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Control of White Pine Blister Rust in Connecticut

1909-1921

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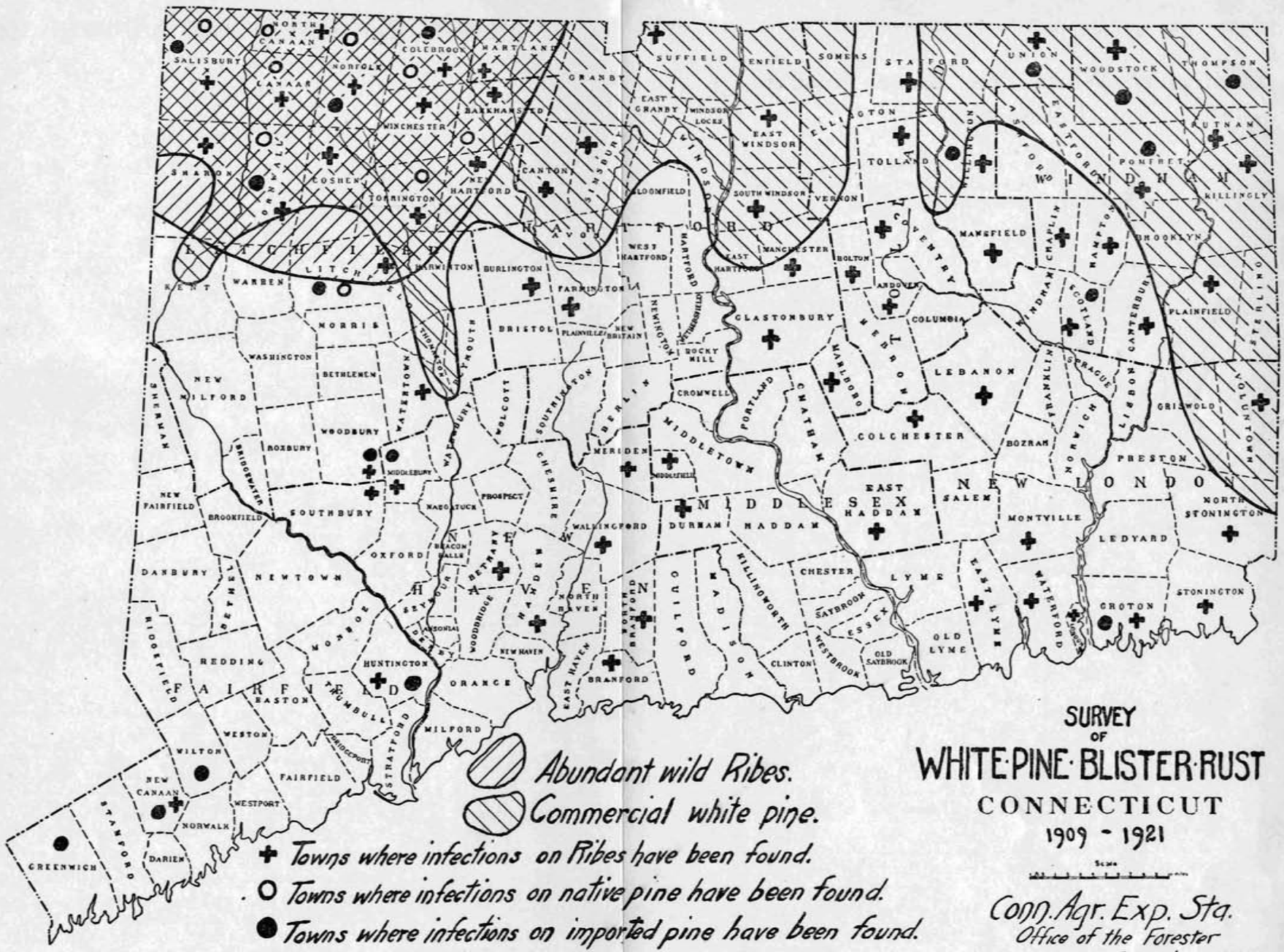

Abundant wild Ribes.
Commercial white pine.
Towns where infections on Ribes have been found.
Towns where infections on native pine have been found.
Towns where infections on imported pine have been found.
SURVEY
OF
WHITE PINE BLISTER RUST
CONNECTICUT
1909 - 1921
Conn. Agr. Exp. Sta.
Office of the Forester
December, 1921.

Control of White Pine Blister Rust in Connecticut

For a number of years it has been evident that the future of the eastern white pine forests depends on the control of a fungous disease known as the white pine blister rust. The purpose of this bulletin is to furnish information regarding this disease, its prevalence in Connecticut, and the practicability of control methods. In order to emphasize the necessity of protecting white pine growth from a very serious menace, a report on the value of white pine timber in the state is included.

In 1916 the rust was found in all the New England States, New York, New Jersey, Pennsylvania, Wisconsin, Minnesota and Ontario, Canada. All these states have taken measures to study and control the disease, and the Connecticut General Assembly of 1917 passed the following legislation for that purpose.

"The director of the Connecticut Agricultural Experiment Station shall have authority to investigate and control the fungous disease known as white pine blister rust or currant rust. Said director may appoint a member or members of the experiment station staff to administer such work under his direction, and may employ other assistance when necessary. All white pine, currants or gooseberries infected with said rust may be uprooted and destroyed forthwith. Said director may designate districts within which currant or gooseberry bushes growing wild, abandoned or escaped from cultivation may be uprooted and destroyed under his direction, and in the performance of his duties, he or any person authorized by him, may at any time enter any public or private grounds, and any person wilfully hindering the performance of such duty shall be fined not less than ten nor more than fifty dollars for each offense. The sum of seven thousand five hundred dollars is appropriated annually for carrying out the provisions of this section." (General Statutes of 1918, Section 2117.)

The discovery of the rust in Connecticut in 1909 resulted in immediate study of its nature and occurrence. This was made by members of the Experiment Station staff, all needed equipment being furnished by the Station. In 1916 it became apparent that active measures for the control of the disease should be undertaken as soon as possible, in addition to a continuation of the studies already begun.

Under an agreement with the Bureau of Plant Industry, United States Department of Agriculture, federal funds for coöperative control work were received in 1916 and have been available each year since. The disease has thus been under observation for twelve years, and for the last six years considerable control work has been done in coöperation with the Federal Government. Under the agreement mentioned the amount of federal funds

expended to September 30, 1921 was $12,124.44, while the total amount expended by the State was $24,080.11.

