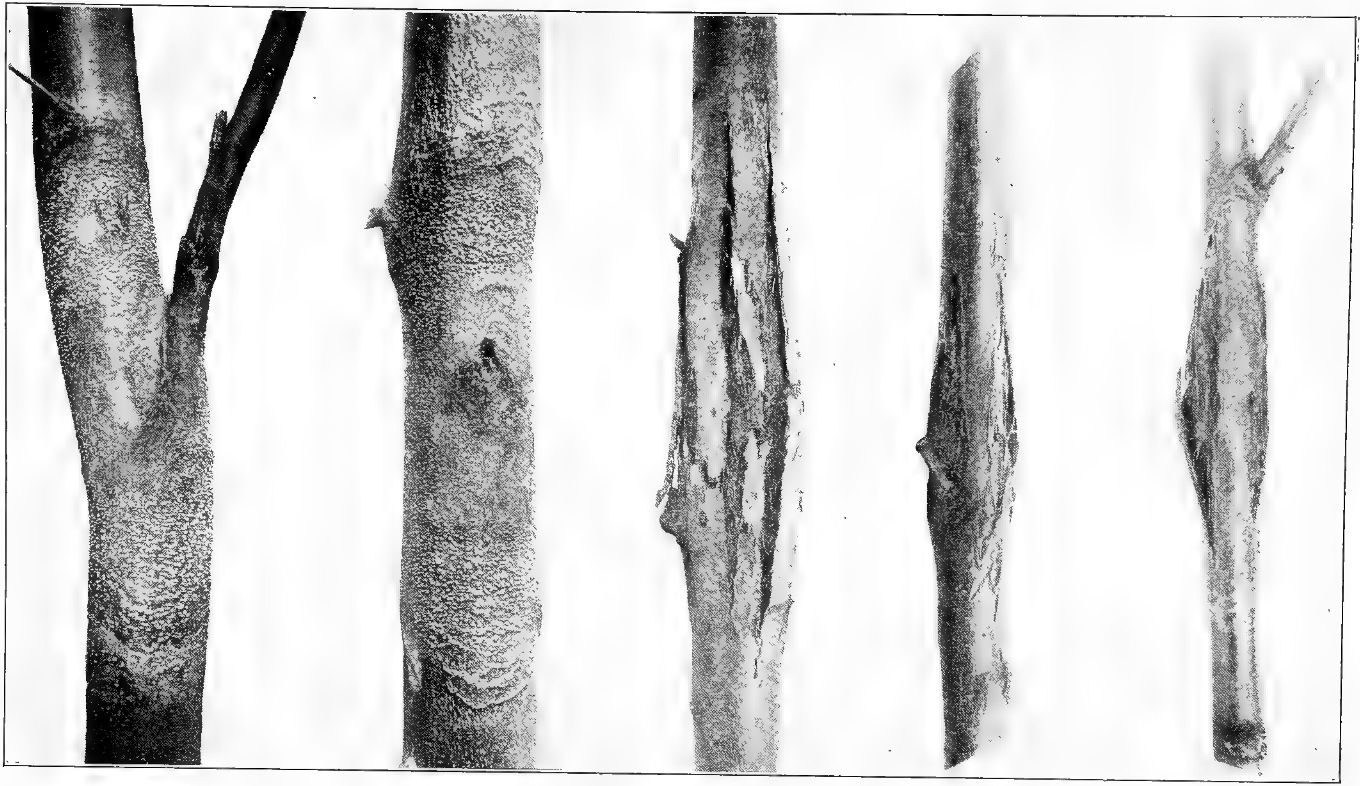
Cankers on smooth bark are especially conspicuous (Plate XXXVI, frontispiece). They can be seen for a long distance because of their reddish tinge in contrast to the healthy green bark. The cankers are either sunken or swollen diseased areas of the bark (Plate XXXVII). They occur on branches of all sizes — only rarely, however, on first-year twigs. The usual shape of the canker is ellipsoidal, being longer

FIG. 81. — *Chestnut woodland devastated by the canker. Photograph taken in midsummer*

in the direction of the long axis of the limb. The margin of the canker is usually fairly regular, but it may be irregular.

Metcalf (1914) says the cankers formed on the Chinese chestnut become deeper year by year as healthy wood is formed about them, thus causing a condition similar to the European apple-tree canker.

Usually about a month after inoculation the bark of the affected area becomes covered with numerous small pimples. Under moist conditions, following rains, long, twisted, yellow tendrils are extruded from the



TYPES OF CANKERS ON CHESTNUT CAUSED BY ENDOTHIA PARASITICA

FIG. 1.— *Part of canker showing twisted pycnospore tendrils*

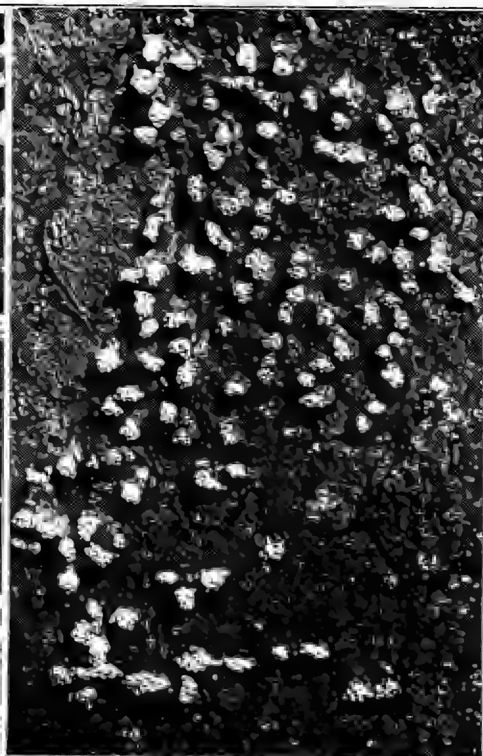


FIG. 2.— *Stromata on smooth bark, showing papillæ, at the tip of which are the ostioles of the perithecia*

FIG. 3.— *Lines of pycnospore tendrils in crevices of rough bark*

EXTERNAL APPEARANCE OF FRUITING STAGES

FANS OF MYCELIUM IN THE CAMBIUM AREA AFTER THE BARK HAS BEEN PEELED OFF

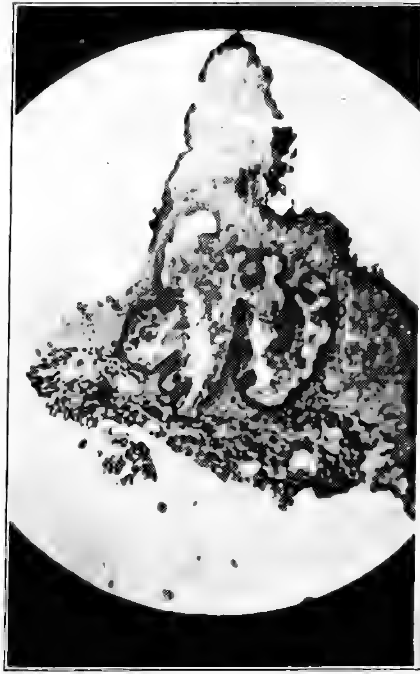


FIG. 1.— *Section of stroma showing mature pycnidium of irregular shape. Pycnidium partly filled with spores*

FIG. 2.— *Longisection of a perithecium partly filled with asci*

FIG. 3.— *Section of stroma showing two empty perithecia with their black necks extending to the ostioles at the surface*

LONGISECTIONS OF STROMATA SHOWING FRUIT BODIES ruptured apices of these blisters (Plate XXXVIII, Fig. 1). Older and larger cankers have the pimples and the yellow tendrils confined to the margin, while nearer the center reddish-brown pustules have been pushed out through the outer bark. These pustules, when fully developed, measure one sixteenth of an inch or more in diameter and have numerous papillæ on the upper surface, each with a black dot at the tip (Plate XXXVIII, Fig. 2). Cankers on rapidly growing limbs are usually outlined by a distinct ridge of slightly hypertrophied tissue. Where the whole cankered area is hypertrophied the bark usually splits longitudinally (Plate XXXVII). As the canker becomes older the bark splits and cracks, and after a few years it breaks away entirely and leaves the wood bare (Fig. 83). When the tree is thoroughly diseased — and this may take only two or three years after the first infections occur if they are at the top of the tree — the brown pustules cover the bark of the trunk and the branches, giving the tree the distinc-

FIG. 82.—*Water sprouts on the trunks, indicating cankers just above them*

tive brown hue. When the fungus affects rough bark, no shrinking nor swelling nor change in color is evident, and it is only when the yellow tendrils, or later the brown pustules, are produced in the crevices of the bark that an outward indication of the diseased area appears (Plate XXXVIII, Fig. 3).

FIG. 83.— *Tree that has been dead for several years, showing the bark falling off in patches and exposing the wood*

By examining the character of the destruction of the bark one may determine other diagnostic characters. When the bark is peeled from the edge of a canker it is found to be flaked with tawny, fan-shaped areas, which, once seen, are easily recognized (Plate XXXIX). The invaded tissue is changed to a light sienna brown and appears in marked contrast to the normal light-colored bark. Thick bark that is affected is reduced to a mass of shreds, which are a uniform dark brown in color. The first layers of wood and the medullary rays also turn brown under the cankered area.

ETIOLOGY

Name of the causal organism

It has been proved by Murrill (1906, a, b, and c) that the Endothia canker of chestnut is produced by a fungus which he refers to the genus Diaporthe, of the Sphaeriales. Believing that it had not been previously described he gave it a new specific name, *parasitica*, recalling its destructive parasitic habit.

Rehm (1907) declares that it belongs among the Hypocreales in the genus Valsonectria, and proposes the combination *Valsonectria parasitica* (Murr.) Rehm.

Clinton (1909:888) quotes Farlow as stating that "it comes more naturally under the genus Endothia, and is closely related to *E. gyrosa*." The latter is a saprophytic species which, as limited by Saccardo, was first described from North Carolina by Schweinitz in 1822 as *Sphaeria* *gyrosa* on Fagus and Juglans, and in 1828 by Fries as *S. radicalis* on Fagus (or Quercus) from the same State, and which is found commonly on oaks, chestnuts, and a number of other trees in Europe as well as in America.

Von Höhnel (1909) says that *Diaporthe parasitica* Murr. is identical with *Endothia gyrosa* (Schw.) Fückel; also that the genus Valsonectria is not different from Endothia, which he would place among the Hypocreales because of its bright-colored stroma rather than in the Sphaeriales where it is usually placed. He gives two reasons why the fungus is an Endothia rather than a Diaporthe: (1) the bright-colored stroma is typical of the former, but not of the latter; (2) the conidial fruit form of Diaporthe is Plenodomus Preuss (Phomopsis Sacc.), while that of Endothia is Endothiella Sacc., characterized by irregular chambers in the stromata, without a definite wall and with small, rod-shaped spermatia.

Clinton (1912 c: 79–80), at the Harrisburg Conference in February, 1912, states that he believes *Diaporthe parasitica* to be closely related to *Endothia gyrosa*, but of a different species. In a footnote, written after the conference, he states that he found *E. gyrosa* common as a languishing parasite or saprophyte on chestnuts and oaks in Virginia, North Carolina, and Tennessee; and that it differs from *Diaporthe parasitica* in that the stromata are less luxuriant, and especially that the ascospores are smaller and narrower, but he is not sure "whether these differences are those of a strain, variety, or distinct species." At the same time Farlow (1912 a: 74) gives it as his opinion that *Endothia gyrosa* and *Diaporthe parasitica* are identical. Rankin (1912 b: 47) states that he found a saprophyte common on the chestnuts in Virginia which is indistinguishable from the canker fungus. So far as the literature shows, Rankin was the first to find this saprophytic Endothia on chestnuts in America.

All the writers quoted above consider *Endothia gyrosa* (Schw.) Fr. and *E. radicalis* (Schw.) de Not. as synonymous. Shear (1912 a) questions their identity, and in the same paper states that there is a specific difference between *Diaporthe parasitica* and *Endothia radicalis* (Schw.). It appears from Shear's later papers (1912 b and 1913 a) that he was applying the latter name to a form with bacilloid spores found commonly in the Southern States, first brought to notice by Farlow (1912 a: 74) and later called by Clinton (1912 a) the "linear-spored Endothia."

Farlow (1912 b) in Science repeats his previous statement that *Diaporthe parasitica* and *Endothia radicalis* (European form) are identical, and states that his opinion is shared by von Höhnel and Saccardo.

Since 1909 the generic position of the fungus has not been seriously questioned, all authorities apparently agreeing that it is an Endothia. Outside those already mentioned, the most valid reason for placing the fungus in Endothia rather than in Diaporthe or Valsonectria may be stated thus: Endothia was erected in 1846, with *Sphaeria gyrosa* Schw. as the type. When the new fungus that causes the canker was studied, it was found to resemble *E. gyrosa* (as defined by Saccardo) so closely that even such authorities as Saccardo, von Höhnel, and Farlow could not distinguish the two species. Also the very few other species that have been referred to this genus resemble these two so closely that no one would think of putting them in different genera. Wherever one is placed they must all go. If one is placed in Diaporthe they must all be placed there, that is, the whole genus must be combined with Diaporthe. But, according to our rules of nomenclature, when the members of two genera are combined they take the name of the species first described, which in this case happens to be an Endothia. Therefore, even if there were not sufficient generic differences to keep the two genera separate, the canker fungus would still be Endothia, not Diaporthe nor Valsonectria — genera which were established many years later. The question from this time on was in regard to the specific name to be applied.

Shear (1912 b), after a summer in Europe, stated that the *Endothia radicalis* of European authors is morphologically identical with *Diaporthe parasitica;* also that the American *Endothia radicalis* (Schw.) is the long-spored form of the Southern States; also that the latter is different from the European *E. radicalis*. He later retracted the first and the second of these statements (1913 a).

Anderson and Anderson (1912 a) made a study of the saprophytic American Endothia, which they found common on chestnuts and oaks in southwestern Pennsylvania, Virginia, West Virginia, and Tennessee. They found marked morphological, biological, and cultural differences between this and the true canker fungus. They consider these differences of specific value, and propose the new combination *Endothia parasitica* (Murr.) for the canker fungus and *E. virginiana* sp. nov. for the saprophytic form. The most noticeable morphological differences are:

E. parasitica	*E. virginiana*
Mycelium forms thick, fan-like mats in the bark and on the cambium	No such mats perceptible
Size of ascospores, 8.6 by 4.5 μ	Size of ascospores, 7 by 2.98 μ
Shape of ascospores, broad: proportion of diameter to length, 1:2.7	Shape of ascospores, narrow; proportion of diameter to length, 1:1.9
Constriction at septum of ascospores distinct	Constriction very slight, if any
Length of ascus, 51.3 μ	Length of ascus, 34 μ

Biologically, the former is a virulent parasite and the latter a saprophyte. Cultural differences were found on every artificial medium on which the two were grown in pure culture. The reasons given by Anderson and Anderson for creating a new specific name for the saprophyte are: (1) Shear had identified the long-spored southern form as *E. radicalis* and this was entirely different from the species under consideration; (2) an examination of the type material of *E. gyrosa* (Schw.) Fr. in the Schweinitzian herbarium at the Philadelphia Academy of Science, and a comparison with the original description and all the early literature on this fungus, convinced them that it was a form entirely different from any species of Endothia now known; (3) there was no other described species of Endothia besides the above two which closely resembled the fungus that they were studying in western Pennsylvania.

Clinton also studied the relationships of these two forms and found practically the same differences as did the Andersons, besides additional cultural differences; but he considers the differences varietal, not specific. Shortly after the appearance of the paper mentioned in the preceding paragraph, Clinton (1912, a and b) published two papers in which he states that the European Endothia and the American *E. virginiana* Anders. are identical with *E. gyrosa* (Schw.) Fr. He proposes *Endothia gyrosa* var. *parasitica* as the proper name for the canker fungus. He emphasizes especially the difference in the shape of the ascospores, and calls the species the " narrowly-oval-spored " and the variety the " broadly-oval-spored " Endothia.

At about the same time, Pantanelli (1912), in Europe, studied the relationship of the European Endothia to the American canker fungus, and found important morphological, biological, and cultural differences which he considers of specific value; he designates the latter form as *E. parasitica* (Murr.) Anders., and the European form as *E. radicalis* (Schw.) Fr.

Shear (1913 b) examined asci and ascospores of the type specimen of *E. radicalis* (Schw.) from the Fries herbarium at Upsala, Sweden, and found them to correspond with those of *E. virginiana* Anders. and the form discussed by Clinton as *E. gyrosa*.

Shear and Stevens (1913 a) were the last to study in detail the relationships of the species of Endothia. They studied especially the cultural characters, and on nearly every kind of medium tried they found characters by which *E. parasitica* can be distinguished from the other species. They give as the correct names of the species here under consideration:

1. *Endothia parasitica* (Murr.) Anders., the true canker fungus
2. *Endothia radicalis* (Schw.) de Not., the saprophyte found first on chestnuts in this country by Rankin, later called *E. virginiana* by

the Andersons (1912, a and b), and discussed under *E. gyrosa* by Clinton (1912, a and b) as the "narrowly-oval-spored Endothia"

3. *E. gyrosa* (Schw.) Fr., the bacilloid-spored southern form, which Shear (1912 b and 1913 a) had previously called *E. radicalis* (Schw.) and Clinton had discussed under the name of *E. radicalis* (Schw.) Farl., or the "linear-spored Endothia"

The last of the three need not be considered especially at this time, since it has not been confused with the true canker fungus. Finding no intermediate forms between the first two, Shear and Stevens conclude that "unless such intergrading forms should be discovered later, there seems to be no way of escaping the conclusion that the two organisms are specifically distinct, according to the most conservative taxonomic standard of species prevailing at present in mycology."

In this publication the canker fungus will be referred to as *Endothia parasitica*. The complete synonymy is as follows:

Endothia parasitica (Murr.) Anders. Phytopath. **2**:210, 262. December, 1912

Diaporthe parasitica Murrill. Torreya **6**:189. 1906

Valsonectria parasitica (Murr.) Rehm. Ann. myc. **5**:210. 1907. Ascom. exs., fasc. 39, no. 1710

Endothia gyrosa var. *parasitica* (Murr.) Clinton. Science **36**:913. December, 1912

Concerning the pycnidial stage of the fungus, it was first referred to the genus Cytospora by Patterson (Clinton 1909:879), and shortly afterward by Clinton (1909) to the same genus. Since that time it has frequently been referred to in the literature under that name. Reasons for considering this disposition of it as incorrect will be given in the discussion of morphology and life history. In 1906 Saccardo (Ann. myc. **4**:272) erected the genus Endothiella, based on the pycnidial form of *Endothia gyrosa* (*E. radicalis* [Schw.] de Not., according to Shear). Since the imperfect stages of our American Endothiae are practically indistinguishable, it is evident that the pycnidial form of *E. parasitica* should be referred to that genus, if there is ever any need of considering it apart from the perfect stage.

History of the pathogen

When the disease was first noticed in this country in 1904 it was a comparatively simple matter to determine the association of the fungus with it. But where did this fungus come from, and why had it not been noticed before? There were only two possibilities: (1) either the fungus had always been here, but was now for the first time brought to notice; or

(2) it was an introduced species. When a fungus produces a sudden and destructive epiphytotic the presumption is that it has been introduced from some foreign country — a presumption that is supported by numerous well-known analogous cases in the past. But, on an investigation of conditions in other countries, no record of a similar disease of the chestnut could be found. This, however, does not invalidate the importation theory, since it is a fact well-known to plant pathologists that a fungus may be an inconspicuous and comparatively harmless parasite in its native country and yet may produce a destructive epiphytotic on being taken to another country.

This theory was first advanced by Metcalf (1908 a). Since he was unable to find any record of the occurrence of the disease in this country, and since he found the Japanese chestnuts more or less immune, he suggested that the fungus was a native of Japan and had been introduced here on imported trees. The presumption would be that, spreading to our native chestnuts, the fungus found these less resistant and more favorable to its growth; hence its rapid spread throughout the eastern States. In February, 1912, just previous to the Harrisburg Conference, Metcalf (1912 b:77–78) discussed his theory in part as follows:

"My own working hypothesis is, that the parasite is an importation from some country other than North America. The resistance of the Japanese and Korean chestnuts, coupled with the fact that the Japanese chestnut has been extensively imported and grown in that part of the country whence the disease appears to have spread, suggests that Eastern Asia may be the home of this parasite. . . . That the parasite has come from Europe seems less probable, in view of the fact that, according to Pantanelli, as well as according to my own inoculations under greenhouse conditions, the European chestnuts show no resistance to the disease. . . .

"The main fact in support of a foreign origin of the disease is its unquestionable spread in all directions from the vicinity of New York City. It is further suggestive that the oldest centers of infection located outside the vicinity of New York City — Bedford county, Virginia, and Baltimore county, Maryland — contained chestnut orchards with Japanese chestnut trees, possibly also European varieties. If *Diaporthe parasitica* is a native fungus, or has evolved from a native saprophyte, it is necessary to assume that the saprophyte was very limited in range, or that the evolution to a condition of parasitism occurred in only one, or at most a very few localities, or that there is a chronological sequence in its evolution proportional to its distance from New York City. Any of these assumptions are a severe tax on the scientific imagination."

Clinton (1909, 1911, 1912 a, 1912 c, 1913) holds to the opposite view;

that is, that the fungus has always been in this country as an inconspicuous saprophyte or a weak parasite, and that it became virulent about 1904 because the trees were in a weakened condition due to winter injuries and unfavorable weather conditions, as well as faulty silvicultural methods such as continuous coppicing. He briefly sums up his reasons for his theory as follows (1913:416–417):

"The writer's reasons for believing the chestnut blight is native to this country may be summarized as follows: (1) It has never been found in any other country. (2) It is very closely related to *Endothia gyrosa*, apparently developing from it as a distinct variety, and this species is a native fungus in this country as well as in Europe. (3) The limits of distribution of *E. gyrosa* and the chestnut blight overlap at least in the region covered by Washington, D. C., to southern Pennsylvania, while *E. gyrosa* occurs south of this common area and the chestnut blight north of it. (4) We have previously had serious troubles of chestnut trees in this country, and there seems to have been a continued northward movement of these, culminating in the recent trouble in the northern limit. While the chestnut blight has been definitely connected only with this last trouble, the previous ones have never been really explained. (5) The suddenness, et cetera, of the recent blight outbreak has been adequately explained by the writer through the unusual environmental conditions that have weakened the chestnuts in the general regions where the outbreak has occurred. (6) The fact that the chestnut blight fungus was never reported before this outbreak is no more difficult to explain than the fact that *E. gyrosa* had never been reported on chestnut in this country until by the writer a year ago, and yet this is a native fungus widely distributed on chestnut in the South, and has been known there on other hosts since 1822, when described by Schweinitz. They both were, in fact, merely overlooked on the chestnut. (7) Our cultures of *E. gyrosa* vary more from their normal type than do those of the variety *parasitica*, and some of these have varied somewhat toward the variety *parasitica* type. This, however, may have been due in part to bacterial contamination, et cetera."

The strong point in Clinton's argument, and the missing link in Metcalf's, was that the fungus could not be found in eastern Asia. But this link was supplied during the last year, when Fairchild (1913) reported the finding of the fungus in northern China by Meyer, an agricultural explorer of the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture. As had been expected, the fungus was found to be only weakly parasitic in that country, judging from Meyer's letter, which is quoted here only in part:

"The blight does not by far do as much damage to Chinese chestnut trees as to the American ones. Not a single tree could be found which had been killed entirely by this disease, although there might have been such trees which had been removed by the ever active and economic Chinese farmers. Dead limbs, however, were often seen and many a saw wound showed where limbs had been removed. . . . The wounds on the bigger majority of the trees were in the process of healing."

Shear and Stevens (1913 b) made cultures from the Chinese specimens and found that all the cultural characters are identical with those of *Endothia parasitica*. Spore measurements agreed very closely, and inoculations made on native American chestnuts produced typical cankers. The writers of this bulletin have grown the Chinese fungus in culture and cannot distinguish it from the American chestnut-canker fungus.

It may now be regarded as practically certain that the early home of *Endothia parasitica* was the Orient.

Morphology

Stromata

Cankers of a season's growth or older show numerous orange-colored or reddish-brown, erumpent and projecting, stromata (Plate XXXVII). On smooth bark the stromata are usually elongated horizontally and average about 2.4 by 1.2 millimeters, by 1.3 millimeter in depth. The part beneath the ruptured cork layer is flattened out on the collenchyma and is broader than the exposed part (Figs. 84 and 85). The stromata, however, vary widely in size with environment and season; they become much larger in moist situations than in dry surroundings where they are exposed to desiccation. On old, rough bark they do not occur singly, as shown in Plate XXXVII, but are found only in the crevices of the bark, often united in solid lines several inches long so that they apparently form one long stroma.

The color varies with age, being sulfur yellow at first, later becoming orange, reddish-brown, and finally cinnamon-brown on the surface, but always lighter-colored on the inside. When in a shaded and moist location — as, for example, on the underside of a log — the stromata remain light yellow.

In the fresh condition the stromata are soft, dry, subcoriaceous, easily torn apart, and of rather loose, indefinite outline. A cross section shows that the center of the stroma is composed of a comparatively loose tangle of branched and septate hyphæ, containing yellow pigment. Throughout the basal parts are scattered stone cells, bast fibers, and remnants of the walls of collenchyma cells. The entire exposed surface of the stroma is covered by a rind layer, in which the hyphal cells are shorter and thicker, almost or quite isodiametric, and with heavier walls than in the interior.

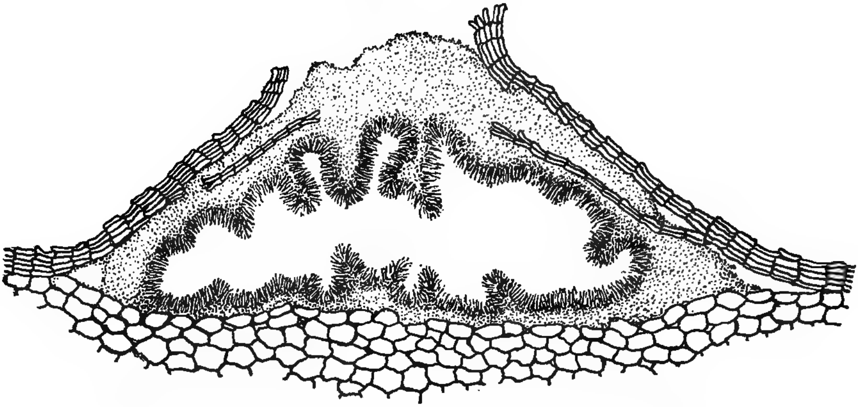


FIG. 84.— *Cross section (diagrammatic) of a mature pycnidium under the cork layer; ostiole not shown. After Heald*

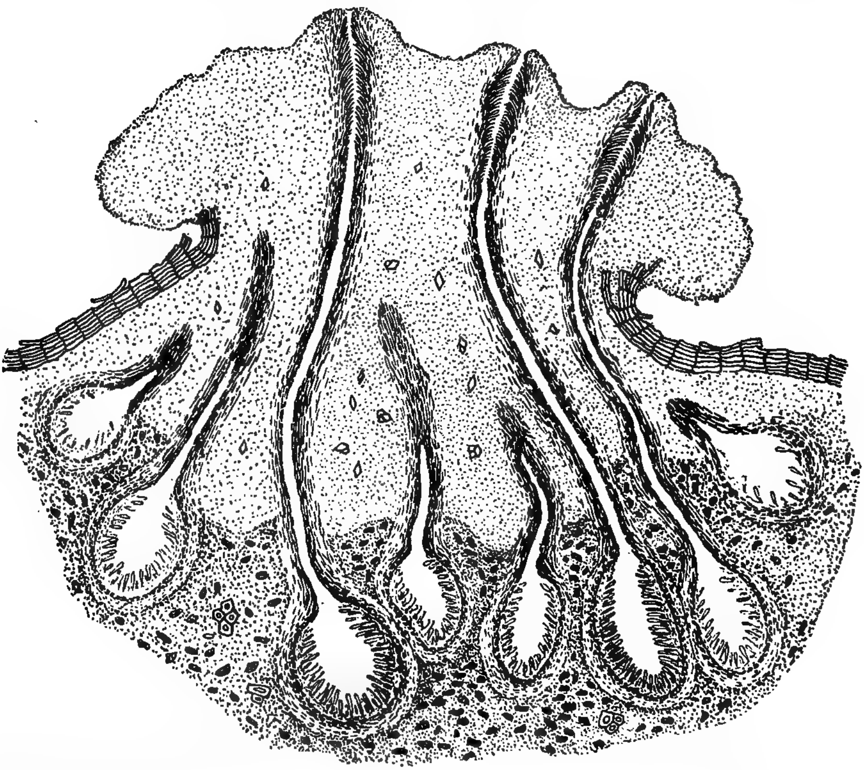


FIG. 85.— *Cross section (diagrammatic) of a stroma, showing mature perithecia. After Heald*

They are closely crowded together, so that in cross section they appear to make up a pseudoparenchymatous tissue. These cells are more densely filled with protoplasm, and contain more pigment, than the interior cells.

