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CONSIDERATIONS OF MICROCLIMATE-LEAF DISEASE RELATIONS IN ARBORICULTURE[1]

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Abstract. This paper describes the interaction of disease propagules with features of the microclimate most likely to result in leaf infection. It discusses how the microclimate can be manipulated by cultural practices and landscape planning to minimize disease occurrence. Keywords: *Spore germination, topography, landscaping.*

At first inspection, the numerous leaf spots, blights, and anthracnose diseases that afflict the foliage of trees seem to present no regular pattern of occurrence and distribution. However, acquaintance with leaf diseases, particularly over several years, often reveals that certain trees are regularly affected while others escape attack. Why certain trees should experience more leaf infections than others near them is often not readily apparent. A leaf disease outbreak on a particular tree can be due to an unusual susceptibility of the tree to infection, to a local situation where a larger than normal number of disease propagules alight on the foliage, or to conditions of the tree's microclimate that favor infection. Phenological studies relating climatic factors to disease development can show whether disease outbreaks are due to microclimatic factors that make certain sites more disease-prone. Such investigations, when carefully carried out, can establish the importance of site in comparison to other factors responsible for disease outbreaks.

The microclimatic requirements for disease establishment are now known for many diseases, especially the diseases of major food crops. The principles that govern these diseases can be applied to most tree diseases. Moreover, the arboriculturist can use these principles to modify existing tree plantings, and to plan future plantings so as to avoid or minimize tree disease problems. Disease-microclimate knowledge should be especially useful in choosing sites for arboretum tree collections where certain selections are ultra-susceptible to diseases.

Microclimate-Disease Relations

Climatic variables. The most important climatic variables for the development of leaf disease epidemics are moisture, temperature, wind, and light. With the major exception of certain rust and mildew diseases, whose spores can be spread by air currents in the absence of moisture, most disease propagules (fungi and bacteria) must be wetted prior to their release from the substrates on which they develop. In addition, the germination of fungal spores after alighting and the penetration of fungal mycelium into the leaf require leaf surface wetness for an extended period (Fig. 1). The form of wetness is not important; it can be provided by rainfall, dew, or even fog under the proper conditions.

The inoculation-wetting time requirements of disease propagules also depend on temperature. Generally, when temperature is excessively low or high, longer periods of leaf wetness are required for spores to germinate and infection to become established. Most leaf pathogens of the temperate zone are mesic in their temperature requirements.

Wind, gravity, and insects are the principal agents responsible for spread of leaf pathogens. Gravity, through the action of falling rain or dew drops containing pathogen propagules, can cause much within-tree disease spread. In addition, because most pathogen propagules are small,

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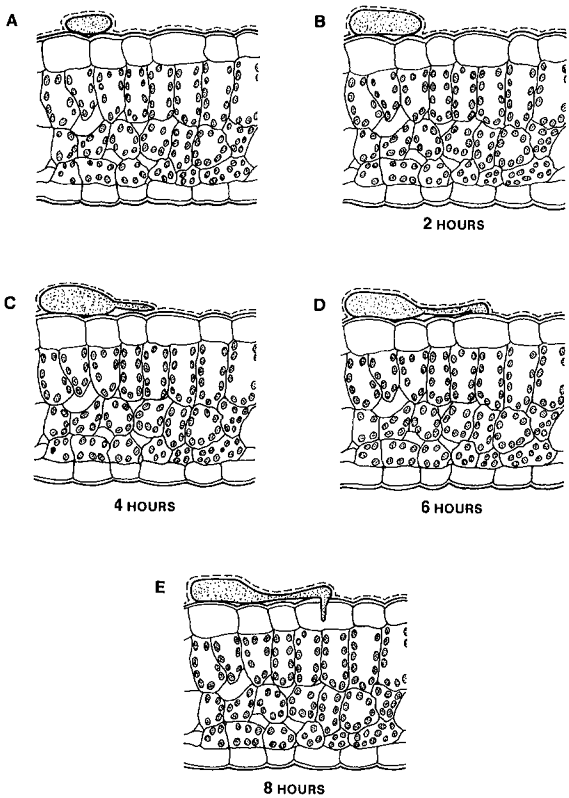

Fig. 1. Typical sequence of events from time a fungal spore arrives on leaf surface to beginning of entry into leaf. A. Spore arrives. B. Spore becomes swollen. C. A germ tube is produced. D. An attachment to the leaf is formed. E. Penetration into the leaf at the attachment location occurs. Until this time, drying of the leaf surface would terminate the germination-host penetration sequence.

their dissemination is influenced by subtle wind flows and convection currents within tree crowns and over local topographic features.