The work of the Experiment Station on the disease has been carried on jointly by the forestry and botanical departments; the former having charge of the administration of funds and of the active control measures, the latter in charge of research and investigations.

The control work has been on an experimental basis for the past six years. The disease develops comparatively slowly and three or more years must elapse before the effects of control are fully apparent. It was necessary to test and compare various field methods to determine which would accomplish the desired results at a minimum cost. Much has been learned regarding the rust and its control. It can now be confidently stated that the eradication of currant and gooseberry bushes to a distance of 1,000 feet from white pine will, in most cases, adequately protect the pine from the disease. The eradication of Ribes is practicable, even in regions where the wild species are abundant, and the work can be done by land owners at a comparatively low cost.

A detailed report of studies by Doctors Clinton and McCormick of the botanical department on new points in the life history of the fungus appeared in Bulletin 214 of the Connecticut Agricultural Experiment Station, but in order that the present bulletin may be as complete as possible, a resumé of these studies is included.

The Importance of White Pine.

At the time of settlement of this country by Europeans, the northeastern United States from Maine to Minnesota and from southern Canada to West Virginia (even as far south as Georgia along the mountain tops) contained many virgin stands of eastern white pine (*Pinus strobus*), both pure and in mixture with hardwoods. The forests were valuable to the early settlers only for fuel and for building materials. Implements for working up logs into boards, shingles and framing pieces were comparatively crude, and only trees which could be worked up easily were selected. Chief among these was white pine. Evidence of this is to be found in the older New England houses today. Built almost entirely of white pine except for the frame, and many of them unpainted, these houses have withstood the elements for nearly three hundred years and are still habitable. White pine was therefore one of the first woods to enter into the domestic life of our forefathers and it played an important part in the early development of New England.

The demand for wood in various forms has increased many fold in the last three centuries. For a considerable number of

these uses white pine has been the first choice, as it always will be if obtainable. Many woods have been substituted for it but few have proved as satisfactory. Inroads on the white pine stands by lumbering and fire have been enormous, so that today the annual cut is far less than the demand and is diminishing each year.

From this brief description of the past and present status of white pine, let us glance into the future to see what part this valuable tree is to play in the forest production of northeastern United States, and more specifically of Connecticut.

A plentiful supply of low priced lumber is essential for the prosperity of any community. This is particularly true of an industrial state like Connecticut. The ideal condition would be for every community to produce all the lumber it needs, thus eliminating high freight rates and stimulating local industry. Since this is impracticable in many cases, the question arises as to what species will most fully satisfy the needs of the community and make it most nearly self-supporting.

The killing of the chestnut trees by the bark disease has left the state practically bereft of a good general purpose timber tree. Of the many other native hardwoods, some produce very valuable materials, but few of them can be grown profitably because of the length of time required to mature. It is generally conceded by foresters that while some hardwood lumber is essential and must be produced, the bulk of the lumber in the northeast must come from coniferous trees. Of these, ten species are found growing native within this state as follows: cedars, three species; spruce, one; balsam fir, one; larch, one; hemlock, one; and pines, three. Because of slow growth, restricted range, or other adverse habits all these species except red pine *(Pinus resinosa)* and white pine may be eliminated in considering the future.

These two trees are quite similar in growth and habits, although the wood of red pine is considered to be slightly inferior to that of white pine. Planting stock of both species is easily raised and set out. With regard to immunity to insects and fungi, red pine has a decided advantage and it is less susceptible to damage by fire. White pine is found throughout most of the northern third of the state and if the species is favored, its range may be greatly extended without excessive cost. The range of red pine, on the other hand, covers only portions of the most northerly towns. Its further extension, therefore, must be by planting until the species is more widely established in the state.

Dr. Haven Metcalf of the Bureau of Plant Industry has stated that the practise of forestry in New England and New York is "impossible" without white pine. Perhaps it would be better to say "very difficult." At any rate it is generally conceded that white pine, because of its excellent qualities and many and diversified uses, is our most valuable timber tree. Foresters claim that

it is one of the few trees that can be grown as a crop with profit under intensive management.

If the future of our local lumber supply depends so much on this one species surely it is worth protecting from fire, insects and fungi. Fire is always destructive to growing timber, and white pine is more susceptible than many other species. There are several insects which damage white pine to some extent, but these pests are either not very serious or can be controlled. Of the various fungi parasitic on the tree, the only one which seems to endanger the existence of the species is that with which this report is concerned.

History of the Disease.

This disease is caused by a parasitic fungus known to science as *Cronartium ribicola*. It is classified among fungi as a heteroecious rust because it develops distinct stages of its existence on different host plants, of which it requires two for its development and spread. They are:—

a. The several species of five needled pines.
b. The several species of currants and gooseberries.

During a complete life cycle this rust produces four different kinds of spores, two on the pine and two on the Ribes host. *Ribes* is the scientific generic name for the plants commonly known as currants and gooseberries, and in this report the term "Ribes" is used to designate them.

About 1856 Dietrich, a German botanist, reported the two stages of the fungus on Ribes and on pine in northwestern Russia. He evidently did not recognize that he had two forms of the same rust on different hosts. Klebahn of Germany in 1888 was the first to prove the relationship of the two forms when he inoculated leaves of Ribes from the spore stage which was found on five needled pines. The fungus has, therefore, been known in Europe by botanists for many years. The five needled pines of the old world are relatively of small commercial importance and it was probably the destruction of the North American five needled pines, introduced extensively for forest and ornamental planting, which really directed the attention of Europeans to the disease.

According to Spaulding's 1911 report,* the blister rust has been found on one or both hosts in Norway, Sweden, Denmark, Russia, Siberia, Austro-Hungary, Italy, Switzerland, Germany, France, Belgium, Holland, England, Scotland and Japan. Losses as high as 100 % have been reported from Europe.

Prof. Tubeuf of Munich wrote a paper in 1905 on the ravages of the disease in Germany on American white pine, a tree which

* Bulletin 206, Bureau of Plant Industry.

has been used there for forest and ornamental purposes for two hundred years. He also cited the damage to nursery stock and young reproduction, and the fact that in some places the use of this species has been abandoned by nurserymen because of the rust.

Moir, after studying the disease in western Europe in 1920, reported* that in Norway, Sweden, Denmark and Belgium the use of white pine in the regeneration of forests had been practically given up because of the rust. Although the necessary control methods are well known there, the cultivated black currant (because its fruit is so highly prized for jam) is considered of more value than the exotic white pine. Moir also studied the effects of the disease on sugar pine (*Pinus lambertiana*), western white pine (*Pinus monticola*) and limber pine (*Pinus flexilis*) planted in western Europe and found all to be as severely damaged as eastern white pine.

