JOURNAL OF
ARBORICULTURE

February 1976
Vol. 2, No. 2

THE BEECH BARK DISEASE[1]

by Alex L. Shigo

Abstract—The beech bark disease, caused by fungi (principally *Nectria coccinea* var. faginata) infecting minute feeding wounds made by scale insects (principally *Cryptococcus fagi)* in the bark of beech *(Fagus grandifolia)*, is well established in the eastern United States and is spreading. Many beech trees are killed and weakened in infected stands, although some trees seem to have a natural resistance to the disease. There was little real concern about the disease in the U.S. until the last few years, when industries learned to use beech profitably. Now there is a need for better understanding of the disease.

The beech bark disease presents an ironic paradox in the Northeast today.

In the early 1930's, there was great concern over the beech bark disease, primarily because it was new. It was spectacular. No one could miss seeing the infested trees, the bright red perithecia and the decimated forests. Then the concern waned rapidly. Forest managers welcomed the disease because it was killing the big weed tree of the forest. Wood industries used very little beech, so there was no economic loss.

In the last decade, however, the wood industries have learned to dry and use beech profitably. The supply was plentiful and the price low.

Now that beech has gained acceptance, the beech bark disease is threatening the supply. For the first time real concern is developing over the disease. Questions are being asked: What can we do? Why don't we know more about this disease that has been here so long? The situation will get worse as the disease moves westward into areas where beech is dying because of a beech decline and injury caused by an oyster scale.

In Europe, the disease has invaded all the beech forests. There are many healthy beech trees in Europe now, but where there are diseased trees only the aftermath stage is present. Mortality is not so common. In the United States, the disease has vast areas of beech forest yet to attack, and the disease is moving rapidly.

This article is a summary of what we know about this disease now, with some pointers toward what we still need to know.

Cause of Disease

The beech bark disease, as it exists in the northeastern United States, is caused by fungi infecting minute feeding wounds made by scale insects in the bark of beech. The principal fungus is *Nectria coccinea* var. *faginata* Lohman, A.J. Wats., and Ayres (*1*). *Nectria galligena* Bres. and possibly other species of *Nectria* are also thought to be involved (*10*). The beech scale insect is *Cryptococcus fagi* Baer. A detailed account of the interaction of these organisms and others in the beech bark disease is given by Shigo (*9*). The hosts are the American beech (*Fagus grandifolia* Ehrh.) and all of its varieties. Trees of all sizes are attacked.

History

The beech bark was known in Europe before 1849 (*4*), and except for a few outbreaks, little little damage was caused by it. The beech scale was introduced into Halifax, Nova Scotia, about 1890. But the first recorded outbreak of the disease was not until 1920 (*4*).

In the United States, Faull (*5*) first published information on the disease in 1930, and Ehrlich (*3*), reported a species of *Nectria* on dying beech trees. At the same time, Ehrlich (*3*) recognized

[1] Presented at The International Shade Tree Conference in Detroit, Michigan in 1975. Previously printed in The Journal of Forestry, May 1972.

the scale insect on ornamental beech trees in and about the Arnold Arboretum in Boston, Massachusetts.

From 1929 to 1934, great concern developed over the disease and a study was made by Ehrlich (*4*). Very little research on the disease has been done in North America since that time.

The Insect

Cryptococcus fagi is a soft-bodied scale insect. At maturity it is yellow, elliptical, 0.5-to-1 mm long, has reddish-brown eyes, a stylet about 2 mm long, rudimentary antennae and legs and numerous minute glands that secrete a white, woollike wax over the entire body.

Reproduction is parthenogenetic, males being unknown. Beginning in midsummer, the insect deposits pale yellow eggs on the bark in strings of four to eight, attached end to end. Depending on temperature, the hatching of eggs usually begins in late summer and continues until early winter.

The larvae emerge from the eggs with well developed legs and antennae. They either remain stationary under the females, which die after egg deposition, or migrate to cracks and other areas where they will be protected, fall to the ground where death is imminent or establish themselves on other trees after being disseminated by various agents.

After the insect becomes stationary, it forces its tubular stylet into the bark. It is then a second-instar nymph without legs and is covered with woollike wax. The insect hibernates in this stage on the bark and molts in the spring to become an adult female.

The Fungus

Nectria coccinea var. *fabinata* produces several types of spores. The conspicuous bright red, lemon-shaped perithecia on trees in clusters of as many as 40 are filled with elongate sacs, each containing eight spores. These spores result from a sexual process, and their production constitutes the perfect stage of the fungus.

The perithecia mature in the fall, and the spores are forced out only when they have been moistened sufficiently. After these spores dry, they appear as white dots on the tips of the perithecia. Perithecia on the dead bark continue to produce viable spores the following year.

Small, white cushions of asexual spores frequently burst through he bark before the perithecia appear. These can easily be mistaken for small isolated colonies of the scale insect. The asexual spores range from single-celled, oval spores to eight-celled, sickle-shaped spores. These spores are produced in a dry head, well suited for wind dissemination. The imperfect stage can be found on the trees from midsummer until fall.

