CONNECTICUT

AGRICULTURAL EXPERIMENT STATION

REPORT OF THE BOTANIST

1911 and 1912

G. P. CLINTON, Sc.D.

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PART V.

REPORT OF THE BOTANIST FOR 1911 AND 1912.

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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, *Ræstelia 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 seedbeds. 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 *Rœstelia koreœnsis,* 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 dif-

ferent 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 Swede 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.*

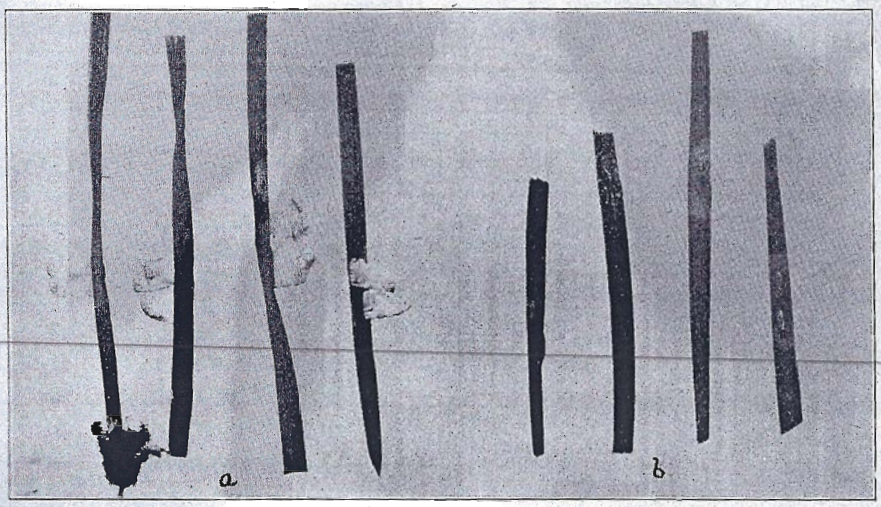
CROWN GALL, *Bacterium tumefaciens* Sm. & Towns. Although we do not find the above host among those mentioned by Smith as infected by the crown gall, yet so far as one can judge from macroscopic examination, it is occasionally infected in this state. Mr. Walden collected specimens in March, 1912, on 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 sepositа* 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.

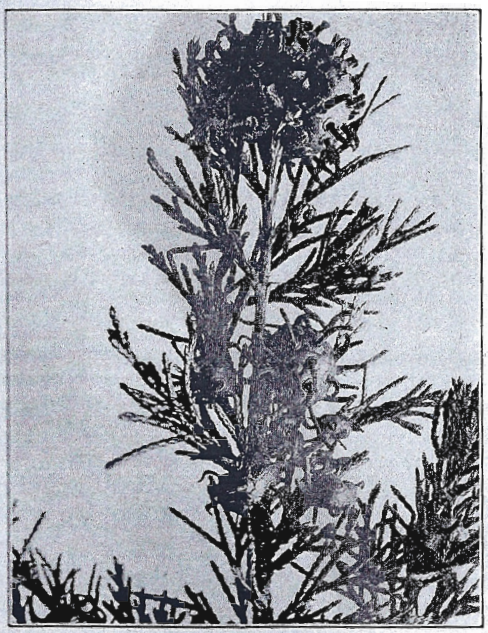
b. White Pine Rust, x 2, p. 347.

c. White Pine Rust, nat. size, p. 347.

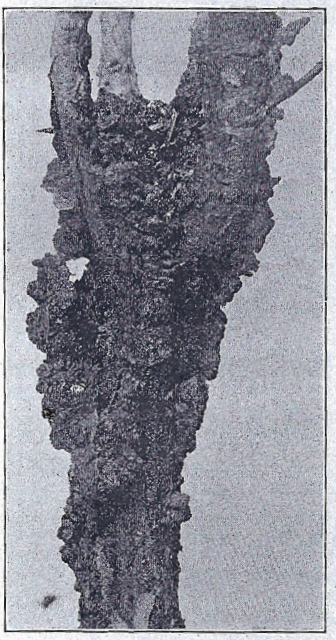
SOME TREE RUSTS.



a–b. Two species of Pine leaf Rusts, x 2–3, p. 352.

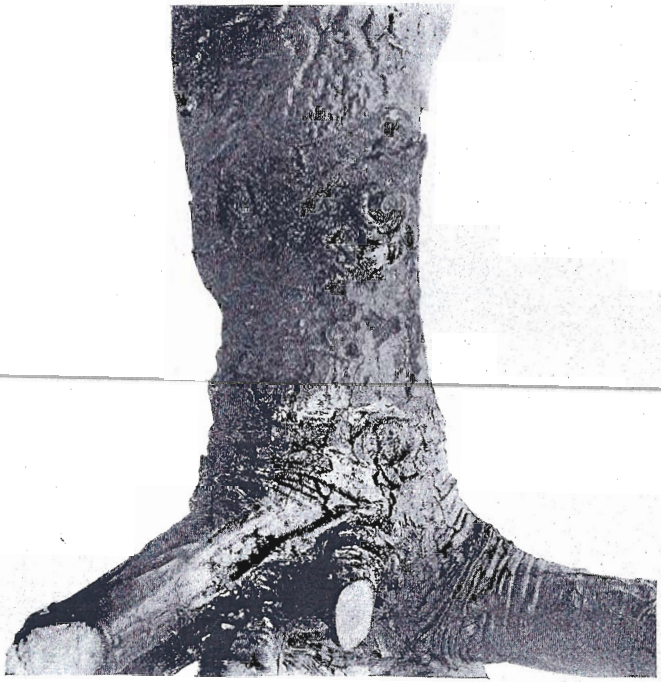


c. Common Cedar Rust, p. 343.