It is very difficult to say just when the disease was first introduced into America. Stewart was the first to identify and definitely report it in this country. In 1906 he found a serious infection on various species of Ribes at Geneva, N. Y., although it was not until 1912 that it was discovered on white pine in that region. The rust was first reported on white pine in 1909 in several of the eastern states where seedlings imported from Europe had been planted. It is very probable that it had been brought into this country in small quantities for many years previous to 1909 when, as is now known, it was introduced in considerable quantities on forest planting stock, chiefly from Heins Nursery in Germany.

In 1908 and 1909 about 750,000 white pine transplants were imported from Germany for forest planting in Connecticut. After planting it was discovered that some of these trees were breaking out with the yellow blisters, or aecial stage of the rust. It was first discovered in April, 1909 by Mr. C. A. Metzger on trees which he was planting in Wilton, specimens being sent by him to this Station for identification.

From more recent investigations, there are indications that infected pines may have been introduced in at least one place in the state before the general introduction of the rust in 1908 and 1909. At the Bowditch nursery in Pomfret, there is a small forest planting about thirty years old which has developed the disease for a number of years. The trees are known to be of European origin and some of them appear to have been infected prior to 1908.

Life Cycle.

As previously stated, the disease is a rust which requires two hosts (one of the five needled pines and some species of Ribes) for

* Bulletin 6, American Plant Pest Committee.

the completion of its life cycle. In describing this cycle, let us assume that we start with a pine which has become infected and is producing spores. These spores (aeciospores) are blown to Ribes leaves in the spring, from early in April until June depending on the season. With proper atmospheric conditions the parasite develops in the leaf and shows on the under side in about two weeks as minute orange-yellow pustules, which mature and break, giving off an orange-colored powdery mass of spores (uredospores). This is the first spore stage on Ribes. These uredospores are capable only of infecting Ribes and during the early part of the summer spread the disease from one bush to another. From midsummer until the leaves fall the second spore stage on Ribes is produced. This takes the form of minute rusty brown hairs (telia) on the lower surface of the leaf. These hairs are made up of single-celled spores (teliospores) which adhere permanently together. Often uredospores and teliospores are both found on the same leaf. The latter upon germination produce minute temporary spores (sporidia) which cannot infect Ribes, but if carried to pine needles may cause infection.

Pines become infected, therefore, only after telia appear on Ribes. Doctors Clinton and McCormick have conclusively demonstrated that the rust enters the pine host through the stomata or breathing pores of the needles and works back into the bark and twig tissues. Needles of the current season are probably more susceptible to infection than older ones.

Once the disease has entered the tree it proceeds to develop parasitic threads (the mycelium) in the tissues of the host. The first outward sign of the work of the parasite is a discoloration of the bark to a yellow or orange-greenish hue accompanied by swelling. In one to several years after infection of its needles the swollen portion of the pine develops what are known as pycnia. These exude on the bark as drops of a sticky fluid containing spores (pycniospores) whose nature in this and other rusts has never been fully determined, but which are considered by some to be spores that have lost their function. When these drops dry out there remain on the bark yellowish spots of varying shape, which later turn a deep reddish brown. They are known as pycnial scars.

Usually during the spring after pycnia are borne the fungus develops the fruiting bodies known as aecia. These never appear until the third year after infection of the pine needles and their development may be delayed until the fourth year, or even longer under adverse conditions. Very small pines are often killed before aecia appear at all. The aecia are the orange spore cases, or blisters, which push through the bark as flattened pustules about one fourth of an inch high. They soon burst and send out a mass of aeciospores which, if carried to Ribes, cause the infection on the leaves mentioned at the beginning of the life cycle. After fruit-

ing, the bark through which the pustules have protruded becomes much seamed and cracked, often exuding pitch and frequently attacked by secondary fungi and insects. Older infections sometimes show constriction with swelling above.

Not infrequently a tree which has been diseased for several years will show a number of distinct zones as follows:—

a. Dead, cracked bark where the disease has fruited in previous years.
b. Fruiting pustules, or remnants of pustules, that have fruited during the current season.
c. Zone of pycnial scars and pycnial drops.
d. A discolored area usually surrounding all other stages and moving forward slowly into new tissues with each year's growth.

Some important points to be noted are:—

1. Two spore stages are borne on each host during the life cycle of this rust.
2. Two hosts must be present if the disease is to spread from pine to pine.
3. Spores from the stage on pine cannot directly infect other pines.
4. The rust is perennial on the pine but not on the Ribes host.
5. The fungus may grow within the pine host for a number of years without fruiting.

Experiments by members of the Bureau of Plant Industry and others show that all five needled pines are commonly infected by this rust. The botanical department of this Station has made extensive experiments with other pines and a summary of the results appears later in this report. Ribes vary considerably in their susceptibility to infection. Black currants are undoubtedly the most susceptible, followed closely by certain wild gooseberries, skunk currants and cultivated flowering currants. The thick leaved variety of cultivated red currant and certain cultivated gooseberries are probably the least susceptible in this state.

Moist, fairly cool weather is apparently the most favorable for the growth of the fungus and the production of spores. The aeciospores which develop on pine may travel long distances and over large barriers, such as mountain ranges, without losing their quality of infecting Ribes. The average longevity of the spores varies considerably according to their kind. The aeciospores which carry the disease from pine to Ribes may remain alive for several months. Dr. H. H. York has made tests showing that with a humidity of 90 and a temperature of 22-25 degrees C. (72°-77° Fahr.) the sporidia which carry the disease from Ribes to pine remain viable for less than ten minutes.

Legislation.

Under the Plant Quarantine Act of August 21, 1912, as amended March 4, 1917, the Secretary of Agriculture was given the power to "quarantine any state or territory or any district of the United States, or any portion thereof" to prevent "the spread of any plant disease or insect infestation." Under this Act the

Federal Horticultural Board established a quarantine against the shipment of five needled pines and black currants out of the New England States and New York, and against the shipment of these plants from the states east of and including Minnesota, Iowa, Missouri, Arkansas and Louisiana into territory further west. Congress also appropriated $300,000 for the investigation and control of the disease, part of which was to be used coöperatively to balance money appropriated by the states.

