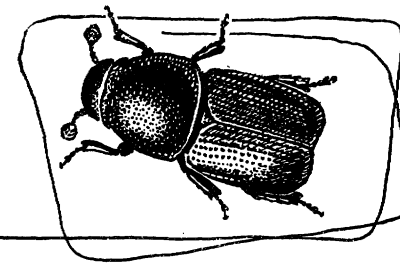
Forests, Trees, and Pests



Insects and Spread of Forest-Tree Diseases

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Insects spread several important forest- and shade-tree diseases. Chief among them are the blue stain fungi, the Dutch elm disease fungus, and the virus of phloem necrosis of elms. The relation of insects to the spread of the blue stain fungi was the subject of early extensive investigations, and this relationship has been known for several years. Recently the large losses caused by the two elm diseases have stimulated intensive research, and much new information has been obtained on the insects that spread them and on their control. Additional investigations undoubtedly will disclose that insects are responsible for the spread of many other diseases of forest and shade trees.

The wind spreads the fungi that cause some forest-tree diseases—for example, the spores of the fungus that causes white pine blister rust. The same is true of the one that causes chestnut blight; insects have only a minor part in its distribution. At best, insects act only as accidental, secondary carriers when they happen to come in contact with spores of the fungus on a diseased chestnut tree and then move to a healthy one where the spores are dislodged from their bodies. No doubt the spores of many other parasitic fungi are thus carried from tree to tree and place to place by accidental insect carriers. The fortuitous relationship between insect and fungus in such instances offers practically no opportunity for the development of control measures through sprays or other treatments for the insects. But there are fungi and viruses that are spread primarily or entirely by insects. Then control of the disease may depend upon finding a satisfactory control for the insect carriers. The relation of insects to the spread of Dutch elm disease and phloem necrosis and their control is illustrative.

THE DUTCH ELM DISEASE is caused by the fungus *Ceratostomella ulmi*. Bark beetles carry the fungus from diseased trees and from dead elms or elm wood or logs in which it is growing to healthy trees or to other dead elms or elm wood. Were it not for these bark beetles, the disease would be relatively unimportant. By the same token, were it not for the destructiveness of the fungus, the bark beetles themselves would be relatively unimportant—before about 1930 they were so considered; only after the introduction of the Dutch elm disease into the United States in the late 1920's did they assume their present importance.

Two kinds of elm bark beetles are important in the spread of the disease. One, the smaller European elm bark beetle, is European in origin. The other, the native elm bark beetle, has been here right along. The European species was introduced 25 or 30 years before the Dutch elm disease fungus came in and, because it bred only in dying or recently dead elm or cut elm wood during the interval, it was relatively unimportant. When the fungus

also was introduced, however, the combination of beetle and fungus produced a disastrous situation. This sequence of events emphasizes the importance of the need for constant vigilance to exclude dangerous or potentially dangerous parasites.

The story of how the elm bark beetles spread the Dutch elm disease fungus was brought to light through the research of many plant pathologists and entomologists in Europe and in this country. Workers in State agricultural experiment stations and divisions of agriculture, several colleges, and the Department of Agriculture have made contributions that have helped to fill out the picture.

The fungus that causes the Dutch elm disease lives in the water-conducting vessels and adjacent cells of the elm, where it grows and produces spores in the vessels. The spores are so small they can be transported rapidly in the sap stream in the trunk, branches, leaves, and roots. When the fungus has become established in the tree or a part of a tree, it causes wilting, yellowing, dying, and dropping of leaves. The symptoms may develop suddenly or slowly and may involve the whole tree or any part of it. The affected tree may be so severely diseased that it dies in a few weeks, or it may decline gradually for several years before it finally succumbs. Occasionally an infected tree may recover. The fungus can live for several years in standing trees; it can also live for a year or two in dead standing elms or in elm logs, wood, and branches broken off or partly broken off during storms. Without aid from elm bark beetles, however, the fungus has no effective way to reach other elms except through natural grafts of roots of diseased elms with nearby healthy elms. Unfortunately for those who wish to save their elms, the dying trees, broken branches, and recently cut logs and wood are soon invaded by the elm bark beetles, which may later carry the disease to the healthy trees.

