SHADE TREE LEAF SCORCH[1]

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Abstract. The term scorch is commonly used to describe foliar symptoms of marginal and interveinal dessication. A diversity of abiotic and biotic agents cause scorch symptoms in shade trees. Thus there are many physiologic and pathologic bases for leaf scorch. Little research has been performed to define these bases; however, recent research involving fastidious xylem-inhabiting bacteria (FXIB) in elm, sycamore, oak, and mulberry has provided some insights while raising new questions and interest about scorch in shade trees. Characteristics of scorched trees are presented which should prove useful for the often difficult task of field differentiation of biotic from abiotic scorches.

The term scorch has been generally and sometimes loosely applied to foliage exhibiting varying degrees of dessication and discoloration. This paper will focus on shade tree scorches exhibiting marginal or interveinal leaf dessication. Affected leaf tissue usually becomes necrotic, often appearing brown, but may also be accompanied by narrower bands of other discoloration. Marginal scorch is a prevalent characteristic pattern on a leaf which develops as tissue dessication proceeds inward from the leaf margin. Symptoms may develop along most of the leaf margin progressing uniformly toward the midvein (Figs. 1, 2, 4, 5) or they may develop as irregular marginal or interveinal zones of expanding necrosis (Fig. 3). The necrotic zone may be preceded by a distinctive band of chlorotic or reddish brown tissue (Fig. 4). Occasionally multiple bands occur suggesting pulses of dehydration (Fig. 5). Leaf curl may accompany scorch in some disorders.

Symptom development may be acute, occurring suddenly, accompanied by dieback or possibly even death of the entire tree; or it may be chronic, gradually increasing in severity over several years. Individual limbs and branches may be affected or symptoms may develop generally throughout the entire canopy.

Leaf scorch is distinguishable from wilt which is characterized by leaf drooping followed by chlorosis, necrosis, and abscission. Scorch and wilt are both consequences of dysfunction of the tree's water system caused by either biotic or abiotic agents. The extent and site of disruption within the plant, regardless of the causal agent, helps distinguish between these two symptoms. Wilt is an expression of an acute moisture decrease in leaf tissue as occurs with such abiotic factors as severe sudden drought and/or root loss, or with biotic agents like vascular wilt pathogens. The disruption is major, primarily affecting the main translocation system of the plant roots, stems, and petioles.

Leaf scorch in contrast reflects a milder, sometimes chronic water system disruption yielding its primary impact in the leaf. A tree's vascular system becomes narrower and consists of fewer elements as it branches from the major veins toward the leaf margin and interveinal spaces. This reduced system and the tissue it supports becomes progressively vulnerable to water system disruption. Such disruption may be the result of a general, but mild reduction of water movement in the plant, or blockage affecting the narrower terminal vessels of the leaf (21, 22). An accumulation of salts at the terminus of the leaf vascular system can also cause localized tissue dehydration or death.

We have segregated the causes of shade tree scorch into two groups, abiotic and biotic, and will provide characteristics that will assist in classifying leaf scorch into either of these groups.

Abiotic Scorch

Abiotic or non-parasitic scorches may be caused by environmental, edaphic, or physiologic conditions. The following conditions can cause leaf scorch: moisture deprivation resulting from drought, dehydrating winds, low and high temperatures coupled with low soil moisture availability, insufficient root system due to confined planting space or to poor soil conditions, ex-

cessive soil salt and salt deposition on leaves; reduction of oxygen from the soil atmosphere such as that resulting from compacting or waterlogging soils, grade changes including filling, and displacement of soil oxygen by other gases; and various other factors such as pesticide phytotoxicity, air pollutants, toxic metals, potassium deficiency, and heavy fruiting. Scorch symptoms could develop as a result of transplanting, construction, or other disruptive activities of man. Also, in some species leaf scorch commonly accompanies fall senescence.