In 1917, the Connecticut legislature passed two laws, which in brief are as follows:—

a. A general plant pest law authorizing the Director of the Connecticut Agricultural Experiment Station to control insects or diseases which are, or may become, serious pests to economic plants. He is given the power to destroy infected plants, prohibit or regulate transportation of the same, and to establish quarantine in such areas and against such pests as he may deem necessary. (G. S. 1918, Section 2106.)

No quarantine against Blister Rust has ever been put into effect in this state.

b. A Blister Rust law authorizing the Director of the Connecticut Agricultural Experiment Station to control the White Pine Blister Rust. He is given the power to order white pines, and currant and gooseberry plants to be unrooted and destroyed. (G. S. 1918, Section 2117.)

This latter act authorizes an expenditure of $7,500 per year for the control of Blister Rust.

Control 1909-1915.

As was previously stated, 750,000 imported white pine trees were introduced into Connecticut in 1908-1909. Records of their distribution were available at the Experiment Station and soon after the infection on pine was discovered at Wilton by Mr. Metzger in April, 1909, most of the plantations originating from this stock were examined by members of the station staff, and by Drs. Spaulding and Graves representing the Bureau of Plant Industry. In addition to the infection in Wilton, five plantations were found to contain from one to several infections and five others had a few suspicious trees. The above eleven plantations and a number of others were inspected in 1910 and in subsequent years. As no further signs of the rust were found, it was concluded that all the infected trees were either destroyed or had died. The importation of foreign planting stock was discouraged by the forestry department of the Station after 1910. In 1912 one lot of stock received from Holland by a commercial nursery contained so many diseased trees that all were ordered destroyed by the state nursery inspector.

The rust was found on Ribes in Meriden in 1912 and again in 1916. In the summer and fall of 1915, the state nursery inspector

of Massachusetts reported many infections on Ribes in that state close to the Connecticut line, and one over the line in the town of North Canaan. Infections reported from other states indicated that the rust had become well established in this country and during the following winter (1915-1916) plans were made for coöperation between the Connecticut Agricultural Experiment Station and the Bureau of Plant Industry for more thorough scouting to determine how serious the infection might be.

Control 1916.

Under this coöperative agreement the salaries of extra men were paid by the Federal Government and their expenses paid by the State. The station forester, then ex-officio state forester, was placed in charge and other station employees were used on the work during all or part of the season. No state funds were available except the appropriation for the care of state forests, a part of which was used. Ten extra men were employed for varying periods from May 1 to September 30.

During May and June two crews inspected eighty plantations and sixteen nurseries where there was reason to think that the disease might exist. Infected trees were found in ten plantations in Wilton, Huntington, Groton, Middlebury, Woodbury, Cornwall, Litchfield (2) and Norfolk (2). Only in Norfolk was there any sign of the disease having spread from its point of introduction, but there numerous secondary infections on native pines were found and destroyed. Wild Ribes were very plentiful and on June 15 the first fruiting stage was found on this host. By July 1 it was too late to prevent the spread of the disease from pine and for the rest of the season, using the infected plantations as a center, a crew of six men worked on the eradication of Ribes. They removed and destroyed many thousand wild and escaped Ribes in an area of approximately three square miles.

In addition, cultivated Ribes were inspected over a large territory. It was thus determined that the infected area included about forty-five square miles inside a triangle with its apexes at Canaan Valley, North Colebrook and South Norfolk. Eradication was discontinued in September and several of the men were used to scout the state for Ribes infections. During the entire season scouting was done in 110 of the 168 towns. Infections were found in 65, of which only 20 were west of the Connecticut River. The infections in these 20 towns were widely scattered except in northern Litchfield County. In the 45 towns east of the river the infections were more numerous but could not be attributed to any known center of pine infection.

Control 1917.

From the work in 1916 it was apparent that the blister rust had become well established and that special funds would be needed to control the disease. Five thousand dollars was granted by the legislature for immediate use and ten thousand dollars for the two years ending September 30, 1919. The Director of the Experiment Station, being charged with the execution of the law, delegated the direct supervision to the forestry department. The botanical department took charge of the identification of specimens and investigational work.

The labor situation in the spring of 1917 was rather acute, but the early closing of the Connecticut Agricultural College to release students for agricultural work made available a number of men for blister rust control. In all thirty-two men were employed in this work but during the latter part of the summer many of the men left to enter some branch of military service, and for this reason the periods of service varied considerably. As in 1916 the Bureau of Plant Industry coöperated by paying the salaries of extra men employed. The plan of work was as follows:—

a. Inspection of pine plantations throughout the state.
b. Scouting for the disease on Ribes.
c. Eradication of Ribes at Norfolk.

In May and June two crews found infections in eighteen plantations, eight of which had been located in 1916, the remaining ten being found for the first time in 1917. Two plantations and one nursery in which infected pines were found in 1916 seemed to be clean the following year. No infected stock, either pine or Ribes, was found in any nursery in the state, although inspections were made both in the spring and in the fall.

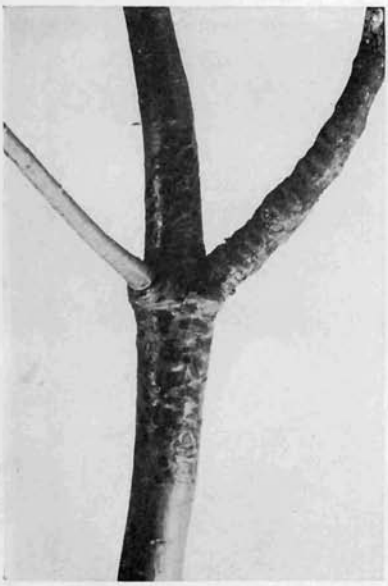
The most serious infection discovered outside of Norfolk was that on the Bowditch estate in Pomfret. Here the infected trees were over twenty years old and had evidently borne the rust for some time, but conditions were not favorable for its spread, as there is almost no native pine in this region and wild Ribes are very scarce.

To facilitate scouting for infection on Ribes, the state was divided into ten districts with a scout for each. These scouts inspected Ribes in yards and along roads in their respective districts once in two weeks and in this way kept track of any new infections that developed. A supervisor of scouts visited each district and spent a day with the scout about twice a month.

