BACTERIAL LEAF SCORCH OF URBAN TREES

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ABSTRACT -- Bacterial leaf scorch is caused by *Xylella fastidiosa* Wells et al. The pathogen causes chronic leaf scorch and decline in elm, oak, sycamore, and maple. *X. fastidiosa* has a wide host range and is responsible for many other serious diseases including Pierce's disease of grape, phony disease of peach, and citrus variegated chlorosis. Its role in shade tree disorders has only recently been recognized. Many questions regarding *X. fastidiosa* and its impact on amenity trees, such as mechanism of pathogenesis, methods of transmission, and management strategies await further study.

INTRODUCTION

In recent years leaf scorch caused by the bacterium *Xylella fastidiosa* Wells et al. (*Wells et a1.1987)* has become widely recognized as a significant disorder affecting several species of landscape trees, including elm, oak, sycamore, and maple. *X. fastidiosa* is not a new pathogen, but its affect on landscape trees is a newly recognized phenomenon that deserves more attention and a better understanding.

X. fastidiosa has a wide host range including both monocotyledonous and dicotyledonous species in over thirty families *(Freitaq 1951, Hopkins and Adlerz 1988, Sherald and Kostka 1992).*

Although many hosts are asymptomatic, others are severely affected (Table 1). The most noted diseases caused by *X. fastidiosa,* Pierce's disease of grape, phony disease of peach, and most recently, citrus variegated chlorosis (CVC), exhibit the wide range of symptoms associated with this unique pathogen. Pierce's disease was first recognized in California in the 1880s and is now endemic in California and the southeastern United States. Grapes develop a late season leaf necrosis and plants decline over several years before death. Phony peach disease was first detected in Georgia in 1885. Trees are dwarfed and develop profuse lateral branching. Foliage is flattened and dark green

and the fruit is reduced in size and quantity *(Cochran and Hutchins 1974).* CVC was first reported affecting orange in Brazil in 1987 (Lee *et al. 1991).* Leaves exhibit foliar and interveinal chlorosis with gummy lesions on the underside. The fruit is reduced in size and develops a hard rind. Growth is slowed and the canopy is thin. Symptoms are often systemic in younger trees, but in trees older than 15 years symptoms may be evident in several major scaffold branches, yet not in the remainder of the canopy. Currently, CVC has not been found in the United States.

Pierce's disease and phony disease of peach were believed to be caused by a xylem-inhabiting virus. Transmission of the causal agent of both diseases was achieved with xylem feeding sharpshooter leafhoppers of the subfamily *Cicadellinae* and spittle bugs, subfamily *Cercopidae (Hewitt et al. 1942, Hopkins 1989, Houston et al. 1947, Turner 1949, Turner and Pollard 1959).* Transmission could also be achieved mechanically with grafts of scion wood containing xylem tissue from affected plants *(Cochran and Hutchins 1974, Esau 1948, Hutchins 1939).* Attempts to isolate the agent on artificial media were unsuccessful leading to the speculation that a xylem-inhabiting virus was the causal agent. In 1971 successful remission of Pierce's disease symptoms was achieved with application of tetracycline to the root zone (Hopkins and Mortensen 1971). This was the first indication that a bacterium rather than a virus was the pathogen. Electron microscopy later associated a morphologically similar, xylem inhabiting bacteria-like organism with Pierce's disease of grape *(Hopkins and Mollenhauer 1973, Goheen et al. 1973),* phony disease of peach *(Hopkins et al. 1973, Nyland et al. 1973),* alfalfa dwarf *(Goheen at al. 1973),* almond leaf scorch *(Mircetich 1976),* and plum leaf scald (Kitajima *et al. 1975).*

In 1978 Davis et a1.(1978) developed the medium which provided the first opportunity to isolate and grow the agent in vitro. It was now possible to fulfill Koch's postulates and describe the pathogen. The description of X. *fastidiosa (Wells et al. 1987)* was based on 25 strains representing 10 hosts. *'Xylella'* denotes the xylem habitat of the bacterium and *'fastidiosa'* refers to its fastidious growth requirements, accounting for the earlier inability to isolate the organism. It was determined that all strains were of the same species, however, there are host specific strains or pathovars.