Sunlight speeds the drying time of wet foliage, thereby reducing the period of susceptibility to infection. Shaded parts of trees, because of slower drying times, will generally be more prone to infection. Prolonged exposure to the ultra-violet portion of the light spectrum is harmful to and can kill many disease propagules.

Spatial relations. As trees become larger, their susceptibility to disease attack can change radically. A young tree growing in a rough, weedy, unmowed field develops in a high humidity zone close to the earth where foliage dries slowly. Here, rain and dew-wetted leaves stay wet longer because of higher humidity, shading, and reduced wind velocity. As the tree grows and its crown gets farther from the earth, it enters a zone of lower risk — of lower humidities and more vigorous drying winds.

The spatial relations of trees to one another and to certain topographic features can noticeably affect the severity of disease attacks. Because dissemination of disease propagules tends to follow the direction of the prevailing winds, trees downwind from other members of the same species are more prone to infection. This is especially true of small trees downwind from larger ones, because gravity as well as wind transports rain and dew droplets containing disease propagules onto understory trees. Special wind conditions, such as mountain-valley and land-water breezes, may dominate some locations and should also be considered when analyzing patterns of propagule dissemination.

Topographic features that contribute to high humidity and shading are often present where diseases develop. Through empirical observation, early mycologists frequently chose as collecting sites for parasitic fungi discharge areas of lateral valleys and watercourses. These locations are regularly subject to descending currents of cool night air that provide conditions for heavy deposition of dew on plant surfaces (Gaumann 1950). Other cold air sinks, such as local ground depressions and forest openings, are also high-humidity areas. Small forest openings have surprisingly long wet periods. In these locations heavy dew deposits condense on leaves as outward radiation to the sky takes place on clear nights. Humid air for dew condensation comes from the ground zone and from the cool, moist air draining from the tops of the surrounding tree canopy into the opening (Van Arsdel 1961). In hilly country the slope degree and aspect affect early morning drying of foliage. At any given point the amount of radiation received will depend on the season, the degree of cloudiness, and the degree and aspect of the slope.

In addition to increasing the microclimatic favorableness for disease some ground features serve as aids for concentrating disease propagules through air flows. Dorworth (1973), for instance, found that the action of wind vortices serves to intensify spore inoculum at the bottom of geographic depressions.

Cultural Practices to Lessen Disease Impact

Chemical control of forest and shade tree leaf diseases is seldom warranted. The arboriculturist's objective should be to minimize disease by cultural practices, proper site selection, and careful matching of species to sites.

Thinning of dense stands increases the distance between infected and uninfected trees. It also reduces the level of inoculum present in the stand and, because foliage dries more rapidly, reduces the period of susceptibility to disease (Heather 1976).

By taking advantage of knowledge concerning the disease resistance of various species and genera, mixed tree plantings can be established which are less susceptible to disease. Such plantings can increase the distance between susceptible trees and thus reduce the likelihood of infection. Trees should be irrigated in a way that avoids wetting of foliage (Hallair *et al*, 1868). Overhead irrigation of black walnut in a young plantation in Illinois produced a premature leaf defoliation caused by the walnut anthracnose fungus (Kessler 1978).

Cultivating and using herbicides to remove competing understory vegetaton helps remove the moisture-entrapping, high-humidity air layer around recently planted trees. In tree nurseries, from a disease-prevention standpoint, the planting of large blocks of trees in relatively small areas should be avoided. A better procedure would be to plant each tree species or variety in long rows or long rectangular beds with their long axes oriented so that prevailing spring and summer winds blow across them rather than down them. This orientation results in the disease propagules being blown away from the trees rather than into them.

Where plantings are very dense, however, it may be more desirable to orient the rows with the prevailing winds. For example, in a Canadian study of a Sclerotinia disease of beans, orienting the rows with the prevailing winds provided more rapid foliage drying conditions (Haas and Bolwyn 1972). In dense plantings, it is also especially desirable to mix the rows or beds so no two adjacent rows or beds contain trees susceptible to the same diseases.

