THE RESPONSE OF URBAN TREES TO ABIOTIC STRESS[1]

by Bruce R. Roberts

Despite environments which are often unfavorable for plant growth, the human inhabitants of most metropolitan areas are increasingly dependent upon urban trees for the aesthetic and beneficial amenities they expect from nature. This rather interesting paradox places considerable significance on the ability of professional arborists to understand the complex economical relationships which exist among trees, urban environments and human populations. Unfortunately, research on the subject of urban vegetation has been largely neglected, particularly in North America. In addition, much of the available information on urban trees has been gleaned from studies on forest trees: a situation that is certainly less than satisfactory.

In terms of physiological response, the most important aspect of urbanization involves the environmental constraints imposed on landscape trees. These restraints may be categorized as biotic or abiotic. Biotic factors, including insect and disease problems, are frequently important only after city trees have been adversely affected by abiotic factors much as moisture, temperature, light, etc. Following is a partial review of some important abiotic stress factors and how they may influence the growth of urban trees.

Moisture

An adequate supply of plant moisture is one of the most critical factors contributing to the physiological well-being of trees in the urban environment. Since large portions of the ground surface area in most metropolitan landscapes are covered with impervious materials that prohibit adequate water infiltration, plant moisture is a common problem in city trees. One of the first direct physiological consequences of moisture stress is the loss of water molecules associated with protoplasmic protein structures. Protein dehydration may, in turn, cause changes in molecular configuration which affect membrane permeability and enzyme activity. In terms of individual physiological processes, moisture stress can reduce photosynthesis by causing a decline in leaf area, stomatal opening and the metabolic activity normally associated with CO_2 fixation. Transpiration, translocation and respiration are also adversely affected by water stress, although many tree species exhibit occasional periods of increased respiratory activity during the stress cycle as a result of the hydrolytic conversion of starch to sugar.

Although alterations in physiological activity are normally associated with water deficits, *excess* moisture can be a problem in urban areas as well. This is especially true of container-grown trees which lack adequate drainage. Injury from too much moisture is usually attributed to desiccation caused by interference with water absorption. In addition, the anaerobic conditions existing in flooded soil may disrupt normal metabolic activity. Although oxygen deficiency is a problem in soils with excess moisture, insufficient aeration can also cause physiological decline of trees growing in compacted soils. Soil compaction is a common abiotic stress factor in urban environments.

Temperature

The physiological response of trees to temperature stress can be quite complex. Whereas gradual temperature fluctuations may alter physiological activity only slightly, sudden changes in temperature may cause serious injury. Freezing temperatures, for example, can result in the formation of ice crystals which cause mechanical damage by disrupting delicate membrane structures and cell organization. These same conditions may also cause desiccation injury by removing moisture in the process of ice crystal formation. Thus, the physiological consequences of temperature and moisture stress are closely related.

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Root growth is severely limited by low soil temperatures and, on occasion, may be adversely affected by warm surface soil temperatures as well. Although the optimum temperature for root growth varies with species, many tree roots attain maximum growth about 17-25 deg. C (63-77 deg. F). In addition to reducing root growth, extremes in soil temperature may also influence water and mineral absorption, root metabolic activity and soil microbial action. Changes in soil temperature can also affect a number of important biochemical reactions which occur in root tissue.

Although the lethal temperature for most plant cells is approximately 50-60 deg. C (122-140 deg. F), many physiological processes are inhibited well below this point. Heat effects may be caused directly by denaturation and coagulation of proteins, or indirectly by numerous metabolic disturbances associated with high respiration rates and desiccation. Direct heat injury is generally more prevalent in young transplants and thus may be an important consideration in urban environments, particularly in above-ground planters.

Light

Plant growth is influenced by light intensity, wavelength and photoperiod, all of which are in turn affected by organization. Light intensity affects tree growth through its influence on the metabolic reactions involved in photosynthesis, stomatal opening and chlorophyll synthesis. In metropolitan areas, there are several factors which influence the quantity of incident light, including man-made structures, atmospheric contamination and artificial illumination sources. Clouds, fog, dust, and smoke may screen much of the available sunlight in industrial areas, and shading, an important ecological consideration in the forest, is an unknown entity in the urban landscape.

Variations in the wavelength of light in nature are probably too small to be of physiological significance, but light quality can be an important consideration in regulating tree growth under artificial illumination. Most plants seem particularly sensitive to long wavelength radiation, and certain tree species may respond to extremely low levels of light when the illumination source is active in this portion of the spectrum. Knowledge of the spectral characteristics of various security and vision lighting sources is an important consideration in assessing the growth potential of urban trees.

Perhaps the most critical aspect of light in the city landscape is the photoperiodic effect. Many important growth processes are influenced by daylength (vegetative growth, diameter growth, dormancy, leaf abscission, frost resistance, flowering), but not all trees respond similarly to the same photoperiodic stimulus. As new artificial lighting sources are developed, their influence on photoperiodism needs to be determined.

