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VIRUS AND MYCOPLASMA DISEASES OF SHADE AND ORNAMENTAL TREES[1]

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Like all plants, shade and ornamental trees are constantly besieged by problems brought about (a) by unfavorable changes in their environment, (b) by insects or other animals and (c) by diseases. Of the diseases, the most common and best known are those caused by fungi, particularly those appearing as leaf spots or blights, as wilts, and as cankers. A few important diseases are caused by bacteria, and perhaps by nematodes.

During the present century many serious diseases of trees were shown to be caused by viruses. Their symptoms are sometimes obvious and primarily on the leaves (mosaics, mottling, leaf distortions, line patterns, ring spots, yellowing, stunting) and sometimes indistinct, present only part of the season or only for a few years, affecting the roots, stem, or any other part of the tree or the whole tree, and resulting in general stunting, dieback, decline and possibly death of the tree.

In 1967, a new kind of pathogens that cause disease on plants was discovered. These are the mycoplasmas. Relatively few mycoplasmas cause disease in humans and animals, but already about fifty plant diseases, including elm phloem necrosis and lethal yellowing of coconut palms, have been shown to be caused by mycoplasmas. These, however, are not new diseases but diseases previously thought to be caused by viruses. The symptoms of mycoplasma diseases of trees consist of either a general yellowing or reddening of the foliage followed by a rapid or gradual decline, dieback and death of the tree or by general yellowing and excessive branching, growth of axillary buds, short internodes and a witches'-broom appearance, followed by decline, dieback and death of the tree.

VIRUSES

What are they?

Viruses are tiny particles too small to be seen with the common microscope but visible under the electron microscope. Their shapes may be fairly long, thin, flexible, hollow threads or short, rigid, hollow rods or small bacilliform (= bacteria-like) particles or polyhedral, almost spherical particles.

Regardless of shape and size, viruses consist primarily of a nucleic acid, which may be an RNA (ribonucleic acid) or a DNA (desoxyribonucleic acid), and a protein. Of the two substances, the nucleic acid is really the active substance responsible for what the virus does, while the protein serves primarily as a protective coat for the nucleic acid. In recent years it has been shown that some viruses contain more than one kind of nucleic acid and more than one kind of protein in the same particle. Some may even contain one or two enzymes and some are surrounded by a membrane. What is even more significant is that many viruses have the different kinds of their nucleic acid in different particles, so that the presence and cooperation of two, three or even four different particles of the same virus are necessary for the virus to carry out its functions.

1. Presented at the 50th International Shade Tree Conference in Atlanta, Georgia in August, 1974.

How do viruses cause disease in trees?

The main property of viruses that betrays their presence in plants is their ability to cause disease. Virus-diseased trees, as well as other plants, are generally smaller than healthy ones, they seem to have a shorter life span and they seem to be generally more weakened and more vulnerable to other disease agents, both microbial infections and environmental stresses. These general effects are in addition to, or the result of, symptoms produced by the viruses on the leaves, fruits, twigs, stems, or roots.

Viruses cause disease in plants in a most unique, apparently simple, yet little understood way. Viruses as such are parasites, yet they do not eat anything. They do not even seem to secrete any toxic or deleterious substances. All they seem to be "interested" in is to multiply themselves. This they can do only inside living plant cells, especially young, active, enlarging plant cells. The reason for this appears to be that viruses do not divide or otherwise multiply themselves, but they must enlist the services of the plant cell to produce more virus. Once inside a living cell, a virus acts as an organizer or agitator that diverts the activities of the cell away from the normal ones so that the cell will use its energy and nutrients towards formation of more virus and of certain other substances prescribed by the virus.

An analogy can be made between virus multiplication in a cell and the photocopying (Xeroxing) of a written page on a photocopier (Xerox machine). The virus, like the written page, contains information but just as the reproduction of the written page is done entirely by the Xerox machine, so the reproduction of the virus is the work of the infected plant cell. The genetic information contained in the nucleic acid of the virus is reproduced by the cell just as each line or sentence on the written page is reproduced by the Xerox machine. Each genetic segment (sentence?) of the virus nucleic acid, however, prescribes the production of an enzyme that leads to the formation of a substance. Some substances are needed and are utilized to produce more virus—usually about one million new virus particles per cell. Some of the additional substances produced by virus-occupied cells lead to further anomalies in the cell activities. The result is a diseased condition in the cell which may be expressed as reduced or excessive growth and division of the cell, loss of the ability to form certain needed substances such as chlorophyll, or as a more general upset of the metabolism of the cell leading finally to the death of the cell.