Trees, particularly because of their size, alter the microclimate of sites upon which they grow. Tree cover slows the rate of heat loss from leaves of understory plants on nights conducive to dew formation and less dew is deposited upon their leaves (Geiger 1966). Shade-tolerant small trees and shrubs planted under or near large trees should therefore suffer less infection during dew periods than open-grown plants. Shading results in increased resistance to some leaf diseases, a phenomenon which seems to be associated with reduction in light intensity rather than a decrease in temperature or moisture. This effect has been noticed with *Dothistroma* needle blight on *Pinus radiata* (Ivory 1972) and *Cercospora* leaf spot of bananas (Thorold 1940). With other leaf diseases, such as anthracnose of black walnut, light has the opposite effect (Black 1977).

In row crops, spacing has a pronounced effect on disease incidence (Berger 1975). Generally the rate of epidemic development is faster among plants at close spacings.

Ponds, Lakes, and Streams. Creating artificial impoundments rather than planting trees is one, albeit drastic, way to utlize these high-disease-risk areas. Water bodies, through gradual heat release to the sky on cool nights, modify the climate near them. One of the effects of this is to lessen dew deposition on trees and shrubs planted nearby (Roberts 1972). While the climate-moderating effects of large bodies of water are well known, relatively small water bodies also influence climate, particularly to leeward.

Paved Surfaces and Stones. During the day, these materials act as heat sinks. At night, through gradual release of heat, they reduce dew formation and sometimes speed drying of rain-wetted foliage. The relatively disease-free foliage often seen in plantings along paved streets, paved malls, etc., may owe its healthfulness at least in part to unfavorable microclimatic conditions for pathogen establishment. Areas near patios, tennis courts and swimming pools can on a smaller scale provide favorable microsites for trees that have particular disease problems, for example, certain varieties of crab apple that are ultra-sensitive to apple scab disease (Nichols 1979).

Buildings and Shade Structures. The microclimatic effects afforded by buildings provide tree planting sites similar to those along forest edges, but without the problems caused by tree competition (Fig. 2). For many trees, the east side of a building provides optimal conditions for rapid early morning foliage drying, and affords protection from excessively high temperatures. Shade structures, such as lath roofs over patios, can provide protection for young, disease-susceptible trees. If desired, the leaves of tree seedlings in the nursery can be kept completely dry at all times by growing the seedlings in inexpensive plastic "tunnels" (Keveren 1974).

Fig. 2. Trees growing in an urban situation where buildings and pavement modify microclimate.

Subjective evaluations of disease likelihood in plantings on selected natural sites and landscape situations are given in Tables 1 and 2, respectively. These evaluations reflect a hypothetical disease on a hypothetical tree species. In practice, one has to know something about the diseases attacking the trees with which one is working. With such information, tables could be constructed for each disease-tree interaction. At present, environmental conditions required for spread of disease propagules and for infection to take place are precisely known for only a few tree diseases. Minimum leaf-wetting time for infection to take place over the temperature range normally experienced for each pathogen-tree combination is probably the most important information needed initially. This information, along with knowledge of the local microclimate, would permit selection of low-hazard planting sites for development of disease-free trees.

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Table 1. Some natural site situations in relation to likelihood of disease.

Location	Principal advantage	Principal disadvantage	Disease likelihood
Open-grown isolated trees, level ground	Trees are isolated from other trees	Conditions for dew formation on leaves	S[1] +++[3] L[2] +
Trees in forest with closed canopy	Dew formation minimal on understory	Understory trees readily infected from diseased overstory	S +++ S +
Small trees in forest opening	Cool shaded environment (good for reducing diseases which can be surpressed by shading)	Optimum conditions for dew formation on leaves; slow drying conditions	S,L ++++
Kettle hole		Conditions for dew formation optimal	S,L +++++
Even-aged trees of same species in a hedgerow		Disease can spread easily from tree to tree	S,L +++
Uneven-aged trees of different species in a hedgerow	Rapid drying of foliage after wetting	Humid zone on lee side of hedgerow	S ++ L +

[1]S = tree less than 3 feet tall. [2]L = tree taller than 3 feet. [3]+ = least disease, +++++ = most disease.

Table 2. Landscaping situations in relation to likelihood of disease.

Location	Principal advantage	Principal disadvantage	Disease likelihood
S side of building	rapid foliage drying	High air and soil temperatures	+++[1]
N side of building	Cool air and soil	Slow foliage drying	++++
E side of building	Most rapid foliage drying in morning	Shaded for part of day	++
W side of building	Delayed dew formation in evening	Shaded for part of day	+++
Around pond edge	*Dew formation inhibited*	*Slow drying of wet foliage*	+++
Paved terrace with tree openings	Rapid foliage drying		+

[1]+ = least disease, ++++ = most disease.

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