Pycnidia

On smooth-bark, young cankers, especially in the summer, the outer cork layer is raised in numerous little blisters, with slender, yellow, waxy tendrils curling from their ruptured apices (Plate XXXVIII, Fig. 1). Under each blister is a single somewhat globose pycnidium, surrounded by a scanty, loose growth of white or slightly yellowish mycelium. There is as yet no definite stroma. The wall of the pycnidium is composed of closely tangled hyphæ; that is, it is not a definite pseudoparenchymatous wall. The cavity may be a fourth of a millimeter in diameter and is almost round in cross section at first, becoming irregular only with age. The conidiophores form a dense, brush-like fringe and extend directly out into the cavity from every point of the wall (Fig. 86). They are of uneven lengths, the majority being 20 to 40 μ long, and are about 1.5 μ in diameter. They may be simple or branched. Spores are cut off successively from the conidiophores or their branches and soon fill the cavity, but, since the production of spores does not cease when the cavity is filled, they are forced out through an irregular ostiole at the top in yellow tendrils. These tendrils take on a reddish tinge as they become old. They vary in thickness from the diameter of a hair to half a millimeter, and in length from a millimeter to three or four centimeters. They occur singly and are usually spirally twisted into one or more coils (Plate XXXVIII, Fig. 1).

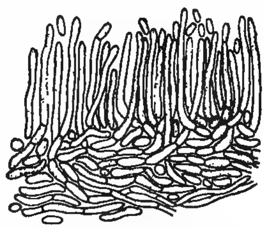


FIG. 86.—*Section of the wall of a very young pycnidium, showing the conidiophores, with the manner of their origin from the hyphæ. Conidiophores become branched in older pycnidia*

The older pycnidia contained in mature stromata differ from these in some respects. The cavity is convoluted or labyrinthiform, and irregular (Fig. 84, and Plate XL, Fig. 1). When cross sections of these stromata are cut, a single section usually shows a number of cavities which do not appear to be connected; but if the entire stroma is cut into serial sections it is found to contain but a single pycnidium with a number of communicating chambers. Only rarely have the writers found stromata containing more than one pycnidium. This stage of the fungus has been referred to the genus Cytospora, on the erroneous idea of a stroma containing many pycnidia. The cavity of the labyrinthiform type of pycnidium often becomes as much as a millimeter in diameter. The spore horns from this type are also usually much stouter than those from the former type, and on the bark of old trees, where they arise from lines of confluent stromata in the crevices, a whole line of them may be united in a comb-like manner. The spore horns of both types are usually flat or irregular in cross section. This accounts largely for the way in which they curl. When dry they are hard and brittle and not easily detached or broken.

Another form of pycnidia occurs on cut ends of stumps and logs, and also on both the wood and the inside of the bark where the latter has broken loose. These are superficial, single pycnidia (Fig. 87). A favorite place for them is on the inside of the bark where it has drawn away from the stump around the top, after the tree has been cut. Also, when a log or a stump on which there was a canker is peeled, these pycnidia develop on the surface very quickly. Their production is largely dependent on the water supply; this is illustrated by the fact that in dry weather they develop on the lower side of a log lying on the ground, but not on the upper side. In moist, shaded places they are long pear-shaped or conical, as shown in Fig. 87, or the base may be flattened out slightly on the substratum; but on tops of stumps — where they occur abundantly on the outermost four or five annual rings and where the supply of moisture is not constant — they are flattened out on the substratum and do not stand out free as shown in the figure, and they also have more of a tendency to run together. In color they are deeper red than the stromata, but have light yellow, conspicuous, beak-like ostioles. They are surrounded by no stroma whatever and stand out free except as stated above. They measure about a quarter of a millimeter in diameter and the same in height. The outer wall is perfectly smooth as seen under a hand lens. Often several pycnidia unite, but their ostioles remain distinct and give the appearance of a single pycnidium with several ostioles.

FIG. 87.— *Superficial pycnidia on wood, developed in a moist situation*

Pycnospores

The yellow tendrils are composed entirely of small, hyaline spores that are held together by a sticky substance the nature of which has not been carefully investigated. When the tendril is placed in water, it first swells considerably, then the binding substance dissolves and the spores float away free from one another. The spores average about 1.28 by 3.56 μ in size, and are oblong or cylindrical with rounded ends, or slightly oval, usually straight but sometimes slightly curved. The fact that they are not typically curved is an additional reason why this stage should not be referred to Cytospora. The spore membrane is thin and smooth. The spores are filled with dense homogeneous protoplasm, and each spore contains a single small, elongated nucleus near the center. There is also a polar body in each end.

Perithecia

The mature stromata on older cankers have numerous projecting papillæ on the surface (Plate XXXVIII, Fig. 2). The black speck at the tip of each papilla is the opening of a perithecium, the body of which is located down in the bottom of the stroma and is connected with the apex by a long, black neck. These papillæ may scarcely project above the surface of the stroma, or, on the other hand, they may be a

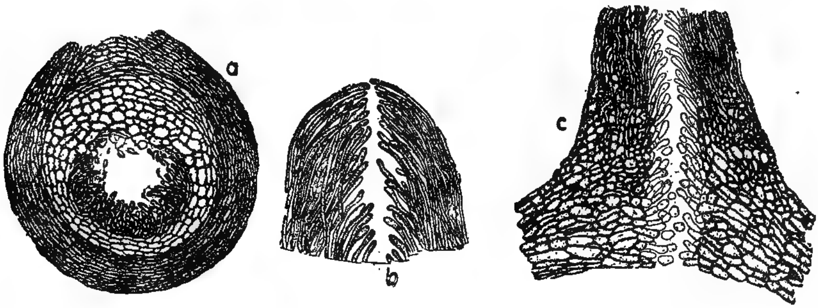


FIG. 88.— *Stages in the development of the perithecium*

a, Cross section at the stage when the cavity is occupied by young paraphyses. The neck is not shown

b, Tip of the neck in cross section as it appears, pushing up through the stroma at the same stage as shown in (a)

c, Lower part of neck and canal when the perithecium is almost mature, showing periphyses projecting into the canal

millimeter or more in length. They are longer in moist, shaded places than in dry, lighter surroundings. There are commonly fifteen to thirty perithecia in a stroma, but the number varies greatly, over forty having been counted in some cases. In Fig. 85 (page 558) and in Plate XL, Figs. 2 and 3, perithecia in longisection are shown. As seen under the hand lens the wall of the body of a perithecium is gray or lead-colored, while the neck is jet black and shining like anthracite. The mature perithecia measure about 350 to 400 μ in diameter and are mostly spherical, but the shape is often modified by pressure of surrounding perithecia.

Since the perithecia are always in the bottom of the stroma next to the host tissue, the length of the neck varies with the luxuriance of the stroma and the length of the papilla; but, in general, it is four to six times the diameter of the body. The black wall of the neck is composed of densely interwoven, septate, heavy-walled hyphæ running longitudinally with the long axis of the neck.

Branches of the same hyphæ project out free into the canal and upward toward the tip (Fig. 88, b). They are thin-walled, and react toward stains in a manner different from that of the other tissues. They are especially prominent at the tip of the neck. They are the periphyses.

In cross section the wall of the body is seen to be composed of ten or twelve layers of flattened, heavy-walled cells, very compact and pseudoparenchymatous (Fig. 88, a). Inside this there is a region of two or three layers of thin-walled cells, from the inner surface of the basal part of which the asci grow out into the cavity.

Asci

When the perithecium has become mature the entire cavity is filled with asci — the older, mature ones in the center, and younger ones around the walls. Mature asci are shown in Fig. 89, b, c, and d. They are broadly clavate or oblong, and each ascus contains eight spores in a matrix of epiplasm. The average size of one hundred and fifty asci measured by the writers was 51.2 by 8.9 μ. The arrangement of the spores is irregularly uniseriate or sub-biseriate; but there is little uniformity in this arrangement, since two asci can hardly be found in which the spores are oriented alike. The wall of the ascus is delicate and hyaline, and for this reason is hard to make out in its entirety in unstained mounts. There is a thickened ring about the upper end of the lumen of the ascus which is prominent and shows peculiar staining reactions. When the ascus is lying flat on the slide, the ring appears in optical section as two highly refractive disks (Fig. 89, c).

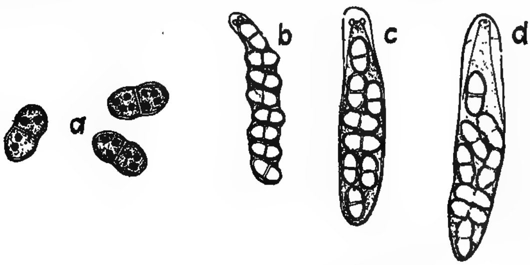


FIG. 89.— *Ascospores and asci*
a, Three ascospores showing nuclei
b, Ascus with spores when dry
c and d, Asci after swelling in water

Ascospores

The ascospores (Fig. 89, a) are oblong to oval with rounded or blunt-pointed ends, two-celled, constricted at the septa when mature, and on the average about 4.5 by 8.6 μ in size. The walls are thicker than those of the conidia; the septum is distinct and is composed of the same material as the walls. The spores are filled with dense homogeneous protoplasm;

only occasionally have anything like oil globules or vacuoles been seen. Each cell of a spore contains two to four nuclei. Like the conidia, the ascospores have a sticky coating on the outside.

Mycelium

The individual hyphæ are branched, septate threads, the branching being always monopodial, and usually not more than one branch is produced from a single cell. The hyphæ are not of uniform diameter, but vary from 1.5 to 12 μ, and the cells vary from 20 to 50 μ in length. Each cell contains several small nuclei. On most culture media the mycelium becomes yellow after a few days, due to the production of a pigment. The pigment is soluble in alcohol and alkalies, and insoluble in acids. In alkaline solutions the pigment becomes purple. It is a chemical compound belonging to the group known as aurines.

A character of this species which distinguishes it from all other related fungi is the presence in the diseased bark and in the cambium of fan-like mats of mycelium (Plate XXXIX). Each mat consists of a number of bundles of parallel hyphæ diverging from a single point like the rays of a fan. They are flat because they have to squeeze between the bast-fiber zones. The edges of the fans are fairly regular and are surrounded by a darker gelatinous band of disintegrating host cells. The fans vary in length from a millimeter to two or three centimeters. The young ones on the advancing edge are pure white, but the older ones become light yellow or buff. The hyphæ composing each ray branch only sparsely, and are more uniform in diameter than those in agar culture. They do not anastomose in any way.

Pathogenicity

On Castanea dentata

Murrill (1906 a) proved that *Endothia parasitica* is pathogenic on the American chestnut. This fact is so easy of demonstration that it has never been questioned since that time. Constant association of the fungus with the canker is readily noticed by all investigators. The fungus has been isolated and grown in pure cultures by a number of pathologists. Inoculations from pure cultures and the production of typical cankers are reported first by Murrill and later by various others. The writers of this bulletin have separately carried out Koch's four rules of proof many times, in New York and Pennsylvania.

On other species of Castanea

Metcalf (1908 a), after having failed to produce the disease by inoculations on Japanese chestnuts in the field, states that this variety is immune.

Murrill (1908 a), however, found cankers on Japanese chestnuts. Clinton (1913:375), after having failed to produce the disease on a Japanese tree inoculated in sixteen different places, states that this variety shows more or less immunity. Metcalf (1914:16), in his latest publication, says. "The Japanese chestnut is highly resistant, and certain strains apparently immune. . . . . . At present we do not know exactly what the Japanese chestnut is; most of the trees that pass under this name in the American market appear to be hybrids with the American or other varieties."

Pantanelli (1911) and Metcalf (1912 b) proved by inoculation that the European chestnuts are not immune.

Murrill (1908 a) found the chinquapin, *Castanea pumila*, attacked.

Morris (Clinton 1913:376) reports that the Chinese and northern Japanese and Corean varieties show decided resistance. Meyer, as stated by Fairchild (1913), finds that the chestnut trees in northern China are not immune, but that they suffer less than do the trees in America. Observations by Morris (1914) and Van Fleet (1914) on the relative immunity of hybrids have been noted above, under the discussion of hosts.

In general, no species nor variety of the genus Castanea has been proved to be immune, but some of the oriental varieties show a certain degree of resistance.

On trees outside the genus Castanea

Fulton (1912:53) reports *Endothia parasitica* on *Quercus alba* and *Q. velutina*, but considers it entirely saprophytic. Clinton (1913:377) adds *Quercus rubra* to the list, but does not believe that the fungus is ever an aggressive parasite on the oaks.

Anderson and Babcock (1913) made cross inoculations, and they discuss this phase in detail. The results of their experiments may be summarized as follows: The fungus was found growing naturally in the woods on *Quercus velutina*, *Q. alba*, *Q. prinus*, *Rhus typhina*, *Acer rubrum*, and *Carya ovata*. Only on the white oak did it seem to have established parasitic relations. (See also Rankin, 1914.) It was isolated from all of these except *Q. prinus*, and when grown in pure culture it appeared identical with the strains from the chestnut. The strains from *Quercus velutina*, *Q. alba*, *Rhus typhina*, and *Acer rubrum* produced typical cankers when inoculated back on chestnuts. The others were undoubtedly *Endothia parasitica*, judging from cultural characters, although no cross inoculations were made. Inoculations with the fungus isolated from chestnut were made on *Quercus prinus*, *Q. velutina*, *Q. alba*, *Q. coccinea*, *Rhus typhina*, *Acer rubrum*, *Liriodendron tulipifera*, and *Carya ovata*. Two trees of Rhus were girdled and killed by the growth of the fungus. It grew and produced spore horns also, on the wounded tissue at the point of inoculation, on all the others except the maple and the tulip. On *Quercus alba* and *Q. prinus* the cankers continued to spread for several weeks, and fan-shaped mats of mycelium were found under the bark. From the fact that such mats are never found, even on the chestnut, except where the parasite is invading living tissue, it was decided that in these cases, at least, it had established parasitic relations. None of these trees were killed. The fungus was reisolated from all these hosts, and in culture proved to be the same as that isolated from chestnuts.

It may safely be said that at present the canker fungus is not a serious menace to any other forest tree except the chestnut.

Life history

Germination of pycnospores

The pycnospores cannot be made to germinate in pure water. The writers have found the most satisfactory medium for this purpose to be a decoction made by boiling chestnut bark. The spores will germinate also on sterilized twigs of a large number of trees, on various nutrient media, and even on humus alone; but these media are not favorable for observation of the process under the microscope.

The time required for germination varies with the temperature. Fulton (1912:52) states that he found conidia germinated best at a temperature of 60° F., and distinctly less rapidly at temperatures 10° below or above that point. The writers obtained the most rapid germination at 89° F., the shortest time for the appearance of germ tubes being twelve hours. At temperatures ranging from 60° to 75° F., germination occurs in eighteen to thirty-six hours; at lower temperatures the process often requires four or five days. From this it appears that the warm periods of summer are the most favorable for infection by pycnospores. All attempts to produce the disease by inoculating with pycnospores in winter have failed.

The process of germination begins with an enormous swelling of the spores. Spores averaging 1.28 by 3.56 μ before germination, were found, at the end of eighteen hours in chestnut-bark decoction, to average 6.86 by 10.53 μ, the largest observed being 9.05 by 14.48 μ — representing an increase in volume of over one hundred times that of the original spore. A germ tube grows out from one end, and usually this is followed later by a second one from the opposite end. The rate of growth and the manner of septation and branching of the germ tube are best understood by reference to the series of camera lucida drawings of a single spore at short intervals, reproduced in Fig. 90. The swelling of the spores is due, not merely to a mechanical imbibition of water, but also to a process of growth.

Pycnospores stained just before the germ tube is started show that the increase in size is accompanied by active nuclear division, two to six

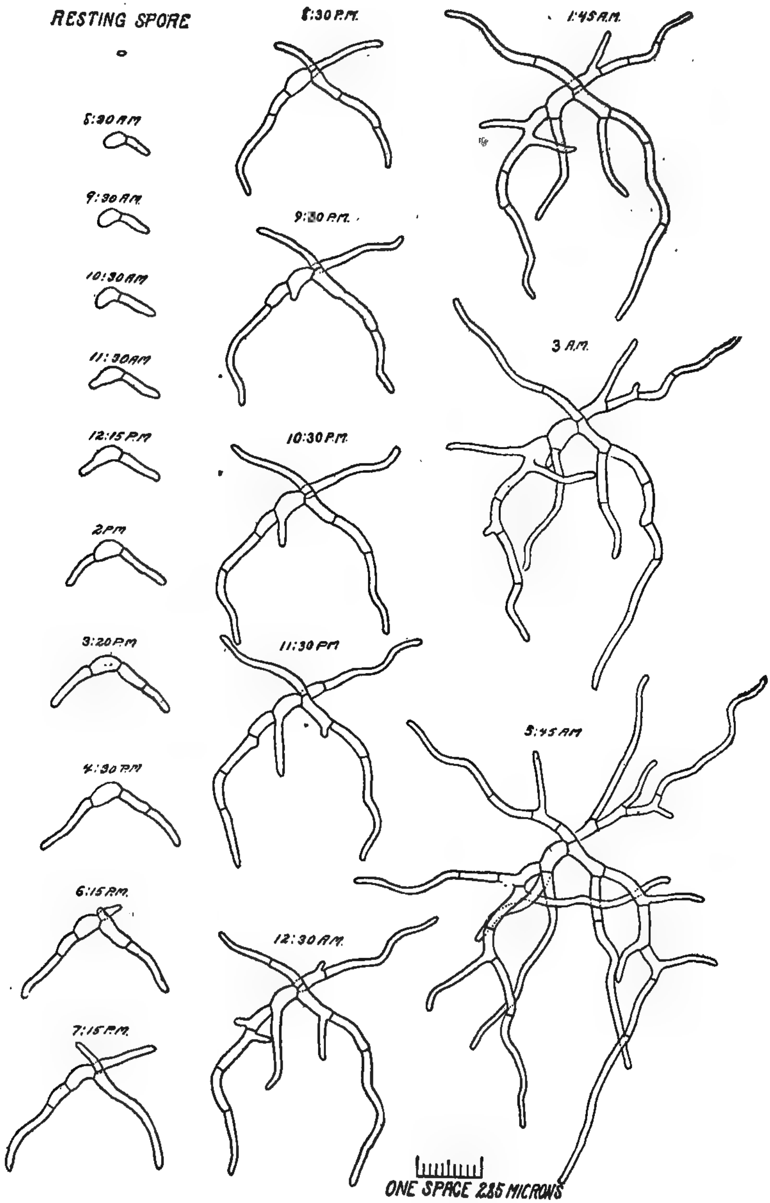


FIG. 90.— *Successive stages in the germination of a pycnospore*

nuclei then being present. The nuclei pass out into the germ tubes almost as soon as they start. The wall, also, has increased in thickness until it almost equals the diameter of the resting spore.

Germination of ascospores

Unlike the pycnospores, the ascospores germinate readily in pure water. They do not require a period of rest, but germinate directly after maturity if placed under proper conditions. The time required for the process to begin after the ascospores are placed in water is much shorter than for pycnospores, being about six to twelve hours at room temperature. In regard to the effect of temperature on germination, Fulton (1912:52) says: "Ascospores germinate best at a temperature of about 70° F., but a good percentage of germination occurs at 85° and 45° F. Even at 38° F. the germination of ascospores was 25 per cent in the first twenty-four hours and reached 70 per cent in three days."

Like the pycnospores, the ascospores swell before germination, but not to so great an extent. The first germ tube usually appears at the end — only occasionally being lateral; the next one comes from the other cell; and these are followed by a second one from each of the cells, making a total of four germ tubes. Their order of appearance, size, and manner of septation and branching are best understood by reference to the drawings of successive stages in Fig. 91. The germ tubes from the ascospores grow much more vigorously than do those from the pycnospores. By sowing ascospores on chestnut-bark agar, mature pycnidia have been produced in five days.

Vitality and longevity of the spores

Pycnospores.— Reasoning from analogy with what is known of the vegetative spores of many other fungi, one would not expect the pycnospores to survive winter conditions; but the fact is quite the contrary. During each month of the winter of 1912–1913, spores were collected in the woods from spore horns, from pycnidia imbedded in the stromata, and from superficial pycnidia on wood, and in every test more than fifty per cent of the spores germinated. It appears, then, that winter conditions have very little effect on the viability of the pycnospores. Heald and Gardner (1913 a) also find that pycnospores can be subjected to freezing temperatures for considerable periods without losing their viability.

The longevity of the conidia varies greatly with the way in which they are kept. Spore horns collected and kept dry in the laboratory and tested each month for germination showed very little diminution in the percentage of viable spores at the end of one year. On the other hand, when the spore horns were dissolved in water and the water was allowed to evaporate, leaving the spores in a separated condition on the slide, they did not retain their viability longer than a month. The difference

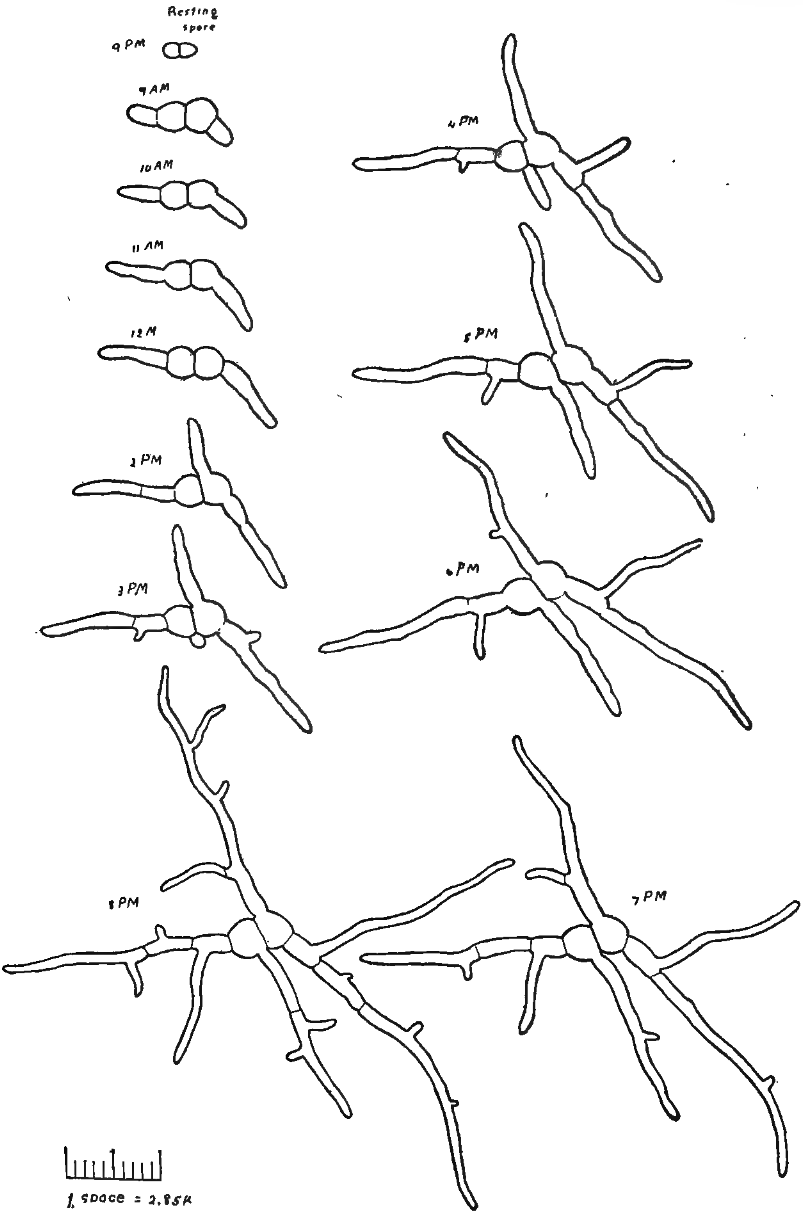


FIG. 91.— *Successive stages in the germination of an ascospore*

has not been explained satisfactorily. It would suggest that possibly the gelatinous substance which binds the spores together in the tendrils may serve also as a protective covering. Gardner (1914), however, finds that when washed down into the soil at the base of the tree the spores retain their viability in every case, in large numbers, until the next rain. Even when such soil is taken into the laboratory and kept dry, he has found the spores still alive at the end of one hundred and nineteen days.

Ascospores.— These were also collected and tested during each month of the winter, but apparently winter conditions had no effect on their viability. Their longevity also seems to vary with the amount of aggregation and exposure. In one series of experiments, ascospores ejected from perithecia were caught on slides and stored in a dry place. Tests showed that the percentage of viable spores decreased each month, until, at the end of five months and six days, none of the spores could be made to germinate. In Bulletin 9 of the Pennsylvania Chestnut Tree Blight Commission, however, it is stated that when the ascospores are washed and then dried they are very sensitive to desiccation, and that " drying alone has been found to kill as many as ninety-four per cent in certain tests." In another series of experiments made by the writers of this bulletin, bark containing stromata with mature perithecia was stored in a dry place and germination tests were made from spores taken from these perithecia each month. At the end of one year very little diminution in the percentage of germination could be seen. In another series of experiments, a large percentage of the ascospores similarly stored germinated after eighteen months, while ascospores from material kept for thirty-one months produced only primary and secondary buds and no germ tubes nor mycelium.

Inoculation and infection

The inoculum.— The disease may be produced on healthy trees by introducing into the bark (1) pieces of diseased bark or wood from other trees, (2) bits of agar or other culture media containing the mycelium in pure culture, (3) pycnospores, either as dry spore horns or suspended in water, (4) ascospores suspended in water or dry. The writers have used all of these in producing hundreds of cankers. The highest percentage of infection was obtained from the first, the next highest from the second; very little difference was noticed in the last two, which have been used more extensively and which best imitate the process as it occurs in nature.

Necessity of a wound.— Murrill (1906 a) failed to secure infection as long as " the thin brown layer of cortex remained intact," and was therefore of the opinion that wounds are necessary; but he also suggested the possibility of lenticels being channels of entrance. Metcalf and Collins (1910) state that " the parasite can enter without visible breaks in the bark, but wounds form the usual means of entrance." Anderson and Babcock (1913) were unable to produce the disease by inoculating with spores without making wounds.

At Napanoch, New York, glass rings were affixed to healthy, smooth bark, which was then sprayed with a suspension of ascospores. The rings were then closed in order to secure moisture conditions favorable for germination. The purpose of the experiment was to see whether infection could take place through lenticels. Forty-nine inoculations made in this way gave negative results. In another set of experiments the rings were placed over natural cracks — which are abundant on heavy-bark trees in spring and early summer, due to the rapid growth of the trees — and these were inoculated as above. The fourteen inoculations made in this way gave negative results. In a supplementary set of experiments, ascospores were sprayed on one hundred and ninety of these cracks and were not protected in any way. All but four gave negative results. In still another set, twenty pieces of bark containing perithecia were placed so that the ascospores would be ejected during rains into these natural cracks. No infection resulted.

As is indicated later under another head, the fungus appears to be incapable of effecting any change in the cork tissue. It should be kept in mind, also, that even when the bark appears sound it may contain small punctures or abrasions which could easily escape notice; and that, unless the point of inoculation is well protected, wounds may be produced subsequent to inoculation which are not taken into account by the experimenter. It is evident, then, that at most the cases in which the fungus enters without an abrasion must be so rare as to be negligible.