The beetles bore into the bark where the females make egg galleries and lay eggs. The young larvae, when they emerge, eat the inner bark and make characteristic channels in it. After a period of feeding, they pupate and come out as adult beetles. The fungus may be carried into the original egg gallery made by the female beetles in the bark, or it may be present in the underlying wood if it was previously infected. The fungus can grow luxuriantly in the beetle galleries and produce spores in great abundance. When the adult beetle emerges from the bark it may be well seeded externally and internally with the fungus spores. It begins to feed soon after it emerges, either in living parts of the tree from which it has emerged, or after it has flown to another elm, which may be nearby or several miles distant.

The adult beetle feeds in the crotches of twigs or at the point of junction of a leaf and twig. While it does so, spores of the fungus may be rubbed off its antennae, mouth parts, feet, or body and become lodged in the feeding wound. Some of the spores, or indeed one of them, may start to grow in the feeding injury and infect the tree. That can happen only if the injury in which the spore is released reaches the wood, however; otherwise, no infection takes place. This limitation on the ability of the fungus to cause infection clinches the need for the assistance of the beetle in spreading the parasite from diseased to healthy trees. On its part, the fungus makes the tree suitable for invasion by egg-laying beetles.

Beetles may lay their eggs in dying elm of elm wood that has not previously been invaded by the Dutch elm disease fungus. If the invading beetles have emerged from diseased trees, however, they may carry the fungus with them into such wood, and it in turn becomes a source of danger for nearby healthy trees when the new brood of beetles emerges the following spring or later during the same season. The smaller European elm bark beetle therefore does not require the presence

of the Dutch elm disease fungus to survive, although the fungus helps to provide it with the type of wood it needs for reproduction. Storms, drought, certain construction activities of man, and old-age decline of elm trees provide elm wood suitable for reproduction of the beetles. These alone would insure perpetuation of the species as it was perpetuated for years in Europe. With the additional assistance of the Dutch elm disease fungus in providing suitable wood there is little reason to hope that the beetle can ever be eradicated.

We have reason to hope, however, that it can be controlled. We know, for instance, that the beetle is highly susceptible to DDT sprays and that its numbers can be kept at a relatively low level by the systematic removal of all elm wood that might serve as breeding material. For weeks or months the beetles will not feed on individual trees that have been thoroughly sprayed with the correct formulation of DDT. If all breeding material is removed from a locality, the beetle population will be limited to migrants flying in from the outside, and will thus be held to a low level. If recommended spraying and sanitary measures are combined, it is likely that little loss from disease will result. Naturally, the larger the area in which sanitary measures are undertaken, the better the results will be.

THE NATIVE ELM BARK BEETLE can also spread the Dutch elm disease fungus. Its life history is different from that of the European species and it has been a less effective carrier in the United States than the latter. The native beetle hibernates mostly as an adult in the bark of healthy elms, although occasionally it overwinters in the larval stage. An adult may carry the Dutch elm disease fungus into its hibernation chamber where the fungus will survive until the following spring. Before it emerges in early spring, the beetle feeds for a short time on the inner bark; it may then come in contact with the wood underlying its hibernation chamber. Elms are invaded by the fungus by way of these contact points, but they are often made so early in the spring that growth of new wood in the trees has not started and no new water-conducting vessels have been formed. When new growth does begin, therefore, it entombs the injury along with any spores that may be in it. Because the fungus has only weak power to penetrate cell walls, few infections can occur.

This beetle has not been an important carrier of the disease in the United States. Nevertheless, its habit of overwintering in healthy elms makes it impossible to eliminate as a source of disease transmission from an area, without at the same time eliminating all the elms of more than 1-inch trunk diameter. The beetle can be controlled, however, by the same spray program recommended for the European species.

In Canada the native elm bark beetle appears to be an important carrier of the Dutch elm disease fungus. We have no satisfactory explanation for the difference in its importance as a carrier in the two countries. We suspect that the seasonal history of the beetle may be more closely synchronized in that country with the development of the water-conducting vessels of elm in the spring. In our more northern and colder sections, therefore, it may prove to be a more effective carrier than it has been farther south. Just how effective the smaller European elm bark beetle will be in the more northerly regions we do not know, because it has only recently invaded these territories.

The importance of dead and dying elm wood, and of the breeding and overwintering habits of the beetles in the spread of the Dutch elm disease fungus, therefore, is apparent. Destruction of as much as possible of the beetle-infested material is of primary importance in any organized program to control the disease.