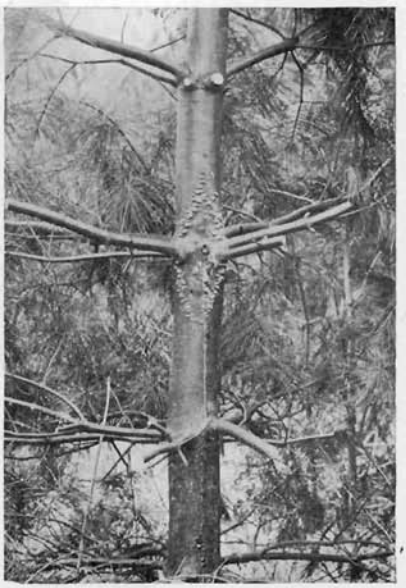
The most important result of this scouting was the finding of the pine infection center in Pomfret. Its presence was suspected from the early and general infection of Ribes reported by the scout in that vicinity. By a careful inspection of planted pine he

a. Primary infection on imported pine.

b. Telial stage on Ribes.



c. Pycnial stage on pine.



d. Aecial stage on pine.

WHITE PINE BLISTER RUST.

PLATE XXIV.

a. Natural reproduction in Cornwall.

b. Plantations in Middlebury.

FUTURE WHITE PINE FOREST.

a. Natural stand unthinned.

b. Natural stand thinned.

YOUNG WHITE PINE FOREST IN UNION.

PLATE XXV.

150 years old; 140 feet tall; 67,000 bd. ft. per acre.

MATURE WHITE PINE FOREST IN CORNWALL.

was able to locate a center of infection on the Bowditch estate. The Ribes infections in other parts of the state, with one exception, were too scattering to indicate infection centers close at hand. The exception was in the vicinity of Branford where there seemed reason to suspect the presence of pine infection, but a careful search failed to show any.

Control work was again confined to the Norfolk region, for nowhere else was there evidence that the disease had spread to pines outside the infection center. The control areas selected covered about ten square miles in the northern half of the town. Work with two crews was begun May 12th and another was organized in July. Early in the season an attempt was made to locate and remove pine infections on those areas from which Ribes was eradicated the previous year. Six hundred acres were covered in this way but the work was slow and expensive. The average cost of $1.80 per acre did not seem justified when compared with the much lower cost of removing Ribes the previous year. Moreover, it is never possible to detect with certainty all pine infections, since some of them may be so well hidden as to be overlooked, while others may not be sufficiently developed to be recognizable.

Systematic scouting for pine infection was therefore abandoned and during the rest of the season Ribes were eradicated from about three thousand acres at an average cost of 85 cents per acre. While no accurate count was kept of the Ribes removed, the number varied from many thousand per acre in some of the swamps to almost none on the hardwood ridges. The cost naturally varied with the character of the land and the abundance of Ribes. From 50% to 60% of all Ribes destroyed showed infection.

Infection on Ribes was found to be fairly general, not only in the control area but for some distance east and west in the towns of Colebrook and Canaan. The various species of Ribes found in the order of abundance were as follows:—*Cynosbati* var. *glabratum, oxyacanthoides, vulgare, prostratum, nigrum, odoratum, Cynosbati, rotundifolium, gracile, triste* var. *albinervium,* and *Americanum.*

Control 1918.

On account of war conditions which prevailed in 1918 practically no eradication work was attempted. Members of the Station staff inspected pine and Ribes in different parts of the state throughout the summer. Two extra men were employed in Norfolk to check over areas previously worked, with gratifying results. On one and one-half square miles of territory worked in 1917 only 386 Ribes were found, or about one for each two acres.

From May 1 to September 1 selected red and black currant bushes were sprayed at ten day intervals with 4-4-50 Bordeaux mixture to determine the possibility of controlling the disease on Ribes by spraying. Unsprayed bushes were used as checks. The results indicated that it might be possible to hold the disease in check on Ribes by frequent spraying, but that the frequency required would make the plan impracticable.

As previously mentioned, infections on cultivated Ribes found in the town of Branford in 1916 aroused the suspicion of a pine infection nearby. Infected Ribes were plentiful at three places and at two of these all bushes were destroyed soon after discovery. The black currant bushes at the remaining place were inspected at frequent intervals, as were the few pines in the neighborhood, but without result. The nearest known pine infection was at Middlebury, some thirty miles away. In September 1918 an intensive survey was made of all cultivated Ribes within three miles of the infected black currants. Of 201 places visited 73 had Ribes and infection was found at 13, but the infections were too widely scattered to indicate the presence of a pine infection center.

Nine plantations and one nursery were inspected in 1918. In six plantations fruiting infections were found, while in two others there were specimens apparently killed by the rust. One new infection was found in the town of Greenwich in a plantation which had not previously been inspected.

During the summer practically all the scattered Ribes infections located in 1917 were visited at least once. A decrease in the number of infections was evident as compared with the previous year. Considerable time was spent in July and August inspecting Ribes in the southwest corner of the state, but infections were not sufficiently abundant to indicate the presence of unknown pine infections.

Control 1919.

From inspections in previous years it was apparent that many of the plantations of imported pine were in no danger from the rust, and these were consequently eliminated from the inspection of 1919. Six plantations were inspected and the disease was found in five, but only in small amounts and with no indication that it was spreading.

Eradication of Ribes was resumed May 1 on areas in Norfolk and Colebrook adjoining those worked in 1917. During the summer a crew of five men covered about 2,500 acres and destroyed 30,000 wild Ribes bushes. The cost of eradication averaged 93 cents per acre, including wages, sustenance, supervision, transportation and depreciation of equipment.

Checks were made to determine the efficiency of the crew in

eradicating Ribes. Four tracts worked earlier in the season were selected and a portion of each reworked. The results showed that the crew removed an average of 90% of all Ribes during the first working of the ground.

During June scouting for infection on cultivated Ribes in 24 towns in Tolland, Windham and New London Counties showed infection in four towns, but only at places where it had been found in previous years. Later in the summer nine towns in Litchfield County were scouted in the same manner and Ribes infection was found to be quite general.

The survey of the Branford area which was made in 1918 (see page 316) was checked up in 1919. All but two places showing infection on Ribes in 1918 showed it in 1919, and one new infection was found. All white pines in the area were inspected for infections but none found.

In order to determine the spread of the disease in Pomfret, a survey covering about 30 square miles adjoining the Bowditch estate was made in July and August, 1919. All pine plantations and cultivated Ribes in the region were inspected and mapped. Eighteen separate infections on Ribes were found, but no pine infection except at the Bowditch estate. Here the scout eradicated a large number of escaped Ribes bushes in and near the pine grove. Wild Ribes are very scarce in this vicinity.

