INFECTIOUS DISEASES OF TREES ASSOCIATED WITH WATER AND FREEZING STRESS[1]

by Donald F. Schoeneweiss

Shade trees are constantly assaulted by agents that may cause disease damage, particularly if environmental conditions are favorable to the disease agent and/or unfavorable to the host (3). Agents that increase in numbers on the host and can be spread from plant to plant, such as fungi, bacteria, viruses, mycoplasmas, and nematodes, are infections agents. Agents that cause damage on contact but are not spread, like air pollutants and toxic chemicals, are noninfectious. When symptoms of damage by noninfectious agents appear, it is usually too late to apply remedial measures, except to reduce or eliminate the source of contamination and prevent additional damage. Infectious agents however grow and colonize host tissues progressively over a period of time. Disease progression and spread of the infectious agent to healthy plants can often be reduced by the use of appropriate disease control practices.

Individuals with training and experience in nursery production, landscaping, or arboriculture should realize that the appearance of disease damage is the result of the interaction of several essential factors in the disease cycle. In order for disease to occur, there must be contact between a pathogen and a susceptible host. Some pathogens can penetrate plant surfaces directly or enter through stomates and lenticels. Many others are strictly wound pathogens, however, most trees have branch stubs, leaf scars, or small breaks or wounds caused by insects, wind, etc. and consequently, entrance of pathogens into trees is quite common. Environmental conditions must be favorable for initial infection and subsequent disease development. Whether disease damage appears may depend upon temperature and moisture, the virulence or aggressiveness of the pathogen, inherent susceptibility of the host, and the state of host vigor at the time of infection.

Most of the stem canker and dieback fungi, as well as several root rot pathogens, are nonaggressive or "weak" parasites; that is, they enter host plants but remain inactive as long as host vigor is high (1). Often these organisms grow as saprophytes in dead branch stubs and roots or in wounds. In many cases, they can be isolated from healthy bark, wood, or pith. Since nonaggressive parasites cause damage only on plants that are weakened or under stress, they have often been referred to as "secondary" organisms and their role in causing plant damage has been disregarded. However, this concept can lead to some erroneous ideas about how to combat such disease problems.

Nursery and landscape trees are periodically subjected to stress conditions throughout their lives from propagation through transplanting, maturity, and old age. Many environmental conditions may cause stress, and reduce plant vigor but most stresses involve unfavorable moisture, temperature, nutrition or a combination of these factors (5). The most common stresses associated with outbreaks of diseases caused by weak pathogens, such as stem canker and dieback fungi, are drought or water stress and freezing stress.

Sub-freezing temperatures and lack of water are the two major factors limiting world-wide distribution and productivity of plants (6). These same stresses limit growth and survival of landscape trees. Although the relation between stress and tree diseases has long been recognized, little information was available until recently as to the level or degree of stress and the length of stress exposure required to break down disease resistance or "predispose" trees to disease.

A major barrier to obtaining meaningful information on the influence of stress on tree diseases has been the lack of suitable techniques for sub-

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jecting whole plants to environmental stresses under controlled conditions. Weather conditions that cause water and freezing stress in the field are highly variable and unpredictable and other factors such as nutrient availability, insect or mechanical injury, etc. may influence stress effects. Thus, results of field studies on stress are difficult to interpret. Over the past decade, methods and techniques have been developed at the Illinois Natural History Survey for subjecting potted or container-grown trees to controlled water and freezing stress, and to assess the influence of these stresses on susceptibility of trees to attack by weak or nonaggressive canker pathogens (4, 7, 9, 12, 13).

Water Stress

Seedlings of sweetgum, European mountain ash, European white birch, and red-osier dogwood, ranging in age from one to three years, were grown in containers until root systems were well established and the seedlings were vigorous. Stems of the seedings were wound-inoculated with *Botryosphaeria dothidea,* a common canker fungus that attacks a wide range of tree species under stress but seldom causes damage on vigorous plants. The seedlings were then wilted to various levels of plant water potential as measured with a pressure chamber (9). When the desired level of water potential was reached, plants were maintained at this level for a 7-day incubation period in a humidity cabinet (9). In this manner, the level of plant water stress could be correlated with changes in susceptibility of stems to attack by the pathogens.

Results of these tests indicated that the level or severity of plant water potential must exceed a threshold level of approximately −12 to −13 bars or atmospheres (1 bar = .987 atm) before stems become susceptible to attack (Fig. 1). Inoculated plants maintained at less severe stress conditions (less negative water potential) remained resistant for over three weeks while stem cankers appeared within five days on plant subjected to stress exceeding the threshold level. As water potentials became more negative than the threshold level, the rate and extent of canker formation increased.