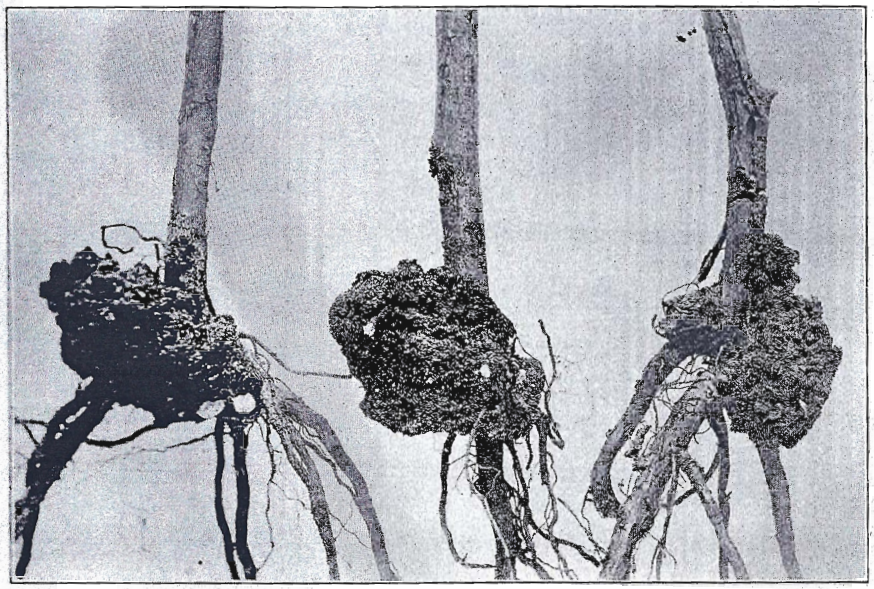


d. Japanese Juniper Rust, p. 350.

SOME TREE RUSTS.

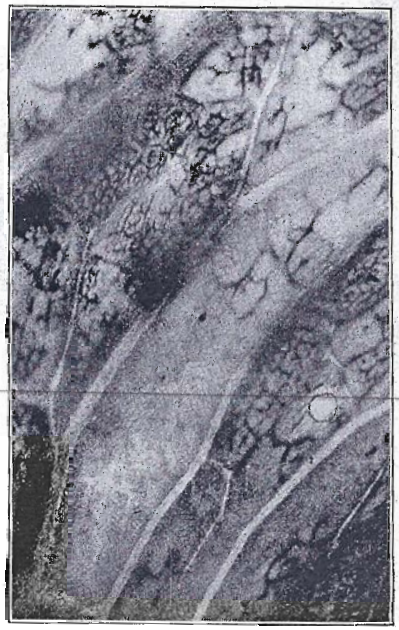


a. Canker of White Pine, p. 354.



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.

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 2.5-4 x 0.75 μ 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 depart-

ments 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 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. 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 sunscorch 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

* 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 Tubercularíae, 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.					Total.		Failed.	
		Good.	Fair.	Poor.	Slight.	Very Slight.	No.	Per cent.	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.

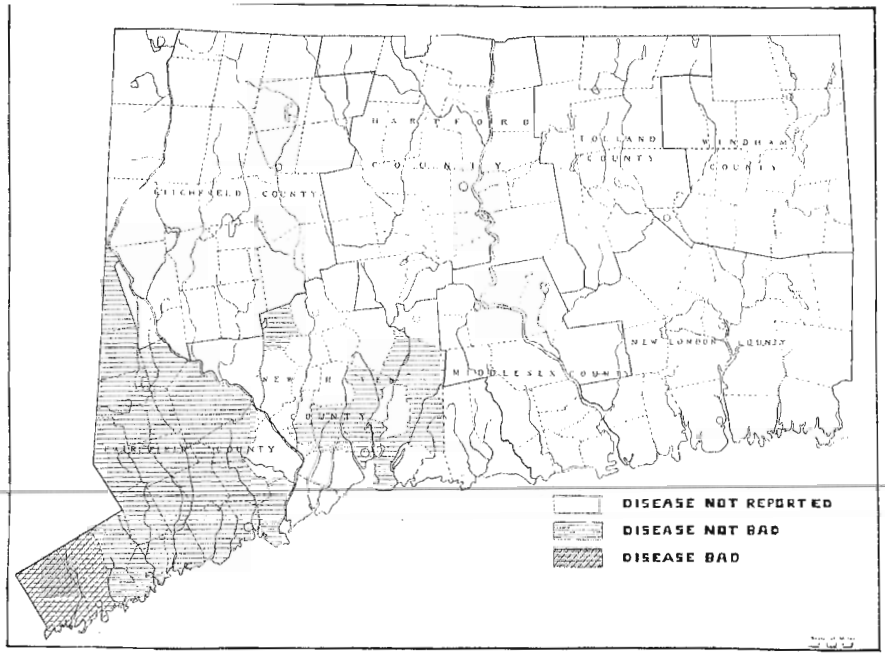
With the check trees the cutting usually killed a little bark on either side, especially if the knife was run under between the bark and the wood. This never grew larger, and the callus of new tissue formed in the wound was always healthy. With