In coöperation with the Bureau of Plant Industry, a pine survey of the state was begun in December, 1919. Its purpose was to obtain information regarding the amount and value of white pine in the state and to demonstrate the importance of protecting it from the rust. One man was employed until June, 1920, mapping the pine lands of Windham, New London and eastern Tolland Counties, reporting on the age, area, percentage of pine in mixture, quantity in board feet and value of all stands containing pine.

Control 1920.

Labor suitable for this work was difficult to obtain until after the schools and colleges closed, when twelve men were secured and put in the field. The area selected for eradication consisted of about 2,000 acres in the town of Colebrook, east of that eradicated in 1919. Forty three thousand Ribes bushes were removed and destroyed. Checks run frequently, according to methods prescribed by the Bureau of Plant Industry, showed that the men were getting 90% to 97% of all Ribes during the first trip over the ground.

As in former years inspection of cultivated Ribes was carried out to determine the approximate limits of the disease. In 1920 this work was confined to Litchfield County where infection on Ribes was found to be quite general. No attempt was made to

check over either the Branford or the Pomfret areas during the season, nor was there any inspection of plantations.

Work on the pine survey, started in 1919, was resumed in November, 1920 and a new line of work, the scouting of native white pine for infection, undertaken. This seemed necessary because of the amount of Ribes infection found throughout the state for a number of years. The Bureau of Plant Industry furnished one man for the survey and two for the scouting. The two lines of work were carried on simultaneously, as this method was considered more efficient than to cover the ground twice for mapping and scouting. The cost of the survey was 2 cents per acre for the area actually mapped and about 3 mills per acre for the entire area covered. The men located infections on native pine in the towns of Cornwall, Barkhamsted, and North Canaan, as well as many new infections in Norfolk and Colebrook. (For results of the survey see page 321.)

Owing to the fact that infection had been found on Ribes in the vicinity of Branford for a number of years, this region was again scouted for infections on pine previous to the start of the regular scouting and survey work. All pines, both native and ornamental, in the neighborhood of known Ribes infections were carefully looked over, but not a single pine infection was found.

Control 1921.

Beginning on April 14 seven plantations and one nursery were inspected for pine infection. One plantation contained several fruiting specimens of the rust and in another two suspected trees were removed. In the remaining plantations and in the nursery, no sign of rust was found.

A crew of five men organized a camp in Norfolk on May 1 and carried on eradication, scouting and checking until September 15. Some 8,000 acres in the towns of Norfolk, Colebrook and North Canaan were covered and 39,000 Ribes bushes were removed and destroyed. Of this area, 4,000 acres was new territory which had not been previously worked. In addition the crew scouted forest and ornamental plantings of imported stock in Litchfield, Cornwall, Norfolk and Colebrook and found infections in all plantations thus inspected.

The effectiveness of Ribes eradication cannot be determined until sufficient time has elapsed to allow Ribes grown from seed, or from incompletely removed root crowns, to become large enough so that they can be readily seen. Furthermore, on pines which have become infected since the Ribes were removed, the disease would require at least two years to reach a stage which could be unmistakably recognized. In order, therefore, to check up the results of previous Ribes eradication in Norfolk, some 4,000 acres

which were worked in 1916, 1917 and 1919 were reworked in 1921 with the following results:

a. Some large Ribes missed in previous years were found, but these were so few in number per acre as to be of minor importance. Numerous small Ribes, originating either from seed or from improperly removed root crowns were found, but the small amount of leaf surface and the fact that these plants were usually growing under dense shade reduces the liability of their acting as transmitters of the disease for several years. Judged by the comparatively small number of Ribes found in reworking, the first eradication appears to have been fairly effective but the necessity for rescouting these areas after a few years, and reworking them if necessary, is indicated.

b. The number of pines showing infection which had occurred since eradication was almost negligible. In contrast with this, on an area from which Ribes had not been removed prior to 1921, twenty-seven pine infections were found, 70% of which took place in 1918 and 1919.

During the winter of 1920 and 1921 scouts had discovered new infections on native pine in several additional towns in Litchfield County. Prior to this time, the only known infection on native pine was in the Norfolk-Colebrook region. Careful investigation of these newly located infections indicated that control must be undertaken on a much larger scale. It was considered advisable, however, to secure further information as a basis for future work in the new areas. During the summer and fall, therefore, a preliminary survey of the towns of Cornwall, Canaan, Salisbury and a part of North Canaan was completed. The towns were subdivided into blocks for each of which observations were made on the prevalence of Ribes, amount and character of pine infection, and other factors bearing on control. Pine infection was found to be quite generally distributed over all the territory scouted and in some places it was very heavy. Ribes were plentiful but not as abundant as in the Norfolk region.

During November a scout covered practically all the towns along the Rhode Island line inspecting native pine but was unable to locate any infection.

The survey made in Pomfret in 1919 was checked up this year. Four fruiting infections on pine were found at the Bowditch estate and one new infection on ornamental pine about one-half mile to the south. The cultivated Ribes scouted in 1919 showed less infection in 1921 than in the former year.

On July 1, 1921 the federal allotment for blister rust control in Connecticut was cut from $5,000 to $2,000. Moreover the Secretary of Agriculture ruled that this allotment should be used for education, demonstration and supervision, but not for eradication as in previous years. The federal money has therefore been used

since July 1 to pay part of the salary of a member of the Experiment Station staff whose time is largely spent in supervising the control work. As a result of this reduction in the federal funds available, the amount of control work which can be done with the present state appropriation is greatly reduced. Moreover the disease has recently been found in alarming amounts in several new sections. To check its spread, prompt action is necessary, or much young pine will be killed before reaching merchantable size. It is imperative, therefore, that owners of pine coöperate in the control work, since state and federal funds are wholly inadequate to care for the present situation.

Future Control Work.

Blister rust control has been in the experimental stage during the past six years. Although its principles were well understood in European countries they had never been practiced extensively there, and many points in the life history of the disease were not thoroughly understood. Its characteristics and life history are now well known as a result of the exhaustive studies which have been made in this country by federal and state agents. There are still many scientific points not fully understood and investigational studies must be continued, but the practicability of control methods has been firmly established. The coöperative work with the Bureau of Plant Industry in the various states has demonstrated that the application of simple field methods at a moderate cost per acre will hold the disease absolutely in check.

These control methods should be carried out locally by pine owners themselves, since they are the ones directly benefited by the results secured. Public funds should be used for supervision, for education and for further experimental work, but not, as in the past, for actual field control on a large scale. Education of pine owners through state and federal agencies is essential, because many of them do not realize the value of their young pine or the necessity of protecting it from the rust.