Viruses, of course, are carried from cell to cell with relative ease and sooner or later, in a matter of days, weeks, months or years, depending on the size and kind of tree and on the kind of virus, the virus spreads systemically throughout the tree and infects almost every living cell of the tree. When many plant cells react to the infecting virus in the same way, the combined result of their reactions appears on the plant as symptoms. Since viruses multiply and exist in young, active cells, it is young organs such as leaves, flowers, fruit, young twigs and roots or new phloem and xylem that are affected and show symptoms. Organs or tissues that were already formed and mature before the virus infection are not ordinarily affected.

How do viruses spread from tree to tree?

In trees that are propagated vegetatively, e.g. by cuttings, budding, grafting, etc., this method of propagation guarantees an almost 100 percent transmission of the virus from an infected mother tree to all the new trees.

In trees that are grown from seed, the spread of virus from tree to tree is less regular. Relatively few tree viruses are transmitted by insects such as aphids, mealybugs, etc. A fairly common means of virus transmission in trees is through seed derived from virus-infected trees, although only a small percentage of such seed produces seedlings infected with the virus. All viruses are transmitted from tree to tree through natural root grafts. Several tree viruses are known to be transmitted by nematodes, the tiny, worm-like parasites that live in the soil. Some tree viruses are known to be transmitted through pollen, i.e., pollen from an infected tree fertilizing a flower on a healthy tree carries with it the virus which moves out of the fertilized flower and into the mother tree which it infects. A few viruses are transmitted from tree to tree by mites. Finally, some tree viruses are apparently transmitted through the sap or tissue fragments clinging onto pruning tools, etc., during various tree treatments. Of course, several viruses are transmitted in more than one of the ways mentioned above. For example, many of the nematode transmitted viruses are also transmitted through the seed as well as through pollen. If, in addition, the tree is propagated vegetatively, the opportunities for virus transmission become limitless!

What virus diseases affect shade ornamental trees?

The number of virus diseases found to affect shade and ornamental trees is proportional to the amount of research done in the area of virus diseases of such trees. Unfortunately, both are very small in comparison with the same items regarding viruses of fruit trees such as peaches, apples or citrus. As a matter of fact, we probably know more viruses and more about the viruses that affect each one of these kinds of fruit trees than we know about all the viruses that affect all the shade and ornamental trees together. Nevertheless, several virus diseases of shade and ornamental trees are known to occur. The identity and characteristics of only a few of these viruses, however, are known, since most of them have yet to be transmitted onto herbaceous plants from which they can be purified and then studied in detail. Below are listed the diseases of some common shade trees known or believed to be caused by viruses.

Maple. i) Maple mosaic, maple line pattern or maple variegation virus reported from Europe, but apparently present in the northeastern United States also. ii) Peach ro-rosette virus on maple, found in the southeastern United States also. *iii*] Tobacco ringspot virus on maple. *Elm.* *i*] Elm mosaic virus. Widespread. *ii*] Elm ringspot, in Europe and the United States. *iii;* Elm scorch virus, in the southeasten United States. *iv*] Elm zonate caker virus, in an area from New Jersey to Missouri. Four other virus symptoms—elm stripe and elm leaf base necrosis have been reported from Germany.

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Ash. i) Ash ringspot, caused by tobacco ringspot virus and ii) Ash line pattern mosaic, caused by tobacco mosaic virus, are both present in the northeastern United States. iii) Ash chlorotic-necrotic leafspot and iv) Ash leaf marbling were reported from Italy, while v) Ash necrotic leaf curl was reported from Germany and Rumania.

Birch i) Birch line pattern, caused by the apple mosaic virus, is present in the United States and Canada.

From various parts of Europe, especially Germany, virus diseases have been reported on the following:

Beech. *i*] Beech ring mottle virus, from Germany. *Horsechestnut.* *i*] Horsechestnut line pattern virus from Germany and *ii*] Horsechestnut mosaic and curl (leaf distortion) from Rumania.

Linden. i) Linden cowl-forming virus. *ii*) Linden little leaf virus.

Black locust. i) Black locust mosaic virus. ii) A virus resembling tomato spotted wilt virus was found to infect black locust in the United States. *iii*) Tobacco streak virus also affects black locust.

Oak. i) Chlorotic leaf mottle virus. ii) Oak blotch virus. iii) Oak mosaic virus. A fourth virus iv) Oak ringspot virus was reported from the United States. Another virus-like condition v) Oak stem pitting seems to be widespread in the United States.