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.

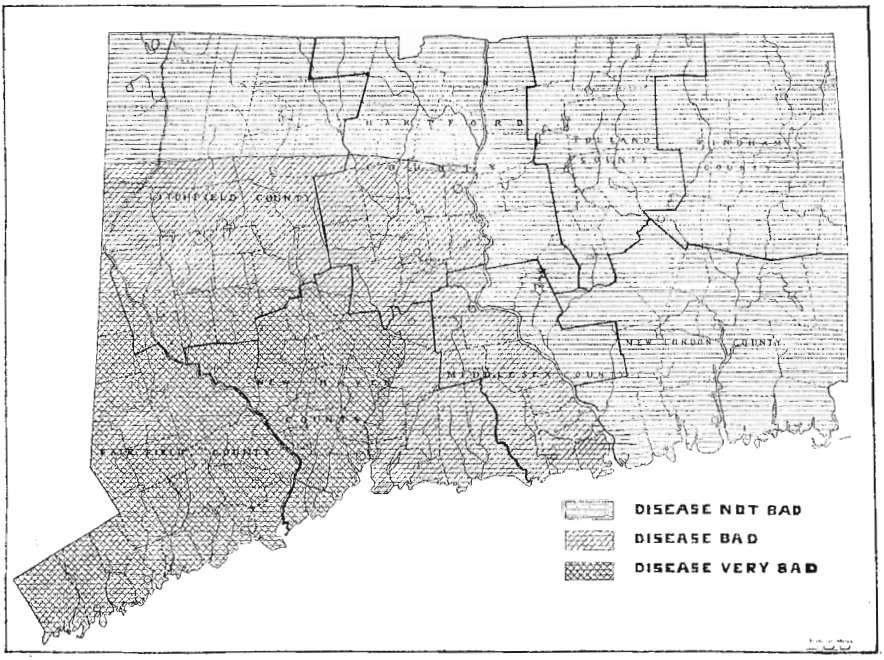
With var. *parasitica,* however, the bark was gradually killed in an increasing area surrounding the point of inoculation, and this had a more or less irregular outline, spreading faster in some directions than in others. Eventually the whole stem or limb was encircled, if the inoculation was made early 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

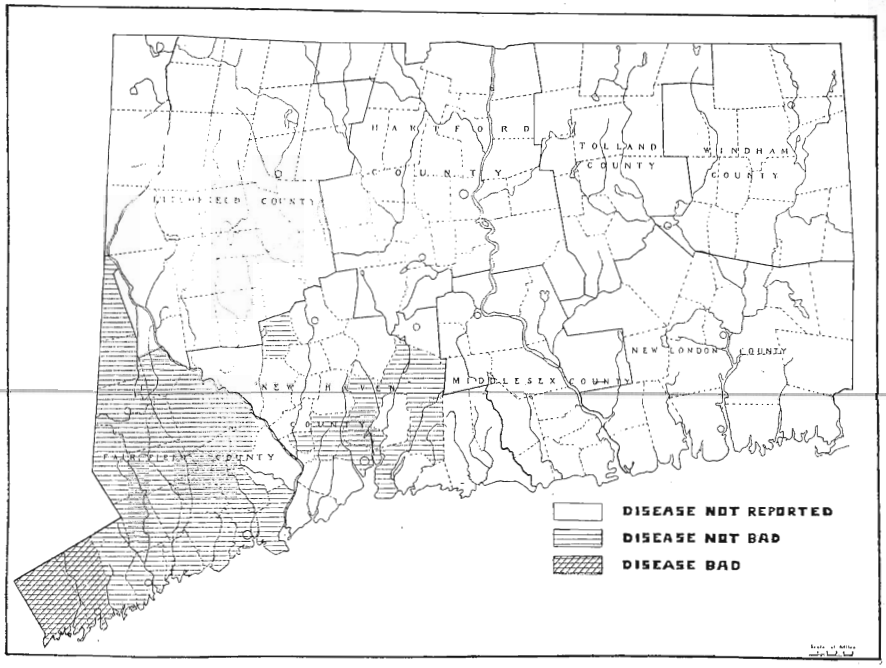


a. Known Distribution of Chestnut Blight in 1908.