Course of the Disease

First signs are isolated dots of white "wool" that appear on roughened areas of the bark, under branches and in the lenticels. Eventually, the entire bole of the tree may be covered with the waxy material secreted by the scale insects as they increase in numbers (*Fig. 1*). The scale insects feeding on the liquids in the bark cells can weaken a tree.

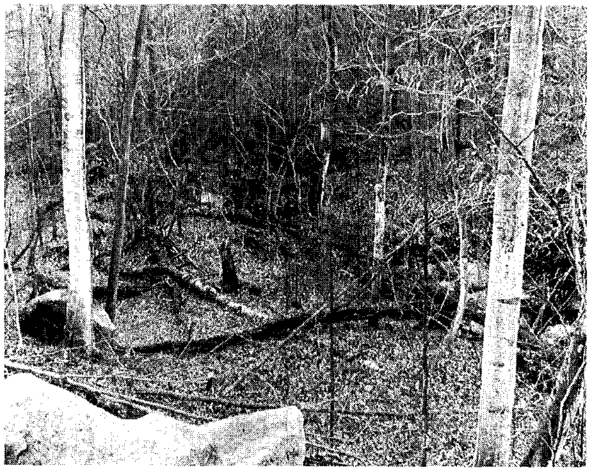

Fig. 1. The large white patches on these mature beech indicate a severe infestation by the beech scale.

On some trees, a red-brown liquid exudes from dead spots near areas heavily infested with the insects. This seeps down the tree, forming a slime-flux or a brown spot. Frequently perithecia of the *Nectria* are later found around these dead spots. The dead areas may extend into the sapwood. These spots are usually delimited by callus tissue.

Areas devoid of the scale insects or patches of black wool indicate one of the first places killed by *Nectria* (*Fig.* 2). The insects cannot live on dead tissue; and, as they die, a black fungus frequently grows over them.

Fig. 2. The strip of bark devoid of the beech scale on this tree indicates that the bark was killed by the *Nectria* fungus. The scale insects cannot live in dead bark.

The fungus may infect large areas on some trees, completely girdling them. The leaves that do come out in the spring do not mature, giving the crowns an open appearance. The leaves turn yellow and usually remain on the tree during the summer season. The chlorotic crowns are typical of trees dying from a water deficiency.

Frequently the fungus infects only narrow strips on the bole, and the subsequent symptoms differ from those of trees that have been girdled. Callus tissue forms around these cankers, and the bark becomes very roughened. Parts of the crown become chlorotic and die. Small cankers may be walled off from the sapwood by callus tissue.

Many of the trees that are partially girdled remain alive in a weakened state for many years, while others are broken by the wind.

Spread

The disease, once established, began to spread rapidly through the forests that contained an abundance of beech. Beech had been considered an undesirable tree, and it was left after other species were cut. It also regenerated quickly in the spaces left after other trees were cut.

The disease spread southward into Maine and then turned westward into the forests of New Hampshire and Vermont. By 1950, the disease was well established on the eastern slopes of the White Mountains in New Hampshire. By 1960, it was entering the center of Vermont.

Now the disease has spread to central New York, throughout Massachusetts and Connecticut and to the northern portions of Pennsylvania. In neighboring Canada, the disease has moved along the northern border of the St. Lawrence River to Lake Ontario.

Impact

Although the disease is now spread over a broad area of the northeastern United States and Canada, the impact of the disease on the trees varies greatly in different areas. One would find it difficult to believe that the disease as it is now found in Maine is the same as that found in Vermont.

The disease can be separated into at least three stages: (1) the advance front, (2) the killing front, and (3) the aftermath stage.

The advance front is now in central New York. Some insects can be found, but the bright red perithecia of *N. coccinea* var. *faginata* are scarce.

The killing front is now in Vermont and eastern New York. Here the trees are dying rapidly over large areas of forests. The insects are obvious, and the red perithecia can be found on some trees.

The aftermath zone stretches from Vermont eastward to the coastal areas. Beech trees that were apparently resistant are still thriving in these areas. There are trees with all gradations of injury from a few small cankers to most of the stem killed, and many other microorganisms and insects have attacked the weakened trees.

Other Microorganisms and Insects on Weakened Beech

A mycoparasite, *Gonatorrhediella highlei* A.L. Smith frequently attacks the beech parasite, *N. coccinea* var. *faginata* (9). In culture, *G. highlei* inhibits sporulation of *N. coccinea* var. *faginata*. The mycoparasite is often seen growing over the white waxy substance produced by *C. fagi*. This indicates that *N. coccinea* var. *faginata* is active under the scale insect and proves that the fungus can be present in the bark very shortly after the scale insects infest.

If the infestation is severe and the subsequent infection is also severe, the bark tissues may die so rapidly that conditions for sporulation of *N. coccinea* var. *faginata* are passed. This probably occurs in the killing front.