Chemical stress

There is probably no other abiotic stress factor which is so consistently unique to the urban ecosystem as that of chemical stress. The increasing use of chemicals for pest and weed control, fertilization, growth regulation and snow and ice removal, makes this stress factor of particular significance in the metropolitan landscape. Organic chemicals of physiological importance in the urban environment include growth regulators, herbicides, fungicides and insecticides. One characteristic feature of most organic molecules is that they exert significant physiological effects at very low chemical concentrations. These physiological effects may include alterations in nucleic acid synthesis, direct enzyme activation, or regulation of some permeation phenomenon. Many organic chemicals have a stimulatory effect on respiration, a condition which results indirectly from the biochemical changes cited above.

Inorganic chemical stress refers to an excess of inorganic salts or ions and the accompanying changes in pH associated with these imbalances. Large-scale applications of deicing salts (primarily $NaCl$ and $CaCl_2$) make this stress factor a potentially serious problem in the contemporary urban landscape. This accumulation of inorganic salts alters the osmotic potential of the soil solution and causes movement of moisture out of the plant, a condition referred to as physiological drought. In addition, excess salt may interfere

Fig. 1. ***The problems associated with moisture and temperature stress are frequently more pronounced when urban trees are grown in above-ground planters.***

Fig. 2. Large-scale applications of chemical compounds for pest control and snow and ice removal make chemical stress an extremely important consideration in the urban environment (Photo credit: J.H. Barger, U.S. Forest Service).

Fig. 3. Air pollution has become an important urban stress factor in the past 20 years. In addition to the physiological consequences of air pollution, a number of importnat mesoclimatic changes can occur because of atmospheric contamination.

with water absorption and have a toxic effect on photosynthesis, respiration, protein synthesis and carbohydrate metabolism. Another important consideration in urban trees is the accumulation of potentially toxic concentrations of heavy metals such as mercury, lead and zinc.

Indiscriminate use of chemical compounds can significantly alter soil pH. Most tree roots grow over a considerable pH range, but reduced growth is often observed at pH values below 4.0. Changes in soil pH may indirectly influence tree growth as a result of differences in the solubility of inorganic nutrients as well as alterations in the activity of soil microorganisms responsible for nitrification.

Air pollution

The stresses associated with air pollution are largely chemical in nature and could logically be included in the discussion of chemical stress. However, air pollution, only rarely a natural hazard for plants in the past, has increased tremendously in most urban areas over the last 20 years. Air pollution is often associated with the physiological decline of vegetation surrounding large metropolitan areas, and manifestations of this decline are characterized by early senescence, changes in plant-water relations and generally poor growth. Growth reduction depends on many factors, including the nature of the pollutant, its concentration, the duration of exposure and the species of plant(s) involved.

Among the most significant physiological effects ascribed to air pollution is the modification of CO_2 exchange. Most experiments indicate that photosynthesis is suppressed in trees with fumigated with gaseous pollutants. Photosynthetic decline may be caused by alterations in chlorophyll content, membrane permeability or stomatal opening. Important biochemical changes are also associated with atmospheric contamination, including changes in enzyme activity and alterations in the pattern of CO_2 fixation.

The various abiotic stress factors reviewed here represent some of the more important environmental constraints which influence the growth and development of trees in urban landscapes. As environmental conditions in most metropolitan areas continue to deteriorate, it becomes increasingly important for the professional arborist to understand the physiological response of urban trees to stress situations. Obviously, it will be much easier to select and maintain trees which can withstand the rigors of abiotic stress if the arborist has some understanding of the physiological basis for stress resistance.

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MUNICIPAL ARBORICULTURE IN CHARLOTTE, NORTH CAROLINA[1]

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In growing cities like Charlotte, North Carolina there is constant need to maintain in the best manner possible the existing street trees, especially when little else other than answering complaints has been the rule for years. But more important to the future treescape of any such city is a vigorous planting program. Given municipal budgets these both need to be done at minimal cost. In Charlotte we are attempting to do both, and keep costs down, by first obtaining pertinent information on the existing street trees as well as suitable locations for future trees. With this background information and through the use of electronic data processing we then hope to develop a scientific, thorough street tree management program as well as an intelligent tree planting plan and implementation. We are in the process of carrying out these procedures. This paper describes some of them.

Charlotte, North Carolina, like many other municipalities, has grown from a small crossroads to a thriving metropolis. In the process of this development Charlotte has undergone also a changing treescape. The future of any city's treescape, Charlotte's included, depends not only on a successful maintenance program of pruning, removal, pest control, etc. but also on what is planted now for the coming generations. Therefore, we would like to emphasize this aspect of our program.

The species that makes up the largest number of Charlotte's street trees is the willow oak

1 Presented at the annual conference of The International Society of Arboriculture by the junior author in St. Louis, Mo. in August 1976.