Agents that produce the wounds.— When the disease was first brought to notice, Murrill (1906 a:151–152) suggested a number of agents that might be responsible for the wounds that give entrance to the parasite — such as lumbermen, nut-gatherers, winter injury, the green fly, the twig-borer, squirrels, birds, insects, mice, moles, and rabbits. Later (1906 b) he suggests dead twigs as a channel of entrance, since he often finds these at the center of young cankers.

Metcalf and Collins (1911:10) believe that insects are responsible for most of the wounds: "When the spores have once been carried to a healthy tree, they may develop in any sort of hole in the bark which is reasonably moist. These may be wounds or mechanical injuries, but by far the most common place of infection is a tunnel made by a borer. . . . In many parts of the country where the disease is prevalent there is very direct evidence that bark borers, and particularly the two-lined chestnut borer (*Agrilus bilineatus*), are directly associated in this way with ninety per cent or more of all cases of this disease." Ruggles (1913) points out that Metcalf and Collins probably had in mind the tunnels produced by the bast-miner, an undetermined species.

Anderson and Babcock (1913) and Rankin (1914) have called attention to the fallacy of basing conclusions as to origin on the wounds found on a canker, since these are quite as likely to have followed as to have preceded the entrance of the parasite. These experimenters made a large number of inoculations in various kinds of wounds, imitating the wounds that are found naturally on the trees. Their results are given in Tables 1 and 2:

TABLE 1. COMPARATIVE VALUE OF DIFFERENT KINDS OF WOUNDS FOR INFECTION. CHARTER OAK, PENNSYLVANIA

Character of wound	Inoculum	Number of inoculations	Percentage successful
Longitudinal slit	Diseased bark	568	93.6
Longitudinal slit	Mycelium from culture	454	89.2
Diagonal slit	Mycelium from culture	25	96.0
Diagonal slit	Dry spore horns	16	93.7
V-shaped cuts	Conidia in water	97	93.8
V-shaped cuts	Ascospores in water	88	94.3
V-shaped cuts	Ascospores shot in dry	1,228	82.5
Artificial borer holes	Mycelium from culture	68	54.4
Natural insect holes	Mycelium from culture	18	0.0
Natural insect holes	Conidia in water	23	0.0
Natural insect holes	Ascospores in water	22	0.0
Peeling down bark	Mycelium from culture	25	88.0
Stab with knife	Ascospores in water	347	36.9
Stab with knife	Conidia in water	81	86.8
Stab with knife	Dry spore horns	96	79.1
Scraping off outer cork layer	Mycelium from culture	25	0.0
Cut stubs	Mycelium from culture	22	81.8
Broken branches	Mycelium from culture	45	71.9
Natural cracks	Mycelium from culture	25	0.0
Gimlet holes	Ascospores in water	135	52.6
Hypodermic needle	Ascospores in water	54	75.9

TABLE 2. RESULTS OF INOCULATIONS MADE IN WOUNDS FROM MAY 1 TO SEPTEMBER 1, 1913, AT NAPANOCH, NEW YORK

Method	Inoculum	Number made	Number infected	Percentage of infection	Average percentage of infection
Slits in bark	Ascospores in water	89	88	99	92
	Conidia in water	116	95	82	
	Mycelium from culture	61	61	100	
	Diseased bark	93	93	100	
	Conidia dry	10	10	100	
	Pycnidia from wood	11	4	36	
Injections	Ascospores	107	74	69	74
	Conidia	56	46	82	
Saw wounds	Diseased bark	50	26	52	52

As to the nature of the wound necessary for infection, they conclude that any kind of wound in the bark deeper that the outer green cortex may furnish an entrance.

The fact that a large proportion of incipient cankers occur about dead twigs, or small branches, has suggested that the pathogen gains entrance to the living tissue through the dead tissue of such branches. But it is usually impossible to tell whether the dying of the twig preceded the entrance of the fungus, or whether the twig died as a result of the canker having been formed about it. Other reasons could be assigned as explaining the above condition. The rough bark around the insertion of small branches remains moist longer than does smooth bark, and thus furnishes more favorable conditions for spore germination. Insect injuries are more numerous at such places and also the bark often becomes cracked above the insertion, thus offering more opportunities of entrance to the parasite.

Age of tree and parts of host affected.—After the first year the age and the size of the tree make no difference in its susceptibility. Not only may cankers be found in the woods just as often on trees an inch in diameter as on those two feet in diameter, but also inoculations on large trees produce the disease just as surely as do those on small trees. Also, there is no difference in susceptibility between the trunks and the branches of any size. Inoculations produce the disease equally well on all.

All inoculations of green leaves have failed. Murrill (1906 a) was unable to produce the disease on green shoots of the first year. Metcalf and Collins also state that green twigs are not affected. Metcalf (1913:365) states: "Late in the season it will readily attack wood of the current year." Anderson and Babcock (1913), however, successfully inoculated first-year green shoots both with ascospores and by inserting diseased bark; Rankin (1914) also produced the disease on first-year shoots by inoculation with ascospores at Napanoch, New York. Yet it is readily apparent that green shoots are less often attacked than are older ones; also the percentage of infection is higher during the latter part of the growing season than during the early summer. All inoculations made by the writers on green burs have failed.

Metcalf and Collins (1910) state that roots are rarely, if ever, attacked, but the pustules of the fungus are commonly found on exposed roots; Anderson and Babcock (1913) were able to grow the fungus on subterranean roots, also, but no typical cankers were produced. It is certain that the roots are not killed by the fungus, because they seem not to lose their power of producing new shoots even when the part of the tree above ground is entirely killed by the parasite.

The orientation of lesions on the trees shows no relation to the points of the compass. Data compiled for nearly a thousand trees taken at random in New York and Pennsylvania showed no preponderance of cankers on any particular side of the trees. (Anderson and Babcock [1913] and Rankin [1914]).

Effect of season.— Beginning with June, 1912, inoculations were made at Charter Oak, Pennsylvania, in every month of the year. Twenty-five or more inoculations were made each time, with each of the following inocula: (1) ascospores, (2) pycnospores, (3) agar containing mycelium, (4) diseased bark. The spores were inoculated by making a suspension of them in water and inserting a few drops into a stab made with a knife in the bark; the other inocula were inserted into a small slit in the bark. In Table 3 are shown the results for the year, the plus sign meaning that infection resulted and the minus sign meaning that it failed. Where the results are marked positive, over fifty per cent of

TABLE 3. RESULTS OF MONTHLY INOCULATIONS

Inoculum	June	July	August	September	October	November	December	January	February	March	April	May
Ascospores	+	+	+	+	—	—	—	—	—	—	+	+
Pycnospores	+	+	+	+	—	—	—	—	—	—	+	+
Mycelium in culture	+	+	+	+	—	—	—	+	—	—	+	+
Diseased bark	+	+	+	+	+	+	+	+	+	+	+	+

the inoculations produced cankers in every case except in the January inoculations with mycelium, of which only a very small percentage were successful. A similar set of experiments at Napanoch, New York, gave like results. The results indicate that infection from spores does not occur during the six months from October to March, inclusive. Apparently, then, even if spores should gain access to wounds during the winter, infection would not necessarily result. Very little difference between the percentage of cankers produced was noticed during the remaining months of the year.

Development of the canker

If the inoculum is diseased bark or agar containing mycelium, the canker usually begins to show externally in about two weeks after inoculation in summer. If either kind of spores are used, the canker does not show until after three to five weeks. A longer time is required in the cool months of spring and autumn. The canker appears first as a darker area about the point of inoculation. In dry periods this affected part soon sinks and at the same time the bark takes on a reddish color. In this case the limits of the canker are easily distinguished on the surface; in rainy seasons the outline at first is not sharp, but if the canker is cut into with a knife a sharp line of demarcation will be found between the brown, diseased bark and the white, healthy, inner bark.

When the spores have germinated in a wound, the germ tube thrives on the injured and dead cells until it has produced a mass of mycelium. Then, gradually accumulating strength as it increases, the mycelium *en masse* pushes out into the living tissue of the bark. Single threads do not seem to possess the power of penetrating alone among the living cells, but the invasion is accomplished by the force of mass action. Starting from a narrow point, the hyphæ grow out in ray-like bundles, completely destroying parenchyma and collenchyma and cambium cells as they go. The rôle of toxins or enzymes in this process has not been investigated. All the rays starting from a single point are contiguous, forming the fan-like mats previously mentioned.

Rate of growth of mycelium.— The rate of growth of mycelium under natural conditions in the tree can be roughly measured by the increase in size of the cankers. The growth varies with the temperature, being the most rapid during the summer months; but the mycelium does not always remain dormant during the winter, as will be shown. For twelve consecutive months at Charter Oak, Pennsylvania, cankers were outlined with a painted white line at the end of each month and the average rate of growth was computed. A second experiment of a similar nature was conducted at Napanoch, New York. The data on these two experiments are given in Tables 4 and 5. These tables give only the rate of growth

TABLE 4. MONTHLY RATE OF GROWTH IN DIAMETER OF CANKERS AT CHARTER OAK, PENNSYLVANIA

Month	Number of cankers	Average growth per month (in centimeters)
1912		
June	31	1.88
July	200	2.78
August	186	2.83
September	140	1.85
October	53	1.92
November	27	0.00
December	27	——
1913		
January	89	0.51
February	89	0.00
March	84	0.7
April	21	1.1
May	41	2.4

TABLE 5. AVERAGE RATE OF GROWTH OF CANKERS DURING SUMMER MONTHS, AT NAPANOCH, NEW YORK

Date when inoculations were made	Number of inoculations	Growth by periods of four weeks (in centimeters)				
		May	June	July	August	September
May 2	60	1.35	1.75	3.0	2.4	2.3
June 1	48	......	2.5	1.72	3.0	....
June 11	16	......	......	2.0	1.9	....
July 3	41	......	......	1.75	......	....
July 11	105	......	......	2.0	1.7	1.7
August 1	11	......	......	......	2.1	....
Average	....	1.35	2.08	2.1	2.2	1.9

of the canker around the tree, the increase in length being considered not so important. It appears that the mycelium continues to grow even during mild periods of the winter, such as were frequent during January of 1913.

As a check on the above data, agar plate cultures were kept out during the winter and growth was recorded during each warm period. In this connection, Shear and Stevens (1913 a:9) note that the minimum temperature for growth of the fungus in culture is 9° C. (48° F.), which temperature was exceeded on ten different days during January.

Even the most rapid growth, as recorded above for the summer months, is less than one millimeter a day. But on artificial media a growth of three millimeters a day is not unusual. Mycelium also spreads at a much more rapid rate in the dying bark after a tree is cut.

Vitality of mycelium.— The mycelium does not seem to be injured in the least by freezing. It remains alive in all parts of the canker during the winter. Cultures were kept frozen for a month at a time, and resumed growth naturally on being brought back into the laboratory. The mycelium is not readily killed by desiccation. Bark removed from a canker and kept perfectly dry in the laboratory for ten months yielded quite as successful isolations as did fresh bark. Chips of diseased bark left on the ground in the woods were found to contain living mycelium one year later. This remarkable vitality of the mycelium is one of the factors that make the disease difficult to control.

Development of pycnidium.— The pycnidial stage usually appears on the cankers in three to six weeks after inoculation. The very earliest stages in the development of the pycnidium are not readily found and studied in the bark, but when the fungus is grown in Van Tieghem cells in drops of agar the process can be easily observed under the microscope. At room temperature it begins in less than a week, in the following manner:

At a certain point on a hypha, short cells are formed by the laying down of new septa. These cells increase in diameter and in amount of contents and each one sends out short septate branches (Fig. 92, a and b),

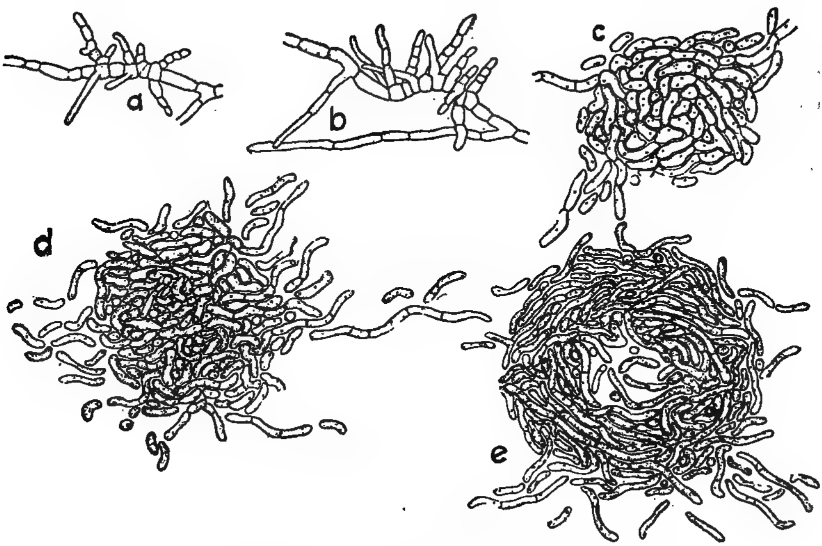


FIG. 92.— *Development of pycnidium*

a and b, Very earliest stages observed in Van Tieghem cell cultures
c and d, Cross sections of pycnidium on agar before the beginning of the cavity
e, Cross section when the cavity first becomes apparent

the individual cells of which in turn put out other short branches, until the whole structure has the appearance of a witches' broom. Other hyphæ, and more distant branches of the same hypha, grow toward it and mingle with its branches. This tangle of hyphæ soon becomes so dense that a surface view does not show what is occurring on the inside, and later stages have to be studied from serial sections after imbedding, sectioning, and staining. Cross sections at this time and for some days later show that the mass is merely an increasing solid ball of hyphæ, which are all alike and densely interwoven but not anastomosed in any way (Fig. 92, c and d). A little later the hyphæ at the center appear looser (Fig. 92, e) and those branches that extend into this loose central area begin to cut off regular cells (pycnospores) from their apices. More branches (conidiophores) now grow in and cut off spores from their apices, until the wall, which constantly recedes as the pycnidium becomes larger, is completely lined with the brush-like hymenium (Fig. 86, page 559) and the cavity is packed with spores. Meanwhile an ostiole is formed by the loosening of the hyphæ at the apex, and the spores are forced out through it in a gelatinous mass. The cells of the loose wall seem never to divide meristematically, and the wall in this type never appears pseudoparenchymatous.

The first outward indication of the formation of pycnidia on the young canker is the appearance of numerous small, raised, smooth blisters just back of the advancing edge of the lesion (Plate XXXVIII, Fig. 1). They show no relation to the lenticels. Under each blister is the beginning of a single pycnidium. At this stage the pycnidia are more or less globose cushions with a moist, gelatinous appearance; about half of the pycnidium is imbedded in the disintegrating collenchyma tissue, the other half projects upward and raises the cork layer to form the pimple. There is no stroma at this time, but each pycnidium is early surrounded with a fringe of loose mycelium which is the forerunner of a stroma. A cross section of this hygrophanous cushion shows it to be a closely wound ball of hyphæ corresponding to the stage represented in Fig. 92, c and d. It increases in size and develops into a mature pycnidium just as the process on agar was described above, pushing up the cork layer and finally causing it to rupture at the tip, from which point the spores are forced out. Meanwhile the stroma is forming about the pycnidium. So far as observed, the stroma never precedes, but always follows, the early stages in the development of the pycnidium. With the active increase in the amount of stromatic tissue which is constantly added from below, the pycnidia are pushed out in the top of the stroma through the cork layer. Meanwhile they continue to increase in size and become irregular in shape. (Fig. 84, page 558, and Plate XL, Fig. 1). Often the entire stroma is found honeycombed with numerous communicating lobulated chambers.

Time of production of pycnospores.— In Pennsylvania during the seasons of 1912 and 1913 the spore horns first began to appear on the cankers about the middle of April; after that they could be found at any time during the summer, being especially abundant after periods of rain. During the season of 1912, on cankers produced by inoculation in the spring, the tendrils were abundant after each rain period until the latter part of the summer, when the perithecial stage began to develop; after that, few spore horns were found on the cankers. Heald and Gardner (1913 a) state that pycnospores are produced in enormous numbers during the winter months. Fresh spore horns are not seen during the winter, but this may be due to the fact that they are produced at such a slow rate that they are washed away before their size makes them noticeable.

Development of perithecium.— The beginning of the perithecial stage is accompanied by a marked increase in the size of the stroma, which now pushes off more of the cork layer and not only fills up the enlarged rent but also grows out over the torn edges so that they are included in it (Fig. 85, page 558). The stroma takes on an erumpent, superficial appearance (Plate XXXVII). This change has been observed within eight weeks after inoculation; on trees inoculated in June the stromata have been found in August.

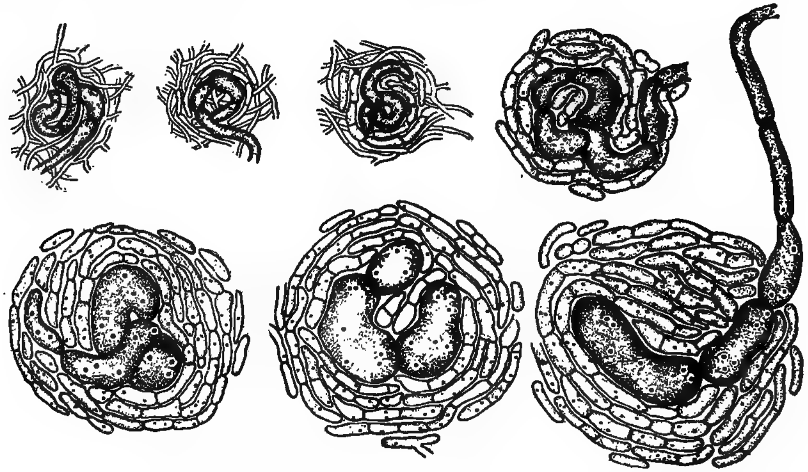


FIG. 93.— *Stages in the development of the carpogonium. The larger, heavily shaded cells at the center are the ascogonial cells, with the cells of the enveloping hyphæ about them. The last figure shows the continuation of the ascogonium into the trichogyne. All figures are drawn to the same scale*

The primordia — beginnings of the perithecia — arise in the base of the stroma or even among the outermost cells of the host. Each primordium consists of two to five large, prominent cells arranged in a circle or a spiral (Fig. 93), closely invested by a sheath of large hyphæ. The central prominent cells form the ascogonium, and the investing hyphæ will here be called the envelope. The ascogonium, which is an enlarged single hypha, is continued up to the surface of the stroma as a prominent thread, the trichogyne. There may be as many as a hundred primordia in a single stroma, but only about one fourth of them ever reach maturity; the others degenerate at various stages of development.

The ascogonial cells are elongated-oval, slightly curved so as to fit the segment of the spiral, deeply constricted at the septa, and only loosely connected. They are filled with dense protoplasm and contain more numerous and more prominent nuclei than do the cells of the envelope. The cells of the trichogyne resemble those of the ascogonium in every way except that they are narrower and are not curved nor so loosely connected. The trichogyne is apparently a useless organ in the formation of the perithecium. During the development of the latter it degenerates and disappears.

The highest stage in the development of the ascogonium is shown in Fig. 93. From this time on it begins to degenerate. The dense protoplasmic content gradually becomes thinner, and later there are only ragged bridles of protoplasm across the lumen and irregular masses around the walls (Fig. 94) or else the entire contents draw up into a misshapen mass. But the behavior of the enveloping cells is quite the contrary. Their contents now become more dense, and their nuclei more prominent and apparently more numerous. Up to this time the individual hyphæ can be traced and open spaces are apparent between them; but now they have increased both in size and in number and have filled up the intervening spaces. They appear as a pseudo-parenchymatous tissue instead of as a coil of hyphæ.

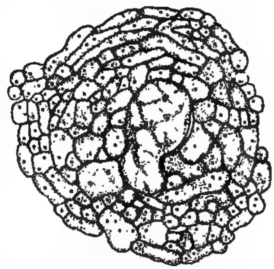


FIG. 94.— *Cross section of the developing perithecium just as the ascogonial cells (one large one shown at the center) are beginning to degenerate and the enveloping hyphæ are taking on a pseudoparenchymatous appearance*

Before degeneration the ascogonia probably give rise to ascogenous hyphæ, but these are very quickly cut off by septa and are indistinguishable among the enveloping hyphæ. The ascogonial cells are soon crowded out of shape by the growth of the enveloping cells, and in later stages they appear only as misshapen masses wedged between the other cells. The whole primordium now increases rapidly in size and takes on the appearance shown in Fig. 95. The beginning of the neck is shown at the top of the figure. Next, the wall is differentiated from the large-celled core. A cavity is formed by the breaking-down of some of the core cells, but is soon almost filled by paraphyses which arise from the bottom of the cavity (Fig. 88, a, page 561). The young asci grow up between the paraphyses, arising from a system of hyphæ which are presumably the continuation of the branches of the ascogonial cells. Eight bicellular spores are formed in each of the clavate asci. The hyphæ that initiated the formation of the neck now push toward the surface, leaving a canal through the center (Fig. 88, b). Branches of these hyphæ extend into the canal to form the periphyses (Fig. 88, c). Meanwhile the cavity has become completely filled with maturing asci and the perithecium is now ready to discharge its spores.

Time of development of perithecia.— On cankers produced by inoculation during spring and summer, mature perithecia are developed in early autumn. It is evident, however, that this is not the only season at which they may be produced, because there is no time of the year at which they cannot be found in abundance, ready to eject spores if the proper conditions of moisture and temperature are supplied.

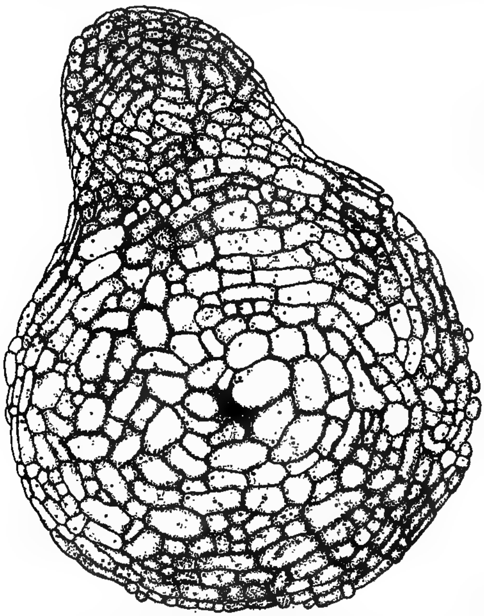


FIG. 95.— *Cross section of the young perithecium before the differentiation of the wall and the core cells, showing at the center the shriveled remains of an ascogonial cell and at the top the beginning of the neck*

Ejection of ascospores

One of the writers of this bulletin (Rankin, 1912 a) discovered that during rain periods the ascospores are ejected with some force into the air from the ostioles of the perithecia. The asci, which usually fill the perithecium, are pushed up through the neck when abundant free water is added to the stroma. This expulsion of the asci is largely due to the swelling pressure of the asci. A dry ascus with its spores (Fig. 89, b, page 562) occupies only about one half the space occupied by an ascus after water is added (Fig. 89, c and d).

Prepared sections of perithecia fixed during the process of ejection of spores show that the spores remain in the asci almost to the tip of the neck. Since the asci themselves are never ejected into the air, it follows that they must burst and liberate the spores when they arrive at the surface of the film of water. The ejection may be observed with a hand lens. The only visible phenomenon is the sudden and regular breaking of the film over the ostiole. This gives for the moment the impression of a point of light. The entire contents of the ascus are ejected at once into the air.

Rankin (1914) has drawn the following conclusions as to the process of the actual ejection of the spores from the asci: The imbibition of water results in the asci being forced out through the ostiole, where, if a film of water is present, the walls begin to gelatinize. Undoubtedly, as more and more asci are pushed out, some arise in the water to the surface and may even project above the surface, due to the disturbance. It might be expected, then, that the increased pressure on the ascus wall due to the swelling of the contents, at a time when the wall is gelatinizing, will result in the sudden rupture of the wall when the ascus arises to or above the surface of the water. Since the lower part of the ascus wall is the thinner and gelatinizes first, freeing the spores, and since no change suggesting pore or other type of apical dehiscence has been found, it is presumed that what proves to be a successful method of ejection is due merely to a combination of physical factors, not to any structural arrangements.

Saprophytic growth

Endothia parasitica may live indefinitely as a saprophyte, In this condition it is not so restricted in its feeding habits as is the case otherwise. Where it is found growing on trees outside the genus Castanea, it usually exists there only as a saprophyte. It may be grown in pure culture on sterilized twigs of almost any of the common forest trees. It has also been grown on a wide range of culture media. Anderson and Babcock (1913) report cases in which trees with scattered cankers were cut and were left lying on the ground during the summer; in the autumn the fungus was found to cover the entire trunk. Also, they found that the fungus spreads rapidly in fire-killed bark. When it grows in dead bark, no canker-like area is formed, and also the mycelium does not progress by the production of fan-like mats but by single threads. The fungus spreads through dead bark many times more rapidly than through living tissue. Anderson and Babcock made successful inoculations on dead bark with ascospores and with mycelium, and on dead leaves and dead burs with ascospores. The fungus grew and produced pycnidia on all of these. Collins (1913) also found the fungus growing saprophytically on burs. Apparently its growth is checked only by failure of the moisture supply.

In order to determine how long the mycelium lives on logs after they have been cut, both with the bark on and with it removed, and also on the stumps from which the logs are cut, and whether the fruiting stages are produced under these conditions, the following experiment was performed: Thirty-two trees, some entirely dead and some still living, were felled, cut into seven-foot logs, and allowed to remain lying on the ground. Some were peeled, others were left with the bark attached. Also some of the stumps were peeled. Isolations were made from the interior of the bark and the wood — care being taken to avoid getting any spores of the fungus in the cultures — during each month for one year. In Table 6 are shown the results of the last set of isolations, at the end of one year; the table shows how well the fungus may maintain itself as a saprophyte. Pycnidia were formed in countless numbers on the peeled logs and on the cut ends of the stumps and the logs. Stromata and perithecia developed on some of the unpeeled logs, but none developed on the peeled logs. The writers have on several occasions isolated the fungus from woodpiles, rustic woodwork, and the like, where the trees were said to have been cut several years previously.

TABLE 6. RESULTS OF ISOLATIONS FROM LOGS AND STUMPS ONE YEAR AFTER TREES WERE CUT

Trees dead when cut	Number containing live mycelium
15 logs, peeled	11 logs
58 logs, not peeled	46 logs
4 stumps, peeled	4 stumps
13 stumps, not peeled	11 stumps
Trees alive when cut	
3 logs, peeled	1 log
38 logs, not peeled	32 logs
1 stump, peeled	1 stump
9 stumps, not peeled	8 stumps

Where the moisture conditions are favorable, the fungus is often found growing luxuriantly in the bottom of piles of chips where diseased trees have been cut. It has also been proved, by inoculation with conidia, that the fungus will grow and produce pycnidia even on humus such as is found about the base of the trees.

Dissemination

That this fungus spreads with astonishing rapidity is a matter of common observation. Not only does it spread quickly from one tree to those standing close about it, but it is remarkable for its long jumps across country. It suddenly appears in a neighborhood far ahead of the main line of advance, without there being another diseased tree for a distance of many miles. Hundreds of these isolated spot infections have come to notice and have given rise to much speculation as to their origin. After the disease has once appeared in a locality it is usually a matter of only a few years until the neighborhood for miles around is thoroughly infested. What agents are responsible for carrying the causal organism from one tree to another, and thus causing this rapid spread? Many answers have been suggested, but unfortunately most of them have been mere conjectures not based on experimental data.

Most of the early writers confined their attention to the pycnospores, and it has only been within the last few years that attention has been called to the fact that the ascospores also are instrumental in the spread of the fungus. Murrill (1906 a) suggests the agency of wind, squirrels, birds, insects, mice, moles, and rabbits, and later (1906 b) rain—the last only carrying the spores from one part of a tree to other parts. Hodson (1908:5) says, in regard to the dissemination of the pycnospores:

"Wind is probably the principal agency, but the spores are no doubt carried by animals, birds, insects and by shipment of infected material.

"The disease spreads locally through the gradual distribution of the spores from tree to tree, and at a distance chiefly through the shipment of infected material, such as nursery stock, bark, nuts, and other products. There is a possibility that long-distance infection is also effected by means of migratory birds."