Xylella fastidiosa and Landscape Trees

ELM

The first evidence of a relationship between Pierce's disease and leaf scorch disorders in trees occurred in 1959, when Wester and Jylkka *(1959)* reported that a leaf scorch of American

elm, *Ulmus americana* L., was similar in symptomatology to Pierce's disease. Although they were unable to isolate the pathogen, transmission was achieved by grafting with scion wood containing xylem tissue suggesting that a xylem-inhabiting "virus" similar to the Pierce's disease agent was responsible. Like Pierce's disease, leaf scorch symptoms in elm begin to develop in mid-growing season and become progressively more severe throughout the summer and early fall. Leaves develop a distinct marginal necrosis proceeded by a chlorotic halo *(Hearon et al. 1980, Sherald and Kostka 1992, Sinclair et al. 1987).* Both grape and elm show a progression of symptom severity from the older to the younger leaves on a stem with newly formed leaves sometimes remaining symptomless and severely affected leaves abscising early. In elm there may be a reduction in flower buds as well as flower bud abortion. Affected branches also show a delay in leaf expansion. As observed in CVC, symptoms in larger elms may be confined to several limbs, while the remainder of the tree appears normal. However, symptoms are often seen throughout the crowns of both smaller and larger trees.

Seedling elms inoculated with an isolate of *X. fastidiosa* from a naturally infected elm developed the characteristic leaf scorch symptoms and reduction in growth as seen in naturally infected trees *(Sherald 1993).* Kostka et al. *(1986)* found that scorch-affected elms had a reduced xylem efficiency or water conducting potential. This is likely because of the direct occlusion of the vessels by the bacteria, tyloses, or possibly extracellular products produced by the pathogen *(Hopkins 2989).* The moisture stress induced is subacute resulting in leaf scorch rather than wilt which occurs with more severe blockage caused by wilt pathogens such as *Ophiostoma ulmi* (Buism.) C. Nannf. Affected elms also have a reduced level of stem starch and reduced stem elongation both characteristic of trees under stress *(Kostka et al. 2986).* The subacute water stress inflicted by *X. fastidiosa* enhances susceptibility to Dutch elm disease. Wester and Jylkka (1963) noted that elms infected with leaf scorch had a higher Dutch elm disease incidence than unaffected trees. It is known that elms under moisture stress are preferred breeding sites for the European elm bark beetle *(Scolytus multistriatus* Marsh.) *(Whitten and Swingle 1958).* Consequently, elms with bacterial leaf scorch are susceptible to contracting Dutch elm disease by beetle breeding attacks to the trunk or major limbs. Inoculations of the trunk and major limbs are far more likely to *be successful than the twig feeding inoculations that occur through feeding attacks of healthy elms (Banfield 1941, Zentmyer et al. 1946).*

Elm leaf scorch has been recognized in Washington, D.C. since the early 1930s *(Wester 1954).* It has been reported as far South as New Orleans, Louisiana and as far north as Baltimore, Maryland. The disease affects the American elm, the Wych elm, *U. glabra* Huds., and the Siberian elm, *U. pumila L. (Kostka et al.*

1982, Kostka 1984). It is likely that it occurs throughout the mid-Atlantic and southeastern United States.