After the bark is killed, species of *Hypoxylon* invade. These fungi incite a whiterot. Following *Hypoxylon* spp., species of *Stereum, Hymenochaete, Polyporus,* and *Fomes* invade the dead wood (9).

Xylococculus betulae (Perg.) Morrison (*6, 8*) is another scale insect that attacks beech. The bark roughening that follows feeding by this insect appears as swollen erumpent spots, 2 to 5 cm in diameter.

In addition, the pigeon tremex, *Tremex columba* L., deposits eggs in the wood beneath the dying bark, and many wood-boring insects mine the dead bark and wood.

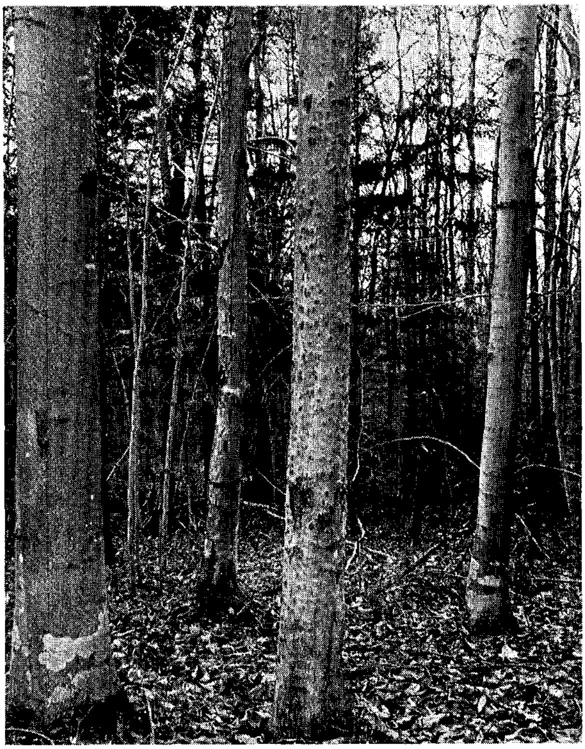

Fig. 3. The beech on the left is free of the disease. The two trees on the right are infested and infected severely.

Resistant Trees

In stands where the disease was severe, some trees remain free of the scale insect and fungus (*Fig. 3*). The trees could not be considered escapees. Many investigators have observed this apparent resistance (*8, 11*), but no sound explanation has been given.

Camp (*1, 2*) attributed this resistance to certain intraspecific varieties of beech and to an admixture of intermediate varieties that are not equally attacked by the insect. He said that no variety is immune, but that there are differences in the type of attack by the insect and fungus and in the response by the host. Of the three basic types of beech, he lists red beech as most susceptible, white beech as intermediate, and northern gray beech as least susceptible. Camp characterized the red beech as very susceptible because of the abundance of protected areas the insect could find in the rough bark.

Present and Future Needs

The best the forest manager can do now is to develop cutting programs that will permit him to harvest as much beech as possible before the trees die and decay. Pathologists have information about the spread of the disease, and they can help develop cutting programs.

A better understanding of this disease is needed. We need to know more about the factors that affect resistance. Is the resistance due to chemical or physical barriers? We also need to know more about the factors that may predispose the trees to the disease. It is possible that the scale insect and *Nectria* spp. are following other stress factors that have weakened the trees.

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UPDATE ON THE TREE INJECTION METHOD TO CONTROL TREE RE-GROWTH[1]

by Leo D. Creed

A project to control tree re-growth was initiated in the early 1960's. The Edison Electric Institute (EEI) contracted with Battelle Memorial Institute to conduct experiments. Many chemicals and combinations of chemicals were tried. Out of this scrutiny napthalene acetic acid (NAA) was selected as the best.

Conclusions were drawn after 10 years of work.

1. New candidate chemicals should be looked at.
2. A more economical method should be found to apply the material.

In 1973 EEI became interested in the control of woody re-growth of trees and asked the Electric Power Research Institute (EPRI) to put a project on its agenda; EPRI agreed. The Ornamental Plants Laboratory at Delaware, Ohio, a research arm of the ARS, was contracted with to perform the necessary research to (1) find a suitable chemical and (2) find a better and more economical method of application. Dr. Charles Wilson was appointed Project Manager. Dr. Wilson in turn appointed two plant pathologists, a chemist, and an agricultural engineer to man the research team.

From the beginning in 1973, the effort was to put the chemicals into the tree by the injection method using from 100 to 400 pounds per square inch pressure.

Problems were encountered:

1. Shape and size of the injection tool.
2. Depth of injection hole.
3. Pressures best suited.
4. Dutch elm disease often would kill the tree before chemicals could work.
5. Trees were killed because of too concentrated a chemical or too much volume.
6. Foliage decline (due to a number of reasons).
7. Tree decay at the point of injection.

The Agricultural Engineer has done a fine job of redesigning the proper tools to do the job. He is presently working to simplify and perfect the tools to do the injection work.

[1]Presented at the International Shade Tree Conference in Detroit, Michigan in August 1975.