On average quality forest soil which could not profitably be used for agriculture, white pine either self-sown or planted will, in 40 to 50 years, produce a gross revenue of over $200 per acre, as contrasted with $75 per acre if the land grows only hardwoods. Unless the blister rust is kept under control, however, it may and probably will, destroy the pine before it reaches merchantable size, as the greatest danger is to trees less than 15 feet high to which the disease is fatal in a very few years.

Assistance must be given pine owners in recognizing the disease, for its presence on pine is very deceptive. It can be identified at the end of the first year only with the aid of a microscope. After the second year a careful scrutiny will reveal its presence,

although to an untrained eye a tree already diseased beyond recovery may outwardly seem to be healthy.

Supervision of Ribes eradication by state or federal agents is of great importance. Unless the work is done with sufficient thoroughness to remove practically all the Ribes in the vicinity of pine stands, the protection secured will not be sufficient to warrant the expense incurred. A trained supervisor will be able to maintain the efficiency of the work and to reduce its cost by eliminating areas where Ribes are not sufficiently abundant to require eradication.

The National Situation.

The introduction of this disease into the United States and its subsequent spread has brought about a condition very different from that in Europe. Our eastern white pine, sugar pine, limber pine and western white pine were formerly used quite extensively in western Europe for forest and ornamental planting. On account of damage by the blister rust the use of these trees is now being discontinued because the cultivated black currant is more highly prized for its fruit than the American soft pines for their lumber. In this country the necessity for protecting the five needled pines at the expense of Ribes should be beyond question, because of the greater importance and value of pine lumber as compared with currants and gooseberries.

In the northeastern United States where the rust was generally introduced some twelve years ago the disease, on account of its deceptive character, became firmly established before the damage it might do was generally realized. In many parts of the range of the eastern white pine, 10% to 15% of all the trees of this species are infected and in some areas infection runs as high as 100%. This condition is very serious because much of the present crop of young pine will be killed before it is large enough to cut and because, if the rust is not controlled in the immediate future, it may become so prevalent as to render the use of white pine impossible in the regeneration of our forests.

In Connecticut the situation is not as bad as in other New England states, because the area in which blister rust can become serious is limited to about 500 square miles in northern Litchfield County. This is the only section of the state where wild Ribes are abundant. It is very probable that infection will occur at many other points because of the presence of cultivated Ribes, but it is believed that such infections will be quite local and easily controlled.

In the western states the danger from blister rust is one of the future rather than of the present. Agents of the Bureau of Plant Industry are constantly on the watch for its appearance and every

possible means of enforcing the quarantine against the shipment of Ribes and five needled pines into the west are being used. Very recently (November 1921) an infection on eastern white pine planted in southern British Columbia has been discovered, and since that time several infections on western white pine have been found over the line in the state of Washington. However, these infections have apparently been located before the disease has spread to any extent, and with sufficient funds it should be possible to control it. Nevertheless, the danger of its becoming established in the west is very great. A strict enforcement of the federal quarantine and continued vigilance on the part of federal scouts will be necessary to prevent its introduction and spread into a region where control may prove impossible.

The territory between British Columbia and Mexico includes the range of the western white pine and sugar pine which are very important timber trees. Several other five needled species found in this section, while valuable to some extent for lumber, are even more valuable as a covering for high mountain water-sheds. Moreover, there are more than 60 species of Ribes native to this region. This combination of several species of pine susceptible to the rust and an extraordinarily large number of Ribes species affords ideal conditions for the development and spread of the disease throughout the entire range of the western five needled pines.

NEW INVESTIGATIONS BY THE BOTANICAL DEPARTMENT.

Though the general life history of the blister rust had previously been worked out in Europe there were some lesser phases, unknown or in doubt, when the botanical investigations were first undertaken by Doctors Clinton and McCormick of this Station. The life history in general has been covered by their work, but special emphasis was laid upon the doubtful or unknown points. A part of these investigations have been published in Bulletin 214 (pp. 428-459) of this Station, and in papers read before the Blister Rust Conferences and the Botanical Society of America. Additional details will be given in a bulletin of the Station to be published during 1922.

The main new points brought out in their investigations were along two lines. First, as regards the point of entrance of the fungus in the pine, it was shown by artificial infections that this takes place through the leaves, and that a very definite method is followed. The germinating sporidia gain entry by a germ tube through the stomates, or breathing pores, into the interior of the

leaf and immediately form an enlargement which may have several functions, such as a hold fast, storehouse for food, etc. From this swelling an infection thread proceeds through the stomatal cavity and comes in contact with the leaf cells. A tube is sent into the cell for food, and then a vigorous growth of threads results in the intercellular spaces, in time forming a sclerotial mass of fungous threads. This development kills the green coloring matter of the cells, with the result that a golden-yellow spot shows on the leaf near the spot where the fungus entered. In time the fungous threads come in contact with the food carrying ducts of the leaf, and then in an inconspicuous manner rapidly work lengthwise of the leaf, especially downward, until they reach the bark, where a vigorous development takes place resulting in the swelling already noted. These facts have all been confirmed by similar observations on infections taking place in nature. While natural infection of the leaves takes place in the fall, the external evidence, through the golden yellow spots on the leaves, is not conspicuous until the following spring or early summer.

The second point brought out was that not only the five needled pines but also seedlings of certain two and three needled pines could be artificially infected, some as readily and vigorously as the white pine. On some of these hosts the infection has proceeded as far as any that has taken place in infection work at this Station with white pine of the same age: namely, to where the infected stems produced the pycnial stage. Altogether some thirty different species of seedlings of the genus Pinus have been experimented with, and at least fifteen of these have become infected in the leaves. The varying vigor of the rust's development indicates difference in resistance of the species inoculated, so that no doubt with certain of them infection proceeds no further than invasion of the leaf, and so fails of true infection.

As regards infection of Ribes with the aeciopores from white pine, successful inoculations have been made with twenty-six species. Some species show much more resistance to infection than do others, cultivated black currants being one of the most susceptible.

A SURVEY OF WHITE PINE IN CONNECTICUT.

The pine survey for Connecticut, which was made during the winters of 1919-1920 and 1920-1921, has been briefly referred to in other parts of this report. The object of the work was to furnish data on the amount and location of white pine growing within the state. As such figures would manifestly not be accurate for any extended period, it was decided to accomplish the work at as low a cost as possible consistent with reasonable accuracy.