SYCAMORE

Sycamore, *Platanus occidentalis* L., is also affected by *X. fastidiosa.* Chronic leaf scorch and decline of sycamore have been associated with *X. fastidiosa* throughout the southeast and mid-Atlantic states *(Haygood et al. 1988, Sherald et al. 1983, Sherald and Kostka 1992).* The disease has been seen in both young and older trees growing in street and open park settings. Symptoms develop in mid-summer and are most pronounced in late summer and early fall. Leaves develop a marginal and interveinal necrosis *(Sherald et al. 1983, Sinclair et al.* 1987). Tissue first develops an olive green discoloration which later turns brown. The margins of the necrotic area are reddish brown. As in elm, there is symptom progression on a branch from older to younger leaves, a consequence of the indeterminate growth of both hosts. In addition to leaf necrosis and dieback, there is also a reduction in growth, delayed foliation and a reduction in fruit set. Affected trees linger for many years before they become too unsightly for the setting and are removed. It is probable that trees suffering for several years from moisture stress caused by chronic *X. fastidiosa* infection will also experience additional stress imposed by opportunistic insects and disease organisms. The final stages of decline may involve a number of contributing factors.

Sycamore seedlings inoculated with a strain of *X. fastidiosa* isolated from sycamore developed leaf scorch and dieback and were significantly smaller in height and caliper after four years *(Sherald et al. 1985). P. X acerifolia* (Ait.) Willd.), *P. orientalis* L., and *P. mexicana* (Moric.) all develop symptoms when mechanically inoculated *(Sherald, unpublished data).*

OAK

Several oak species, *Quercus* spp., predominantly in the red and black oak group, are susceptible to bacterial leaf scorch *(Chang and Walker 1988, Hearon et al. 1980, Hopkins and Adlerz 1988, Kostka et al.* 1984) (Table 2). Oak has determinate growth, so unlike elm and sycamore, symptom development does not show an acropetal progression, but rather all leaves on a branch are affected simultaneously. Discoloration progresses from the tips and leaf margins to the midvein and petiole *(Hearon et al. 1980, Sinclair et al. 1987).* Tissue turns olive green and then brown. The margins of the necrotic area may be reddish brown with a chlorotic halo abutting green tissue. A pattern of concentric zones or waves of necrosis may appear on the leaf. As in other tree hosts, the symptoms may occur localized in a single limb or segment of the tree, or may develop throughout the canopy. Trees are eventually removed because of their unsightly appearance.

The presence of canker causing fungi, *Armillaria* or other stress agents may, in the long term, obscure the presence of *X. fastidiosa.* The disease has been found as far south as Florida and as far north as New York *(Hopkins and Adlerz 1988, Kostka et al.* 1984). To the west it has been found in Kentucky, Indiana, and Tennessee *(Hartman et al. 1991, Hartman, personal communication).*

MAPLE

The reports of X. *fastidiosa* in red maple, *Acer rubrum* L., are few. The disease has been reported in Maryland, Virginia, and South Carolina *(Blake, 2993, Sherald et al. 1987).* Red maple may not be highly susceptible to X. *fastidiosa* or there may simply be inadequate recognition and reporting of this disease. Leaves develop an irregular pattern of light and dark brown tissue preceded by a narrow band of chlorotic tissue. The pattern is quite distinct from the symmetrical marginal scorch that occurs commonly in street tree plantings that are experiencing abiotic moisture stress *(Hammerschlag and Sherald 1986).*

DISCUSSION

The distribution and significance of *X. fastidiosa* in landscape trees is far from well established. A systematic survey of all known affected species would help define the factors, such as climate and vector relations, that establish the range and severity of these diseases.

The significance of *X. fastidiosa* as a pathogen in shade and street trees may be far greater than generally recognized. Several communities have reported large numbers of scorch-affected oaks. In Morrestown, New Jersey the disease incidence in a pin oak population of approximately 1000 trees is approaching 20% (C. Pfleider 1994 *personal communication).* The community of Alapocas in Wilmington, Delaware found that approximately 50% of their street oak population was affected *(personal communication, R.E. Carlson, Bartlett Tree Experts, 1987).* In a survey of the 101 ha East Potomac Park in Washington, D.C, where growing conditions would be considered optimal, it was found that of 129 sycamores, 86% exhibited symptoms. Recent plantings of new sycamores in the same location have also contracted the disease. The 600 elms of the National Mall in Washington, D.C. were examined for leaf scorch symptoms from 1986 to 1992 *(Sherald et al. 1994).* The annual mean disease incidence over the period surveyed was 30% and increased by 10% over 6 years. Symptoms did not necessarily increase annually in affected trees, but rather there was a fluctuation in symptom severity from year to year.