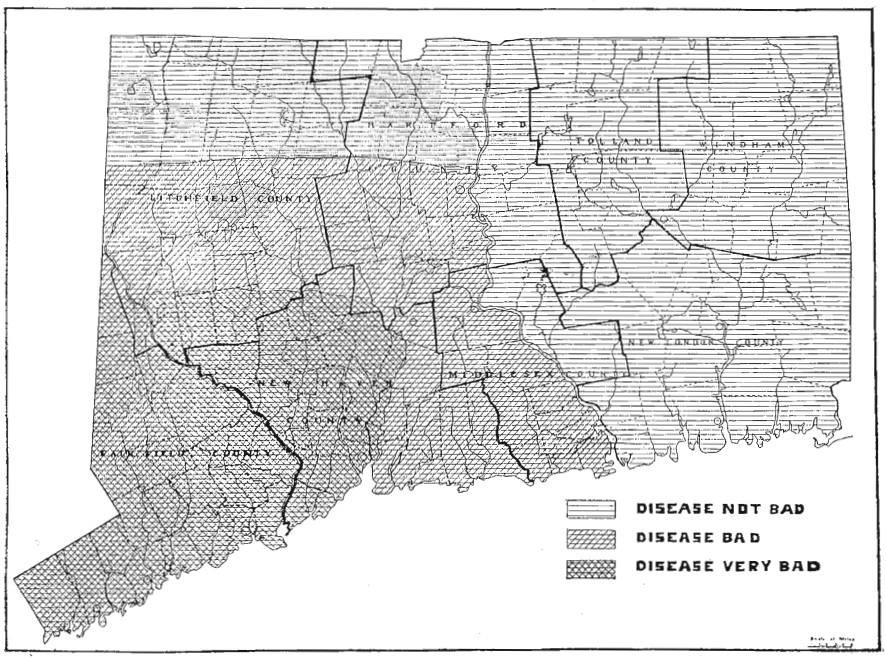


b. Known Distribution of Chestnut Blight in 1912.

DISTRIBUTION OF CHESTNUT BLIGHT IN CONNECTICUT, p. 371.



a. Known Distribution of Chestnut Blight in 1908.



b. Known Distribution of Chestnut Blight in 1912.

DISTRIBUTION OF CHESTNUT BLIGHT IN CONNECTICUT, p. 371.

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

Fungus.	From Host.	Locality.	Culture obtained.	Age of Spores.	Cult. No.	Date Inoc.	Place.	Host Inoc.	Protection.	No. of Inoc.	Failed.		Very doubtful.	Took slightly.	Took well.
											%	No.			
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[a]	Paper	2	100	2	0	0	0
Check	.....	.....	.....	..	.....	June 4	Greenh.	C. dent. sdl. 2[a]	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[3]	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.[3]	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[2]	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-a] 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.

1. **Anderson, P. J. and H. W.** The chestnut blight fungus and a related saprophyte. Phytop. 2: 204-10. O. 1912.
2. **Anderson, P. J. and H. W.** *Endothia virginiana.* Phytop. 2: 261-2. D. 1912.
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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 41st: 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.
21. **Farlow, W. G.** The fungus of the chestnut tree blight. Science 35: 717-22. 10 My. 1912.
22. **Francis, T. E.** Field work of the chestnut tree blight commission. Penn. Chest. Blight Confer.: 233-5. 1912.
23. **Fullerton, H. B.** Chestnut blight. Long Isl. Agron. 5: 9-10. F. 1912.
24. **Fulton, H. R.** Recent notes on the chestnut bark disease. Penn. Chest. Blight Confer.: 48-56. 1912.
25. **Gaskill, A.** The chestnut blight. N. J. For. Pk. Res. 1907: 45-46. 1908. *Ibid.* 1908: 33. 1909. *Ibid.* 1909: 48. 1910. *Ibid.* 1910: 69-70. 1911.
26. **Giddings, N. J.** The chestnut bark disease. W. Virg. Agr. Exp. Stat. Bull. 137: 209-25. Mr. 1912. [Illust.]
27. **Graves, A. H.** The chestnut bark disease in Massachusetts. Phytop. 2: 99. Ap. 1912.
28. **Hodson, E. R.** Extent and importance of the chestnut bark disease. U. S. Dept. Agr. For. Ser. Circ. 21 O. 1908.
29. **Höhnel, Fr. v.** Fragmente zur Mykologie. Sitz. Kais. Akad. d. Wiss. Wien 118[1]: 1479-81. N. 1909.
30. **Manson, M.** The chestnut tree disease. Science 35: 269-70. 16 F. 1912.
31. **Marlatt, C. L.** Pests and parasites. Nat. Geogr. Mag. 1911: 345. Ap. 1911. [Illust.]
32. **Merkel, H. W.** A deadly fungus on the American chestnut. N. Y. Zool. Soc. Rept. 10: 96-103. Ja. 1906.
33. **Metcalf, H.** Immunity of the Japanese chestnut to the bark disease. U. S. Dept. Agr. Bur. Pl. Ind. Bull. 121[6]: 1-4. 10 F. 1908.
34. **Metcalf, H.** Diseases of ornamental trees. U. S. Dept. Agr. Yearbook 1907: 489-90. 1908.
35. **Metcalf, H.** The chestnut bark disease. Journ. Eco. Ent. 5: 222-30. Ap. 1912. [Illust.]
36. **Metcalf, H., and Collins, J. F.** The present status of the chestnut bark disease. U. S. Dept. Agr. Bur. Pl. Ind. Bull. 141[6]: 45-54. 30 Au. 1909.
37. **Metcalf, H., and Collins, J. F.** The chestnut bark disease. Science 31: 749. 13 My. 1910.
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39. **Metcalf, H., and Collins, J. F.** The present known distribution of the chestnut bark disease. Science 35: 421. 15 Mr. 1912.
40. **Mickleborough, J.** The blight on chestnut trees. For. and Irr. 14: 585-8. N. 1908. [Illust.]
41. **Mickleborough, J.** A report on the chestnut tree blight, the fungus *Diaporthe parasitica* Murr. Penn. Dept. For.: 1-16. My. 1909.