As a final word concerning the role

of insects in spreading Dutch elm disease, it might be well to emphasize that there is no obligate relationship between the two species of beetles and the fungus they distribute. Both kinds of beetles can survive without the fungus, but they and the fungus are complementary in their activities, and together they form a formidable coalition that is causing tremendous losses of elms. The destruction being wrought by the Dutch elm disease is serious enough in itself. Unfortunately, however, it is supplemented in the Midwest by the killing of scores of thousands of elms by another disease known as phloem necrosis, which is caused by a virus and spread by quite a different kind of insect.

THE VIRUS that causes phloem necrosis of elm cannot be transmitted by mechanical means. Healthy trees cannot be inoculated with the virus by grinding, extracting, or macerating infected tissue and then injecting or rubbing it into them. However, the virus can be transmitted experimentally to a healthy tree by grafting into it a small piece of bark from a tree infected with the virus. The virus does not seem to exist outside of living plant cells except when it is in the body of an elm leafhopper.

One kind of elm leafhopper, *Scaphoideus luteolus,* can transmit the virus of the disease from diseased to healthy trees. Only a short period of intensive research by entomologists and plant pathologists was required before proof was obtained of the role of the leafhopper in transmitting the virus.

The leafhopper overwinters as an egg in the bark of elms. The eggs are laid late in the summer. They hatch the following spring, about May 1, in the latitude of Columbus, Ohio. The young nymphs crawl immediately to elm leaves where they feed on the leaf veins. All through the nymphal period they continue to feed on the juice of elms. The beak is sunk into the phloem tissue of soft bark and leaf veins and the plant juices are sucked into the growing insect. The insect also feeds on elm as an adult. If feeding occurs on an elm infected with phloem necrosis, the insect may become infective. The virus does not seem to harm the insect.

The adult leafhopper, a capable flier, may move from elm to elm and feed for long periods during the summer. The virus is transferred to healthy trees during this process. Within a short time the virus can move from the point of injection by the insect to other parts of the elm tree where it may be picked up by other feeding leafhoppers.

As far as we know now, the virus does not live over winter in the eggs of the leafhopper. It must therefore survive from one year to the next in diseased elms, which become infected late enough in the season to escape death from the disease before winter. The trees that carry the virus over the winter leaf out weakly the following spring and die within a short time. However, they do not die soon enough to prevent the newly hatched leafhoppers from feeding on them and becoming infective. The relationship between the leafhopper and the virus disease is much more restrictive than that between the Dutch elm disease fungus and the bark beetles that transmit it from tree to tree. As a matter of fact, it would seem that without the leafhopper carriers, the virus causing phloem necrosis would soon cease to exist.

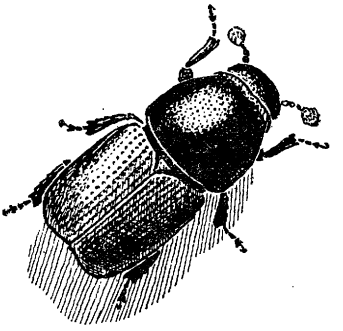
This leafhopper can be controlled by spraying elms with DDT, provided all leaf surfaces are covered thoroughly. Two applications of the spray are required—the first when elm leaves become full-grown and the second from 1 to 2 months later. The spray may be applied with hydraulic equipment or with a mist blower. For hydraulic equipment a 1 percent DDT emulsion spray is required. With the mist blower it is necessary to use a 6 percent DDT emulsion.

In certain sections of the Midwest both phloem necrosis and the Dutch elm disease occur. In such areas it may be desirable to control the insect vectors of both diseases at the same time.

That can be done by covering all elm bark and leaf surfaces thoroughly with DDT: A total of three separate spray applications are recommended. The first should be made early in the spring before elm leaves appear. It should consist of a 2 percent DDT emulsion if hydraulic equipment is to be used, or a 12½ percent emulsion if a mist blower is used. The second and third applications are made with the same formulations and at the same times as recommended for control of the vector of phloem necrosis alone.

THE ROLE OF the beech scale in the spread of nectria disease of beech represents a somewhat different kind of relationship between insects and forest-tree disease. The scale insect apparently reached the United States from Europe by way of Canada and is now fairly widespread in the Northeastern States. It establishes colonies on the lower trunks of beech trees, particularly on trees growing in cool, shady places. The colonies are small at first but enlarge and spread to new spots on the tree trunk within a few seasons. The scale inserts its beak into the bark and sucks up plant juices. As a result, there are many thousands of tiny punctures in the bark of infested beech trees. The injuries appear to be the entrance point through which the beech-bark canker fungus, *Nectria coccinea* var. *faginata*, invades the tree. Without these injuries, the fungus cannot invade the bark. Once it has gained entry through them, it rapidly kills the area of bark previously occupied by the scale, and produces a great abundance of spores on the affected bark. These are probably spread widely by the wind. Often the bright-red, spore-bearing structures on the surface of the bark can be observed in large patches from a distance.