Unfortunately, symptoms of bacterial leaf scorch are quickly dismissed as consequences of the environment. Although local

environments and edaphic factors may contribute to symptom development, there are numerous examples of trees growing in ideal surroundings yet still severely afflicted by the disease.

Leaf scorch and dieback are symptoms common to many disorders. The pattern of bacterial leaf scorch can often be distinguished from abiotic moisture stress, however, the disease may still not be readily recognized. Isolation and identification of the pathogen provide direct confirmation of the disease, however, *X. fastidiosa* is a fastidious pathogen requiring special media and handling. The development of the enzyme linked immunosorbent assay (ELISA) kit 'PATHOSCREEN Xf' (Agdia Inc., Elkhart, IN) has provided a diagnostic tool that can be used with crude tissue extracts (Sherald and Lei 1991).

As is true of any newly recognized disorder, there are many important questions that must be answered. The answers to some of these questions are critical to the management of these diseases in landscape trees. The vector of *X. fastidiosa* in grape and peach and other agronomic hosts are xylem feeding leafhoppers and spittle bugs. The same vectors are probably involved in transmission of *X. fastidiosa* in trees, however, this has not been confirmed. It is also possible that other species, not previously associated with *X. fastidiosa,* may play a role. Several studies are now underway to determine the potential vectors and demonstrate their role in these diseases.

Although there have been no deliberate surveys, anecdotal observations suggest that bacterial leaf scorch is not a common occurrence in natural settings. The prevalence of bacterial leaf scorch in developed landscapes may be significant and raises several questions. For example, are trees in urban settings already under stress and therefore more prone to exhibit symptoms of a chronic bacterial infection? Hopkins (1989) notes that since X. *fastidiosa* inhabits many asymptomatic hosts, it might be considered a weak or opportunistic pathogen. Symptoms in even some of the severely affected hosts, like grape and shade trees, do not appear until late season when environmental stress may be most common and when natural senescence has begun. Studies of plant growth regulators that promote senescence have shown that promoters such as ethephon and abscisic acid will enhance symptom development in grape (Hopkins 1989). Indoleacetic acid and kinetin which retard senescence, prevented symptom development and bacterial colonization in the less Pierce's disease susceptible *Vitis rotundifolia* Michx. 'Carlos,' but did not have the same affect on a more highly susceptible variety.

Developed landscapes may also have an influence on the vectors responsible for transmission. The vectors may be more prevalent in open than forested areas. There may also be a vector relationship between landscape trees and other host species, possibly asymptomatic, that may occur commonly in open landscapes. For example, species such as California mugwort *(Artemisia vulgaris* L. var. *heterophylla* Jepson) and Bermuda grass *(Cynodon dactylon* (L.) Pers.) have been found to be natural hosts of *X. fastidiosa (Freitag 1951).* Recently, we have found leaf scorch symptoms characteristic of Pierce's disease in porcelain berry, *Ampelopsis brevipedunculata* (Maxim.) Trautv., a member of the *Vitaceae. X. fastidiosa* was isolated and confirmed by ELISA. Porcelain berry was introduced as an ornamental from northeastern Asia in 1870 (Wyman 1966). It has rapidly become an exotic pest occurring in the open and on the edge of wooded areas. Porcelain berry, as well as other hosts, may serve as reservoirs for *X. fastidiosa* and play a significant role in the spread of the disease.