42. **Morris, R. T.** Chestnut timber going to waste. Conserv. 15: 226. Ap. 1909.
43. **Morris, R. T.** The Sober chestnut. Conn Farm. 41^{10}: 2. 11 Mr. 1911.
44. **Mowry, J. B.** The chestnut bark disease. Rept. Comm. For. R. I. 6: 30-7. 1912. [Illust.]
45. **Murrill, W. A.** A serious chestnut disease. Journ. N. Y. Bot. Gard. 7: 143-53. Je. 1906. [Illust.]
46. **Murrill, W. A.** Further remarks on a serious chestnut disease. Journ. N. Y. Bot. Gard. 7: 203-11. S. 1906. [Illust.]
47. **Murrill, W. A.** A new chestnut disease. Torreya 6: 186-9. S. 1906. [Illust.]
48. **Murrill, W. A.** Spread of the chestnut disease. Journ. N. Y. Bot. Gard. 9: 23-30. F. 1908. [Illust.]
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52. **Pantanelli, E.** Sul parassitismo di *Diaporthe parasitica* Murr. per il castagno. Rend. Accad. Lincei. s. 5 20^{1}: 366-72. 5 Mr. 1911.
53. **Pantanelli, E.** Su la supposta origine europea del cancro americano del castagno. Rend. Accad. Lincei. s. 5 21, 2, 12: 869-75. D. 1912.
54. **Penn. Blight Comm.** The Penn. Chest. Blight Confer.: 1-253. 1912. [Illust.]
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56. **Penn. Blight Comm.** Treatment of ornamental chestnut trees infected with the blight disease. Penn. Chest. Tree Blight Comm. Bull. 2: 1-7. O. 1912. [Illust.]
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63. **Rumbold, C.** The possibility of a medicinal remedy for chestnut blight. Penn. Chest. Blight Confer.: 57-8. 1912.
64. **Shear, C. L.** The chestnut bark fungus, *Diaporthe parasitica*. Phytop. 2: 88-9. Ap. 1912.
65. **Shear, C. L.** The chestnut blight fungus. Phytop. 2: 211-12. O. 1912.

66. Shear, C. L. *Endothia radicalis* (Schw.). Phytop. 3:61. F. 1913.
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68. Smith, J. R. The menace of the chestnut blight. Outing 1912: 76-83. O. 1912. [Illust.]
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70. Stewart, F. C. Can the chestnut bark disease be controlled? Penn. Chest. Blight Confer.: 40-5. 1912.
71. Stoddard, E. M. The chestnut tree blight. Conn. Farm. 41[25]: 1-2. 24 Je. 1911.
72. Wells, H. E. A report on scout work on the north bench of Bald Eagle mountain, Pa. Penn. Chest. Blight Confer.: 235-41. 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.

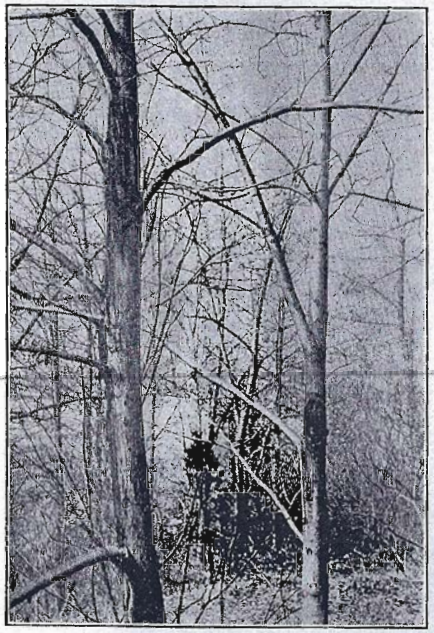
(7) These conditions unfavorable to the host were in part the unusually severe winter of 1903-04, which injured trees in general in the northeastern United States, and after which the blight suddenly made its appearance, and in part the subsequent unfavorable seasons for trees, especially the last four 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.