Poplar. i) Poplar mosaic virus is widespread in Europe. A similar disease seems to also be present in the United States.

Elder. i) Elder ringspot virus. ii) Tobacco ringspot virus in Canada and the United States.

Mountain ash. i) Apple mosaic virus. ii) Mountain ash infectious variegation.

Spruce. i) Spruce mosaic virus. ii) Spruce mottle virus. iii) Spruce virus.

Virus diseases of flowering cherries, peaches, crabapples and other flowering trees. There are dozens of viruses that affect the flowering equivalents of fruit trees and the information available to these viruses is too large to attempt to give even a summary of these viruses here. The flowering species of these trees which are most commonly planted as shade trees are susceptible to viruses to a variable extent. Some of these trees, as well as other shade trees, are extremely susceptible to certain viruses and are killed by them. Others develop symptoms on the leaves, flowers, fruit, stem, etc. The growth of virus-infected trees is usually stunted and sometimes; the virus makes them unattractive for the purpose they are intended, since infected trees often exhibit malformations in the leaves, stem, fruit, or the entire growth habit of the tree may be altered. A few of the viruses affecting flowering trees and the main, although not the only symptom they cause, are the following: chlorotic leaf spot, leaf pucker, mosaic, rosette, necrotic ring spot, leaf roll, tatter leaf, vein yellows, bud abortion, scaly bark, stem pitting, blister canker, black canker, rough bark, bark necrosis, stunt, diamond canker, dwarf, quick decline, etc.

MYCOPLASMAS

What are they?

Mycoplasmas are microorganisms with variable shape and size, varying from small spherical bodies of about 100 nm in diameter to large irregular bodies of 1000 nm ($= 1\,\mu$) or more in diameter, to small or long filamentous or helical bodies of 100-200 nm in diameter and several microns long. Mycoplasmas are much larger than viruses but smaller than bacteria some of which they resemble in shape, size and properties. The most important difference is that while bacteria have a cell membrane and a cell wall, mycoplasmas have only a cell membrane but no cell wall. This important characteristic plays an important role in the variable morphology of mycoplasmas, in the way they move from one cell to another, and in the kinds of antibiotics to which they are sensitive.

Of the nearly 50 plant diseases caused by mycoplasmas, only the mycoplasma of one disease (citrus stubborn disease) has been isolated and cultured. The mycoplasmas of the other plant diseases have been seen with the electron microscope inside cells of diseased plants and in sap extracted from such plants, but they have not yet been cultured on nutrient media. Almost all plant mycoplasmas look alike inside the cells of the different plants they infect, and therefore it is not known how many different mycoplasmas are actually responsible for the 50 or so mycoplasma-caused diseases of plants.

Inside infected plant cells mycoplasmas multiply in one of the three or all three ways listed below: a) by binary fission, in which one mycoplasma constricts in the middle and divides in two; b) by budding, in which one or more small spherules protrude on the surface of a large body and are subsequently pinched off and form new mycoplasmas; c) by formation of constrictions in regular or irregular intervals along the body of filamentous forms of mycoplasmas and resulting in the production of several new mycoplasmas.

Mycoplasmas cannot move by themselves but are carried throughout the plant and cause systemic infections. In the plant, mycoplasmas are present primarily in the sieve elements of the phloem and less so in adjacent phloem parenchyma cells. Mycoplasmas move from cell to cell by forming filaments thin enough to pass through the plate pores of sieve elements and enlarging again or breaking up into new mycoplasmas in the newly invaded cells.

How do mycoplasmas cause diseases in trees?

Very little is known about the mechanisms by which mycoplasmas make plants sick. Electron microscopic observations indicating that mycoplasmas are located primarily in the phloem suggest that mycoplasmas may clog some phloem sieve elements and may interfere with the translocation of sugars from the leaves to the roots, fruits and other plant organs.

On the other hand, most mycoplasma-induced plant diseases, in addition to the general yellowing or reddening of the leaves, are characterized by stunting, break of bud dormancy, witches'-broom growth of axillary shoots, and a change from floral to sterile leaf-type structures in the flowers (phyllody). Furthermore, in some diseases there may be production of abnormal phleom cells and/or necrosis of phloem cells, excessive proliferation of stems or roots, swelling of buds or stems, or decline and death of the plant. No single mechanism of action can explain the wide variety of symptoms observed and no doubt more than one factor is responsible for them. However, most of these symptoms appear to be the result of an imbalance in the kind, amount, or timing of action of growth regulators present in the plant. Whether the mycoplasmas themselves secrete growth regulators or inhibitors of plant growth regulators, or whether they interfere with the plant systems that normally produce and regulate the activity of growth regulators is at present unknown.