Metcalf and Collins (1911:9) state: "As both kinds of spores appear to be sticky, there is no evidence that they are transmitted by wind except where they may be washed down into the dust and so blown about with the dust. The spores are spread easily through short distances by rain; particularly they are washed down from twig infections to the lower parts of the tree. There is strong evidence that the spores are spread extensively by birds, especially woodpeckers, and there is also excellent evidence that they are spread by insects and by various rodents, such as squirrels. The disease is carried bodily for considerable distances in tan bark and unbarked timber derived from diseased trees. One of the most prolific sources of general infection has been the transportation of diseased chestnut nursery stock from infected to uninfected localities."

One of the writers of this bulletin (Rankin, 1912, a and b) called attention to the fact that the ascospores are forcibly ejected into the air, and that these can be caught up by the wind and carried for considerable distances and may well be responsible for a large part of the infection. Fulton (1912:51) reports experiments in which he tried to dislodge spore horns by a strong blast from an electric fan. He found that bits of the spore horns were sometimes broken off and carried for short distances, but were too heavy to be carried for great distances.

Anderson and Babcock (1913) have considered the problem of dissemination more in detail than have the other writers. Unless otherwise mentioned, the matter considered below is taken from their bulletin.

Man

Murrill (1908 a) was the first to call attention to the danger of spreading the disease into new localities on diseased nursery stock. Metcalf and Collins (1909:49) gave especial attention to this phase of the matter, and believe that it is largely responsible for the long-distance jumps of the disease. They state:

"It becomes more and more evident as this disease is studied that diseased nursery stock is the most important factor in its spread to distant points. In that part of the country where it is already well established in the native chestnuts its progress is rapid and sure, but there is no evidence at present that it is able to pass to remote districts, tens or hundreds of miles away, except on diseased nursery stock. Of course it is conceivable that the spores are carried by birds. Such distribution would, however, follow in general the great lines of bird migration north and south and hence would not be an important factor in the western spread, except locally. During the summer of 1908 nearly every chestnut nursery and orchard of importance in the Atlantic States north of North Carolina was visited, and very few were found free from the bark disease. Several cases were observed where the disease had obviously spread from the nursery to adjacent wild trees."

Five prominent cases of spot infections far ahead of the main line of advance in western Pennsylvania were traced to nursery trees or scions shipped there from infested territory.

In order to see whether the fungus could be carried on tools that were first used on diseased trees and then on healthy ones, thirteen cuts were made on healthy trees with an axe after having chopped into diseased logs with this ax. Cankers developed later about twelve of these. One of the writers performed an experiment of a similar nature, in which a saw was first used in sawing diseased wood and then in sawing off healthy branches. Cankers were developed about twenty-seven of the fifty stubs treated in this way. There is no doubt, then, that the disease may be spread by pruning saws, axes, climbers, and other tools used about the trees.

Metcalf (1913) and others have also suggested the possibility of the fungus being carried for long distances by the shipping of ties, poles, tanbark, and the like. The experiments previously described in treating of saprophytic growth show the remarkable ability of the fungus to maintain and propagate itself under saprophytic conditions. The writers of this bulletin also found that perithecia retain their ability to eject spores for at least seven months under perfectly dry conditions. There is no reason why the disease cannot start in a new locality to which affected logs are shipped, if in that locality the logs are placed near growing chestnut trees. It must be admitted, however, that no case of outbreak of the disease in a new locality has ever been traced to the shipment of such material.

Insects

Insects are found in great numbers both in and on chestnut bark, and the possibility that they may crawl over sticky spore horns and carry spores away to deposit them in wounds, and thus start new cankers, has occurred to the majority of writers who have mentioned dissemination. It is reasonable to believe that many infections do occur in this way, but the mere statement of the probability without experimental data is not convincing; and unfortunately such data are meager in the literature.

In order to prove that an insect — or anything else, for that matter — is a direct agent of dissemination, three points must be demonstrated: (1) that the insect is in the habit of visiting cankers and actually carrying away spores on its body; (2) that it deposits these spores in wounds favorable for germination; (3) that infections do result from wounds inoculated in this way. To induce insects to crawl over damp spore horns or active perithecia and then demonstrate the presence of spores on their bodies, is no proof that they are in nature responsible for the spread of the disease. Ruggles (Penn. Chestnut Tree Blight Com., 1914) has shown the fallacy of this argument. After allowing ants and about twenty other species of insects to run over spore horns and active perithecia, he was able to isolate spores of Endothia from all of them. Yet he proved to his own satisfaction that ants are not responsible for infection. The following is from the summary of his work in Bulletin 9 of the Pennsylvania Chestnut Tree Blight Commission: "Two rooms were set off in an insectary. The inner of these two rooms being thoroughly sterilized was called the sterile room, the outer room was called the blighted room. In the latter as much blight material as could be obtained of the kind required was kept and placed on the ant table, where three colonies of ants made their homes. From the table in this room the ants were allowed to run through a glass tube to sterile seedlings in the sterile room. . . . The result of the experiment was that with the exception of a few dried leaves on each tree which were chewed or worked on by the ants, the trees in the sterile room are as healthy as when first placed on the table to be run over by the ants. The indication, therefore, is that ants are not responsible for blight infection."

Studhalter (1914) also reports the presence of spores on the bodies of twenty-four out of seventy-five insects after they had run over cankers or had been taken directly from diseased trees in the field.

Indirectly, insects may be connected with the spread of the disease by making wounds in the bark where spores may gain entrance after having been carried by some other agent. Anderson and Babcock (1913) and Ruggles (Penn. Chestnut Tree Blight Com., 1914) are of the opinion that this is the most serious way in which insects are related to blight dissemination. Ruggles states that in some places in eastern Pennsylvania, 86 to 93.8 per cent of all infections were in wounds produced by the seventeen-year cicada. The bast-miner larvæ, which are present in great numbers on smooth-bark trees, have often been said to be responsible in this way. Ruggles states that fifty per cent of the infections in smooth-bark trees originated in the exit holes of these insects. He also suggests their responsibility for the numerous crotch infections, since they oviposit near crotches. Anderson and Babcock, on the other hand, were unable to produce infection by making inoculations in exit holes of these insects.

The pustules of the fungus are often eaten by some insects, the most common of these being *Leptostylus maculata;* but experiments have proved that the spores, after being eaten, are digested and do not serve to spread the disease. Craighead (1912) reports five different species of insects which he found eating the pustules, but believes that they contribute to the control of the disease rather than to its spread. The United States Bureau of Entomology has made much of these discoveries and has suggested that these beneficial insects may be a large factor in the final control of the disease (Pennsylvania Chestnut Tree Blight Commission, 1914). Ruggles, however, shows that the insect mentioned above, *Leptostylus maculata,* carries enormous numbers of spores on its body, and suggests that it is more injurious as a disseminator of spores than beneficial as a destroyer.

Metcalf and Collins (1911) state that in many parts of the country the two-lined chestnut-borer (*Agrilus bilineatus*) is directly associated with ninety per cent of all cases of the disease. It was to the so-called bast-miner, however, that they referred, rather than to the borer mentioned (Ruggles, 1913).

Davis (Penn. Chestnut Tree Blight Com., 1913:48) attributes to ants seventy-five to ninety per cent of the cases of infection in the locality where he was working. The grounds for the statement are the fact that no summer nor winter spores could be found and yet the disease continued to spread, and also the fact that ants were found carrying mycelial threads of the fungus. The anomalous condition of trees in an affected area not producing any spores, and Davis' proof that the mycelium carried by the ants was really that of *Endothia parasitica* and that it was deposited in wounds favorable for infection, require further explanation.

Rain

Rain dissolves the mucilaginous matrix of the spore horns, and the pycnospores are washed down the trunks where they lodge in wounds and produce cankers. They may also be splashed to other trees that are in close proximity to diseased ones. This accounts for the fact that most trees with cankers above are also diseased about the base. Also, ascospores, which sometimes ooze out instead of being forcibly ejected, may be carried down in this manner. It was proved by a large number of inoculation experiments that either ascospores or pycnospores suspended in water in this manner and introduced into wounds will produce a high percentage of cankers (Tables 1 and 2, page 571).

In another set of experiments, wounds were made beneath cankers on which there were only spore horns. The cankers were sprayed with an atomizer and the water containing the spores was allowed to run down into the wounds. Of twenty-three wounds treated in this way, sixteen developed cankers later. There is no doubt, then, that rain is an important agent in spreading the spores to different parts of the same tree. Rain also plays an important part in bringing about the conditions necessary for the ejection of ascospores.

Birds

It seems reasonable to believe that birds alighting on cankers and picking at them carry spores to other trees and deposit them in wounds where they may germinate and produce cankers. Anderson and Babcock (1913) shot birds during the summer, but no spores could be isolated from them. Heald and Studhalter (1913) tested the washings from thirty-six birds of nine different species, all of which were shot on diseased parts of trees between February and May. Downy woodpeckers, nuthatches, golden-crowned kinglets, sapsuckers, brown creepers, and juncos were found to carry enormous numbers of pycnospores, the smallest number per bird being 5655 and the largest 757,074. No ascospores were found on the birds.

There can be little doubt that birds aid in the dissemination of the fungus.

Wind

Unlike the agents mentioned heretofore, the wind as a disseminator has to do mostly with ascospores. In a number of the earlier contributions to the literature it is stated that the summer spores are blown about by the wind; but this belief was gradually abandoned when it was pointed out that the spore horns are so hard when dry that they cannot be broken even by a strong blast, and when wet they are of a sticky nature and can hardly be detached by the wind. Metcalf (1913:366), however, still believes that under certain conditions they may be carried by the wind, for he says:

"It is conceivable that they may be blown by the wind as far as rain or spray is blown or, mingling with the dust at the foot of the tree, be blown about with the dust."

Experimental data are not cited.

The writers performed experiments in order to determine the conditions necessary for ejection, rate of ejection, spore content of the air, ability of wind-blown spores to produce infection, and the like.

Ascospores are not peculiarly winter spores, but they may be found maturing and ready for ejection at any time of the year. Experiments by Heald and Gardner (1913 a), however, indicate that they are not ejected during the winter. These experimenters found that after the stromata were subjected to low temperatures they did not resume ejection of ascospores again for three or four days after being brought into favorable temperatures, and that the minimum temperature for spore ejection varies from 52° to 60° F. Experiments show that during the summer spores are ejected only during and shortly after rains — in fact, just as long as the bark remains wet. This may be a half hour or it may be more than a day. The same stroma may resume expulsion any number of times during the summer. Alternating periods of abundance of moisture and desiccation were not found to interfere with the ability to eject spores. In case the bark remains wet continuously, it was found that a single stroma would continue uninterrupted ejection for twenty-six days. One case is reported in Bulletin 9 of the Pennsylvania Chestnut Tree Blight Commission, in which bark containing ascospore pustules continued to expel ascospores for over six months (in the laboratory). The rate of ejection from a single ostiole was determined to be one ejection for each two seconds, that is, about four spores a second. This would be 14,400 spores an hour from a single perithecium. The maximum height of ejection found was twenty-two millimeters. Horizontally, from a stroma two centimeters above an agar plate, spores were ejected to a distance of eighty-nine millimeters on the plate, the experiment being performed under a bell jar.

The spore content of the air was determined by two methods. The first was the usual aspirator method used in quantitative analysis for bacteria. By this method no spores could be found in the air during dry weather, but when the air within a few feet of wet cankers was tested there was an average of four and three tenths spores per liter. The second method was the exposure of sterile agar plates at varying distances from moist cankers. When these plates were exposed for a short time close under a canker, as many as 9000 spores were caught on one plate, but the number decreased as the distance between the canker and the plates was increased. Spores were easily secured at a distance of fifty-one feet with a moderate wind blowing from the diseased bark toward the plates on a level with it. No greater distances were tried; but if spores can be so easily caught at that distance on a ten-centimeter plate in a moderate wind on a level place, one can well imagine their being blown for miles in a strong wind from tall trees and from the tops of the mountain ridges where the disease is frequently found. Heald, Gardner, and Studhalter (1914) were able to catch the spores over three hundred and eighty feet from the nearest tree.

Having proved that the spores are ejected all through the summer and that they are carried about in great numbers by the wind, only one link of a solid chain of evidence was missing: that was to prove that such wind-blown spores produce cankers when they fall into wounds. In the first series of experiments in order to determine this point, bark containing active perithecia was supported within a few inches of sterile wounds in healthy trees for a short time and then the wounds were wrapped with cotton in order to exclude later inoculation. Of the 1395 wounds treated in this way, seventy-eight per cent developed cankers. In the next set of experiments, the distance was increased to one to four feet and a wind was artificially produced by bellows. Seventy-four per cent of the 185 wounds treated in this way had cankers about them later. Wounds treated in the same way but not exposed to shooting perithecia remained uninfected.

In another experiment, groups of trees were selected in which some had cankers on them while others were free from disease. Sterile wounds were made in the healthy trees and protected by fine-meshed wire screen and cotton bands, so that it was believed that spores could not be introduced in any way except by the wind. The cankers on the diseased trees were frequently drenched in order to induce spore ejection. Of the 559 wounds treated in this way, 114 developed cankers.

The results of the above experiments lead the writers to believe that wind is an important factor in the spread of the disease.

Other animate agents

It is easy to believe that the sticky pycnospores remain attached to the feet of animals, such as squirrels, mice, and numerous others which run over the cankers. But after the spores are isolated from them, as undoubtedly they could be, it would still be necessary to prove that such spores are deposited in wounds where they produce infection. Statements made with respect to the agency of animals in dissemination should be supported by more complete chains of experimental data than have been commonly adduced.

It can be said at present only that it is possible that the fungus is spread by such means.

PATHOLOGICAL HISTOLOGY

Keefer (1914) reports detailed microchemic and histologic studies of the effect of the fungus in the bark and the wood of the tree. He finds that the outer and internal cork layers, sclerenchyma (bast fibers and stone cells), and crystal-containing cells are not in any way affected. All tissues composed of cells having more or less pure cellulose cell walls are destroyed (except medullary rays). The collenchyma and the thin-walled parenchyma of the primary cortex, the parenchyma of the pericycle, the sieve tubes and the phloem parenchyma of the bast zone, and the fascicular cambium, are enumerated as the tissues that are in most cases wholly destroyed and replaced by the fans of mycelium. It was found that cellulose cell walls became partially lignified in proximity to the advancing edge of the mycelium fan. The degree of lignification, however, is not sufficient to furnish immunity of the tissues to the action of the fungus, as seems to be the case with the more completely lignified tissues, such as the sclerenchyma. The cells of the medullary rays in the bast zone are partial y lignified, but the cells are not individually affected or broken. There is an increase in the number of medullary ray cells, due probably to a stimulating action by the fungus. The original cells divide and redivide until great masses of new cells are formed, so that there is a crowding of the phloem tissues and a radial and tangential separating of the segments of the bast zones. This is the histologic change, evidently, which accounts for the slight, and at times pronounced, hypertrophy of the cankered area. The destruction of the various tissues of the bark is explained on the basis that the cells are broken and destroyed by the mechanical action of the advancing mats of mycelium. Since these are the only tissues affected to any extent, the fungus must utilize some of the material for food. Whether or not enzymic activity precedes or follows the apparent mechanical destruction of the tissue was not determined. Until the enzymes and the toxins of the fungus are studied, the actual biologic relation of the host and the parasite cannot be accurately determined.

CULTURAL STUDIES

Media

Endothia parasitica grows luxuriantly on a wide range of culture media. The writers, as well as other investigators, have grown it on sterilized twigs of many forest trees, on roots, and on bean plugs, carrots, potatoes, sweet potatoes, bread, corn meal, oatmeal, rice, sugar solutions, bouillon, various synthetic media, and a large number of agar media. In fact, in the saprophytic condition the fungus seems to be almost omnivorous.

Isolation

The fungus is most readily isolated by removing, under sterile conditions, a small piece of the diseased tissue of the inner bark, especially in the youngest part of the canker, and transferring it to agar tubes. Anderson and Anderson (1913) have described in detail various other methods of isolation. Either kind of spores may be sown on the agar, or streaks may be made on agar slants with the spore horns, or the ascospores may be permitted to fall on agar plates after natural ejection.

General cultural characters

There are certain characters that are common to the growth of the organism on most of the artificial media commonly used, particularly the agars.

Murrill (1906 a: 146) says: " When grown in artificial culture, the mycelium of the fungus is at first pure white, changing to yellow with age, and the fruiting pustules are a beautiful yellow." He finds that the fruiting pustules are produced in eleven days, and mature spores in the process of discharge in twenty days. Neither Murrill nor any writer since 1906 has succeeded in producing the ascospore stage in culture.

Clinton (1909:886) describes the same color change on lima-bean agar, and adds: " The threads form a rather hard crust on the surface of the medium, and in this the Cytospora fruiting stage develops as numerous small elevations. The spores, after maturity, ooze out on the pustules as lemon-yellow drops, which later become light chestnut-brown in color."

Anderson and Anderson (1912 a) advocated the cultural characters as a means of distinguishing this species from the other very closely related and confusing species of Endothia. Since then, Pantanelli (1912), Clinton (1913), and Shear and Stevens (1913 a) have studied this phase, and they all find additional cultural characters on a number of media by which these forms may be distinguished. It is not our purpose to discuss these differences in this publication, since they do not directly concern us at this time. Only the most important characters that relate to *E. parasitica* will be mentioned. For a more complete discussion the reader is referred to Shear and Stevens (1913 a), where the cultural characters on a large number of media are described in detail.

Sterilized twigs

On twigs of all the common forest trees that were tried (Anderson and Anderson, 1912 a), the fungus produces a short, white, web-like growth over the surface of the twig, with heavier bunches of mycelium which later become orange-colored, where the pycnidia are to develop. On the cut ends of the twigs there is developed a thick, felt-like, orange mycelial growth, but this never extends out on the bark as in *E. radicalis*. The same characters were found by Shear and Stevens (1913 a), except that these investigators call the color of the mycelium on the cut surface " cadmium yellow."

Potato agar slants

When streak cultures are made on potato agar slants with spore horns, the mycelium begins along the streak as a white weft and spreads rapidly toward the edge. In four days, at ordinary room temperature, the orange color begins to appear along the streak, and it broadens as the mycelium grows out until the whole surface of the slant is covered with a deep orange growth. This test was used most extensively by the Andersons in distinguishing this species from the other Endothiæ. Shear and Stevens (1913 a: 12) record the same phenomenon on this agar, and add: " Within six days, the mycelium, especially at the base of the agar slant took on a peculiar granular metallic appearance. . . . This portion of the culture was light orange yellow by reflected light and orange by transmitted light. The peculiar surface appearance might perhaps be called ' brassy.' This metallic appearance has been found to be the most constant and reliable distinguishing character of *E. parasitica* on potato agar. In twelve to fourteen days small pycnidial pustules appeared in the upper portion of the tubes, and the agar just below the mycelium became warbler green, changing later to olive green."

Often potato agar cultures after three or four months turn to a deep purple or wine-color. H. W. Anderson (Anderson, P. J., 1914) found that this purple color is due to the fact that the long growth of the organism on the agar causes the latter to lose its acid character and become alkalin. The yellow pigment (aurine) in the mycelium goes into solution in an alkalin medium and turns purple. The pigment then escapes from the cells and is suffused throughout the agar.

Relation of light

The fungus grows just as rapidly in darkness as in light, and also produces the yellow pigment but not so abundantly. D. C. Babcock, working with one of the writers of this bulletin, found, however, that in total darkness no pycnidia are produced, but just as soon as the culture is brought into light the pycnidia begin to form. This fact accounts for the concentric rings of pycnidia so noticeable on plate cultures. One circle is produced each day. Doctor Shear, in a letter to the writers, states that pycnidia are produced in darkness.

Relation of temperature

Shear and Stevens (1913 a:9) studied the relation of temperature to the growth of the mycelium in pure cultures. Their results are thus summed up: "From these records it will be noted that the minimum temperature for all was 9° C. and that all failed to grow at 7° C. The maximum temperature for *Endothia parasitica* . . . was 35° C. . . . The optimum appears to be near ordinary room temperature, that is, about 22° to 24° C."

Tannic acid

Since the chestnut tree has a relatively high tannic-acid content, the question naturally arises as to the relation of tannic acid to the growth of the fungus. Clinton (1913:407) grew the fungus on cultures containing various amounts of tannin, and summarizes his results thus: "(1) Both fungi [referring to *E. parasitica* and *E. gyrosa*] can use tannic acid, at least in small amounts, as food — shown by the blackening of media through oxidation, loss of acidity, more luxuriant growth, with a low per cent of the acid added, than without it, and a slight growth on agar-agar with tannic acid as the available source of food. (2) Higher percentages of tannic acid (four per cent and above) are detrimental to a vigorous growth of either of these fungi, and finally (10 to 14 per cent) entirely inhibit their growth. But with the true blight the tolerance is apparently greater by 2 to 4 per cent than that of the saprophytic *E. gyrosa*. (3) Long-continued cultivation of the parasitic variety in artificial cultures without tannic acid probably lowers its tolerance to the higher percentages of tannic acid. (4) Gradually passing these fungi in cultures from the lower to the higher percentages of tannic acid apparently raises their tolerance to it." Clinton suggests that the tolerance of a higher percentage of tannin probably bears some relation to the parasitism of *E. parasitica*.

ECOLOGIC RELATIONS

Murrill (1906 a:153) gives his opinion (1) that winter injury possibly accounted for the epiphytotic, (2) that there was a decline in constitutional vigor, because of coppicing, which predisposed the tree to attack, and (3) that cultural conditions could determine relative resistance to attack. The effect of these ecologic conditions, as well as of drought, in increasing the susceptibility of the tree is upheld by Clinton (1909:887–889; 1911: 717; 1913:389–407). In the last publication Clinton (1913:390–391) writes:

"Now, if the condition of the host bears no relation to the rise and spread of the disease, the writer knows of no satisfactory explanation for its sudden and destructive appearance in this country except its importation from some foreign country. The evidence to date, however, is very strongly against the idea that it is an imported pest, as we shall show later. Among the farmers in Connecticut who have been able to watch this disease rather closely there are many who believe that the weakened vitality of the chestnuts has had considerable to do with its development and spread in this State. The writer more than any one else has advocated this view, and we propose to give here the reasons we have for holding it. Briefly expressed, they are as follows:

" The chestnut blight was brought to sudden prominence just after the severe winter of 1903–1904, which injured and killed fruit and forest trees in general along the coast and watercourses, of which New York City was the central point. The resulting enfeebled condition of the chestnut enabled the blight, a previously inconspicuous parasite, to spring into sudden prominence on these trees and to gain credit for the death of others which had been largely or entirely due to winter injury. Since then we have had one or two severe winters, and more especially several dry summers, that have injured not only the chestnut, but other forest trees over an extended area. Due to its successful attack on the weakened trees, the blight fungus has perhaps acquired an added virulence that has enabled it to attack apparently healthy trees, especially those of sprout renewal. The enfeebled condition of the chestnut trees and their consequent susceptibility to the blight may possibly be related to some lessened chemical activity in the bark and newly-formed wood, such as the production of tannic acid, for instance. If so, then when this has returned to its normal production through favorable weather conditions, the blight should gradually become correspondingly less aggressive."

Opposed to these views we have those of Metcalf and Collins (1910): " A debilitated tree is no more subject to attack than a healthy one. [See also Metcalf, 1910.] Dry weather checks the disease by suppressing spore production. . . . Winter injury is not common over the whole range of the bark disease, but may be locally important in producing lesions through which the parasite enters. Winter injury bears no other relation to the bark disease." Metcalf (1912 a:225) writes: " No definite evidence, experimental or otherwise, has been adduced to show that a tree with reduced vitality is more susceptible to infection, or that the disease spreads more rapidly in such a tree than in a perfectly healthy and well-nourished tree of either seedling or coppice growth, provided that such reduced vitality does not result in or is not accompanied by bark injuries through which spores can gain entrance." (See also Metcalf, 1912 b: 79–82.) The writers think that in the above quotation Metcalf has well summed up the apparent fallacies in the preceding statements made by Clinton.

By observations the writers have found no connection between any ecologic conditions and any variation in the susceptibility of the tree. However, ecologic conditions may determine the rapidity of spread of the fungus through the infection courts opened up, such as winter- and drought-injured bark and limbs, hail, and other mechanical injuries, and the like.

The writers have proved, through thousands of inoculations made in the States of Pennsylvania and New York, that the healthiest trees are entirely susceptible. Winter-injured trees, even if dead, could not be more susceptible.

Anderson and Babcock (1913) were unable to find any conditions under which one tree is more susceptible than another. One of the writers of this bulletin (Rankin, 1914) has shown by a careful series of inoculation and growth studies, along with accurate determinations of the water and air content of the bark, that in 1912, at least, no connection between drought and change in susceptibility was found. The majority of the inoculation work reported in the same paper was performed on coppice growth which had grown from trees cut about five years previously. These trees had not, therefore, been subject to the severe winters which Clinton has claimed, predisposed the chestnut. In no way were the results of inoculations made on this five-years-old coppice any different from those made on older trees. In cutting several trees near Napanoch, a few were found that showed a dead area which may have been produced by the severe winter of 1903–1904. In one case the injured area had decayed, leaving a ring-shake. In other trees no injury was apparent. No difference in susceptibility, however, was noted.

The writers would summarize their belief, based on observation and experiment, that, without regard to any ecologic relations, the native chestnut is entirely susceptible because of the parasitic potentialities of the fungus, which have not heretofore had an opportunity to be demonstrated.

CONTROL

METHODS THAT HAVE BEEN ADVOCATED

Merkel (1906:101–103) attempted to control the disease in the New York Zoölogical Park, where he first discovered it. In the summer and fall of 1905 he had all the diseased limbs removed from four hundred and thirty-eight trees, and the trees were then sprayed with bordeaux mixture. Only one application was made. No further report appeared on this experiment except the statement of Murrill (1906 b:205): "An attempt was made by Mr. Merkel, chief forester at the Zoölogical Park, to control the disease by spraying, but I believe he considers the condition quite hopeless. Practically all of the chestnut trees within his jurisdiction appear to be dying rapidly."

Murrill (1906 a:152–153) was the first to give advice on control, his advice being as follows:

"The treatment of a disease of this nature must, of course, be almost entirely preventive. When once allowed to enter, it cannot be reached by poisons applied externally, nor can the spores, which issue continuously and abundantly through eruptions in the bark be rendered innocuous by any coating applied at intervals. On the other hand, no poisonous wash, even though covering every part of the tree, can prevent the germination of the disseminated spores when they fall into a wound, since the wound opens up fresh tissues unprotected by the poison.

"The spraying of young trees with copper sulfate solution, or strong bordeaux mixture, in the spring before the buds open might be of advantage in killing the spores that have found lodgment among the branches during the winter, but the real efficacy of this treatment is so doubtful that it could not be recommended for large trees, where the practical difficulties and expense of applying it are much increased. Nursery trees should be pruned of all affected branches as soon as they are discovered, and the wounds carefully dressed with tar or paint or other suitable substance. Vigilance and care should largely control the disease among young trees. With older trees all dead and infected wood should be cut out and burned and all wounds covered without delay."

Murrill (1906 b:209) says also: "I have no treatment to suggest further than the preventive measures already mentioned." In 1908 he adds (1908 a:24–25): "Preventive measures have apparently not affected it in the slightest degree. The pruning of diseased branches has entirely failed to check it, even in the case of very young trees. Branches have been carefully removed and wounds covered, leaving the tree apparently entirely sound, but upon inspection a few weeks or a few months later they would be found badly diseased at other points." In the same publication (page 30) he advises eradication measures for spot infections in the woods: "Owners of standing chestnut timber within the affected area are advised to cut and use all trees, both old and young, that stand within half a mile of diseased trees, unless protected from infection by wind-blown spores, by dense forest growth, or some other natural barrier." Hodson (1908:7) advises: "(1) To cut out the diseased trees, (2) to institute a quarantine against the shipment of infected material."

Metcalf (1908 b:490) also advocated the cutting-out method for limiting the spread of the disease. He writes: "In certain localities where the disease is just appearing it would undoubtedly be possible, by prompt cutting down or treatment of all infected trees and by very careful inspection, to maintain a zone free from the disease, and hence keep the disease out of the still uninfected country beyond." Clinton (1909:890) writes: "No efficacious treatment for the prevention of the trouble has yet been found, though spraying, pruning, and burning of infected trees have been advocated."