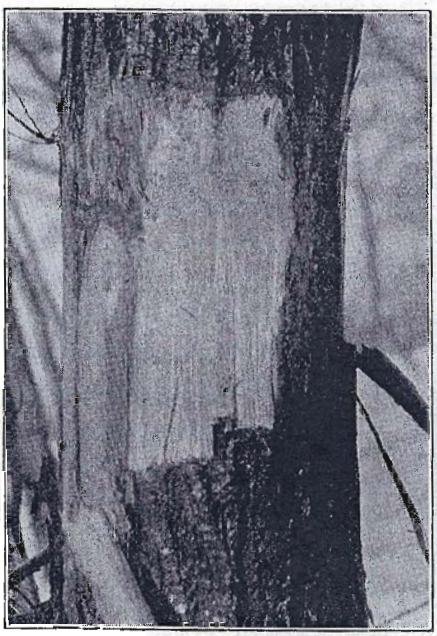
a. Tree with single branch killed, p. 365.

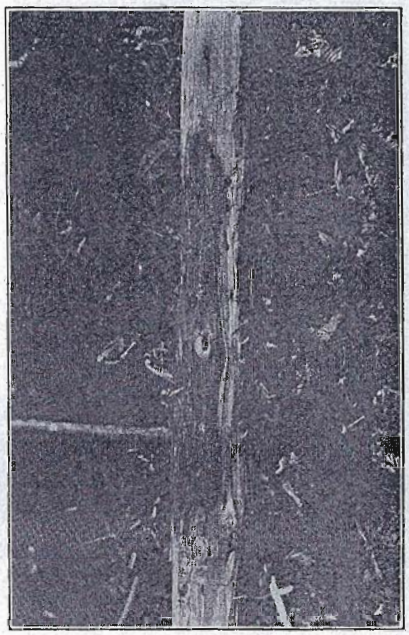
b. Trees killed by Chestnut Blight.

CHESTNUT TREES INJURED BY BLIGHT.



a–b. Cankers on smooth (a) and rough (b) barked trees, p. 364.



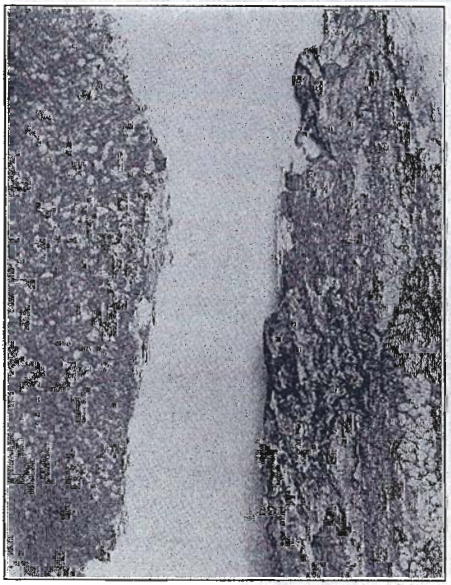


c. Winter-injured tree, p. 392.

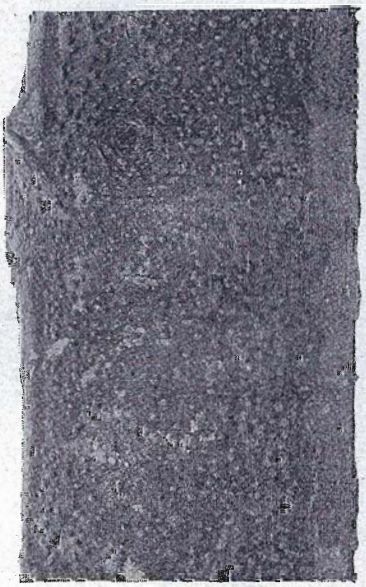
d. Injury showing on pole, p. 365.

CHESTNUT BLIGHT INJURY, ETC.

a–b. Blight started through insect injury (a), and pruned branch (b);
c. Mature fruiting pustules on smooth bark, p. 366.