Field diagnoses of abiotic leaf scorch may seem difficult because of a long interval between the occurrence of the stress and symptom development; inability to readily see the conditions that cause stress, such as poor root function; or technical problems with identifying the agent, such as a pesticide or toxic material. The following discussion will assist in field diagnoses.

A scorch pattern that develops symmetrically on a leaf and progresses uniformly from leaf margins or tips is usually of abiotic origin (Figs. 1, 2, 4, and 5). Uniform necrosis is related to the symmetrical distribution of xylem elements within the leaf. For example, restricted water movement or accumulation of solutes along the leaf margin would yield a uniform marginal necrosis.

Abiotic scorch can affect all leaves on a twig at the same time or it may even begin with the newer of the existing leaves (Fig. 6). In the case of trees exhibiting indeterminant growth, where the first flush of leaves display scorch, it is possible that leaves formed later may be symptomless. For example, leaves scorched by road salt or summer drought may be followed by a flush of nonaffected foliage in late summer if growing conditions improve.
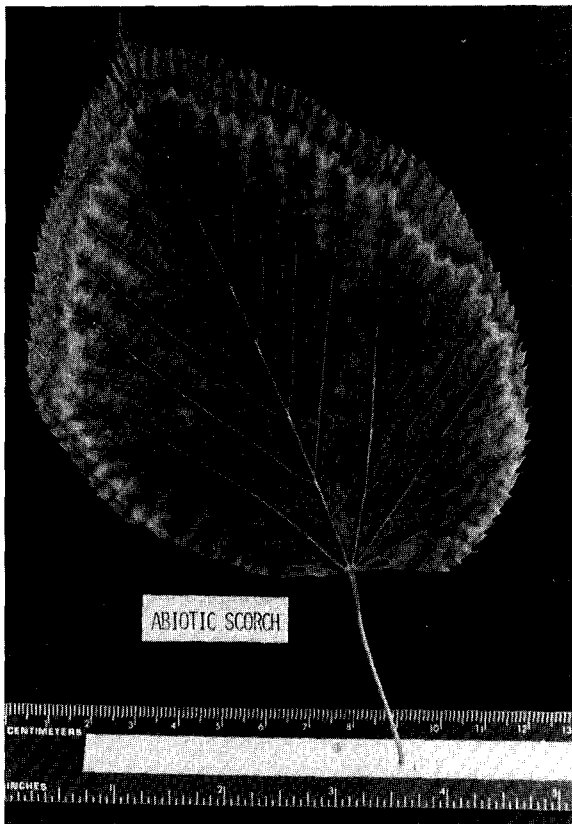

Figure 1. Marginal leaf scorch symptoms on American linden. The banding pattern parallel to the leaf margin is typical of site related (abiotic) scorch.
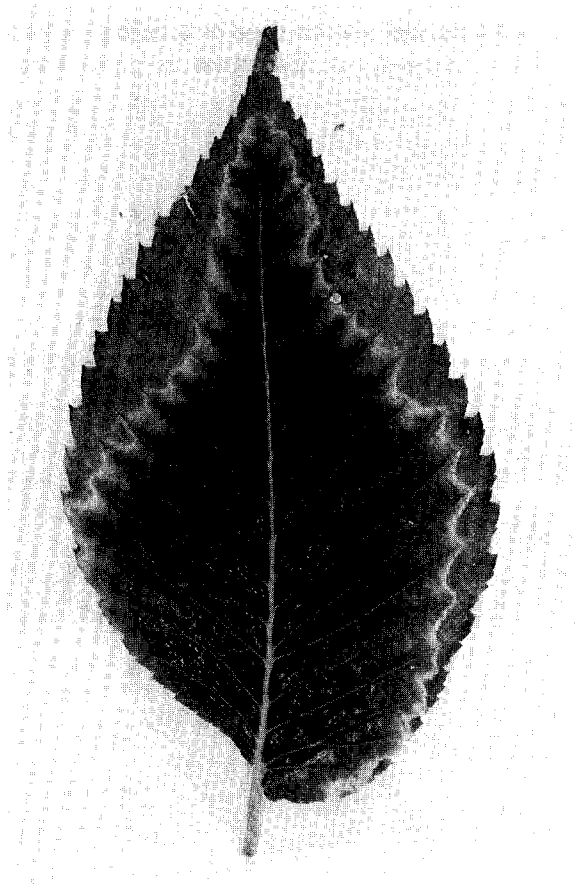