Metcalf and Collins (1909:49–52) take up in detail the means of control of the disease. After stating that the distribution of the fungus to distant points would be accomplished largely by the shipment of diseased nursery stock, they point out the necessity of rigid inspection of nursery stock shipped into uninvaded territory. They also advise a campaign of education in order to acquaint the public with the nature and appearance of the disease. They then point out the necessity of promptly cutting and burning newly affected trees so that spot infections may be arrested. They say: "Almost the only treatment that can at present be safely recommended as surely retarding the spread of the disease to a greater or less extent is one which will never be of practical use except in the case of orchard trees or certain valuable ornamental trees. It consists essentially in cutting out the infected branches or areas of bark and carefully protecting the cut surfaces from outside infection by means of a coat of paint or tar. This cutting must be thoroughly done and the bark of every infected place entirely removed for a distance of at least an inch (where the size of the branch permits) beyond the characteristic, often fan-shaped, discolored areas produced by the growing fungus in the inner bark. All small infected twigs or branches should be cut from the tree, the cut being made well back of the diseased area. A pruning knife with an incurved tip, a hollow gouge, or any other clean-cutting instrument will serve for cutting out diseased spots. . . . The paint or tar may be applied by means of a good-sized brush, care being taken to cover every part of the cutting." (See Figs. 96 and 97.)

It remained for Metcalf and Collins (1911:10–24) to suggest definite methods for arresting the country-wide progress of the disease. They outlined their method of scouting and cutting-out in detail (pages 12 to 17 of reference cited). The procedure is summarized thus (page 24):

"The only known practical way of controlling the disease in the forest is to locate and destroy the advance infections as soon as possible after they appear and, if the disease is well established near by, to separate the area of complete infection from the comparatively uninfected area by an immune zone. Advance infections should be located by trained observers and destroyed by cutting and burning. As the disease develops almost entirely in the bark, this must be completely destroyed (burned).

"In order to carry out the above methods it is essential that the several States concerned secure necessary legislation and appropriations, following the example of Pennsylvania, as no law exists whereby the Federal Government can undertake such work and cooperation among private owners without state supervision is impracticable."

The method proposed led to much discussion among pathologists. There were a few who openly criticized the method as impractical, and pronounced it a possible source of wasteful expenditure of state money. Others were more neutral and awaited additional evidence. The majority, however, were of the opinion that further research must be made before the practicability of any method could be actually proved. Stewart (1912) gave many reasons for not indorsing the method. He said: (1) the method was not supported by experimental evidence; (2) "no such method of controlling a fungous disease has ever been attempted"; (3) known facts concerning the disease did not make the method appear feasible; and (4) "it is better to attempt nothing than to waste a large amount of public money on a method of control which there is every reason to believe cannot succeed."

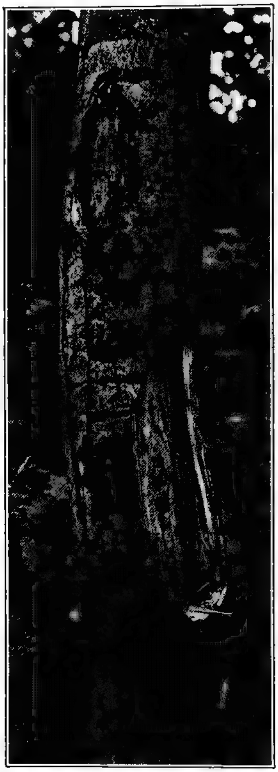


FIG. 96.— *Method of cutting out a canker on the trunk. The wood is cut out an inch below the bark*

Murrill (1912) thus presents his views as to why the chestnut canker cannot be controlled by the cutting-out method:

"1. It is impossible to locate all advance infections, these not being apparent even under close inspection.

"2. It is practically impossible to cut down and burn all infected trees after their discovery.

"3. Even if these trees are cut, it is impossible to discover and eradicate the numerous infections originating from millions of spores produced on these trees and distributed by birds, insects, squirrels, wind, and rain.

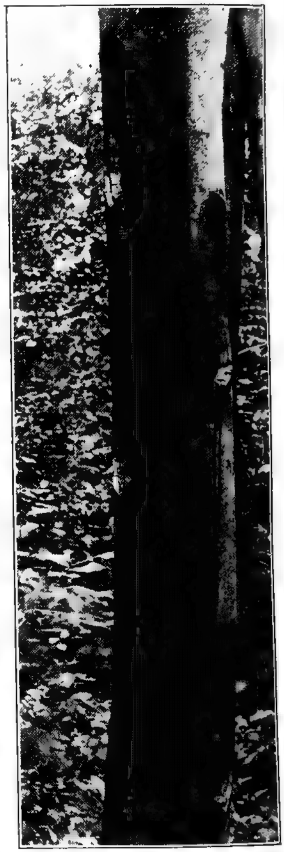


FIG. 97.—*Trunk from which four cankers have been cut out. After sterilization the wounds are completely coated with a wound dressing*

"4. Even if it were possible to cut and burn all affected trees, for ten to twenty years afterwards numbers of sprouts would grow up from the roots of these trees and continue to die from the disease and to spread the infection.

"5. Supposing that it might be possible to eradicate all advance infections, what method is proposed that is at all feasible for combating the disease in its main line of advance? All of the foresters connected with the United States Government and the entire army of the United States would be utterly powerless to oppose its progress.

"6. Although the chestnut canker has been known and experimented with since 1905, there is not a single instance where an individual tree or a grove of trees affected by the disease has been saved. If it is impossible to combat the canker under the most favorable circumstances, how would it be possible to succeed with an extensive forest? The published account of the extermination of the chestnut canker in the vicinity of Washington, D. C., cannot be relied upon. The trees most conspicuously affected there have been cut and burned, so that the presence of the disease is not readily apparent, but with each season additional trees will be affected and the attempt to stay the disease will be abandoned, especially when the main line of advance, which is now in northern Maryland, reaches the Potomac River."

Clinton (1912 c:82) says that in the main he agrees with Stewart and Murrill.

Some months previous to this discussion the State of Pennsylvania had appropriated a large sum of money for the investigation and control of the chestnut-tree blight disease. Metcalf and Collins (1911:14–17) quote this act, which embodies the scouting and cutting-out method described in the same publication.

During the summer of 1911 Doctor Metcalf appointed several agents who scouted in a preliminary manner the different States concerned in the control of the disease. With the information thus available (Metcalf and Collins, 1911:6), the authorities of the different States considered means of controlling the disease. Those States north of Pennsylvania took no definite action, mainly for two reasons: (1) the cutting-out method (the only method proposed) was not sanctioned by some persons to whom the state authorities looked for advice; (2) the disease had gained such a foothold that its economic control by the cutting-out method could hardly be expected by the most radical supporters of the method.

The published reports on field operations for the control of the disease in Pennsylvania are limited to the reports for the period from July 1 to December 31, 1912. The work of organization and preliminary scouting occupied the interval from the time of the appointment of the Commission in the summer of 1911 until the spring of 1912. The Commission reports (Penn. Chestnut Tree Blight Com., 1913:11):

" From the beginning, a more or less definite division has been maintained between the slightly infected western portion of the State and the badly infected eastern portion, these divisions being called the Western and Eastern Districts, respectively. In the two districts quite different restrictions are maintained with respect to the method of procedure in handling diseased trees. The line of demarcation between these districts, as at present understood, is the eastern boundary lines of Fulton, Huntingdon, Mifflin, Center, Clinton, Lycoming, Sullivan, and Bradford Counties. . . . The field work [page 21] west of the advance line has for its object primarily the total eradication of the blight, and the checking of further westward spread. East of the advance line where the bulk of the chestnut trees is located, it is the duty of the Commission to acquaint owners of timber with the facts relating to the blight. . . . at least in time to cut out the diseased trees before they deteriorate in commercial value. . . . In each district a district superintendent has been appointed to direct the field work. . . . The western district was subdivided into seven divisions of five to seven counties each, and five divisions were made in the eastern district. Each division has been in charge of a Superv sor. A field agent was detailed to conduct the work in a county and as many scouts as necessary were assigned him as assistants. . . . When the examination [page 23] of each tract was completed a data card, giving all the necessary information relative to the tract, was sent to Field Headquarters . . . The plan [page 25] now being followed when a spot infection is found is to blaze the infected trees at breast height and also at the base . . . and the infected trees numbered consecutively. . . . The points [pages 26–27] to be emphasized in eradicating spot infections are:

" 1. Take all possible care to prevent injuries to surrounding chestnut trees and sprouts in felling the infected tree. If it is necessary to clear away brush to facilitate cleaning up after felling, any small chestnut sprouts should be cut flush with the ground. Experience has shown that such stubs often become infected if near a diseased tree.

" 2. Cut all stumps as low as possible, to lessen expense of peeling and to save merchantable timber in the log.

" 3. Destroy all diseased portions of the tree showing pustules, by burning on the spot, immediately, either the bark or entire sections of the tree which show cankerous areas.

" 4. Either utilize all unbarked portions of infected trees within a brief time after they are cut, or, if it is desired to permit this material to remain in the vicinity of healthy chestnut trees, peel the bark from all portions of the trees which it is desired to retain.

" 5. In every case peel the bark clean from the stumps to an inch or two below the surface of the soil. Experience has shown that the stumps of infected trees and portions of the green tops which are permitted to lie for several months on the ground, are almost certain to become infected if the bark is permitted to remain on them, even though no cankers exist on the stump at the time the tree is cut. Some of the largest spots of infection have developed from unpeeled stumps. The spores germinate on the sappy surface of the stump and the mycelium grows downward through the cambium, and in the course of a year or two reaches the sprouts which come around the base of the stump. Little infection in the sprouts is found where the stumps have been carefully peeled. Furthermore, the sprouts have more vigor and are better rooted when they come from peeled stumps, since in this case they must start from beneath the soil and can so form their own roots." (Figs. 98 to 101.)

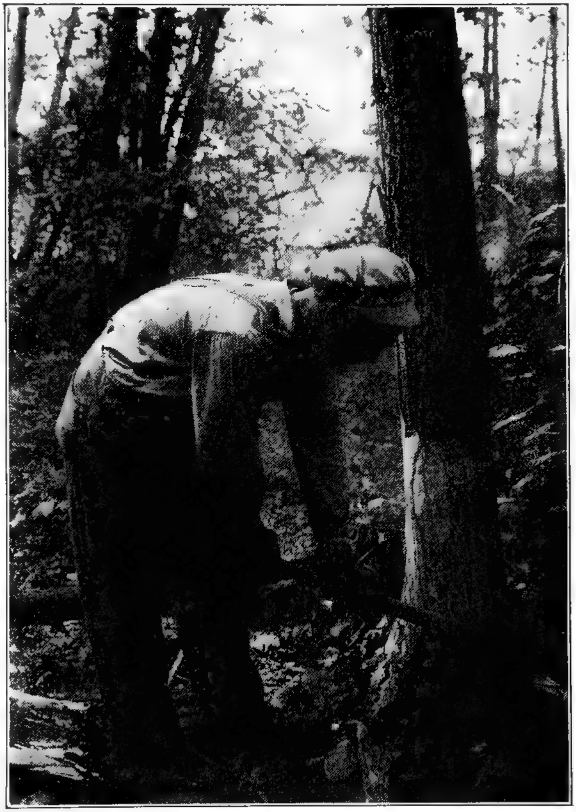


FIG. 98.— *Peeling the base of a diseased tree. Woodsmen find this easier than peeling the stump after the tree is cut*

As to the results of the cutting-out method, the following is quoted from the same report (page 27): " Sufficient time has not elapsed since the Commission began work to determine the efficiency of sanitation in checking the disease. . . . Forty-two tracts on which the original infection was cut out during the early part of 1912 were reinspected during November and December of this year (1912). The number of diseased trees in these spots prior to cutting ranged from a single tree to ninety-three, the total number of diseased trees on the forty-two spots being five hundred and fifty-six. On reinspection, twenty-eight out of the forty-two spots showed no recurrence of the blight; in three cases a single new infection was found, and in six cases there were two recently infected trees. The highest number of new infections numbered thirteen trees. In the forty-two spots averaging 13.25 original infected trees each, one hundred and fifty-six reinfections occurred, or 3.7 infections per spot. In two thirds of the forty-two spots no blight reappeared, and the new infections which developed in the remainder equaled only two sevenths of the number of trees originally diseased. These spots were located in the region of very slight infection in Elk, Clearfield, Center, and Fulton counties."

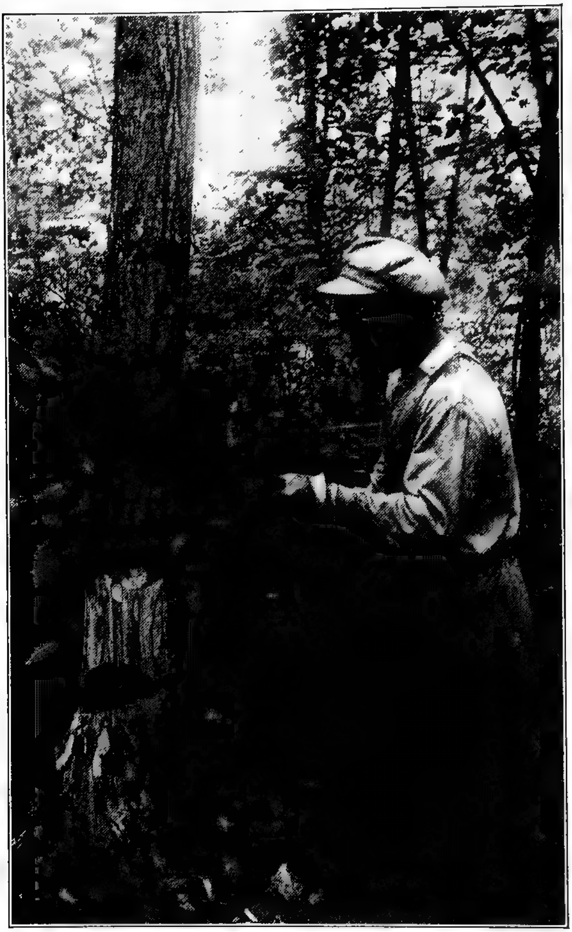


FIG. 99.— *Cutting down the tree that has been peeled at the base*

The results of the oldest experiment that is reported are as follows (pages 32–33 of the same report):

"In order to get information concerning the effectiveness of two different methods of cutting out diseased chestnut, a stump-to-stump count of 100 stumps each was made in November, 1912, on two different tracts located at Haverford. In one of the woodlots the infected trees were cut in the fall of 1910, and the stumps peeled, and all brush destroyed by burning, but the burning was not done over the stumps. On this tract a hundred stumps had 1354 vigorous sprouts, on 254 of which the blight was present. In other words, 82 per cent of these sprouts were free from disease, and of the infected sprouts, 99, or 39 per cent, were infected at the base mostly from diseased bark left on the stump.

"The second tract, used for comparison with this, is located about one half mile distant from the first tract and was cut about the same time. The brush was burned and all the merchantable wood used, but the stumps were not peeled. As near as could be determined, the two woodlots received identical treatment except that the stumps were peeled in one case while they were left with the bark on in the other. On this

FIG. 100.— *Peeling the trees that had cankers*

tract the 100 stumps had 1406 vigorous sprouts, 1115, or 79.3 per cent of which were infected, 22.2 of the infections were basal."

The Pennsylvania Commission, after having started these extensive state-wide experiments in control, passed out of existence in July, 1913, through failure of the Legislature to appropriate sufficient funds with which to continue the work as it had been begun. Much that was valuable had been accomplished in scientific research, but the field experiments in cutting-out, on which the greater part of the $275,000 was spent, were only begun and can in no wise be of more than very temporary benefit to the State.

In New York State the survey made by one of the writers of this bulletin proved that the disease had a greater stronghold than had been supposed. With the vast area that was then affected, the problem of control presented many difficulties. The chestnut in the part of the State west of the line of advance (Fig. 78) was of considerable value and worthy of being saved if this had been economically possible. The region that contained the greatest amount of the valuable chestnut timber of the State, however, lay in the hopelessly affected area. One of the writers, in making a report to Doctor Metcalf in October, 1911, made the following statements: "It is well, however, to consider the difficulties involved. The advancing line [Fig. 78] is in a region in which the topography is extremely rough, the hills are thickly wooded, and the chestnut is

FIG. 101.— *Burning the branches over the stumps. All broken-off branches and chips are raked up and burned*

abundant. Under such adverse conditions, it would be, to say the least, a gigantic task if not indeed an impossible one. If natural barriers were more favorable, such a scheme might be more feasible." No special appropriation or plan to control the disease was made. The position of State Forest Pathologist was inaugurated in July, 1912, and one of the writers was appointed to this position. Field investigations on the chestnut canker were conducted until October, 1913. These are reported elsewhere (Rankin, 1914).

The writers understand that West Virginia and Virginia (Gravatt, 1914) are scouting for spot infections and eradicating them as fast as possible. No elaborate organization has been attempted and no large sums of money have been appropriated for these operations. The regular authorities are in charge of the work. The Office of Forest Pathology at Washington is still maintaining research work on the disease and has employed S. B. Detwiler, formerly in charge of the field operations in Pennsylvania, to check the results of the cutting-out done in western Pennsylvania. The report on this work is soon to be published (Detwiler, 1914). North of Maryland no attempt is being made to control the disease.

GENERAL DISCUSSION OF CONTROL MEASURES

Exclusion measures

In regions still unaffected the consideration of exclusion measures is highly important. Diseased nursery stock has been proved the most dangerous means of introduction of the fungus into new localities. The original spot infections in this country were, without much doubt, started from diseased nursery trees shipped from the Orient. Five out of nine of the spot infections in western Pennsylvania were traced to diseased nursery stock. The only spot infection known in western New York — at Penn Yan — was in an orchard.

In order to prevent the shipment of diseased stock the trees should be inspected when they are packed and again when they reach their destination. A blanket certificate issued yearly to nurseries is worthless in the case of this disease, as with many others. As a part of the control measures instituted by the Pennsylvania Commission, all nursery trees were inspected and tagged individually before packing. The inspection of trees at their destination is not always sure to exclude diseased trees, for incipient infections are likely to be overlooked.

Because of the uncertainty of inspection of shipments and the extreme virulence of the parasite, it seems highly desirable that an absolute quarantine be placed on the affected region of the eastern United States, which would prevent the shipment of chestnut stock outside the prescribed limits. This would protect outlying or distant parts of our own country and would aid foreign countries in excluding the disease. It is especially incumbent on foreign countries that have chestnut to protect, to take the most rigid measures in order to prevent this disease from gaining a foothold.

The fact that diseased nursery stock is not the only means of transporting the fungus from an affected region must not be overlooked. Parts of diseased trees barked or unbarked may serve to carry the fungus. The following points show the danger there is in transporting unpeeled logs or tree parts outside the affected regions: (1) ascospores will germinate after having been kept dry for two and one half years; (2) conidia will germinate after having been kept dry for at least a year; (3) mycelium retains its vitality after having been kept dry for at least ten months; (4) perithecia, after having been kept dry for seven months, will again eject spores on being moistened.

Peeled timber may serve to carry the fungus; for the mycelium, which penetrates at times to the fifth annular ring of the wood, will under moist conditions produce superficial pycnidia and spore horns on the surface of the wood.

There are chances, of course, that even a strict quarantine on nursery stock or chestnut products will not eliminate all the means of introduction into a new territory. The fungus, in the form of either mycelium or spores, may be carried on or in other plant parts or by birds, wind, or other uncontrollable agents.

Eradication measures

There are two kinds of conditions under which eradication measures may be carried out, namely, arboricultural conditions and forestry conditions. In the case of orchard and ornamental trees the principles of sanitation and tree surgery have been advanced for the control of the canker. But even as early as 1908 Murrill says these means are without avail. Vast sums of money were expended by individuals in order to save such trees in cities and on private grounds in the regions first affected. Failure attended all attempts. This was largely due to four reasons: (1) the work was done by commercial tree surgeons who had had no special training; (2) it is impossible to find and remove all affected parts of a diseased tree, especially incipient infections and cankers under rough bark; (3) reinfection is constantly possible; and (4), a reason not the least in the majority of cases, the fact that the mycelium entered deeply into the wood was ignored, and the cankers renewed growth by the mycelium growing from the wood back into the bark. The last-named fact has been brought out by experiments conducted by Collins (1912 a) and by members of the staff of the Pennsylvania Commission (1912 b:2).

The removal of dead and dying trees and of all refuse from the surgical operations is necessary. Also all wounds must be protected immediately by an enduring covering (Fig. 97, page 598). Ample suggestions in regard to surgical methods are given by Metcalf and Collins (1911:18–20), Collins (1912 a), Pennsylvania Chestnut Tree Blight Commission (1912 b), and others. A later report (Pennsylvania Chestnut Tree

Blight Commission, 1914) says that careful tree-surgery work will often save affected trees.

With regard to the eradication measures to be applied in the forest, the cutting-out method of Metcalf and Collins (1911: 10–17) embodies the principles mentioned above. The method, although put into practice in Pennsylvania in 1912 and 1913, will not now, it seems, be demonstrated, since all concerted attempt at country-wide control has been abandoned. At the present time, however, we can theorize on the practicability of the method with more certainty than was possible at the time of its original consideration in 1911.

The writers believe that the method would not have succeeded economically even if it had been vigorously prosecuted from the time of its proposal. In addition to the reasons given by Stewart (1912) and Murrill (1912) which in their opinion make the method impossible, later research has constantly added evidence of the important part played by numerous disseminating agents that must be reckoned with. Careful surveys and the elimination of all spot infections outside the affected region would accomplish temporary control. But even with a carefully executed quarantine on nursery stock and chestnut products, the chances of reinfection from a distance or reappearance at an old spot infection would necessitate constant resurveys, which, if thorough, would be expensive and could not even then be expected to absolutely eradicate the disease. The principal difficulty, however, would be the main line of advance, where on the one side nothing would be done and immediately adjacent complete control would be attempted by eradication. The immune zone suggested in this scheme is the only way of meeting this. Just how wide such a zone would have to be in order to obviate infection due to wind dissemination of ascospores would vary with conditions. The chestnut-free belt in the Catskill Mountains, varying from thirty to forty miles in width, has apparently furnished protection for the area west of the mountains. The mere felling and utilization of all the trees, however, in a zone twenty miles around the affected area as it was in 1911, would be an enormous task, consuming much time and money. Taking into consideration the work and the money required in order to put the whole scheme into operation, it does not seem logical to believe that the chances of success warrant the risk.

Hope is expressed in a publication by Craighead (1912), who states that certain insects found eating the perithecial pustules of the canker fungus may aid in eradicating the fungus. Ruggles (Penn. Chestnut Tree Blight Com., 1914), however, writes: "The particular insect (*Leptostylus maculata*), carrying the 336,900 spores mentioned is one of the beetles named in a recent press notice of the United States Department of Agriculture, as being very active in eating spores of the blight fungus. Therefore this beetle while destroying spores of the blight is at the same time covering its body with thousands of other chestnut blight spores which it carries from tree to tree, making it probably an injurious insect instead of a beneficial one in this respect."

Protection measures

The only experiments reported on spraying were those of Merkel and the Pennsylvania Commission. The single application of bordeaux mixture made at the New York Zoological Park by Merkel in 1905 failed to check the disease. The Pennsylvania Commission conducted spraying experiments at Kenneth Square, Pennsylvania. Bordeaux mixture 4-4-50 was applied with a power sprayer every two weeks from April until the middle of November, 1912. No definite results are reported from this experiment (Penn. Chestnut Tree Blight Com., 1913:51, Figs. 53-55).

Immunization measures

Many writers have suggested the possibility of selecting and breeding immune varieties. Morris (1914) sums up observations on different varieties planted among affected American chestnuts. Van Fleet (1914) has found Asiatic chinquapin hybrids promising. With the relatively high degree of resistance shown by the Japanese and Chinese chestnuts, there may be a possibility of breeding within these varieties. Crosses with the American chestnut seem hopeless. Metcalf and Collins (1911:20) write: "If the seed [of Japanese chestnuts] is raised in America, the trees are more than likely to be hybrids with the American chestnut and to vary greatly in resistance to the bark disease."

The investigators of the Pennsylvania Commission applied many kinds of fertilizers around trees and carefully recorded the effect on the rate of growth of cankers. At Mount Gretna, Pennsylvania, the following substances were used in different combinations and quantities: burned lime, nitrate of soda, acid phosphate, muriate of potash, and kainit. At Emilie, Ambler, and Valley Forge, Pennsylvania, iron filings and coal and wood ashes, in addition to the substances mentioned above, were applied. At Mount Gretna the trees were old and thick-barked. The cankers were outlined in spring at the time of application, and again in late fall. When the measurements were compared with the checks no differences were found except within the limits of the usual variations. In the experiments at Emilie, Ambler, and Valley Forge no variation on rate of growth of cankers was obtained.

Also, at Emilie many secret preparations, applied as fertilizers or as injections, were tried. These were methods advocated by various laymen who considered they had a specific for the control of the canker. One of the writers of this bulletin served as a member of the Board of Review (Penn. Chestnut Tree Blight Com., 1914) which passed on the records of these tests as well as on those of the fertilizer tests. The report of the board stated that not one of the treatments had affected in the least the rate of growth of the cankers. In a large number of cases, only single very small cankers were present on the trees at the time of treatment, so that the tests were fair.

Many methods of tree medication have been brought forth by quacks since the chestnut canker began its ravages. The Pennsylvania Commission furnished trees for testing these methods to all who applied for a test to be made of their specific. As mentioned above, these all failed to produce the desired effect.

Dr. C. Rumbold (Penn. Chestnut Tree Blight Com., 1913:45–47) has been working on the effect of different substances injected into the chestnut, but as yet has reported no successful results.

RECOMMENDATIONS FOR TIMBER OWNERS IN NEW YORK STATE

The warning may well be repeated against planting chestnut anywhere for orchard or ornamental purposes. The speedy utilization of all diseased trees may serve as a local temporary control measure if carefully carried out. However, as it is now apparent that little can be done to control the disease, the consideration of the best means of utilizing the present stand is important to the timber owner (Nellis, 1914).

Three separate conditions exist in New York State at present: (1) in the Hudson River valley, conditions exist varying from total destruction to more or less numerous spot infections; (2) in the Roundout and Delaware River valleys, spot infections are numerous and probably but little damage has been done to the trees as a crop; (3) west of the Delaware River valley, spot infections are few and of small extent. It is important, then, to consider what can be done in these different sections in order to minimize the damage.

In the Hudson River valley it is a question of speedy utilization of dead and dying trees for the most part. This is a necessity for two reasons: (1) in order to obtain profit for the owner which will otherwise be decreased, and (2) in order to rid the section of this disease- and insect-breeding material. The owner will undoubtedly find some more or less profitable market for the greater part of the accessible timber now going to waste, if he makes a study of his local conditions. He may also obtain information from the federal and state departments. The importance of ridding the country of the dead material, which will otherwise become a breeding-place for other fungi and insects, cannot be overestimated.

In the Delaware and Roundout River valleys it is a question of utilization of immense quantities of second-growth chestnut of small dimensions. It seems that the work in this region, as well as in the Hudson River valley, is of a magnitude sufficient to warrant a careful study by the proper state officials in order that owners may receive helpful advice on conditions, markets, and methods. This would be an immediate phase of conservation worth while to the State of New York.

In the central and western parts of the State a careful watch should be kept for new spot infections, and the diseased trees eradicated as soon as discovered. Plans for future replacement of chestnut by other species should be made now, even before the chestnut dies, so that a forest may be growing up in the meantime.

One important factor to be considered at present through the whole State, and especially the eastern part, is what will become of the land that previously has grown chestnut. Careful study should be made of silvicultural conditions in these regions, followed by an attempt to obtain a stand of a desirable species that will replace the chestnut. Otherwise the tree weeds and other factors will interfere and will increase indirectly the damage done by the canker.

THE OUTLOOK

At present we know of nothing that will prevent the extermination of the American chestnut tree. Every measure of control that has been tried has been abandoned north of West Virginia and the Potomac River. Some persons have expressed the belief that nature herself will intervene to prevent destruction of the species; the virulence of the pathogen will abate, the resistance of the host will be increased, or natural enemies — insects or fungous parasites — will destroy, or at least check, the pathogen. Up to the present, however, there has been no indication of relief along any of these lines. But we do not believe that the ingenuity of our scientists has been exhausted; that further research will bring to light some method of combating the disease is not beyond the limit of probability. Such research not only should be continued, but also should be augmented; even if effective control measures will not be evolved until it is too late to save the present stand of chestnut, they will be of service in combating other forest epidemics which will undoubtedly come in the future.