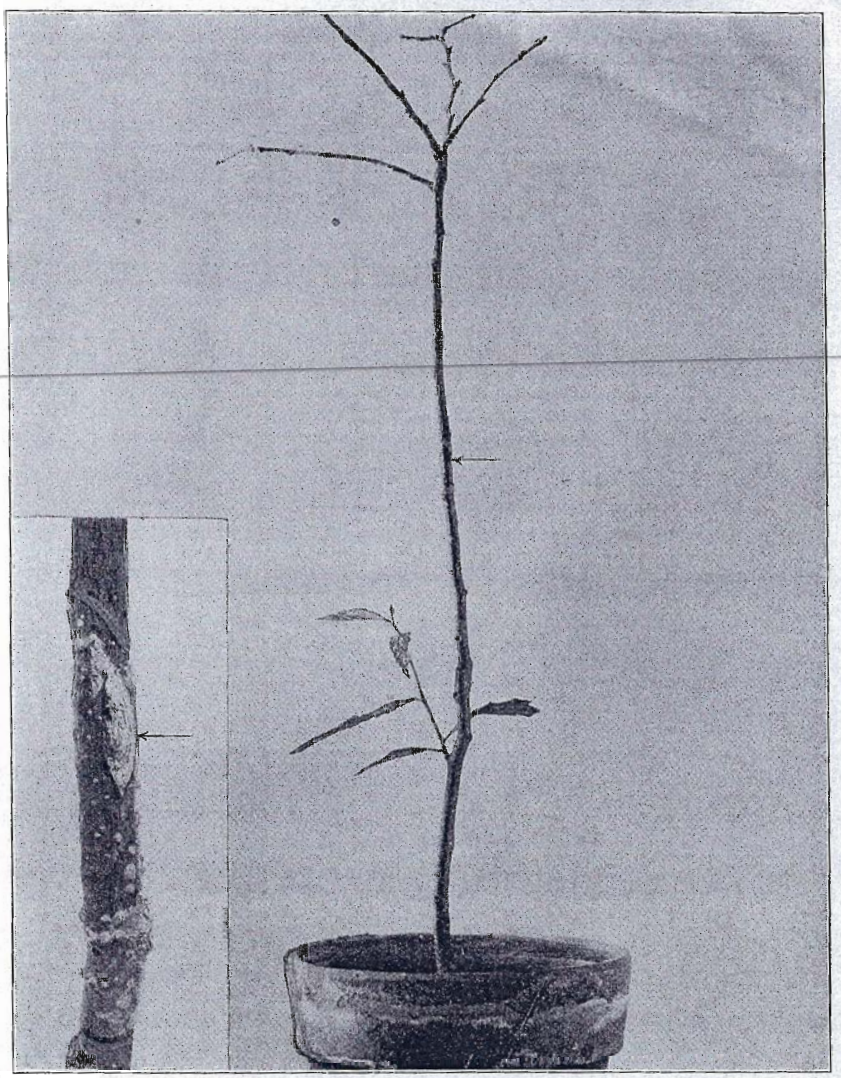


d. Blight on rough bark.

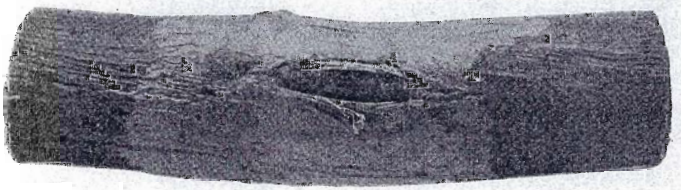


e. Fruiting pustules of *E. radicalis*, p. 419

FRUITING PUSTULES OF BLIGHT AND ENDOTHIA RADICALIS.



a. Tree killed above inoculation point ; canker shown by the enlarged stem, p. 436.