The beech scale and the nectria disease can be controlled by spraying with lime-sulfur to eliminate the scale from infected trees. Such a direct method is not practical under forest conditions, although it may be used to protect ornamentals and trees in parks. In the forest, where spraying is not practicable, there is as yet no proved control for the trouble.



Bark beetle.

INSECTS ARE also responsible for spreading the destructive fungi that cause blue staining of standing coniferous trees, logs, and lumber. The stains do not weaken the wood, but they often cause a reduction in the value of wood products.

The relationship of insects to the spread of blue stain fungi resembles that of Dutch elm disease. The reason may be that the fungus causing that disease is closely allied to those causing blue stain. Again, as was true of the Dutch elm disease fungus, the insects that carry blue stain fungi from tree to tree are bark beetles. The habits of this group of beetles make them effective in transporting the spores of fungi from one tree and placing them in another.

Broods of the bark beetles develop between the bark and wood. That happens because adult beetles emerge from one tree and seek out another, alight on it, and bore through the bark, where they excavate tunnels and lay their eggs. Thus they carry the fungi into the bark with them. Once the fungi are implanted in the bark they begin to grow and produce spores in the tunnels and chambers occupied by the developing insects. When the beetles complete their development they bore their way out through the bark and,

loaded both externally and internally with fungi, they seek out new trees to attack, thus starting the cycle over again.

All trees in a stand are not attacked equally by the bark beetles. We do not know why. We do know that fire-damaged trees are heavily attacked and that trees weakened by drought and root rot are more likely to be attacked than vigorous ones.

In logs and lumber, the beetles have a minor part in the spread of blue stain fungi. That is because wind and rain easily dislodge the spores of the fungi from the surface of the wood, where they are produced in abundance, and scatter them widely. Damage to logs and lumber can be prevented by the application of chemical sprays. When timber values are high, losses among standing trees can be offset considerably by the salvage and sale of the stained timber.

OTHER FOREST DISEASES are also carried by insects. It has been shown by J. G. Leach and his coworkers at the University of Minnesota that a definite relationship exists between the amount and rapidity of decay in Norway pine logs and the extent that two species of wood-boring insects tunnel into the wood.

The fungus causing persimmon wilt has been isolated from the wood immediately adjacent to insect-feeding injuries in otherwise healthy trees, indicating that some of the spread of this wind-borne fungus to healthy trees is related to the abundance of such insect-caused wounds.

A vascular disease of willow, caused by the bacterium *Pseudomonas saliciperda* is transmitted by the poplar and willow borer. The beetles become contaminated with the bacteria while feeding upon diseased willows. When they fly to healthy trees and resume their feeding, disease transmission takes place.

The fungus *Polyporus volvatus* is common in dead or dying trees of several species of conifers killed by bark beetles. It causes decay of the sapwood and is probably introduced into the trees by the beetles.

The pattern of occurrence of oak wilt suggests that the fungus causing it may be transmitted from tree to tree by insects, but experimental proof is lacking.

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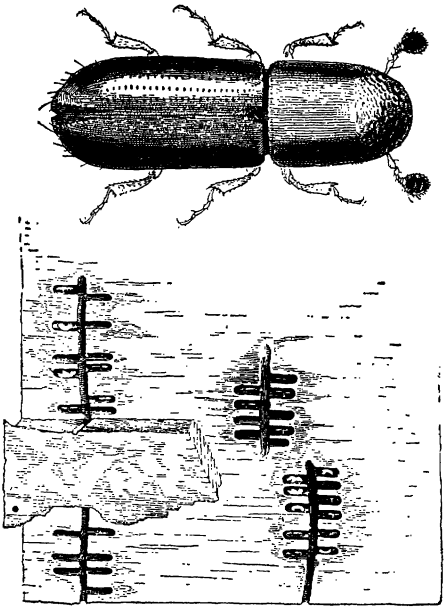

The western hemlock stainer is a very small beetle that constructs individual cells for rearing its young in timber trees.