ACKNOWLEDGMENTS

The writers wish to acknowledge their indebtedness to Professors Reddick and Whetzel, of the Department of Plant Pathology, New York State

College of Agriculture, for suggestions during their investigations and for criticism of their manuscript; to the New York State Conservation Commission and the Pennsylvania Chestnut Tree Blight Commission, in whose employ the majority of the writers' investigations were made; and to Dr. Haven Metcalf, of the Office of Forest Pathology, Washington, D. C., for much valuable collaboration.

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CHESTNUT BLIGHT IN MICHIGAN

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AGRICULTURAL EXPERIMENT STATION

MICHIGAN STATE COLLEGE
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SECTION OF BOTANY

East Lansing, Michigan

CHESTNUT BLIGHT IN MICHIGAN

DOW V. BAXTER and FORREST C. STRONG[1]

Although chestnut formerly held a leading place among eastern hardwood trees because of its abundance, rapid growth, and wood properties, it has never been commercially important in Michigan for lumber. This is due to the fact that its occurrence in Michigan has been limited to local areas in the southeastern part of the State. Chestnut extends naturally as far north as St. Clair county and it occurs abundantly on the sandy loam soils in eastern Monroe and Wayne counties. (Plate I.) Much of this remaining natural chestnut, however, is threatened by the rapid industrial development and expansion of nearby cities.

A number of chestnut plantations have been established in Michigan with native and hybridized stock. The oldest planting was made, according to the best records available, about sixty-five years ago. (Plate IIB.) Although these trees have been injured by ice storms and have been badly damaged by grazing, the trees continue to produce nut crops. The chestnut here were set out in a sandy loam, 25 to 40 feet apart, and were cultivated for the first 12 or 15 years. Since that time, the area has been closely pastured by sheep and cattle. As a result of this grazing, many of the trees have been injured as indicated by the presence of such chestnut heart-rotting fungi as *Polyporus spraguei* and *P. sulphureus*. As early as 1888, these trees, on an area of about one acre, produced nuts worth $10 or $15 each year (5).[2] Today orchards planted at the same time are producing 5 to 8 bushels of nuts per acre practically every year which bring a price of from $60 to $160 per acre to the grower.[3]

Numerous other plantations are to be found in Michigan. (Plate IIA.) Some of these date back to 1894 and 1896. Measurements given by Chittenden (2) for some of these plantations are presented in Table I.

The 37-year-old planting, according to this author, has yielded 15 bushels of nuts to the acre some years.

In forest plantations of chestnut, the trees are usually spaced 6 by 6 feet instead of the required wider spacings of 20 by 20 feet or more for nut culture. Very few forest plantations, however, have been established in

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[2]The numbers in parentheses refer to the literature cited at the close of this paper.

[3]From information furnished by the late Professor A. K. Chittenden which he obtained through correspondence with owners of chestnut orchards in Michigan.

Plate I. Native chestnut near Wayne, Michigan.

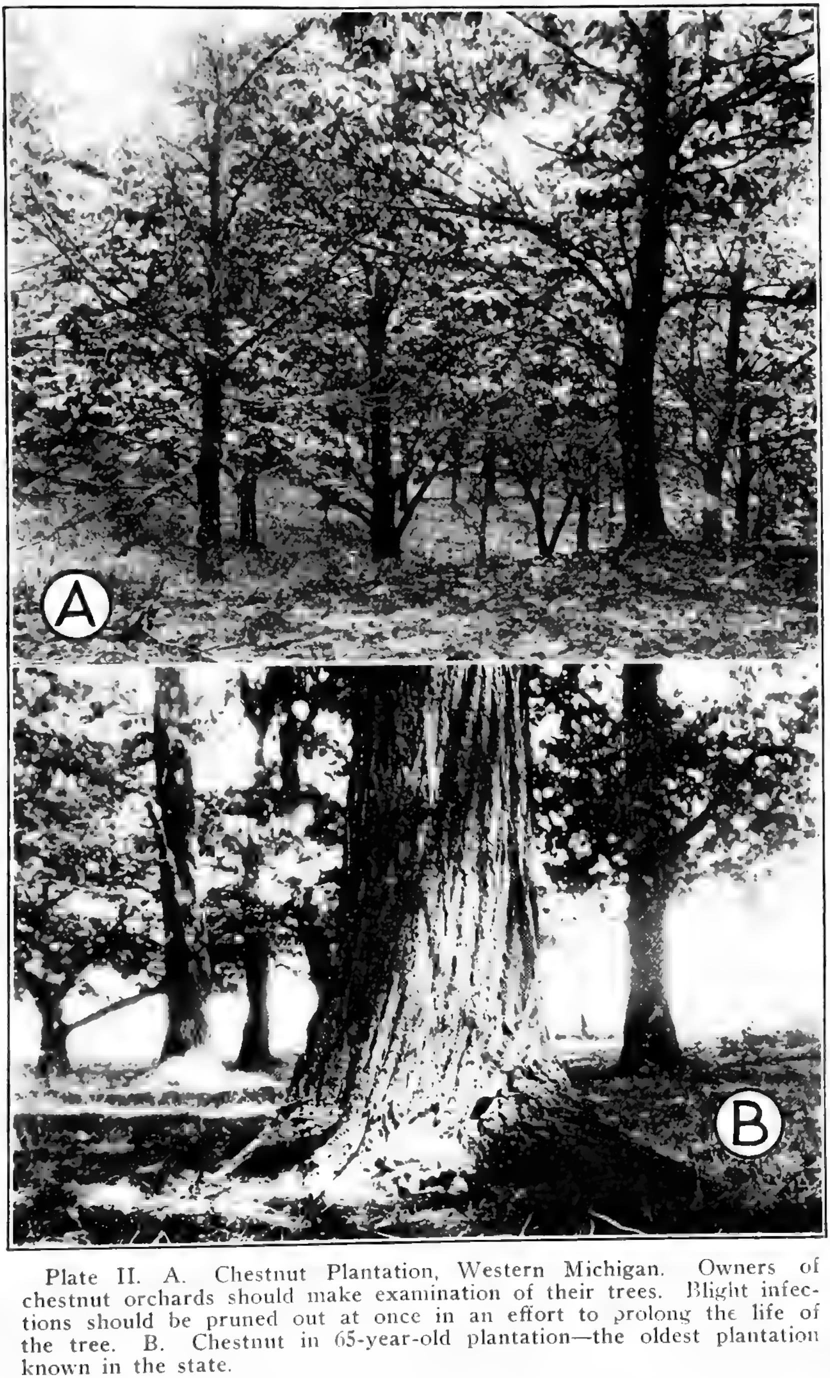

Plate II. A. Chestnut Plantation, Western Michigan. Owners of chestnut orchards should make examination of their trees. Blight infections should be pruned out at once in an effort to prolong the life of the tree. B. Chestnut in 65-year-old plantation—the oldest plantation known in the state.

Table I.—Growth of Chestnut in Michigan

Species	Age, years	No. of trees per acre	Diameter average tree, inches	Diameter maximum tree, inches	Height average tree, feet	Yield per acre, cubic feet
Chestnut	12	100	4.0	7.5	20	78
Chestnut	37	67	14.4	20.0	65	2,100
Chestnut	45	51	19.9	27.0	65	2,700

Michigan. The oldest forest trees set out in the state were planted in 1876 by Dr. William James Beal of the Michigan State College. Although many of the trees died, several are still rather successfully competing with such species as oak, beech, maple, and a great variety of other hardwoods as well as conifers.

Referring to this mortality, Coons (3) states, "Dr. Beal, who planted nearly all of the trees and who has watched their growth for years, attributes the death of the trees to severe winters."

The planting of chestnut on sites similar to those found on their experimental forest areas near Ann Arbor is not recommended by the University School of Forestry and Conservation. While other hardwoods, such as sugar maple, cottonwood, black locust, yellow poplar, and red oak, have shown a mean annual height growth of approximately one foot or more, chestnut has shown a mean of less than 0.5 feet. The trees in this plantation were set out in 1906. The trees were planted 6 by 6 in a deep fresh clay loam with little organic matter in the soil. At 19 years of age the average height was only 8.3 feet, according to Young. (6) A great number of the trees were winter-killed in 1910 and in 1911. Mice girdled many of these chestnut trees in 1912, 1913, and 1914. As the vacant spaces in this plantation were filled in with white pine, red oak, and European larch in 1917, and in 1925 with Scotch pine, the plantation is now a mixed one. Although chestnut blight infection occurs on native trees only a few miles east of Ann Arbor, no blight has been found in this plantation.

The Spread of the Chestnut Blight

That chestnut blight infection has spread rapidly from the original center of its introduction at New York City is well known to everyone interested in forestry and chestnut culture. The unchecked spread of the parasite into New England forests and its advance in a southwesterly direction along the slopes of the Blue Ridge and Allegheny mountains has wrought more destruction than any other forest-tree disease known. The blight organism has invaded the forests of the Southern Appalachians and has been found in Ohio, Indiana, Kentucky, and Michigan. Although a spot infection has been reported in a commercial orchard in western Illinois, this blighted chestnut was destroyed.

The chestnut blight was first discovered in Michigan in 1916. It was found on Paragon nursery stock which had been shipped into this state from New York and planted in the forestry nursery at the State College. The diseased plants were destroyed as soon as they were discovered and no

[4]This infection involved only one limb and was eradicated at the time.

blight has been found in this vicinity since that time. The writers found blighted trees in 1927 near Wayne in Wayne county and near Tecumseh and Clinton[4] in Lenawee county. In 1929, the blight was found in seven counties in Michigan, namely: Jackson, Lenawee, Monroe, Oceana,[5] St. Clair, Washtenaw, and Wayne. (Plate IVC.) In 1930, blighted chestnuts were found in Oakland county. Blight infection virtually covers the entire range of the native chestnut in the southeastern part of the State; it is firmly established on planted stock in Lenawee and Jackson counties and in the western part of the State it has killed several planted trees in Oceana county. It can be seen that the blight organism has infected not only the native chestnut but also chestnut which has been planted beyond the natural limits of the distribution of this tree.

The finding of chestnut blight on planted trees near Tecumseh in 1927 presents evidence indicating that the causal organism had been present in the State probably several years previous to its discovery. One of two trees found to be blighted was practically dead, the other nearly half dead. (Plate IV, A and B.) The first tree had only a narrow strip of bark a few inches wide and extending up one side of the trunk for about 15 feet as can be seen in Plate IV B. The remainder of this tree had already lost all of its bark. Examination of this nearly dead tree gave ample evidence of the presence of the blight fungus previous to the death of those parts as well as fresh blight cankers on the remaining living area.

Although the falling of the bark is extremely erratic and, according to Baxter and Gill (1), cannot in itself be used as a criterion for estimating the number of years a tree has been dead, it is evident that chestnut does not become completely decorticated for several years after death. In general, Baxter and Gill find that as much as 23 per cent of the bark-area on the first log remains seven years after the death of the wood. From this determination, which is based upon a great number of trees on numerous permanent and temporary sample plots, it seems safe to conclude that the chestnut blight fungus had been present in this region of Michigan several years prior to 1927.

The fungus has not been reported in the valuable chestnut orchards in the southwestern part of the State. These orchards, however, should be carefully watched as the blight was found by the writers in 1927 in a chestnut orchard of almost 100 trees at Bristol, Indiana. This particular location is within six miles of the Michigan and Cass county southern boundary lines.

Blight Symptoms

The first evidence of this disease is to be found generally on branches and sprouts. If the branches are killed during the growing season, the leaves die and cling to the twigs in very characteristic drooping clusters. This condition of the dead branches persists through the winter. So conspicuous is the appearance of these dead branches with their leaves still hanging on them that they have received the name "flags." (Plate III.) These flags are visible considerable distances from the infected tree and offer one of the first signs of the disease to the observer. In trees which are planted in isolated, exposed places, the breaking of the rather brittle branches in wind storms is of quite common occurrence. At first glance

[5]This infection was first reported by E. C. Mandenberg and H. H. Wedgeworth.

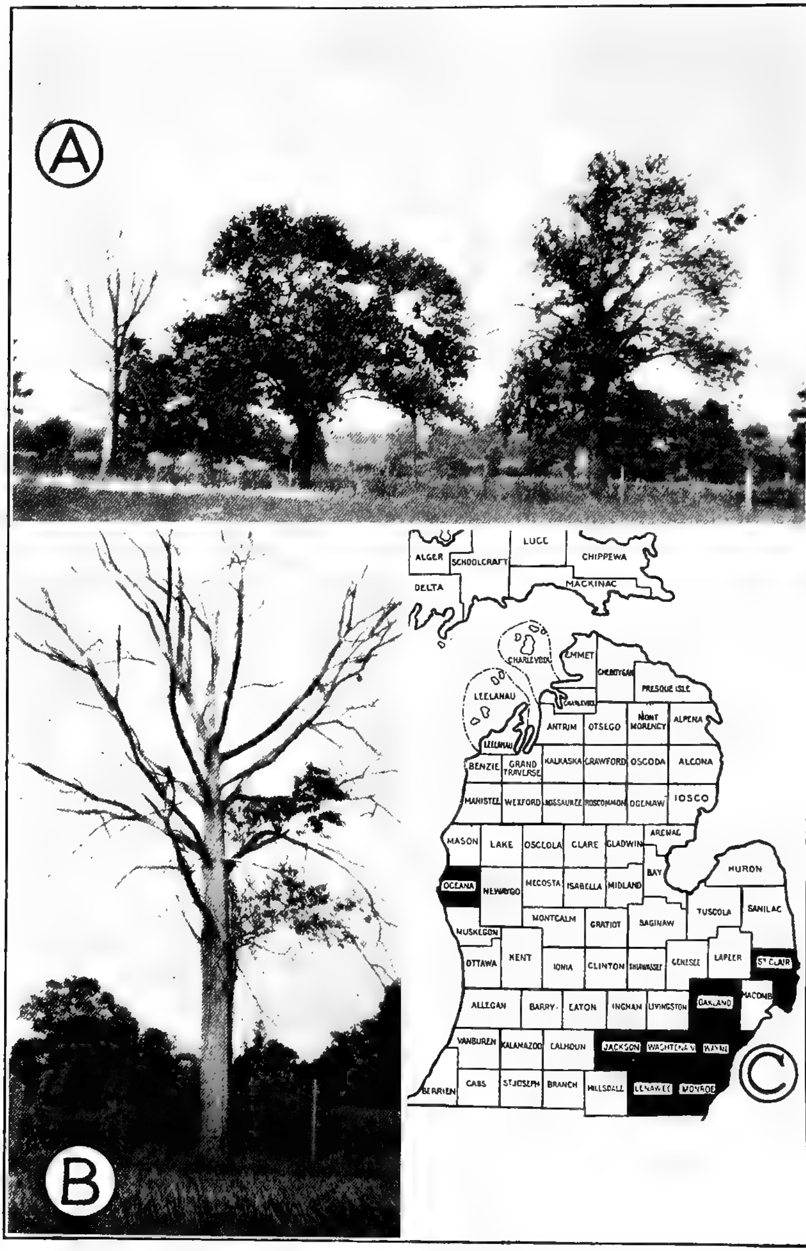

Plate III. A. Blighted chestnut trees found near Tecumseh, Michigan. B. Old blight infected chestnut found near Tecumseh, Michigan. C. Counties in which infected chestnuts have been found.

Plate IV. Native chestnut infected with blight. The characteristic "flag" in the top of the tree indicates an early stage of infection. Wayne, Michigan.

Plate V. A. "A chestnut branch, showing a young blight canker at the base of a side branch in contrast with the rough split older canker on the main stem." Courtesy Office Forest Pathology, U. S. D. A. B. "A chestnut blight canker with swollen edges and with the dead bark peeled from the wood in the center." Courtesy Office Forest Pathology, U. S. D. A.

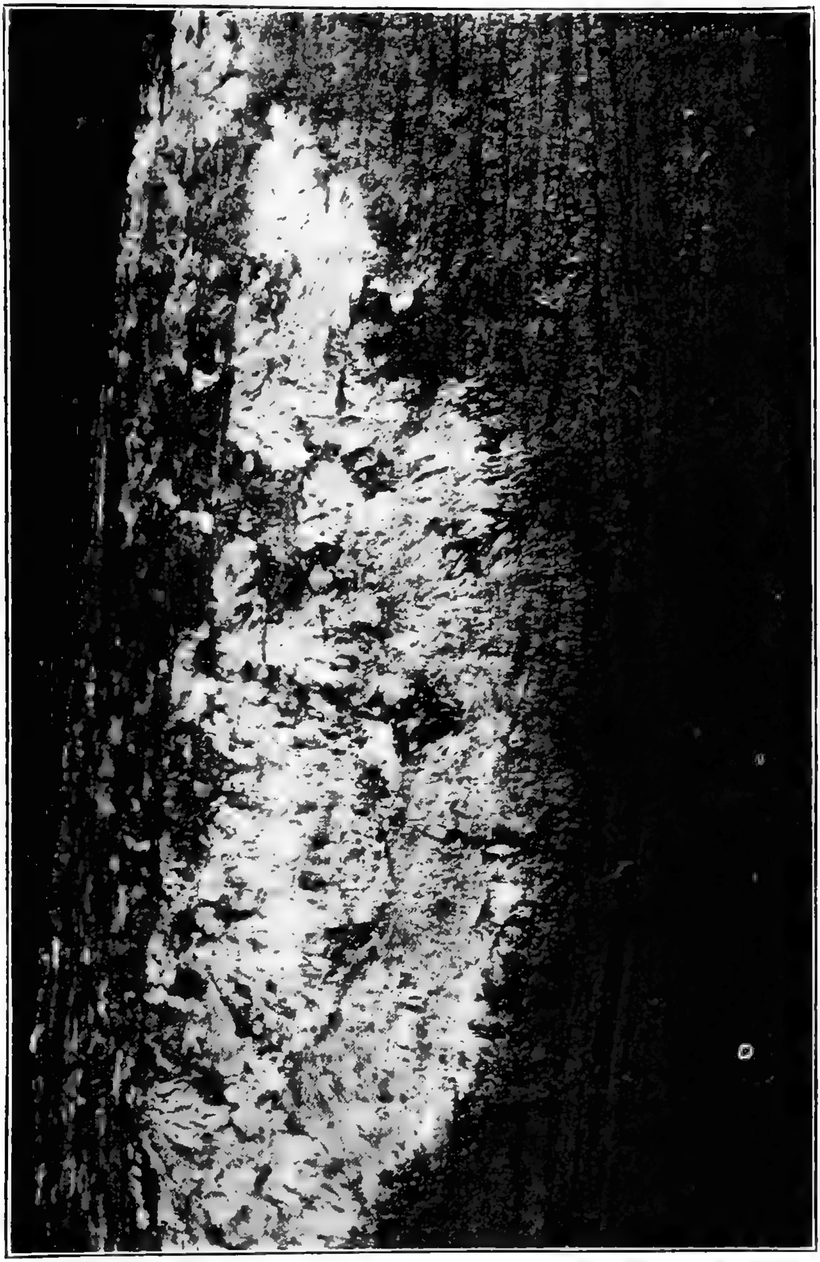

Plate VI. "Fans of white or buff-colored mycelium of chestnut blight." Courtesy Office of Forest Pathology, U. S. D. A.

branches broken in wind storms have the same appearance as those which have been killed by the chestnut blight organism. Closer inspection, however, shows these branches to be hanging down from the break rather than in the natural position of an unbroken but blight-killed branch. In Michigan, where most of the chestnuts have been planted, many have been observed with broken twigs and larger branches broken by wind storms.

The undersized burrs which are borne on infected branches are also an important and conspicuous sign of the presence of this disease. Close examination of dying twigs and branches or larger parts of the tree shows the presence of cankers. These cankers are more or less elliptical areas of discolored portions of the stem which may be either sunken below or swollen above the surrounding bark. The areas invaded by the causal organism become yellowish-brown in color and gradually spread and enlarge until the branch is completely girdled. The cankered areas may crack open and form longitudinal fissures or checks into the inner bark. (Plate V, A and B.) If the bark is laid back from the cambium region in these cankered areas, layers of the mycelium of the fungous plant are visible as radiating masses, buff-yellow in color. This is a characteristic diagnostic symptom of the disease. Such radiating mats are called mycelial fans. An excellent example of such a fan is shown in Plate VI.

Water sprouts arise below the cankered areas soon after the fungus has made a good growth in the bark. These water sprouts arise due to the stimulus brought about by the interference with the food transfer in the inner cortical region of the bark where the fungus has invaded the food conducting tissues. Although water sprouts are not an infallible sign of this disease, chestnut trees bearing them may be suspected and should be examined more closely especially if these sprouts are being produced in the upper parts of the tree. Another symptom often associated with this disease when the fungus has first attacked the tree in the uppermost branches is "staghead," a condition in which dead leafless branches stand up above the green foliage of the living parts. This symptom is especially noticeable in regions where the chestnut blight fungus has been present for several years. Again, this is not an infallible sign of the disease because other things, such as root rot or change in water level, can bring about this condition.

Causal Organism

The chestnut blight is caused by the fungus *Endothia parasitica* (Murr.) A. and A. As the mycelium penetrates the branch it forms in closely appressed plates of fungous growth already referred to as "mycelial fans." When the fungus has grown for a time there are produced in the bark pycnidial pustules which appear as minute raised papillae. These pustules, which are rarely larger than the head of a pin, are fruiting bodies. Each pycnidium contains enormous numbers of spores known as pycnidiospores. In damp weather sticky spore masses embedded in mucilaginous material ooze out from these bodies in the form of yellowish-orange "spore-horns" or tendrils. (Plate VII.) The presence of these spore horns together with the mycelial fans under the bark furnish infallible macroscopic evidence of this disease, especially when found on living branches. As in many fungi, two forms of spores are produced. Pustules which appear on the surface of the bark as small black dots with minute openings contain the second type of spores produced. (Plate VIII A.) These openings are the mouths of flask-shaped structures which are buried beneath the surface and which contain the spores known as ascospores. These spores are shot out directly into the air from the mouths of these fruiting structures.

The type of spores which ooze out in the spore-horns are released from their gelatinous matrix when the tendrils or horns become soaked with water in the form of dew or rain. They can be spread by rain splashings, by birds, and by crawling and flying insects. Since these pycnidiospores from the spore-horns are viable and able to germinate after considerable periods of time, days or even months, they constitute active spreading agencies of the fungus. The ascospores which are largely borne away from the diseased area by air currents are also able to disseminate the fungus to considerable distances. Man and other agencies may also bring about the spread of the fungus.

As both types of spores seem to be equally effective in producing infection and as the enormous numbers of both spore types produced are so readily disseminated, it has been impossible to eradicate the chestnut blight from other States, and it will be impossible to eradicate it from Michigan. The blight usually appears as it has in Michigan ahead of the general infection. In such instances it is usually assumed that the sticky spores of the fungus have been carried on the feet of birds.

This organism, being strictly a wound parasite, is unable to invade the tree tissue except through openings previously made in the bark, such as by splits, cuts, or abrasions where the bark has been broken. Once having entered the tissues of the tree the fungus grows with great rapidity and kills the tree. Branches or entire trees are killed by the girdling effect produced by the mycelium, which causes the formation of a cankered area which eventually encircles the twig, branch, or bole.

Previous Attempts at Control or Eradication of Chestnut Blight

Early in the period of invasion of the blight in the eastern forests of the United States it was apparent that the fungus threatened to kill the chestnut throughout the entire commercial range of this species. Realizing the significance of this pest, attempts were made to check the rapid spread of the pest. The strenuous efforts made to completely eradicate and burn the diseased trees in the known infected areas failed to yield the desired results.

In the endeavor to stamp out advance infection, the diseased chestnut in local or spot-infected areas were destroyed, but this method, too, failed to prevent the spread of the blight. Removal of the chestnut in the spot-infection areas did however cause a very pronounced delay in the spread of the blight. Some hope was expressed that possibly the elimination of chestnut from areas surrounding the infected regions might be helpful, but it became evident that the establishment of such immune zones was not an effective method for control. Many other control measures, such as the cutting out of cankers on individual trees, spraying, the injection of chemical compounds into the trees were attempted. Soil treatment was also advocated as a possible means of stimulating growth of the tree and thereby increasing its resistance to the fungus. In addition to the above-mentioned control measures, the establishment of quarantines against transportation of diseased stock was immediately put into effect in hopes that such quarantines would

Plate VII. "Hairlike spore horns which coil out from certain of the blight pustules during damp weather." Courtesy Office Forest Pathology, U. S. D. A. Magnified several times.

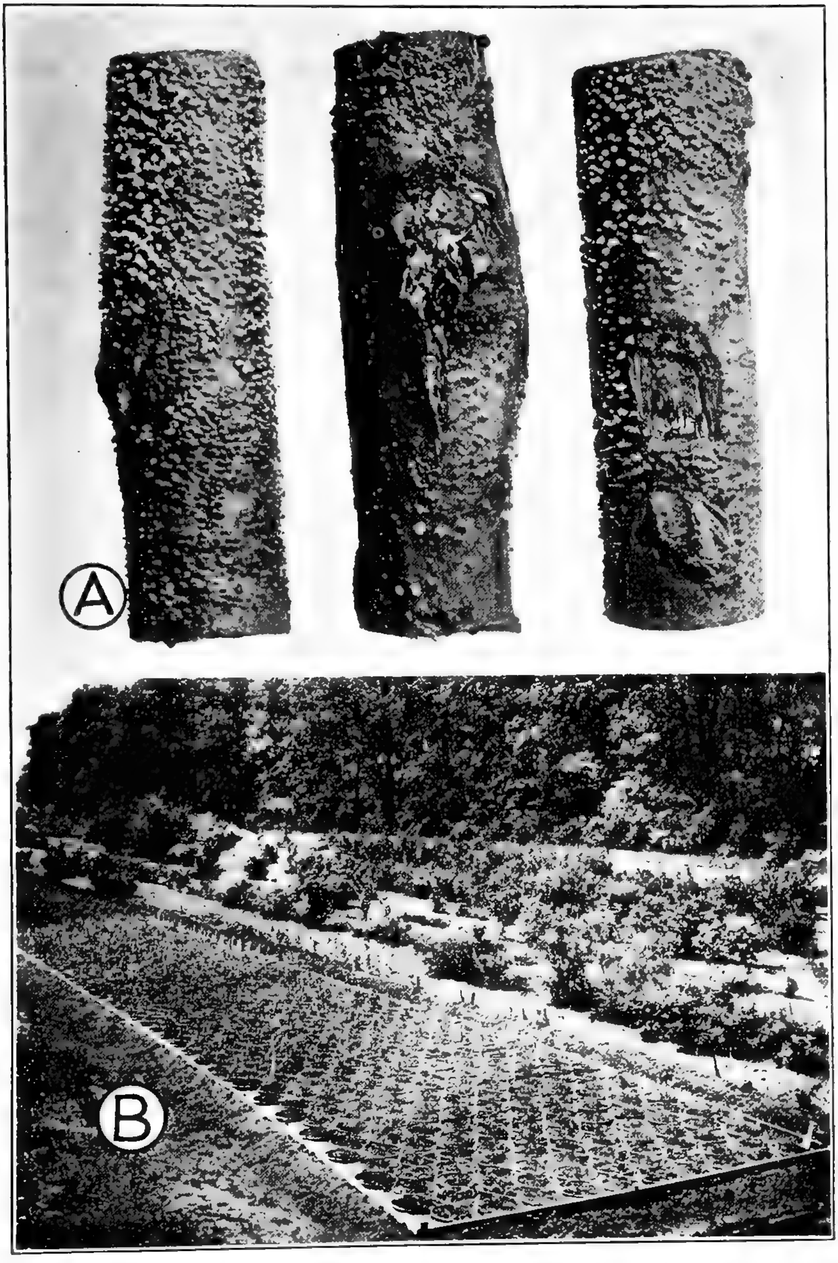

Plate VIII. A. "Blight pustules on chestnut." Courtesy Office Forest Pathology, U. S. D. A. B. Seedling trees grown from seeds collected in Korea and Japan.

delay the rapid spread of the fungus. Such quarantine regulations have been very important means of slowing up the spread of the blight across the country. It is no doubt due to these strict quarantine measures that the invasion of this state has been so long after the initial outbreak of this fungous disease in the United States.