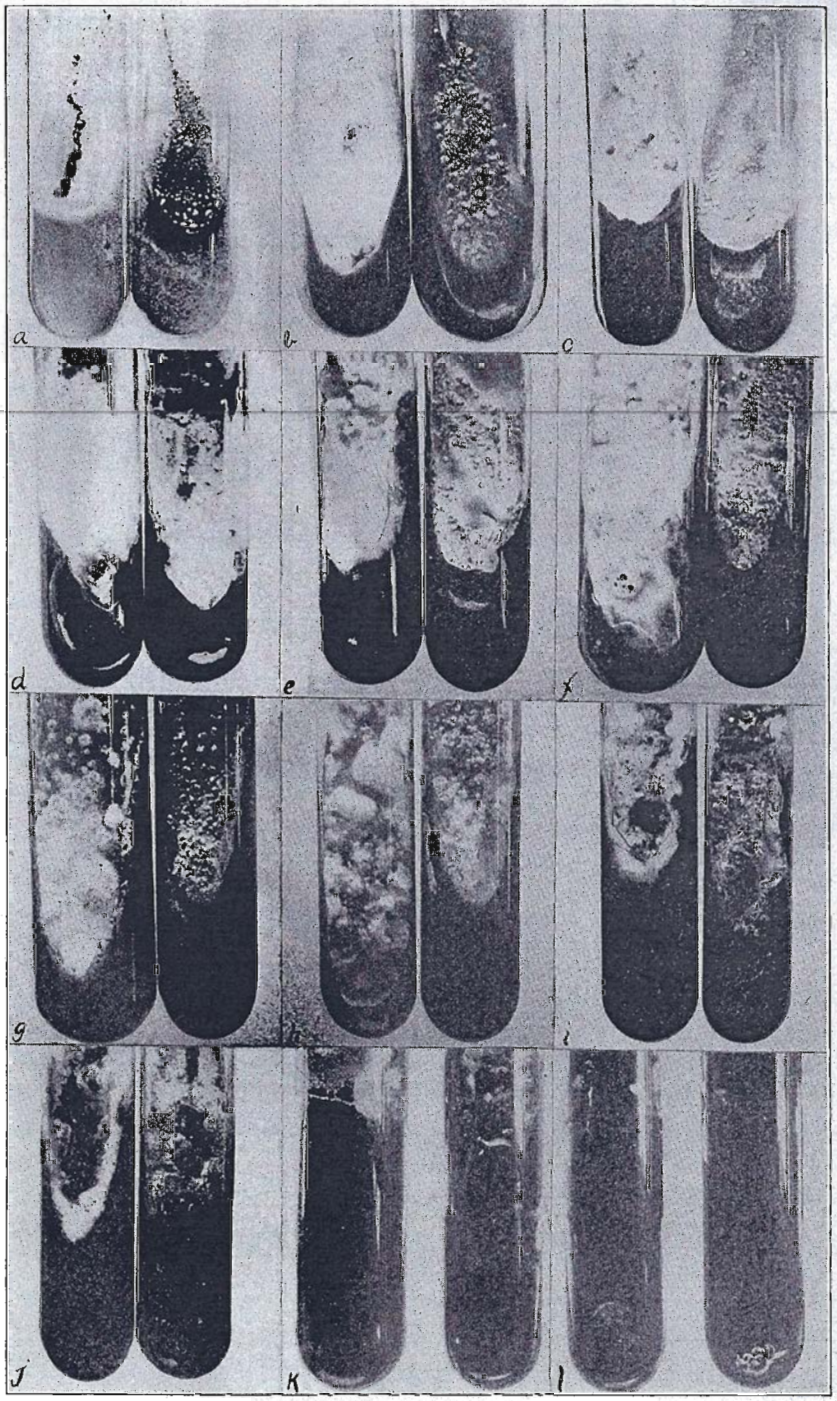


b. Sprout with dead bark around inoculation point, p. 366.

ARTIFICIAL INOCULATIONS OF BLIGHT.

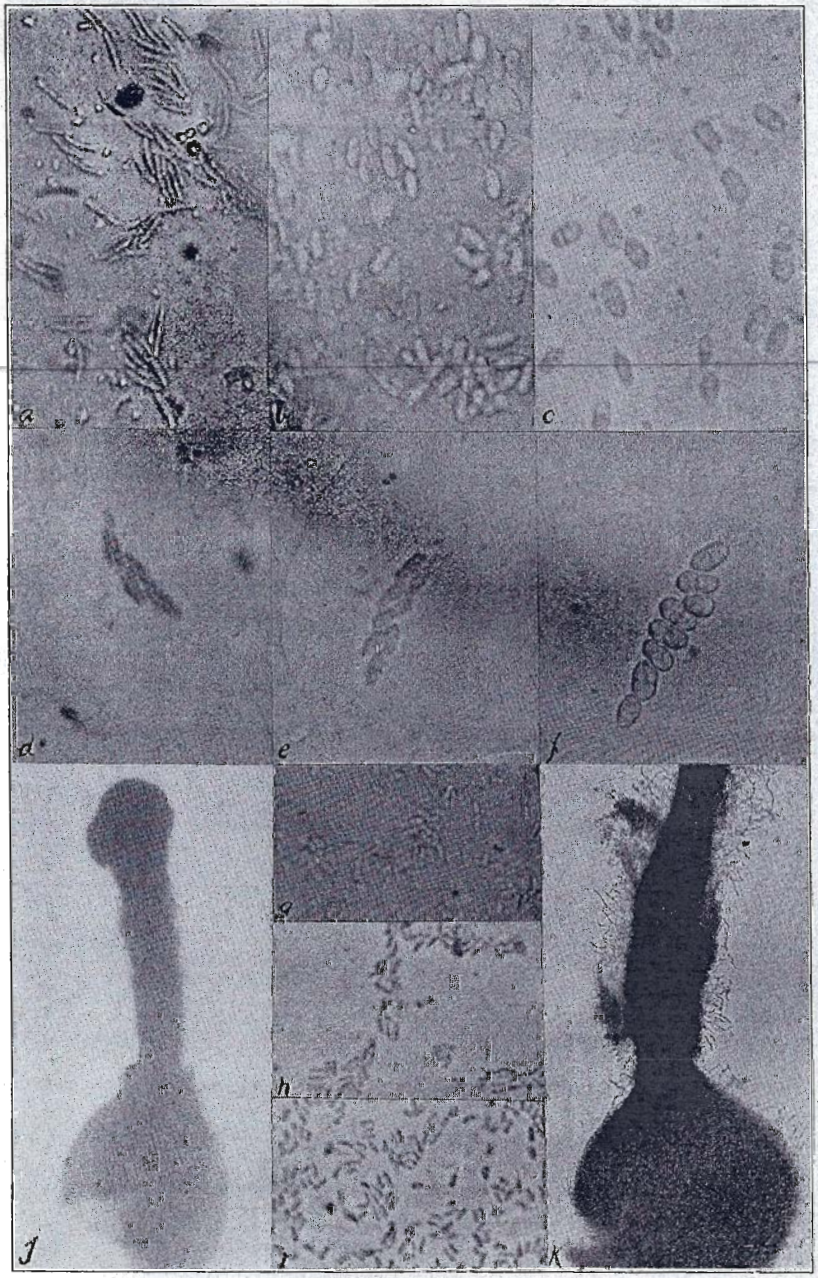
7596. *E. radicalis*. 7590, 7584. *E. gyrosa*. 7582, 7581. *E. gyrosa* var. *parasitica*.

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.