The host / pathovar relationships remain one of the least understood areas of interest. Pierce's disease, alfalfa dwarf, and almond leaf scorch are caused by the same strain or strains *(Davis et al. 1980).* Another strain or strains cause phony peach disease and plum leaf scald *(Wells et al. 1981).* Cross pathogenicity between these two groups has not been demonstrated. Since elm, oaks, and sycamore affected by bacterial leaf scorch are often growing in close proximity to one another, they may be affected by the same strain or strains. However, in one cross pathogenicity study with strains of *X. fastidiosa* from elm and sycamore it was found that strains would infect their natural hosts, but would not infect the reciprocal host *(Sherald, 1993).* This demonstrates that there may be a more complex pathovar relationship among tree species. Further studies to distinguish pathovars and their host relationships are in order. Particularly important would be to determine if strains present in asymptomatic hosts, especially common herbaceous species, are serious pathogens in trees.

The management of these diseases in urban / suburban settings is limited because of our lack of knowledge. Elm, oak, and sycamore are some of our most commonly used landscape trees. If trees are affected should they be removed? The fact that symptom expression may fluctuate from year to year and in the first few years may be hardly noticeable would weigh against immediate removal. On the other hand, the risk associated with leaving infected trees as potential reservoirs of inoculum for surrounding trees is unknown. Chemical therapy has barely been explored. Tetracycline injections have caused symptom remission but no cure *(Chang 1988, Kostka et al. 1985).* Treatments, however, have involved small volumes of material applied over a short period of time. More extensive testing of antibiotics and other materials, as well as methods of application are warranted. Also, cultural tactics, e.g. fertilization and irrigation, may improve the survival of infected trees and mitigate their attack by other debilitating secondary agents. The pruning of infected trees is successful in the early treatment of Dutch elm disease *(Campana 1978).* The same tactic should also be explored with bacterial leaf scorch. A basic question associated with pruning therapy, however, is the distribution of the pathogen in the tree. Studies are necessary to examine the systemic movement of X. *fastidiosa in* infected trees and determine the rate of spread. The possibility also exists that root graft transmission occurs as is true of vascular wilt pathogens in elm and oak. If so, the severance of root grafts may be another management tactic that should be considered.

SUMMARY

Bacterial leaf scorch of landscape trees is not a new disease, but one that has simply been overlooked. We are now aware of the symptoms and consequences of this disorder in landscape trees and have the technology available for diagnosis. Considerable information, however, is lacking on the host pathogen relationships, transmission, and most importantly, disease management. Undoubtedly, now that the significance of the disease has been recognized, research will proceed at a more rapid pace.

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Table 1. Diseases associated with *Xylella fastidiosa*.

Disease	Reference
Alfalfa dwarf	Goheen et al. 1973, Hopkins and Mollenhauer 1973
Almond leaf scorch	Mircetich et al. 1976
Citrus variegated chlorosis	Lee et al. 1993
Elm leaf scorch	Hearon et al. 1980 Sherald 1993
Maple leaf scorch	Sherald et al. 1987
Mulberry leaf scorch	Kostka et al. 1986
Oak leaf scorch	Chang and Walker 1988, Hearon et al. 1980
Periwinkle wilt	McCoy et al. 1978
Phony peach disease	Hopkins et al. 1973
Plum leaf scald	Kitajima 1975
Sycamore leaf scorch	Sherald et al. 1983

Table 2. Species of oak (*Quercus* spp.) diagnosed with bacterial leaf scorch caused by *Xylella fastidiosa.*

Species	References
Laurel oak (*Q. laurifolia* Michx.)	Hopkins and Adlerz 1988
Live oak (*Q. virginiana* Mill.)	Mullen 1993
Northern red oak (*Q. rubra* L.)	Hearon et al. 1980, Hartman et al. 1991
Pin oak (*Q. palustris* Muenchh.)	Hartman et al. 1991
Scarlet oak (*Q. coccinea* Muenchh.)	Hartman et al. 1991
Shingle oak (*Q. imbricaria* Michx.)	personal communication - Longwood Gardens 1988
Shumard oak (*Q. shumardii* Buckl.)	personal communication - Longwood Gardens 1988, Mullen 1993
Southern red oak (*Q. falcata* Michx.)	Hopkins and Adlerz 1988
Water oak (*Q. nigra* L.)	Hopkins and Adlerz 1988