Figure 2. Abiotic leaf scorch on American elm. Note the difference between this marginal leaf scorch on elm with that of the biotic scorch pattern pictured in Figure 3.

Abiotic stress often affects all or large sections of a tree. Consequently, leaf scorch caused by abiotic factors is usually distributed throughout the tree or predominates on the side of the tree most impacted by the stress. Many soil related problems impact the entire root system ultimately leading to scorch symptoms in most of the tree canopy. Scorch symptoms on one side of a tree could result from a directional abiotic stress such as road salt deposition or salt spray being much higher on the curb side of a tree than on the side away from the road (10). Similarly, leaf scorch due to the combination of hot winds and exposure to the sun may be most noticeable on the south side of a tree (15). Unilateral scorch might also result from construction activity which severely impacts roots on one side of a tree.

Abiotic scorch may correlate in time with the occurrence of a particular environmental condition. For example, leaf scorch seen on a curb side tree in June following an icy winter is more likely related to road salt than heat or drought. Similarly, scorch symptoms that appear in curb side trees while not in others close to them or across the street may be due to toxic gas accumulation in the soil or root injury due to prior construction activities. It is important to obtain a thorough history of previous site disturbances when diagnosing leaf scorch disorders.

Where one has the opportunity to observe a tree over a number of years it may be possible to relate abiotic scorch to irregular or non-repetitive conditions. Drought scorch would be expressed most severely during dry years; air pollution scorch would be expected following severe and prolonged atmosphere inversions; fertilizer scorch would be seen following excessive fertilizer application. However, trees suffering from persistent stress, such as compacted soil or insufficient planting space, may tend to display scorch symptoms yearly, as commonly observed in street plantings of little leaf and American linden (Fig. 1).

The authors have had the opportunity to follow one disorder which perhaps represents another type of abiotic scorch. A planting of buckeye

Figure 3. Scorch symptom expressed as an irregular banding pattern associated with fastidious xylem-inhabiting bacteria on American elm.
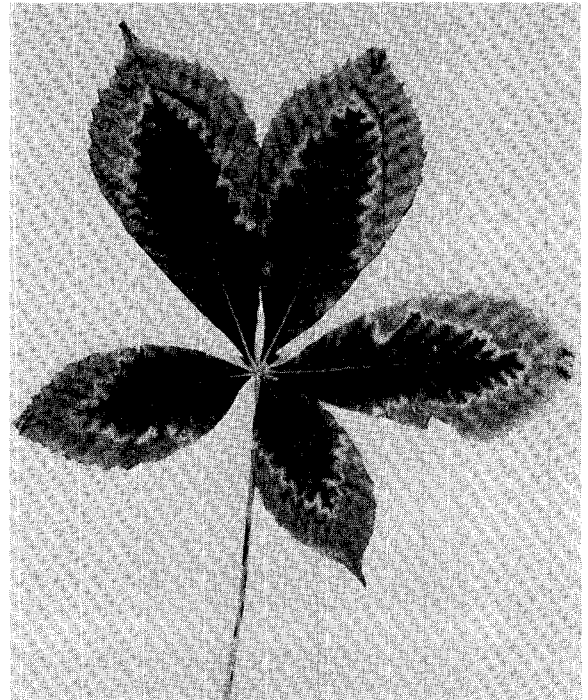

Figure 4. Symptoms typical of abiotic scorch on buckeye (*Aesculus carnea*). Note the distinctive band of chlorotic tissue preceding the marginal necrosis.