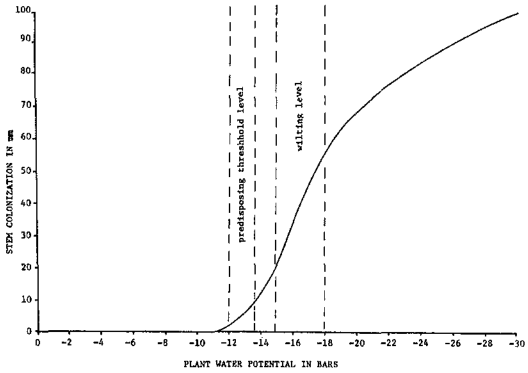

Fig. 1. Extent of colonization by *Botryosphaeria dothidea* in woody stems predisposed by water stress.

With all tree and shrub species studied thus far, the threshold level of water stress at which stems become susceptible to canker fungi is less negative than that which results in wilting symptoms (Fig. 1). This means that by the time trees show signs of wilting, they may have become predisposed to fungal attack. Obviously watering trees on a regular schedule during droughts, without waiting for leaves to wilt, is an effective means of preventing damage by stem canker fungi.

Exceeding the threshold predisposing level of water stress alone will not predispose plants to disease unless the plants remain under this stress for some minimal period of time. On a hot, dry summer day, plant water potentials often fall below the threshold level, then recover at night when water uptake exceeds water loss by transpiration. In studies on duration of water stress conducted in our lab, E.G. Wene (13), found that plant water potentials of several trees and shrubs must exceed the threshold level for at least three days before stems become predisposed to attack by *B. dothidea.* Thus, water stress predisposition involves a combination of level or severity and duration of exposure. When plants subjected to predisposing water stress were watered prior to inoculation, stems again became resistant to attack after three days, indicating that the increase in susceptibility due to water stress was a reversible response. However, prolonged drought over several years may stress trees to the point where disease predisposition becomes irreversible and trees continue to decline from attack by canker and dieback pathogens. Extensive losses occurred due to attack by canker fungi on a number of tree species following the dust bowl years of the 1930's.

The development of predisposing plant water stress is also common in trees following transplanting. Whether trees are bare-rooted or balled and burlapped, there is a loss of absorptive root surface due to root pruning when trees are moved. In one experiment, we found the European white birch seedlings that were root-pruned and transplanted remained resistant to attack by *B. dothidea* as long as plant water potentials were maintained above the threshold level of −12 bars. If plants were allowed to wilt to −16 bars, *B. dothidea* colonized the stems (10), thus, water stress appeared to be a major factor responsible for disease predisposition following transplanting. Even plants grown in containers in artificial mixes may undergo predisposing water stress when transplanted to field soil unless irrigation is increased beyond that required for normal container maintenance (10).

Freezing Stress

Temperatures below freezing also may cause trees to become susceptible or predisposed to attack by weak pathogens. Extreme low temperatures in mid-winter may kill buds and occasionally stems or roots of trees native to a milder hardiness zone. However, fully acclimated trees adapted to the region in which they are grown are seldom injured by even record low temperature (2). Most of the freeze injury and weakening of hardy tree species in the midwest is caused by rapid and extensive drops in temperature following extended mild weather during the dormant season. Outbreaks of stem cankers and diebacks are common on trees that were not fully acclimated in the fall when they were exposed to a hard freeze.

To gain some insight into how freezing predisposes tree stems to weak canker fungi, a method was developed at the Survey for freezing container grown trees under controlled conditions. One- to three-year-old seedlings of several tree and shrub species were placed outside in a lath house until the plants were dormant and exposed to several light frosts, but were not fully acclimated by low temperatures. Stems of the various species were inoculated with canker fungi that attack winter injured plants and the plants were placed in a walk-in freezer. The containers were insulated to prevent root freezing and the stems were then frozen to temperatures ranging from −20 to −30°C (−4 to −22°F). After stem temperatures had remained at a given level for 30 minutes, some plants were removed and the remaining plants were frozen to lower levels. The plants were thawed slowly at 0°C overnight and examined over a 2-week period for canker formation and stem colonization by the pathogens.