Resistant Trees

Since direct efforts for the control of the blight have failed, hope has been expressed by many chestnut owners regarding the development of immunity to the fungus by the native trees. The Office of Forest Pathology (4) and other agencies have made extensive searches for blight resistant plants throughout the entire range of the chestnut, and especially in the regions where the blight has been present for several years. Individual trees have exhibited some differences in their susceptibility but the results of these surveys show that the majority of trees which are seemingly blight-resistant have simply escaped infection. It has also been noted that the many sprouts which so frequently appear at the base of blight-killed trees are merely blight-escaping and do not indicate that the tree has developed a resistance to the fungus. As this new wood becomes infected and dies it is replaced by younger sprouts which in turn escape infection for a period. Although continued effort is being made to locate chestnuts which are immune, there is little evidence at hand which gives immediate promise of the native trees exhibiting even a relatively high degree of resistance.

The European chestnut, *Castanea sativa,* also known as the French, Spanish, and Italian chestnut, is likewise susceptible to the chestnut blight. This chestnut is not, therefore, recommended to the growers for planting purposes in Michigan. A large number of Asiatic species and varieties, however, are less susceptible to the blight, not only in their native habitats but they have exhibited also such resistance in experimental plots and orchards in this country. Some of these trees have indicated a marked resistance to the blight.

In view of these facts, the United States Department of Agriculture has collected thousands of nuts from such blight resistant trees in Korea and Japan. The seedlings obtained from these nuts will be observed for their hardiness and their ability to resist the blight in various parts of the United States. Over 2,000 of these trees have been planted in the vicinity of Ann Arbor, Michigan and an additional number have been set out in southwestern Michigan. (Plate VIII B.)

Realizing the desirability of securing more immediate results, efforts have been made to graft scions from Asiatic trees on American stock. In spite of the fact that the scions from many foreign trees have shown resistance, the stocks have succumbed to the blight, resulting, of course, in the death of the entire tree. Experiments in grafting scions from various foreign varieties in Asiatic stock are now in progress at Washington and in other localities in the United States.

Attempts have been made also to hybridize American stock with native chinquapin and with various species and varieties of Asiatic stock. Although it is at present too early to predict the results of these experiments, it seems reasonable to assume that they should yield a highly resistant tree which will produce nuts equal in size and quality to the native chestnut.

The majority of the older orchards and experimental plots in the United States, which contain the Chinese chestnut *Castanea mollissima* and the Japanese chestnut *Castanea crenata* are located in the East. Comparatively little can be said at this time regarding their suitability for planting in Michigan. The chestnut blight organism has been able to attack these trees in orchards in this country but, without doubt, many of these chestnuts exhibit considerable resistance. Undoubtedly, individual specimens of these foreign trees may attain large size in the Orient but the trees already planted in orchards in this country seem to indicate that this foreign stock generally exhibits a small spreading form and rarely grows over forty feet in height. The flavor of the Chinese chestnuts is said to be superior to the Japanese or European species. However, due to the dwarf nature of these trees, it is doubtful if they will ever be of value in forest planting work.

Control and Recommendations

All efforts to control the chestnut blight in the American forests, as well as in orchards where the stock is native, have failed. Many such practices have simply served to prolong the life of the affected trees. It is believed that native chestnut will largely disappear from the State.

Although direct control is impracticable, hope has been expressed by many chestnut owners regarding the development of immunity to the blight by the native trees. Little evidence is to be had at present which supports this view. It seems that the immediate development of the native chestnut to a relatively high degree of resistance to this disease is very remote.

A number of varieties and species of chestnut from China and Japan which have been planted in this country show different degrees of blight resistance. The Office of Forest Pathology, United States Department of Agriculture, has been making an extensive study of chestnut blight in Asiatic stock. This office has found that some of the trees are highly resistant and that the blight can be controlled by constantly pruning out the infections in the infected trees.

Although it is not likely that such foreign stock will ever be planted extensively as forest trees under the present economic conditions, and because of the dwarfed habits of the majority of these foreign trees, Asiatic stock may offer a solution of the problem for the orchardist. The nuts are inferior in quality to those of the American tree but it seems reasonable to expect the results from hybridization experiments to yield a highly resistant tree which produces nuts equal in flavor and size to the Paragon and native chestnut tree.

It is evident that native chestnut trees should not be planted in Michigan orchards and forest plantations. In orchards already established, a careful and frequent examination should be made of the trees. Slight infections should be pruned out and burned in the effort to prolong the life of the tree. Although it is useless to try to save badly infected trees, such trees in the orchard are sources of infection and should be burned promptly.

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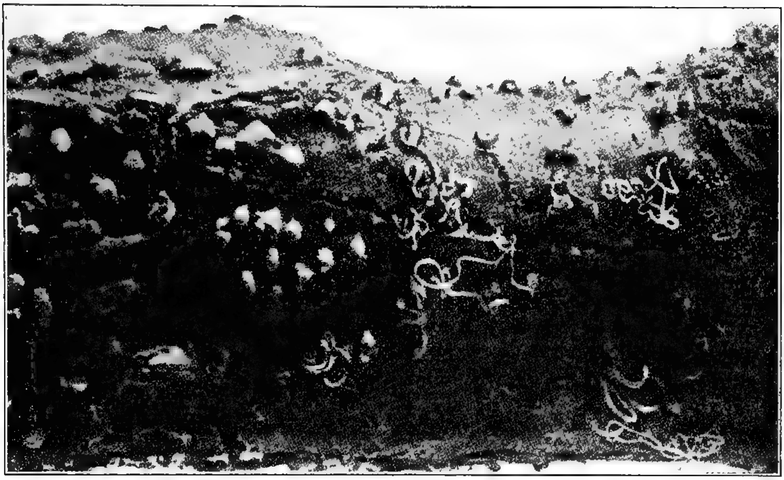
Number 27

Tree Pest Leaflets

RESISTANCE of CHESTNUT to the BLIGHT

(*Endothia parasitica* (Murr.) P. J. and H. W. And.)

Prepared by ARTHUR HARMOUNT GRAVES, Curator, Brooklyn Botanic Garden, and Collaborator, Division of Forest Pathology, Bureau of Plant Industry, U. S. Dept. of Agriculture.



Courtesy of Brooklyn Botanic Garden

Fig. 1 — Part of a diseased branch of a Chestnut tree, showing typical pustules and form of spore discharge in damp weather. (Magnified 3 diameters).

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The State Foresters, State Departments of Agriculture, State Agricultural Experiment Stations, Extension Services, Forest Schools and Forest and Park Associations of New England and New York, and the Northeastern Forest Experiment Station, the Division of Forest Pathology, Bureau of Plant Industry and the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture.

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May 1938

RESISTANCE of CHESTNUT to the BLIGHT

(*Endothia parasitica* (Murr.) Ander. and Ander.)

History:—Chestnut blight was brought into this country apparently on nursery stock imported from the orient a few years before 1900, and first attracted attention at the New York Zoological Park, New York City, in 1904, when it was discovered killing native chestnut trees. In 1913 the causal fungus was found in China under conditions which left no doubt that its original home was in Asia.

Host trees:—All species of Castanea are hosts of the fungus. The most susceptible species is the American chestnut, *C. dentata.*

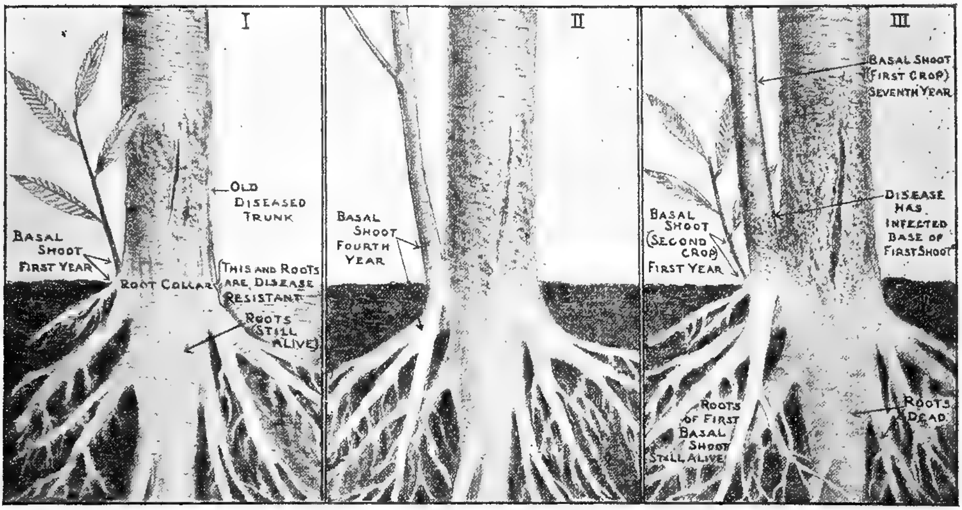
Symptoms:—During the growing season, the yellow or brown leaves of a killed branch stand out in strong contrast to the green foliage, and these dead leaves may remain on the diseased parts throughout the following winter and spring. On the affected stem a canker may be found located usually below the lowest killed foliage, with sprouts commonly developing below the canker. Young cankers on smooth-barked stems have a yellowish brown color, contrasting strongly with the olive-green color of normal bark. Cankers may be either sunken or swollen. Later, longitudinal splits often appear in the bark of cankers. Small yellow, orange or reddish-brown fruiting pustules about the size of a pinhead break through the cankered bark. On large stems with thick, fissured bark the disease is difficult to detect until finally the longitudinal splits appear or fruiting pustules develop in the bark fissures. (Fig. 1)

Description of the Disease:—The fungus responsible for the blight enters the trunk or branches through a dead branch, a broken branch stub, or through dead or dying areas resulting, e. g., from winter injury. Living and growing in the bark, the fungous mycelium gradually extends the radius of its operations until the branch or trunk becomes girdled. Then, or before, spores are produced in tiny pustules breaking through the surface of the bark. The spores are of two kinds: (1) conidia, tiny one-celled spores produced in enormous numbers, in moist weather oozing forth from the pustules and cemented together in long, thread-like formation, and (2) ascospores, 2-celled spores which are ejected forcibly from their spore-cases into the air from the pustules. Both kinds of spores are capable of reproducing the disease when carried to a suitable host, or to another part of the same host.

Extent of Damage:—Without doubt this causal fungus has proved to be the most destructive fungous parasite on forest trees that we have thus far known in this country. From an economic standpoint the chestnut was one of our most valuable timber trees; prized for its tall, straight, durable timber, its ease of coppicing, its bark used in tanning leather, its edible sweet nuts, and its beauty and dignity as an ornamental tree. At the present time all marketable chestnut within the natural range of the tree has been virtually killed out. No definite figure or the amount of loss sustained can be given, but it must run into many millions - perhaps billions - of dollars.

Blight Resistance:—Certain of the oriental species of chestnut, e.g. *Castanea crenata*, the Japanese, and *C. mollissima*, the Hairy Chinese chestnut, offer varying degrees of resistance to the attack of the fungous parasite.

Unfortunately these species are comparatively low-growing trees and can therefore not replace the American chestnut as timber-producing trees. For many years the Division of Forest Pathology, U.S.D.A., and more recently the Brooklyn Botanic Garden, have been breeding these resistant orientals with the native American species in the hope of developing a disease-resistant stock of tall timber quality suitable for replacing the American species. To date more than 30 hybrid chestnut types, new to science, have been developed, from some of which, by further breeding, it is probable that types desirable for reforestation can be produced. The experimental plantation of the Brooklyn Botanic Garden is located at the eastern end of the Sleeping Giant Mountain, in Hamden, Connecticut, about 10 miles north of New Haven. At present more than 750 young trees are growing there: more than 250 of these are hybrids, the rest are distributed among various species and varieties from Asia, Europe, and Eastern North America.



Drawn by Miss Maud H. Purdy, Staff Artist, Brooklyn Botanic Gardens.

Fig. 2—Diagram of stages of growth and development of basal shoots from blighted chestnut trees

Basal shoots:—Throughout the range of the chestnut young shoots are continually arising from the base of diseased trees or stumps, to such an extent as to produce a widespread belief that the chestnut is "coming back". The key to this situation is the fact that the roots are more resistant to the attack of the fungus than the trunk or branches. When the tree dies down to the ground, adventitious buds at the root collar produce new shoots which utilize the main root of the old tree, usually still healthy in certain parts, for their support from the soil. Soon, however, they develop their own roots, while in the meantime, the disease progresses further down into the roots of the old tree. For, although the roots are more resistant to the disease, they are not immune. The fungus does advance into them, but it advances more slowly. Eventually, therefore, the fungus penetrates into the adventitious shoot from the old diseased "mother" tree. But, meanwhile, one or more of the shoots may have lived 4, 5, or 6 or even more years, and, possessing at the start the roots of the mother tree, their growth may be remarkably vigorous. When the fungus finally advances into one of these adventitious shoots, the same thing happens (on a smaller scale) which occurred before, i. e., one or more new shoots arise at the base of the old adventitious shoot, below the lesion. I have seen as many as four generations of such shoots, and in all probability, more can be found in some cases. Eventually, however, as far as our experience goes at present, the whole clump dies out entirely. (Fig. 2.)

There are several important considerations resulting from this situation:

1. The continued development of these shoots gives the fungus a continual fresh supply of food. As a result the fungus is kept *alive and vigorous.* A fresh supply of chestnut means prolonged life for the fungus, which can live only on chestnut. Rarely it occurs as a weak parasite on oak.

2. The fact that the shoots often live long enough to *bear nuts* means that the chestnut will not be lost as a species, at least not for some time to come. What has happened, so far, is that it has been degraded from the position of a forest tree to that of a lowly forest shrub.

3. The rapid multiplication of these basal shoots all over the natural range of the chestnut offers chances for *bud variation* or "bud sporting", in the direction of blight resistance, so that the types of chestnut which are more resistant may develop in the future.

Outlook for the future:—In recent years the basal shoots seem to live longer and get larger. This may be due to the fact that fewer spores of the fungus are now abroad for infection. It also may be due to a slow process of bud variation and natural selection; for, although 25 or 30 or even 40 years is a very small amount of time when compared with all biological history, yet it may be long enough for us to perceive an appreciable effect.

We should also bear in mind that a possibility of variation exists in the fungus itself. It may become less virulent as time goes on.

What can be done to help:—For these reasons it is of the utmost importance for us to be continually on the lookout for vigorous and *long-lived* shoots. All nuts from such growth should be carefully collected and planted and the succeeding generation or generations watched. Any nuts sent to the Brooklyn Botanic Garden will be carefully planted and the resulting trees labelled with the name of the finder and the locality. We already have 76 such trees, from nuts coming from locations ranging from Asheville, North Carolina, to Portland, Maine. The nuts should not be allowed to become dry before mailing. A few days in a heated room are apt to be fatal. They should be wrapped in moist cotton, paper napkins, or moss, immediately after gathering, and mailed to the Brooklyn Botanic Garden, 1000 Washington Avenue, Brooklyn, N. Y.

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Diseases of the Chestnut and Poplar

in Europe

OEEC

Published by
the Organisation for European Economic Co-operation
Paris

Diseases of the Chestnut and Poplar

in Europe

Published by
the Organisation for European Economic Co-operation
Paris 1952

The Organisation for European Economic Co-operation (O.E.E.C.) was constituted in Paris on 16th April, 1948. Its members are Austria, Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Portugal, Sweden, Switzerland, Trieste, Turkey, and the United Kingdom. The United States and Canada, although not members of the Organisation, participate in its work. At O.E.E.C.'s headquarters at the Château de la Muette, Paris, representatives of each of these countries meet to discuss their economic problems and to work out a common plan of action. It has been through O.E.E.C. that the national recovery programmes of the Member countries have been co-ordinated so as to ensure the most effective use of American aid. Among the measures that European countries have agreed in O.E.E.C. to adopt, have been the liberalisation of trade and payments and the setting up of a European Payments Union.

DISEASES OF THE CHESTNUT AND POPLAR IN EUROPE

REPORT BY G.F. GRAVATT

1. The Council decided [C(50)150(Final)] to propose that arrangements be made, under the Technical Assistance Scheme, for an American Expert to visit Europe and to study and suggest remedies for certain diseases of [the] chestnut and poplar.

2. The services of the E.C.A. agreed to this proposal and G.F.Gravatt, Senior Pathologist Plant Industry Station of Belstville (Maryland), made a study visit to Europe in the summer of 1950, from July to September.

In the course of his journey Mr. Gravatt visited eight Member countries: France, Greece, Italy, the Netherlands, Portugal, Switzerland, Turkey and the United Kingdom.

3. This paper constitutes Mr. Gravatt's report, and embodies his own views for which neither the O.E.E.C. nor any Member country assumes responsibility.

Paris, 9th February 1952

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I

BLIGHT OF CHESTNUT AND THREE EUROPEAN OAKS

A. INTRODUCTION

1. Chestnut blight, caused by the fungus *Endothia parasitica*, is a disease of Asiatic origin. This disease was first reported at New York City in the United States of America in 1904. It spread rapidly through the abundant native American chestnut stands and has now destroyed all chestnut timber in a vast area extinding from Canada to the Gulf of Mexico. The chestnut blight fungus is also seriously attacking and killing many trees of one important American oak, the post oak, *Quercus stellata.*

2. In Europe, chestnut blight is now widely distributed in Italy and is also present in Tessin Province, Switzerland. The disease is rapidly killing European chestnut in the affected areas and is spreading into new areas. In Italy, the blight is also killing some trees of *Quercus pubescens* and is attacking trees of *Q. sessiliflora* and *Q. ilex.* How soon the disease will spread into and kill the chestnut growth in other countries and damage the oaks is difficult to forecast. Its spread may be very materially delayed by quarantines and eradication of advance infections. Complete destruction of the chestnut and damage to the oaks can be expected in each country where the disease becomes established. As the chestnut and affected oaks play an important part in the forest and food economy of many European countries, the situation is very serious.

3. Because I had had many years of experience with chestnut blight in the United States, the Office of European Economic Co-operation made arrangements for me to spend several months in the late summer and fall of 1950 visiting six European countries and Turkey, advising on the chestnut blight problem. Conferences were

held with local people having an interest in this problem, and field examinations were made in the more important places where chestnut work was in progress. Many persons helped in my work but space permits mention of only a few of them : Prof. A. Pavari, Dr. A. Biraghi, and Mr. Walter J. Quick, Jr. in Italy; Dr. Emil Hess and Dr. E. Gaumann in Switzerland; Mr. A. Chistodoulopoulos and Dr. C. Moulopoulos in Greece; Mr. Admed Berger and Dr. Refik Erdman in Turkey; Mr. Felipe J.M. Frazao and Dr. B. d'Oliveira in Portugal; Dr. C. Schad and Dr. H. Darpoux in France; and Dr. T.R. Peace in England. The local Economic Co-operation Administration officials and the Agricultural Attaches in the different countries assisted in this project. Two unofficial trips were made into Spain to look into the threatening blight situation there. Dr. Miguel Ganuza and Mr. Elorrieta were very helpful on these trips.

B. IMPORTANCE OF NATIVE CHESTNUT AND OAKS IN EUROPE

4. Chestnut is unique in its yield of valuable food from rough land unsuited for cultivation. Maximum food production is vital to Europe with its rapidly expanding population. Even if the maximum volume of food is produced per acre, the total will be insufficient to meet the pressing needs. The regularity of the chestnut crop year after year is unusual among trees. In addition to producing nuts, chestnut orchards usually are grazed. The dead branches are used for firewood and the older orchard trees, when they become unproductive or die, are used for fence posts, firewood, and tannin extract. Italy, for instance has 31 chestnut extract plants, producing most of the tannin used for making leather in that country. Europe should grow more chestnuts, not lose all that it has.

5. European chestnut is valuable as a forest tree, especially when managed on a short coppice rotation. The high yield of valuable products, such as stakes, durable posts, handle and box stock, and basked material, makes the chestnut one of the most useful of forest trees. The older forest chestnut trees are useful for poles, lumber and extract wood. Many mountain communities depend on chestnut nuts and forest products for over three-fourths of their economy, and the death of the chestnut will create many major problems.

6. In Italy, three European species of oak, *Quercus sessiliflora*, *Q. pubescens*, and *Q. ilex*, have been found infected by blight but how seriously they will be damaged cannot be forecast with any

degree of definiteness. The combined ranges of these oaks extend over a vast area in Europe and Asia Minor, from England and Portugal east into Russia and into Turkey. In most of these countries, these oaks are more important than chestnut. The fuel, lumber, and mast for animal feed that they supply are very vital to families in many areas. In many cases one or more of the affected oaks are mixed with other tree species that will take over the land if the blight should prove to be serious, but in other cases they grow in more or less pure stands and therefore the replacement situation is more serious. In some cases the land will become poorer, because it will revert to over-grazed pastures.

C. THE BLIGHT ON CHESTNUTS

7. Chestnut blight was reported in the vicinity of Genoa, Italy, by Professor Paoli in 1938. It had undoubtedly been present there for a number of years. Serious infections near Udine in northeast Italy in 1940 and severe infections near Avellino in the southern part in 1943 indicate a rather wide distribution some 10 years ago. The blight has increased steadily each year, extending into additional territory. The disease is also spreading rapidly in Tessin Province, Switzerland.

8. Wherever I examined infected chestnut growth in Italy and Switzerland, I noted that the cankers indicated that the disease was steadily and rapidly increasing. There was very little indication of more resistance in European chestnut than one sees in American chestnut. The reports of Dr. A. Biraghi as to the condition of these stands in 1949 indicated rapid increase of the disease. The degree of infection in some of the coppice growth varied considerably, but in general infection was less heavy than one would expect in comparable American chestnut coppice. The possibility of utilizing infected and dead coppice shoots as thinnings, and so of bringing part of the stand through to a profitable age, does not look promising, but further observations are needed.

9. Presumably the chestnut blight infection that I examined near Bilbao, Spain, on Asiatic chestnuts has now been eradicated by the Spanish authorities. These Japanese chestnuts were more severely affected by the blight than they are in the United States, but strains of Japanese chestnut vary considerably in susceptibility. Fortunately, no stands of European chestnuts were growing near the infected Asiatic chestnuts; the one European chestnut noted within

the stand of Asiatic chestnuts was heavily infected in the outer bark.

D. THE BLIGHT ON THREE OAK SPECIES

10. Dr. A. Biraghi, who first reported the blight on oaks in Italy, accompanied me in examining infections on *Quercus pubescens*, and *Q. ilex* near Avellino. The trees of *Q. pubescens* were small standards, 15 to 30 feet tall, left after a coppice cutting. A large proportion of them had the top half or more of the trees killed by the blight and yellow leaves were attached. Cankers with typical mycelial fans and with fruiting bodies on the bark surface were evident. The stand over an area of several acres was being ruined by the blight.

11. Adjoining this stand there was a planting of about 50 trees of *Quercus ilex* remaining in an old abandoned nursery. A number of these trees had the blight growing in the outer bark, without the mycelium penetrating into the cambium region, in very much the same way the blight develops in the outer bark of the Chinese chestnut. It was disturbing, however, to find two *Q. ilex* trees with the blight fungus making extensive growth in the cambium region, with typical fans of mycelium. Further observations are needed under various conditions before definite predictions can be made as to the damage to be expected on this oak, but it is my opinion that it may be quite serious.

12. Several small limbs of *Quercus sessiliflora* were noted as killed by typical blight cankers, with dead leaves attached, at two points in central Italy. Dr. Biraghi had seen a number of cankers on larger stems of this species of oak. What has already been noted makes one fearful of what may happen in some of the extensive stands of this oak, managed on a long rotation under moister climatic conditions.

13. Detailed observations are needed on all three of these important oaks as a basis for more accurate forecasts of what to expect on them in the future. Plants of these three oaks from other countries can be sent to Italy or Switzerland where it can be determined how susceptible the strains are to blight. However, inoculations on small stems are often unsatisfactory.

14. A number of trees of *Quercus pedunculata* were examined in the vicinity of blight-infected chestnuts but no blight was noted.

It is very disturbing to find that three of the first four European oaks exposed to blight are somewhat susceptible, as the implications are that other species will be found susceptible.

E. SYMPTOMS OF THE BLIGHT

15. The first apparent symptom of the blight on chestnut is the dying of a limb or a part of the tree. Sometimes the entire tree may be affected. During the growing season, the leaves of the affected part turn yellow and brown and usually hang on tenaciously. If the killing of the part takes place during the late fall or winter, the affected part, or the intire tree, may not leaf out in the spring. The girdling or death of the part is brought about by the growth of the blight fungus in the bark and outer layers of the wood. If one cuts into an infected area, he will note fans of buff to whitish mycelium in the bark. These fans of mycelium are very characteristic of the chestnut blight fungus and are helpful in distinguishing blight from other causes of death. On the surface of the bark, there are produced small reddish-bronze fruiting bodies, usually about the size of a pinhead. Two forms of spores are produced in these fruiting bodies.

16. One characteristic feature of blight infections on chestnut is the abundant sprouts that usually are present below a girdled canker or when the entire tree is killed at ground level.

17. A number of European countries have published circulars or bulletins describing blight, and these can be referred to for more detailed description of the disease.

Symptoms of blight on oaks are discussed on page 12.

F. DISTINGUISHING CHESTNUT BLIGHT FROM INK DISEASE

18. Over 100 years ago a destructive introduced root disease was reported as causing losses of chestnut in Portugal and Spain. Now this disease, known as the ink disease, has spread through many parts of the chestnut growth in the Mediterranean countries; in the last 50 years, in many areas, it has killed a large proportion of the chestnut trees, particularly those growing at the lower elevations. It is caused by two fungi, *Phytophthora cinnamomi* and *P. cambivora*, which kill the roots. I examined stands of trees infected with this ink disease in a number of countries and noted that actual damage now being caused is small as compared with the destruction being caused by chestnut blight in Italy.

19. From a distance, ink disease and blight are sometimes difficult to distinguish, but on close inspection the infected trees are easy to differentiate. Entire trees may be killed by both diseases, but trees killed by the ink disease do not normally produce sprouts from the base while those killed by chestnut blight nearly always sprout vigorously. On examining the bases of trees affected with blight, one will find white- to buff-colored mycelial fans in the bark; these are lacking in trees affected with ink disease. Trees that are weakened by ink disease, sometimes with limbs killed, turn brown and look as though they were infected with the blight, but closer examination of the bark will reveal which of the two diseases is present.

G. MEANS OF SPREAD OF THE BLIGHT FUNGUS

20. Detailed studies in the United States indicate that there are various ways in which the blight may be spread. These same means of spread undoubtedly are operating in Europe.

21. The blight fungus is well equipped for local spread. In moist weather spores of one kind ooze out of infected trees in small yellowish-buff tendrils ; these are sticky and can be carried easily to other trees by squirrels, birds, insects, knives, and other means. Spores of the other kind are shot into the air and are carried by wind. Usually both kinds of spores are produced in abundance, but a spore must be deposited in a wound or break in the bark of a chestnut or susceptible oak before it can cause infection.

22. Shipment of infected nursery stock is the most important means of long-distance spread of the blight. In the United States, infected nursery stock shipped from Pennsylvania to Oregon resulted in a spot infection over 2000 miles from the original infection. Planting of infected nursery plants resulted in numerous advance spot infections in the Eastern States, far ahead of the main line of advance of the disease. The disease increased in the native chestnut growth around these advance spot infections that resulted from infected nursery shipments, and so the time of death of the stand in those sections was years ahead of what it would have been if they had been killed by blight that spread naturally. Early stages of blight infections cannot always be detected by inspection of nursery stock. This also applies to infected scion wood, but the danger in the latter case is much less.

23. The blight organism attacks the nuts of American chestnut and eastern American chinkapins very readily. In one test, nearly a third of the nuts were infected. The only known blight infection so far reported in the State of Washington, on the Pacific Coast, was presumably the result of planting infected American chestnut seed.

24. The Spanish authorities indicate that the blight was introduced direct from Japan to Bilbao, Spain, on Japanese chestnuts. We have made many fungus isolations from Japanese and Chinese seeds shipped from Asia to the United States but have not isolated the blight fungus in a single case. Blight is present in many plantings or orchards in Asia, but it is not so prevalent as in American or European infected areas.