(putative *Aesculus glabra* X *A. octandra*) in Washington, D.C. regularly begins showing scorch symptoms every June regardless of all other factors (Fig. 4). Analyses of scorched leaf tissue yield high chloride levels, generally near 1% (10,000 ppm) on a dry weight basis. It is possible that this hybrid is naturally prone to accumulate chloride and/or poorly equipped to restrain evapotranspiration. A similar scorch affects the common horsechestnut *(A. hippocastanum)* and Ohio buckeye *(A. glabra)* (1). No pathogen has been isolated from affected trees.

Biotic Scorch

There are several reports of biotic agents involved with leaf scorch. For example, insects such as aphids and mites, most notably on pecan trees, may cause leaf scorch; a virus has been associated with tomato leaf scorch; and a nematode with wheat scorch. Some cases of purported scorch, particularly on herbaceous plants, such as narcissus, strawberry, and azalea, are caused by leaf infecting fungi. Scorch symptomology has been associated with shade tree disorders such as Norway maple decline (16), sycamore canker (7, 19), and oak wilt (23).

Figure 5. Drought scorch symptoms on Japanese dogwood with several distinctive bands probably corresponding to periods of water stress.
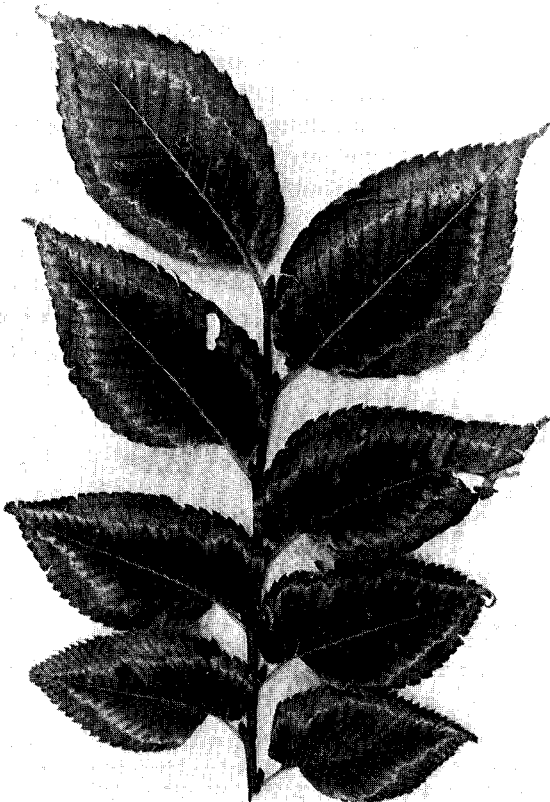

Figure 6. Abiotic leaf scorch on American elm with leaf symptoms expressed uniformly along the twig.
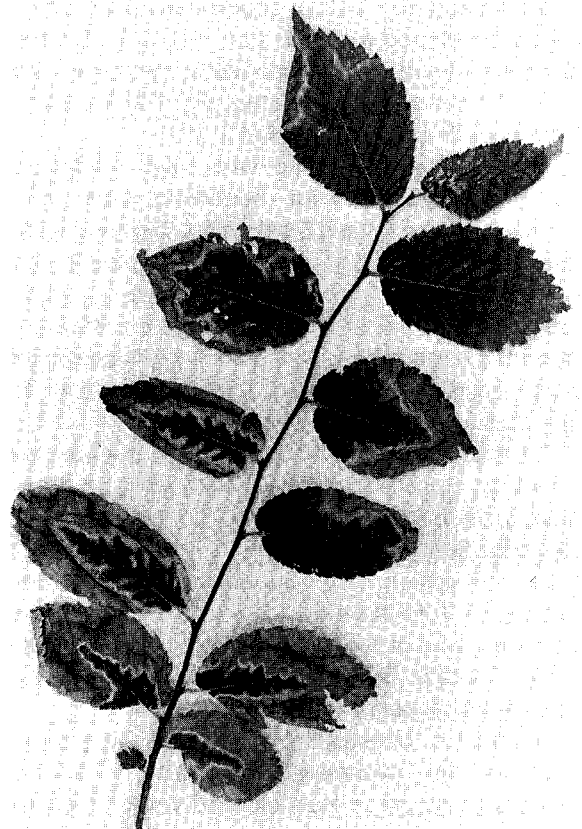