Our experimental results lead us to believe that a threshold level of freezing is required to predispose woody stems to attack by nonaggressive canker fungi (Fig. 2). European mountain ash, European white birch, sweetgum (8), and red-osier dogwood (13) were predisposed to *B. dothidea*, and tallhedge buckthorn was predisposed to *Tubercularia ulmea* (7) by exposure to

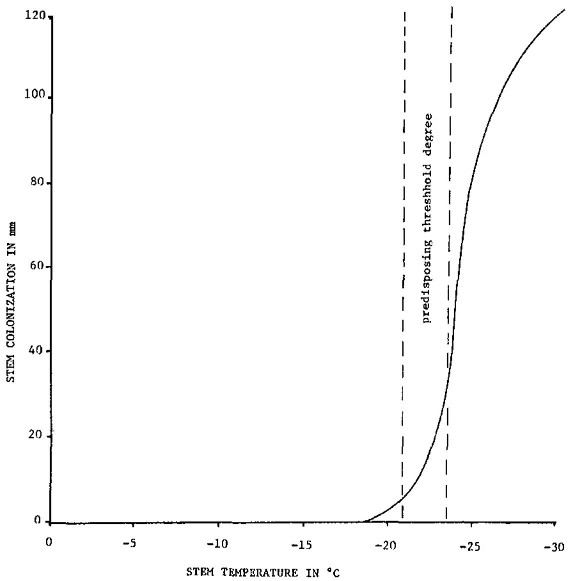

Fig. 2. Extent of colonization by *Botryosphaeria dothidea* in woody stems predisposed by freezing.

freezing temperatures between −20 and −30 °C. In a more elaborate study, the threshold temperature at which *Euonymus alatus* became predisposed to *Nectria cinnabarina* basal canker was found to be approximately −22 °C (12). In all cases, plants frozen to −20 °C or above remained resistant to attack by these weak pathogens. As stem temperatures fell below the predisposing threshold level, the rate and extent of stem colonization increased.

Some additional information derived from controlled freezing experiments provides new insight into the relation between freezing stress and plant disease. Stems of plants that were frozen to −30 °C but not inoculated showed no signs of freezing injury. No damage to bark or cambium appeared and buds were not killed. Microscopic examination of xylem tissues failed to reveal any browning or discoloration of xylem ray parenchyma cells, which is reported to be one of the most sensitive indicators of freezing injury (2). In addition, use of techniques developed for plant hardiness studies to detect cell injury and mortality, such as thermal analysis (2) and triphenyl tetrazolium chloride reduction indicated that xylem ray cells were not killed by freezing to −30 °C. The only evidence of freezing stress in stems was the rapid and extensive increase in disease susceptibility in stems frozen to temperatures below the threshold level. Predisposition to canker pathogens appears to be a very sensitive indicator of freezing stress and outbreaks of stem cankers on trees in the spring may indicate that the trees were stressed by freezing the previous fall or winter, even though no typical symptoms of winter injury appear.

Predisposition to weak canker fungi caused by freezing is reversible once the stress is relieved, similar to water stress predisposition. Wene (13) inoculated stems of freeze-stressed red-osier dogwood seedlings with *B. dothidea* at daily intervals after thawing. He found that susceptibility of stems to attack by the pathogen began to decline after nine days and by fourteen days previously frozen stems were as resistant as stems never frozen.

Although water and freezing stress predispose woody stems to attack by canker fungi, the regions of the stem tissues affected are quite different. Water stress predisposes bark and wood tissues near the cambium and has less effect on older wood, while freezing stress predisposes older wood surrounding the pith (Fig. 3). Canker fungi colonize bark and wood beyond canker margins in wilted stems but cannot be recovered from either bark or young wood near canker margins in frozen stems. Drought and freezing both result in dehydration of plant cells and Levitt (5) reported that many plants sensitive to drought are also sensitive to freezing injury. Cold tolerance of some woody plants has been increased as much as several degrees by partial dehydration of tissues prior to freezing (2). However, not only do drought and freezing stresses have different predisposing effects on woody stems, we have found that some tree species are predisposed by drought stress but not by freezing and vice versa. Apparently much additional work is needed before we understand how these stresses affect disease resistance mechanisms in plants.

Discussion

Very few stem canker and dieback pathogens attack vigorous trees. Outbreaks or epidemics of these diseases are usually an indication that the trees have been predisposed by stress, the most common ones being water stress and freezing stress (Figs. 4 and 5). Since the pathogens involved are often present within plant tissues at the time stress occurs, the application of protective fungicides is not likely to give effective control. Proper maintenance to promote vigor and hardening, particularly during and after transplanting, is the most effective way to avoid damage by stress-related pathogens (11).

Trees often recover from predisposing water and freezing stress if canker and dieback pathogens are not present in the host. Therefore the idea that these organisms are secondary and of little importance in causing injury is not valid. They should be considered a vital part of the complex of factors resulting in damage in plants subjected to environmental stress. Since most of the canker and dieback fungi invade and grow saprophytically in dead and dying plant tissue, careful handling of plant material to avoid