How do mycoplasmas spread from tree to tree?

Like viruses, mycoplasmas spread through vegetative propagation of trees by budding, grafting, or cuttings, if the tree from which the vegetative part is taken is already infected with mycoplasmas. Similarly, mycoplasmas spread between adjacent trees through natural root grafts developing between an infected and a healthy tree.

The only other important means of spread of mycoplasmas is by insects, primarily leafhoppers. A few mycoplasmas are transmitted by psyllids, plant hoppers, and possibly aphids. Mycoplasmas transmitted by insects seem to multiply in and spread through the cells of the insect vectors. When an insect, e.g. a leafhopper, feeds on an infected plant it sucks up mycoplasmas along with the sap but it cannot transmit the mycoplasma to another plant immediately. A period of 10-20 days must pass until the mycoplasmas finally reach and multiply in the salivary glands. Then the insect vector can transmit the mycoplasmas to every plant on which it feeds. In most insect-mycoplasma combinations, the mycoplasmas remain in the insect throughout the life of the latter, and in some, the mycoplasmas even pass from the adult insect to its eggs and thence to the new generation of insects which then can transmit the mycoplasma to more plants.

Most of the mycoplasmas as well as the viruses causing plant diseases can also be transmitted from one plant to another through dodder, a leafless, orange-colored parasitic plant, the stems of which sort of form bridges among the plants they infect and allow viruses and mycoplasmas to pass through them and infect new plants. Two mycoplasma diseases, lethal yellowing of coconut palms and sandal spike, have been reported to be manually transmissible through sap.

What mycoplasma diseases affect shade and ornamental trees?

Several mycoplasma diseases of shade and ornamental trees are of extremely serious importance due to their severity, the rapidity with which they spread and the importance of the trees they attack. Some of those known or believed to be caused by mycoplasmas are listed below:

Elm phloem necrosis. It kills elm trees within 2 to 3 weeks when infection occurs early in the season, or within 1 to 2 years if the infection is late. The disease was present in some midwestern states for years but recently it has also been found in Pennsylvania and New York.

Lethal yellowing of coconut palms. It kills coconut palms in the Americas and Africa within three to six months from appearance of the first symptoms. Present for some years in the Caribbean and the Keys, it has now become established in Florida.

X-disease of ornamental cherries, peaches and other stone fruit trees. It causes a general yellowing or reddening of leaves, decline and death of the trees within 2 to 4 years from infection. Widespread in North America.

Ash witches'-broom. It results in small, yellow leaves, witches'-broom growth of axillary shoots, decline and death of trees. Present in the United States.

Walnut bunch disease. It produces bunched, wiry shoots on main stems and branches. Branches die back and entire tree may die. Present in the eastern United States.

Black locust witches'-broom. Widespread in the United States and Europe.

Willow witches'-broom. Present in the United States.

Several other mycoplasma diseases cause serious losses to pome fruit trees and to citrus trees (apple proliferation in Europe, apple rubbery wood in Europe and the United States, pear decline in western United States, citrus greening in the Far East, citrus stubborn in the United States and the Mediterranean countries). The importance, however, of these mycoplasma diseases to shade and ornamental trees of the same, related or unrelated genera is not yet known.

CONTROLS

When a tree becomes infected with a virus or mycoplasma, the pathogen spreads throughout the tree and remains in it until the tree is dead. By the time symptoms appear on some part of the tree, the virus or mycoplasma has already spread internally to an unknown distance within the tree and, therefore, pruning is impractical in attempting to stop the spread of the virus or mycoplasma.

Chemicals that could be used as sprays, injections, or drenches for controlling a virus within the tree are not yet available.

A group of antibiotics called tetracyclines, and which include Tetracycline, Terramycin, Achromycin, Aureomycin and demethylchrortetracycline, have been shown to cause temporary remission of the symptoms but not permanent cure of plant diseases caused by mycoplasmas. When these antibiotics are applied to plants immediately before or after inoculation with the mycoplasmas, infection appears to be prevented to some extent, but in plants showing full symptoms, particularly older plants, the effect of tetracyclines is much slighter. Tetracyclines are absorbed more readily from roots dipped in a solution of tetracyclines than from foliage, but soil drenches with tetracyclines have not proven effective. Repeated foliar sprays with tetracyclines of recently infected plants provides only temporary suppression of symptoms which reappear soon after treatment stops. Reappearing symptoms sometimes remain even when tetracycline applications are being continued, which may indicate an induced tolerance of the mycoplasma to the antibiotic.