Since there is no considerable amount of white pine outside of Litchfield, Hartford, Tolland, Windham and New London Counties, the survey was limited to such portions of these counties as were known to contain pine.

The U. S. G. S. topographic sheets were used for the mapping. With the aid of a pocket compass and pacing, the boundaries of the various blocks of pine were sketched in. Three general types were plotted upon the map.

a. Pine reproduction; stands under 25 years of age with pine forming 60% or more of the mixture.

b. Pure pine; stands over 25 years of age with pine forming 60% or more of the mixture.

c. Pine-hardwoods; mixed stands with other species forming more than 40% of the mixture.

The country was divided into blocks with the highways as boundaries and further subdivided into the various types, for each of which notes were made showing:—

a. Age class.
b. Percentage of pine.
c. Area in acres.
d. Volume in board feet per acre.

Areas were obtained by scaling the map. Age was roughly determined by counting the whorls of branches. The estimates of percentage and value were, of necessity, made largely by eye but were checked by the frequent laying out of plots on which more careful estimates were made. In practically all cases supplemental notes regarding the character of the timber, reproduction, etc., were kept for each type.

From field data thus gathered it was possible to compile figures on area of reproduction, area of pure pine, area of pine in mixture with other species and the stand in board feet for each town surveyed. Figures of total forest area were taken from the Forest Survey of Connecticut, published in the annual report of this Station for 1915. Fifty-two towns were covered in whole or in part. A summary of the information for each county by towns follows.

HARTFORD COUNTY.

Town	Pure Pine Reproduction Acres	Pure Pine Acres	Pine-Hardwoods Acres	Forest Area Acres	Stand of Pine B. F.
Avon	686	445	110	7,400	1,260,000
Bloomfield	34	38	20	4,350	430,000
Canton	127	479	78	11,600	370,000
E. Granby	386	198	..	4,300	240,000
E. Hartford	35	123	..	2,100	800,000
E. Windsor	16	77	125	3,400	450,000
Enfield	832	765	424	7,000	6,760,000
Farmington	500	70	...	8,000	710,000
Granby	888	923	1,446	17,000	5,550,000
Hartland	108	9	613	15,700	350,000
Manchester	84	212	45	5,700	1,650,000
Simsbury	1,216	1,252	150	10,500	8,830,000
S. Windsor	12	92	145	4,800	990,000
Suffield	215	203	115	5,450	450,000
Windsor	30	455	352	7,300	4,210,000
Windsor Locks	685	271	...	2,550	890,000
Totals	5,854	5,612	3,623	117,150	33,940,000

LITCHFIELD COUNTY.

Town	Pure Pine Reproduction Acres	Pure Pine Acres	Pine-Hardwoods Acres	Forest Area Acres	Stand of Pine B. F.
Barkhamsted	1,129	336	3,141	15,300	5,480,000
Canaan	157	333	9,587	15,500	1,372,000
Colebrook	1,211	964	8,613	15,400	6,120,000
Cornwall	700	444	803	18,100	6,920,000
Goshen	20	133	192	15,100	2,040,000
Harwinton	75	36	150	11,700	340,000
Litchfield	35	67	73	16,000	780,000
Morris	28	6	40	3,550	130,000
New Hartford	781	257	1,092	13,000	2,250,000
Norfolk	835	1,437	10,394	22,300	12,100,000
North Canaan	768	889	3,928	5,850	1,980,000
Salisbury	496	1,424	6,581	17,800	10,420,000
Sharon	...	42	862	17,000	310,000
Thomaston	...	3	30	4,550	60,000
Torrington	46	154	55	16,200	680,000
Winchester	433	185	2,813	12,700	1,400,000
Totals	6,714	6,710	48,354	220,050	52,382,000

NEW LONDON COUNTY.

Town	Pure Pine Reproduction Acres	Pure Pine Acres	Pine-Hardwoods Acres	Forest A ea Acres	Stand of Pine B. F.
Griswold	25	5	725	9,450	40,000
Voluntown	250	437	8,812	22,500	4,910,000
Totals	275	442	9,537	31,950	4,950,000

TOLLAND COUNTY.

Town	Pure Pine Reproduction Acres	Pure Pine Acres	Pine-Hard-woods Acres	Forest Area Acres	Stand of Pine B. F.
Elllington	20	40	20	11,300	90,000
Mansfield	..	3	..	12,600	35,000
Somers	392	424	280	9,000	1,800,000
Stafford	38	447	5,341	28,800	2,980,000
Tolland	20	58	89	16,500	250,000
Union	1,000	1,594	9,831	15,000	15,920,000
Willington	73	32	145	15,900	250,000
Totals	1,543	2,598	15,706	109,100	21,325,000

WINDHAM COUNTY.

Town	Pure Pine Reproduction Acres	Pure Pine Acres	Pine-Hard-woods Acres	Forest Area Acres	Stand of Pine B. F.
Ashford	..	342	3,093	14,600	1,590,000
Brooklyn	75	69	1,770	7,500	320,000
Canterbury	..	87	932	12,800	400,000
Eastford	150	417	3,261	13,100	4,720,000
Killingly	200	274	11,556	19,100	1,020,000
Plainfield	50	36	1,873	13,000	160,000
Pomfret	100	42	2,775	12,500	440,000
Putnam	100	409	3,495	5,550	1,290,000
Sterling	50	30	4,210	13,600	300,000
Thompson	400	672	11,760	16,400	2,480,000
Woodstock	600	1,352	11,836	19,800	10,050,000
Totals	1,725	3,730	56,561	147,950	22,770,000

TOTALS BY COUNTIES.

County	Pure Pine Reproduction Acres	Pure Pine Acres	Pine-Hard-woods Acres	Forest Area Acres	Stand of Pine B. F.
Hartford	5,854	5,612	3,623	117,150	33,940,000
Litchfield	6,714	6,710	48,354	220,050	52,382,000
New London	275	442	9,537	31,950	4,950,000
Tolland	1,543	2,598	15,706	109,100	21,325,000
Windham	1,725	3,730	56,561	147,950	22,770,000
Totals	16,111	19,092	133,781	626,200	135,367,000

In the remaining 117 towns there are scattered plantations and native stands of white pine which should be included in totals for the state. The following figures are therefore thought to be conservative.

	Pure Pine Reproduction Acres	Pure Pine Acres	Pine-Hard-Woods. Acres	Forest Area Acres	Stand of Pine B. F.
State of Connecticut	20,000	20,000	150,000	1,483,300	150,000,000