25. We have not conducted any isolation work with nuts of the European chestnut. Dr. A. Biraghi, of Italy, stated that he had not found the blight fungus on such nuts and that if it should occur he did not think that it would survive the treatments given most of the nuts going into the export trade. Opinions differ as to the probability of the blight being carried on nuts of the European chestnuts and experimental data on this subject are not available.

26. In the United States, we found that infected bark fell to the floor of railroad freight cars used for hauling blighted extract wood. If the next load of freight happened to be rough material not requiring sweeping of the car, the infected bark might be carried a thousand miles before it was swept out along the railroad tracks, where it may become moist and produce spores, possibly resulting in an advance spot infection.

27. Chestnut and oak wood used for boxes and staves in Europe sometimes have a little bark left attached. If the boards are from infected trees, the fungus in the bark and wood remains alive for months, and if the material becomes moist spores may be produced. There is also the possibility of the fungus being carried in the chestnut and oak sapwood without bark. The sticky spore stage is the only one found on wood. This stage was noted on sapwood of cut chestnut stumps in Italy. The probability of a piece of infected crating wood being left on the ground, where spores would be produced, and of these in turn producing infections on living trees is small, however.

28. There is much greater possibility of spreading the blight from logs, poles, piling, mine props, and railroad ties of chestnut and oak. Small pieces of the inner bark are sometimes left attached, and

the blight fungus will fruit more readily on such material than on wood. Fans of blight mycelium sometimes can be seen on such shipped material.

29. In considering the question of preventing or retarding the spread of the blight over Europe and the relative danger of different means of spread, one must realize that the means of long-distance spread in many cases are not known. Three introductions of the blight into Europe are known. The first infection, reported in 1923 in a botanical garden in Belgium, was stopped by its removal. The second, reported at Genoa in 1938, origin unknown, was widely distributed when found. It may have come in on Japanese chestnuts or on some shipment of wood products from the United States. The third, near Bilbao, Spain, resulted from importation of chestnut seed direct from Japan.

H. BLIGHT-RESISTANT EUROPEAN CHESTNUTS

30. In my brief examination of infected chestnut stands in Italy and Switzerland, I noticed some trees that were being killed much more slowly than others. However, I noted nothing that gave me any hope that any considerable number of European chestnuts would ultimately escape being killed by the blight. Near Bilbao, Spain, one European chestnut in a blight-infected stand of Asiatic chestnuts had been exposed to the disease for many years and had abundant growth of the fungus in its outer bark without any damage to the cambium region. American chestnuts sometimes reacted in this way but were finally killed by the disease. In the United States, tests of Russian chestnuts from the Caucasus Mountains indicated that they are highly susceptible to blight, just as most other European chestnuts from different countries growing in the United States have been. However, the natural survival of a few European chestnuts in the United States indicates that they are more resistant than the American.

31. Italian authorities have collected many varieties and strains of the European chestnut from different countries, to determine the more resistant ones. The best of these will be valuable for crossing with the best of the Asiatic chestnuts.

I. RESISTANT ASIATIC CHESTNUTS

32. In general Chinese chestnut, *Castanea mollissima*, and Japanese chestnut, *C. crenata*, are very resistant to chestnut

blight; Chinese chestnut as a class in the more resistant and the hardier of the two. Fortunately, these two Asiatic chestnuts are also very resistant to ink disease. Japanese chestnut has been introduced into Europe in many places because of its resistance to root disease. Because of the spread of blight in Europe, these old Japanese chestnut introductions and their hybrids are receiving increased attention, even though Japanese chestnut lacks some of the desirable qualities of European chestnut.

33. It is recommended that each country interested in chestnut make a survey of its introduced Asiatic chestnuts. Arboretums and botanical gardens are easily checked, and usually they have good records as to the source of their plants. Private gardens, estates, and horticulturists sometimes have Asiatic chestnuts unrecorded by chestnut workers. Some of these may be very desirable in a planting of bredding program. Even if they are not growing well, some of their progeny may have more value under different soil and climatic conditions. In a breeding and propagation program, it is quite an advantage to have seed and scion wood easily obtainable.

34. It would be valuable to have records on Asiatic chestnuts of known origin listed for the possible use of European breeders. Collections of the best material of known origin, or of demonstrated outstanding value, should be assembled at several European locations with different climatic conditions.

35. In France there are more old Asiatic chestnuts and their hybrids than in any other European country, and more breeding work has been done there. Most of these Asiatic chestnuts are of the Japanese species. At Brive, France, there is a very fine collection of Asiatic chestnuts, grown from seed that the United States Department of Agriculture Division of Forest Pathology sent to Dr. J. Dufrenoy in the spring of 1929. It is my understanding that the records on these trees have been lost. The material sent to Dr. Dufrenoy included seed from many different parts of Japan and Korea, as well as some from China. It should be valuable for testing under different conditions even though the parentage is unknown. Nuts from this orchard planting will be hybrids between many different strains and selections from different parts of Asia, and among the progeny tested in different parts of Europe there may be some valuable material adapted to local conditions. There are also in France a considerable number of hybrids between European and other Japanese chestnuts. The seedlings of some of these

which I noted growing in two nurseries in Italy were making faster growth than comparable pure European chestnuts. Testing the available seed of these hybrid chestnuts is recommended.

36. Italy has been purchasing chestnut seed, scions, and plants with Economic Co-operation Administration funds handled through the U.S. Division of Forest Pathology, Plant Industry Station, Beltsville, Md. In the fall of 1950, the authorities in Italy estimated that they had growing in their nurseries 100,000 plants of Asiatic chestnuts and hybrids from the United States. These will be tested under various soil and climatic conditions in Italy. Large quantities of seed and plants were sent to Italy again in the spring of 1951. This material is composed of the offspring from many different introductions into the United States and their hybrids from different parts of China, Korea, and Japan. The major portion are pure Chinese chestnuts of various selections because this species has been more resistant to blight, is hardier, and produces a sweeter nut than the Japanese chestnut.

37. There are also some old plantings of the Japanese chestnut in Italy. I examined some 20-year-old plantings that were very promising. Dr. A. Pavari indicated, however, that in Italy many of these plantings have not done as well as the European chestnut.

38. At Bilbao, Spain, I examined plantings of Chinese and Japanese chestnuts. The older ones had made good growth and were doing very well. Chestnut blight was present on some of the Japanese chestnuts, and the Spanish authorities agreed to eradicate all trees that were infected.

39. In Portugal, considerable breeding and selection work has been done with Japanese and hybrid chestnuts resistant to ink disease, and probably many of these selections will be resistant to blight.

J. PROPAGATION OF ASIATIC CHESTNUTS

40. Grafting, budding, and topworking of Asiatic chestnuts and their hybrids by the usual horticultural methods are being done in various countries. It is known that certain selections or varieties are much easier to graft and bud than others and that certain rootstocks are better than others. There have been some failures of graft unions from what seems like uncongeniality. The general recommendation is made that a variety or clone be grafted or budded on seedlings of the same variety or clone.

41. In Portugal and France, a method of placing a wire around young coppice shoots in the early part of the season and of mounding earth and humus material around the shoots has given good rooting by fall. Propagation by leaf bud cuttings under continuous mist has given very limited success in the United States and is being further tested. Extensive tests of propagation of Asiatic chestnuts by root and twig cuttings have in general resulted in failure even when various root-inducing chemicals are used.

42. One of the most rapid methods of increasing a variety or clone, now in use in Italy and elsewhere, is to top work Asiatic chestnut on vigorously growing European chestnuts 2 or 3 inches in diameter. Frequently a very large quantity of the Asiatic chestnut or its hybrid is produced in one year of growth. Of course, in an area where blight is present, the disease has a tendency to develop very quickly in the wounds. In fact, in all nursery operations it is necessary to take precautions against the blight organism getting into wounds, because even with resistant selections the fungus will frequently kill the material before the scion starts to grow.

43. In Italy, limited success has been obtained by grafting scions of Asiatic chestnut on European chestnuts cut off at or near the ground level. Precautions are taken to prevent the blight getting into the scions or stock in the operations, and then the earth is mounded up around the base of stock plants. In nature, chestnut blight usually extends only a short distance below the ground level. If the roots of susceptible trees are exposed to light by erosion, the blight will develop on them abundantly.

44. Some methods of chestnut propagation are briefly mentioned because it is felt that the subject should receive further attention from the various countries interested in growing Asiatic chestnuts. There are a sufficient number of individuals interested in Asiatic chestnut propagation to work out in detail the very best methods of handling these chestnuts under different conditions.

45. However, to secure this desirable result it is necessary that experiments be more carefully planned and that better records be kept on the stock and scion material and the various conditions of the experiment. It is very important that the best clones or horticultural varieties of Asiatic chestnuts and their hybrids, as developed in Europe, be adequately tested in carefully planned experiments so that all countries concerned can benefit more from the respective work done in the different countries. Planning and

correlating the experimental work on chestnut propagation and breeding will probably be considered at the October 1951 International Chestnut Meeting.

K. PROBABLE FUTURE SPREAD OF THE BLIGHT

46. One factor influencing the thinking of the governmental authorities responsible for the protection of chestnut and oak growth is how soon the disease is going to reach their trees by natural spread. There are many elements of uncertainty in attempting to make such a forecast. From the spread that has taken place already, it is to be expected that blight will continue to spread fairly rapidly over contiguous chestnut growth in Italy and Switzerland. How fast it will spread around the southern edge of the Alps into the southeastern corner of France is somewhat questionnable, because, while chestnut is not very prevalent in some of these areas, there are extensive stands of some of the susceptible oaks running up over the rough mountainous areas at the lower elevations. It is predicted that the spread of the blight through oak stands without chestnut will be at a very much slower rate than through the European chestnut stands. In the United States blight has made very slow progress in spreading through chestnut oak stands away from the original native chestnut stands. The affected oaks in Europe seem to produce more spores than the affected oak in the United States, but further studies on the disease on the different oaks in Italy are needed.

47. From experience in the United States, it is to be expected that if the first spot infections of the blight are not already present in France, Austria, and Yugoslavia and the Lake Geneva region in Switzerland, they will soon be showing up. The blight may already have been spread to the islands of Sicily, Sardinia and Corsica by migrating birds or by transportation of the disease in other ways. But it may be some years before the first infections appear there.

48. It is hoped that the Spanish authorities will continue their efforts for complete eradication of the chestnut blight near Bilbao and that also they will do inspection work in the European chestnut growth for many miles around these spot infections. Thorough and continuing work over a number of years will probably be necessary to eradicate these infections. If the chestnut blight should escape from these Asiatic chestnuts into the stands of native chestnut and oaks, the time of death of the chestnut stands and heavy

damage to the susceptible oaks in Spain, Portugal, and the western half of France may be very materially hastened.

49. Chestnut blight can be kept under control in small isolated orchards of European chestnut under conditions such as exist in the central part of California, U.S.A. There is an extensive European chestnut orchard established there, and in 1934 the blight was found in several of the orchards. Immediate steps were taken for inspection and eradication of the infected trees, and though the blight still continues to appear there each year on a limited number of trees, it has been kept under control. It is difficult to find all of the new infections before they have time to produce spores and cause additional infections. The chestnut orchards in California are growing in an area of low rainfall and are mostly irrigated, producing heavy yields of nuts.

50. The chestnut blight infections in the states of Oregon and Washington were eradicated and no additional infections have been reported in these two States in recent years. These trees were growing in areas with heavier rainfall under quite different climatic conditions from those in California where European chestnuts are growing. A number of advance spot infections of the chestnut blight were successfully eradicated in native American chestnut growth in eastern United States but very thorough and careful work is required to eradicate and control such infections.

51. From experience with conditions in the United States, it is thought that small spot infections which appear long distances ahead of the main areas of spread of the disease can be successfully eradicated or kept under control. It is also possible to cut out and treat individual infections on the trunks of the trees and in this way save the trees.

52. Extensive studies on the spread of the chestnut blight into new territory have shown that spot infections occur long distances ahead of the main infection sometimes as much as 100 to 500 miles. The disease spreads around these spots in all directions. It may be 10 to 20 years before the main heavy infections of blight the blight has advanced into the territory where the spot infections have been steadily enlarging. We know that by eradicating these early spot infections progress of the disease over a watershed, valley, or other area can be greatly delayed, even though ultimately the blight is going to sweep over such areas.

L. SUMMARY OF RECOMMENDATIONS

53. Each country should estimate the annual value of the chestnut in comparison with the probable annual value of the replacement growth on the land when chestnut is gone. Estimating the damage to be expected on the oaks is very difficult. The annual loss from death of chestnut, with some addition for oak damage, gives some basis for determining what steps are justified in delaying spread of the disease. It also gives a basis for determining the extent of the effort to be put on development of blight-resistant chestnuts and replacement of European chestnuts with them.

54. The prompt development of extensive experimental plantings of blight-resistant chestnuts as a source of seed and scion material is recommended for all countries that expect to do something about the problem of replacing their present chestnut growth. Determining the best types for various regional growth conditions and having at hand a source of seed mother plants in advance for the larger replanting job that is coming later are needed.

II

THE DANGER OF SPREADING DISEASES ON POPLAR CUTTINGS

55. During my visit to Europe under the auspices of the Organisation for European Economic Co-operation to investigate chestnut blight on European chestnuts and oaks, field observations were also made in different countries on diseases on poplars. Poplar diseases were discussed with various European pathologists, foresters, and growers. In general, there seemed to be a lack of appreciation of the destructiveness of the various poplar diseases, though, of course, many people recognised the danger and were taking precautions to lessen the risk of bringing in new diseases on poplar cuttings. The widespread exchange of cuttings from country to country, in some cases in large numbers, and particularly the shipment of cuttings by the thousands from one continent to another, may result in heavy losses from introduced diseases. Once a disease becomes widespread in an area, it is usually there forever, plaguing future tree breeders and foresters. In some areas breeding disease-resistant poplars may soon be as difficult as breeding resistant tomatoes in Florida, where there are nine different diseases for which resistance in tomatoes must be combined. In Europe, the forest tree disease problem is further complicated by the ease of natural spread of many diseases from country to country; therefore the efforts of many countries to keep a particular disease from other continents from becoming established are nullified by lack of proper quarantine restrictions in some one country.

56. Melampsora rusts were noted in European countries on plantings from which propagating material was distributed. These rusts are widespread around the world, but there are different

species, strains, and even hybrids, according to the studies of Dr. Ir. H. van Vloten*. Some of the American Melampsoras are different from those in Europe. Some poplar species and hybrids are much more susceptible to certain rusts than other poplars; in fact, some poplars are so susceptible that their growth is greatly reduced and they are valueless for planting.

57. European bacterial canker was noted in some nurseries and plantings from which cuttings had been distributed. *Populus* species and hybrids vary in susceptibility to this disease, some being highly susceptible. This disease is not known in America.

58. In Italy, there is a new canker disease of poplars, and according to discussions with Dr. G. Scaramuzzi**, there is still considerable doubt about the cause. It threatens to become serious on some poplars.

59. In southern Denmark I examined a forest planting of poplars, perhaps 30 to 40 feet tall, that was being seriously damaged by some disease with which I was not familiar. According to two of the foresters, this disease had only been noted in the last 2 or 3 years in areas where the poplar clone had been growing for many years previously without trouble. My kodachromes showing trees of one poplar clone attacked by this disease, with nearly all of the leaves and small twigs dead and brown in contrast with trees of adjoining clones with all leaves a healthy green, are quite striking.

60. In Holland, Dr. van Vloten and I found the Septotinia leaf blotch in a poplar planting, the first report for Holland. The determination of the fungus was made by Alma Waterman and Edith K. Cash***, who recently published on this leaf blotch of many kinds of poplars. This leaf disease was first reported from Latvia in 1932 and it is thought the few infections in the United States are from an introduction from Europe. The conspicuous white fruiting bodies on the leaves make the disease one that is easily detected

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* Dr. Ir. H. van Vloten. Crossing experiments with strains of Melampsora larici-populina Klebahn. Overdruk uit het "Tijdschrift over Plantenziekten," 55 : 196-209. 1949.

** Baldacci, E., R. Ciferri, M. Orsenigo, and G. Scaramuzzi. Osservazioni sul "cancro batterico" del pioppo in Lombardia. Notiziario sulle malattie delle piante. Istituto di Patologia Vegetale dell'Universita Milano, via Celoria 2, N. 9, Marzo-Aprile 1950. Pp. 15-25.

*** Waterman, Alma M., and Edith K. Cash. Leaf blotch of poplar caused by a new species of Septotinia. Mycologia XLII (3) : 374-384. May - June, 1950.

when one is looking for it. Dr. H. Johannes* recently reported a very similar disease attributed to a species of *Septogloem* in Germany, except that some of the symptoms are different. The imperfect stage of the *Septotinia* reported by Waterman and Cash** was first described as *Septogloem*. In Germany, the disease, or a combination of diseases, is reported as killing the parent stocks and cuttings to a serious extent in the Helmstedt district of Brunswick. The Septotinia leaf blotch in the United States, and as noted in Holland, is primarily a leaf disease and so far has not been observed as causing any material loss. How it may develop under different conditions and on different hosts remains to be seen.

61. The disease caused by *Dothichiza populea* is serious at times on some poplar species and hybrids both in Europe and North America. It is especially prevalent in the United States as die-back of the very common Lombardy poplar, *P. nigra italica*, and in some localities seems to be the primary factor in reducing the normal life cycle of these trees to a mere 15 or 20 years.

62. The leaf spot and canker caused by the fungus *Septoria musiva**** in North America has not been reported in Europe. I expect it has been introduced into Europe, as thousands of cuttings from infected stands have been shipped to Europe and requests from Europe for more cuttings continue to come to this country. Our quarantine inspectors carefully examine all cuttings before they are shipped, but no one can detect incipient cankers caused by fungi and bacteria, As this Septoria disease is so destructive to some poplar species and hybrids, and has not yet been reported as having become established in Europe, a definite inspection for this specific disease should be made of all poplar plantings grown from imported cuttings from the United States, Canada, and Argentina. If there are only a few infections of this disease established in Europe, it may be possible to eradicate it.

63. Another serious poplar disease of North America, which has not been reported from Europe, is the canker caused by *Hypoxylon pruinatum* on aspens.

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* Johannes, H. Ein Pappelsterben, hervorgerufen durch den Pilz Septogloeum populiperdum sp. n. Nachrbl. dtsch. Pflsch. Dienst (Braunschw.) 2,5, pp. 67-69, 3 figs., 1950 [Rev. Appl. Mycol. 30 (1) : 5-6, Jan. 1951]

** Waterman, Alma M., and Edith K. Cash. Leaf blotch of poplar caused by a new species of Septotinia. Mycologia XLII (3) : 374-384. May-June, 1950.

*** Waterman, Alma M., Canker of hybrid poplar clones in the United States, caused by Septoria musiva. Phytopath. 36 (2) : 148-156. Feb. 1946.

64. There are other diseases of poplars in North America, some of which are of unknown causation, that are not reported from Europe. Little is known about poplar diseases in Asia, but there undoubtedly are many diseases there in the widespread native poplars that have not been introduced into Europe.

65. To what extent poplar diseases are spread by cuttings is not known but as it is difficult or impossible to detect small incipient infections such spread undoubtedly has taken place. Surface treatments with fungicides followed by cutting off and destroying both tips of the cuttings will decrease the risk of importing diseases. Little is known about the effects of fungicides on the growth of cuttings, but a surface washing with water after treatment will decrease the danger of any adverse influence. Particles of leaves that may carry diseases are sometimes found around the buds. As the number of cuttings increases, the danger of disease introduction also increases.

CONCLUSION

66. My conclusion is that European countries should discontinue the widespread introduction of poplar cuttings from other continents before they bring in new diseases that may greatly limit the future development of European poplar culture. In the United States, we now permit the introduction of only a few poplar cuttings of some clone not available in this country, and these few cuttings are grown in posg entry quarantine before being released. Sometimes the introduction of seed will suffice.

67. The present widespread exchange and distribution of cuttings from one European country to another should also receive more attention from pathologists, quarantine officials, and persons interested in the future of poplar culture. Is the risk of bringing in new pests worth the gain ? How can the risk be decreased without interfering too seriously with poplar culture ?

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The Present Status of Screening the American Chestnut for Blight Resistance

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Will chestnut blight, introduced into this country over 60 years ago, wipe out the last remnants of our once prolific American chestnut forests? Will a few scattered trees continue to escape infection, merely because they are not exposed to the disease under the right circumstances? Or will some of those chestnuts that still survive be found to possess inherent resistance to the blight?

These questions have been asked time after time, and a few individuals have not yet given up hope for the discovery of blight-resistant American chestnut trees.

The U. S. Forest Service has received many reports about the existence of large and old American chestnut trees during the past decade. Of special interest are those reported from the Middle Atlantic States, the area in which the blight has been killing chestnut trees for 50 years. The Forest Service would like to know if these old trees are blight-resistant—or if their survival has been due only to chance escape.

Because the reported trees are so widely scattered, it has been necessary to enlist the cooperation of numerous individuals. The owners of chestnut trees have collected herbarium specimens for authentic identification and upon request have forwarded scionwood to be tested for possible genetical resistance to the blight. By making grafts of such material onto Asiatic chestnut rootstock, a rapid test for disease resistance can be obtained. Such tests are more significant when the grafted trees are exposed to natural infection of the blight in a number of scattered localities.

Since the spring of 1954, the U. S. Forest Service at its Laurel Research Center has carried on an intensive testing program in cooperation with the owners of surviving large old trees. The tests have been limited to trees having a trunk diameter greater than 8 inches at 4½ feet from the ground.

Though the Forest Service occasionally receives scions from unusually large old trees located outside the botanical range of our native chestnut, for the most part the only trees tested are those from areas where the blight has destroyed our chestnut forests.

Owners send in 15 to 20 scions from the current year's growth, taken from the ends of sun-exposed branches in mid-February. They label the material as to ownership, tree location and size, and condition of health. The bundle of scions, wrapped in moist newspaper with an outer waterproof covering, is then mailed to the U. S. Forest Service Research Center at Laurel, Maryland.

Cooperators were found who would accept a limited amount of scionwood each spring—in early March—for grafting onto Asiatic chestnut rootstock. About 50 people—in federal, state, and private employment—expressed an interest in doing this work and they now receive propagating material from the trees under test.

Ten scions representing 10 accessions are sent to each cooperator. They report their results in August. Even though many of the cooperators had no previous experience in grafting, their work is the basis for success of the program. The cooperators were given a free hand to use whatever grafting technique and rootstock they chose—except American chestnut rootstock, since it has been found to be too susceptible to blight.

Since the spring of 1954, a total of 146 American chestnut (accessions) trees have been included in screening tests, and a total of 4,950 scions have been distributed to field cooperators (table 1). Each year new

TABLE 1. American chestnut scionwood accessions, screened for blight resistance, 1954–60.

Year	Scionwood accessions received from—		Scions distributed to—	
		No.		*No.*
1954	Md., Mo., Va.	5	Md., Ga., Tenn.	100
1955	Conn., Md., Mass., Mo., Mich., N.Y., Va.	25	Ala., Ark., Ga., Ill., Md., Mich., Mo., Ohio, Pa., S.C., Va., W.Va.	800
1956	Conn., Ill., Ia., Md., Mass., Me., Mo., N.H., Minn., N.Y., Ohio, Pa., Va., W.Va.	47	Ala., Ark., Conn., Del., Ga., Ill., La., Me., Md., Mass., Mich., Miss., Mo., N.H., N.J., N.C., Ohio, Pa., R.I., S.C., Tenn., Texas, Vt., Va., W.Va.	800
1957	Conn., Md., Mass., Mo., N.H., N.J., N.Y., Ohio, Pa., Va., W.Va.	51	Ark., Conn., Del., Ga., Ill., Mass., Md., Mo., N.J., N.H., N.Y., N.C., Ohio, Pa., R.I., S.C., Tenn., Vt., Va., W.Va.	900
1958	Conn., Ind., Ky., Md., N.Y., Ohio, Pa., Vt., Va., W.Va.	35	Ala., Conn., D.C., Ill., Ind., Ky., Md., Mass., N.H., N.J., N.Y., Ohio, Pa., Vt., Va., W.Va.	700
1959	Ind., Md., Me., Mich., Mo., N.Y., Ohio, Pa., Vt., Va., W.Va.	42	Conn., D.C., Ind., Md., Mass., Me., N.H., N.J., N.Y., Ohio, Pa., R.I., Vt., Va., W.Va.	650
1960	Conn., Md., Me., Mich., Mo., Minn., N.Y., Ohio, Pa., S.C., Vt., Va., W.Va., Wis., Nova Scotia, Ontario	49	Conn., D.C., Ind., Ky., La., Me., Mass., Mich., N.H., N.J., N.Y., Ohio, Pa., R.I., Vt., Va., W.Va.	1,000

accessions are included; and each year certain earlier accessions that failed to show promise—either because their grafts blighted during the first growing season, or because of consistently poor results with grafts—are discontinued in the screening test.

Scionwood has been received from the following states: Connecticut, Illinois, Indiana, Iowa, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, South Carolina, Vermont, Virginia, West Virginia, and from Nova Scotia and Ontario, Canada. Well over half of the chestnut trees under test are from five states: Maryland (33), New York (22), Pennsylvania (13), Virginia (11), and West Virginia (14).

Successful unions have been obtained in about 25 percent of the grafts made during the past 7 years. However, some cooperators always report 40 to 60 percent of successful grafts, while others report only 5 to 15 percent of takes. Many of the cooperators have shown definite improvement in the art of grafting.

Factors responsible for failures in grafting are: (1) weak scionwood, i.e., scionwood that is "pithy" and has poorly developed buds; (2) scionwood that has been mishandled, i.e., either too dry or too wet; (3) using dull cutting tools in performing the grafting operation; (4) placing the graft on a suppressed rather than on a dominant branch in the crown; (5) neglect in after-care of the graft, i.e., failing to remove competing rootstock branches near the American graft; and (6) unfavorable climatic conditions immediately following the grafting operation, i.e., a prolonged dry spell.

Factors that contribute to success in grafting are: (1) a razor-keen grafting knife; (2) a tight-fitting surface between scion and rootstock, i.e., to preclude air and/or water; (3) covering the entire scion (bark and buds, as well) with the same water-proof material used to seal the union; (4) using only vigorous undisturbed rootstock, preferably 3- to 4-year-old trees; and lastly, (5) placing the graft in the upper one-third portion of the tree crown, regardless of the size or age of the rootstock.

About 90 percent of all the successful grafts made have died. This does not mean that the screening for blight-resistance is a failure. If only one or two accessions prove to have sufficient resistance to withstand the blight fungus, our efforts will be justified.

Some of the American chestnut grafts succumb to the blight during the first growing season; others succumb during the second, third, or even fourth growing season. But the point is that we still have a few of the original grafts—made in 1954—that are still blight-free. These too, may eventually succumb to the blight; but even if they do, we expect to continue the search for still other heretofore unreported old surviving chestnut trees, and to keep the performance of the rest under constant observation.

Because the number of surviving grafts is so small, we feel that no valid conclusions can be drawn that sufficient resistance is present to warrant their wholesale propagation. Furthermore, when these grafts are much older, we shall test them by artificially inoculating them with the chestnut-blight fungus. The old surviving native chestnut trees, from which the most promising scionwood accessions were obtained, will also be inoculated.

There are still many unanswered questions about the screening studies under way, and the occurrence of these large old surviving chestnut trees in the area swept by the blight: Why, for example, are the largest and oldest American chestnut trees reported from five states —Maryland, New York, Pennsylvania, northern Virginia, and West Virginia? Past experience with other plants would suggest that a resistant sport would be expected to appear anywhere, anytime—but particularly in areas of greatest plant population. In the southern Appalachian region the American chestnut represented one tree in every four as a component in the forest. Yet we have not received any scionwood from large recorded survivors in this general area. There are, of course, still many single trees or groups of old American chestnut trees scattered throughout the Midwestern and Pacific Coast States (planted outside their natural botanical range), but most of these have never been exposed to blight infection.

In summary, nearly 150 American chestnut trees over 8 inches in diameter have been included in our screening program. Most of these have apparently been escapes, since they succumbed to the blight when grafted onto scionwood in other locations. Yet some of the grafts are still living. This gives us hope that there may be genetically resistant trees that survived the original blight. This progress is heartening. It has been made possible through the cooperative efforts of many people who are willing to find these surviving trees and to assist in screening them for blight resistance.