Symptoms in three of the most serious mycoplasma diseases of trees (lethal yellowing of coconut palms, elm phloem necrosis, and pear decline) were greatly suppressed or almost entirely disappeared when tetracyclines were injected into the trunks of infected trees through either gravity flow or pressurized trunk injection. Doses of 1 to 3 g of tetracycline antibiotics per tree produced remission of lethal yellowing symptoms in coconut palms, especially recently infected ones, while two or three annual treatments, each consisting of 6 to 8 quarts of tetracycline solution (100 μg/m1) per tree, restored pear trees previously severely diseased with pear decline to normal or near normal conditions.

Some other antibiotics, e.g. erythromycin, tylosin, carbomycin, seem to be very toxic to mycoplasmas in laboratory tests but show little activity when they are applied to diseased plants. On the other hand, foliar sprays with sulfa drugs such as sulfadiazine induced recovery of mycoplasma-infected plants from severe stunting. Disease expression was suppressed more and for longer periods by the combined application of sulfa drugs and tetracyclines than by either alone.

Certain other control measures can be taken to protect against the introduction and spread of virus and mycoplasma diseases of trees. Only virus-free plants should be bought and planted. This in most cases can be achieved only by a concerted effort on the part of nurserymen to propagate trees from healthy mother stock trees which are indexed periodically to ascertain their freedom from virus or mycoplasma. When a serious virus or mycoplasma disease is present in the area, species, varieties or clones of trees known to be resistant to the particular virus or mycoplasma should be preferred for planting. Once a virus-or mycoplasma-free tree has been planted it can still become infected with one or more viruses and mycoplasmas during its long life span. A growing tree can sometimes be protected from being infected with a virus or mycoplasma when the methods of spread of these pathogens are known and means of checking their spread are available. Insect-transmitted viruses and mycoplasmas, for example, could conceivably be controlled by controlling with insecticides the insects that spread them. For a number of reasons, however, this method of control of tree viruses and mycoplasmas is seldom satisfactory, since a few insects almost always manage to feed on a sprayed tree long enough to transmit the pathogen before the insects are killed by the insecticide. Control of the other vectors of tree viruses is just as difficult. With some virus and with all mycoplasma diseases it is best to remove and destroy diseased trees as soon as symptoms are detected. It is also important to know what other trees, shrubs or other plants are infected by the same virus and mycoplasma and to remove them too, so that the insects and other vectors will not have a chance to carry it from them to new, healthy trees. Unfortunately, neither all the alternate hosts nor the methods of natural spread of shade and ornamental tree viruses and mycoplasmas are known, and much more information is needed in this area as well as in the area of chemical controls before effective control measures against tree viruses and mycoplasmas can be formulated.

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ABSTRACT

Scharf, R.F. and F.G. Hawksworth. 1974. **Mistletoes on hardwoods in the United States.** USDA Forest Service, Forest Pest Leaflet 147. 7 p.

The traditional use of mistletoes during holiday seasons, their involvement in folklore and legend, their consumption by domestic and wild animals, and their use for medicinal purposes make mistletoes of widespread interest to the public. The fact that these plants are parasites that injure and eventually kill trees—both conifers and hardwoods—is not well known.

The mistletoes are green, flowering plants that require a living host. Some are rather specific and grow on only a single genus of tree; others occur on a wide range of hardwood species. Even though they are completely parasitic, they do manufacture much of their own food materials by photosynthesis and in general require only water and mineral elements from the host plant. In the absence of the green aerial portions of the mistletoe plant, however, the root system of the parasite can utilize host nutrients and remain alive within an infected branch for many years.

Infection takes place by means of a specialized, penetrating structure that forces its way through the bark and into the living host tissues. Once infection has occurred, the root system of the parasite grows within the branch. The aerial shoot system begins to develop shortly after the root system is well established. Often several years are required after infection for a new seed-bearing plant to develop.

The damage caused by mistletoes in most cases outweighs their economic values. Trees heavily infected by mistletoe are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attack by insects and often succumb during periods of drought or other adverse conditions.

Homeowners with only a few to several infected trees will not find control difficult. Infected limbs can be pruned off, if possible. If this is not practical for esthetic or other reasons, the mistletoe shoots can be broken off periodically. Planting resistant trees that are not susceptible to local species of mistletoes is a sound approach to control.