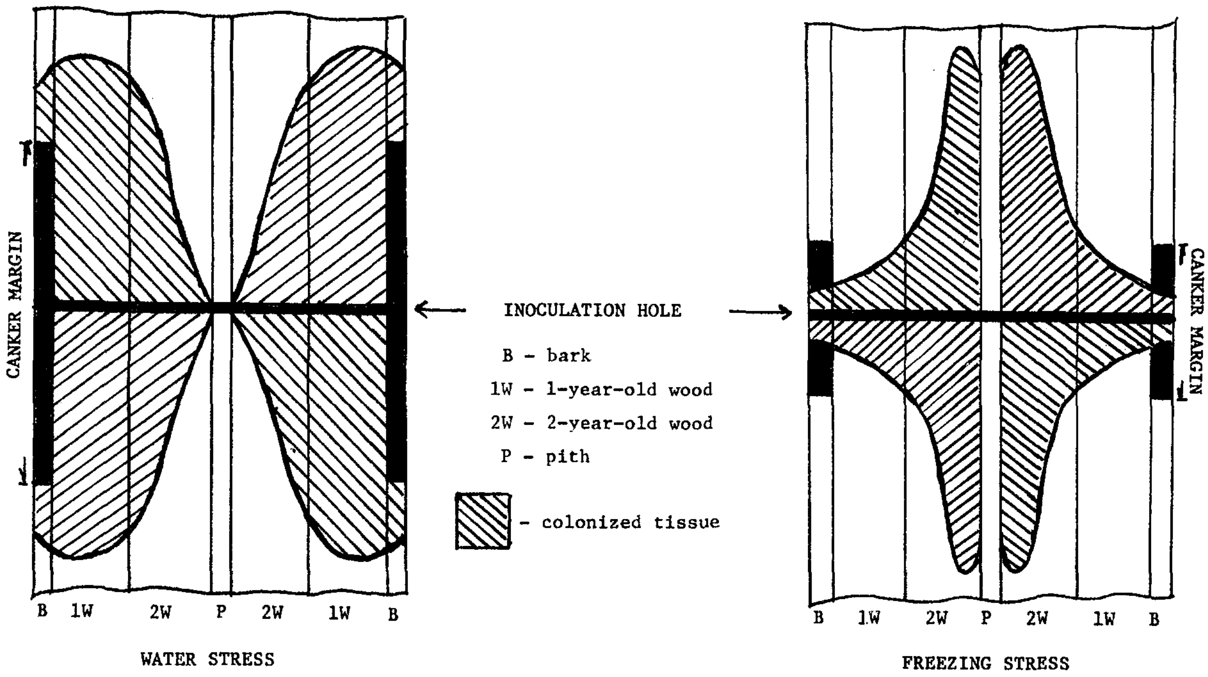

Fig. 3. Patterns of colonization by *Botryosphaeria dothidea* in woody stems predisposed to disease by water and freezing stress.

Fig. 4. Stem cankers caused by *Cytospora chrysosperma* on weeping willow following water stress. Note dead branch stubs associated with cankered areas.

Fig. 5. Basal stem cankers caused by *Tubercularia ulmea* on tallhedge buckthorn following freezing stress. Note fruiting bodies of the pathogen on girdled stems.

breakage, elimination of branch stubs, pruning of shaded or weakened branches, removal of plant debris, and disinfection of tools and equipment will help reduce the likelihood of spread and infection.

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ABSTRACTS

Haller, J.M. 1979. **Galls.** Am. Forests 85(12): 12-15, 51-53.

Galls are globular, semiglobular,, cylindrical, or disklike swellings produced on leaf blades, leaf petioles, or twigs by the sting of parasitic wasps; by midges, aphids, or other insects; or by the infestation of bacteria or fungi. Although each gall is characteristic of the insect or bacterium or fungus that causes it, the gall itself is actually part of the plant. It is composed of plant tissues diverted from their normal development and forced to serve the ends of the parasite. The gall is alive only so long as the plant is alive. The great majority of shade-tree galls are caused by egg-laying insects, especially tiny wasps. Uninformed homeowners discovering galls for the first time often take them as symptomatic of a dangerous disease and may resort to drastic remedies. Felling and topping are, of course, useless, since the gall-producing insects may fly to any tree from any point of the compass. Spraying is similarly of very doubtful value.

Shurtleff, M.C. 1980. **Fungicides for ornamentals — selection and use.** Grounds Maintenance 15(1): 20-21, 24, 82-83, 86.

Fungicides are available to protect plant seeds, foliage, flowers, fruits and roots from infection, but no single fungicide is suitable against all types of disease-causing fungi. Because most fungicides in general use have protective-contact action, they must uniformly coat all susceptible plant parts before fungus invasion occurs. Systemic fungicides, however, are absorbed and translocated within the plant to control a disease. In general, fungicide sprays, dusts, dips and soil drenches will not check or eradicate disease that is well established or protect against diseases caused by bacteria, mycoplasmas, spiroplasmas, viruses, viroids, nematodes or parasitic plants. See the chart and tables for information on fungicide efficacy for various categories of diseases and lists of generic (common) names followed by their trade names.