Figure 7. Progressive development of leaf scorch symptoms from older to younger leaves on American elm infected with fastidious xylem-inhabiting bacteria.

Recently, fastidious xylem-inhibiting bacteria (FXIB) have been associated with leaf scorch in elm, sycamore, red oak, and mulberry (6, 11). Wester and Jyllka demonstrated that elm leaf scorch was caused by a graft transmissible xylem-inhibiting agent (24). They postulated that the agent was a virus, similar to the virus then believed to cause Pierce's disease, a leaf scorch disorder of grape. Pierce's disease is now known to be caused by a FXIB sometimes referred to as rickettsia-like bacteria (2, 5, 8). Likewise, FXIB cause leaf scorch in almond (3) and plum (18) and have been associated with diseases in other hosts (4, 9, 17).

The presence of FXIB in vessel elements of leaf scorch affected elms, red oaks, sycamores, and mulberries have been confirmed by electron microscopic examination of leaf vein tissue (6, S. Kostka unpublished data). Bacteria, serologically related to the Pierce's disease bacterium have been isolated from all four species and cultured on media developed for FXIB (11, 13, 20). Scorch symptoms have been produced in sycamore and mulberry seedlings inoculated with FXIB isolates from scorch affected trees (12, 20).

Leaf scorch associated with FXIB begins to develop in mid-summer becoming most pronounced in August and September. Depending on the extent of infection, scorch may appear in one limb or several limbs in a sector of the crown. In severe cases the entire crown may be affected. Scorch symptoms will reappear in the same limbs each year with symptoms also spreading to previously nonaffected limbs.

The leaf scorch pattern varies with the species affected. Generally, necrosis develops in localized, irregular areas along the leaf margin and interveinal tissue progressing toward the primary veins and petiole (Fig. 3). Green tissue is often separated from the expanding necrotic zone by a chlorotic band or halo and in some cases a reddish brown band(s). Severely scorched leaves may roll or curl and in some trees abscise early.

In species possessing indeterminant growth, such as elm, sycamore, and mulberry, scorch symptoms progress from older to younger leaves (Fig. 7). A general decline, characterized by dieback, and ultimately death, has been observed in elm, oak, and sycamore. The rate of decline

may depend on other contributing stress factors. For example, scorch affected elms are more likely to contract Dutch elm disease, since weakened trees are attractive to the European elm bark beetle (25), a vector of the fungal pathogen inciting Dutch elm disease.

The following generalizations may be useful in distinguishing biotic leaf scorch, particularly that caused by FXIB, from abiotic disorders. Biotic scorch may appear in distinctly limited sectors of the tree. Affected sectors will not be readily associated with directional environmental factors. Biotic leaf scorch may appear in the same sector and spread to adjacent sectors in successive years. In contrast to abiotic scorch, symptoms may appear in older leaves and progress into newer leaves, when a biotic agent is involved. Symptom progression from older to younger leaves may reflect the movement of the causal agent from infected tissue into newly formed tissue.

Though a commonly occurring phenomenon, leaf scorch represents a complex area of shade tree physiology and pathology that to date has received little attention. Leaf scorch should alert the arborist that a tree is stressed and may warrant treatment for some abiotic factor(s). Arborists, however, should be aware that FXIB, a novel group of pathogenic bacteria, may cause leaf scorch. Currently, there is no known treatment from FXIB in shade trees, although preliminary studies have shown that oxytetracycline can cause symptom remission in elm (14).

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