EVALUATING STREET TREE MICROCLIMATES IN NEW YORK CITY

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Abstract

Street trees in New York City are exposed to a variety of environmental stress factors. Because of the way in which trees are typically planted, in isolated small openings in the concrete, with the built-up city infrastructure all around them, they often experience water deficits. Investigations of street tree environments in New York City revealed that the immediate microclimate around the tree can be very different from the official weather report for that area. Side of the street, surrounding city structures and tree species affected water relations in street trees.

Introduction

Trees are a valued component of cities, providing shade, humidity, wildlife habitats and visual relief from the built-up landscape. Street trees, especially, serve as buffers between human beings and what is arguably a stressful physical environment. Much is expected of street trees, yet little is known about their physiological responses to the urban habitat. It is estimated, however, that of the 1000 or so street trees planted in New York City each spring, roughly, half will die within ten years. At a cost of approximately $300.00 per tree, this premature death constitutes a sizable investment in plants which will never reach adult size and never provide the expected amenities.

What is it about city conditions that cause trees to die at an age of between 3-15 years? Many features of the street tree habitat have been implicated.

Below ground the factors affecting root growth can be numerous. De-icing salts (NaCl primari.ly) in European and North American cities where winter driving conditions are hazardous can do tremendous damage to street trees. High salt levels in the soil can decrease the availability of water to the roots causing a 'chemica1 drought'. Moreover, chloride ions are readily taken up by plant roots and can accumulate to toxic levels in the leaves resulting in the commonly seen symptom of margina1 leaf necrosis or 'scorch'. Cur analysis of chloride in _Tilia cordats_ 'Greenspire' trees growing in New York City showed chloride levels to be 1.8% of leaf dry weight. Sodium can also have a detrimental effect on soil structure leading to increased soil compaction, while salt spray from dissolved road salts can desiccate evergreen leaves directly.

Barriers to root growth resulting in de-facto containerization of street trees is also a common occurrence. Utility pipes, asphalt and concrete curbs, rubble in the soil, underground subways and basements and soil compaction all serve to limit the amount of soi1 tree roots have to explore to acquire needed water and nutrients. Compaction may limit root growth directly by mechanical impedance or indirectly by reducing soil pore space and thus oxygen diffusion to the root zone. Waterlogged conditions often follow where drainage is severely restricted.

The soil itself in urban areas can contain anything from good top soil to brick rubble and builders fill. Because many of these anthropeic materials contain limestone, street tree pit soils are often found to be alkaline which limits the availability of certain nutrients such as iron and manganese. Pin oak (Ouercus _palustris_) is particularly sensitive, resulting in widespread clorosis for this tree in city streets with high pH soils.

Urban soils can be extremely variable in fertility and toxic substances as well. 'Gray-water' is often poured onto street tree pits in a well-meaning attempt at watering. However, if this spent wash water contains bleach or other toxic chemicals it can be lethal to tree roots.

Above ground there are still other ways in which the city causes stress in street trees. Foremost among these is reradiated heat from buildings asphalt, car tops and concrete. The hotter the air-temperature around tree canopies, the faster trees lose water and deplete already limited underground supplies, given the containerized nature of street trees in general.

In certain urban areas, wind also increases leaf desiccation as it speeds up when channelized in 'urban canyons' between tall buildings.

Tall buildings causing false horizons alter light patterns for many urban trees. Trees on the north side of an city block see far less direct sunlight than those on the east, west or south sides. This phenomenon has been shown to cause changes in tree form; some trees such as Liquidamber styraciflua lose their central leader.

Air pollution is often cited as a problem for plant growth in cities; however, this depends very much on the air drainage patterns of a particular location. In New York City it is rare to see field symptoms of air pollution injury whereas in Los Angeles it is more common. The major pollutants are ozone, SO_2, Nitric oxides and Peroxyacetyl nitrate, (PAN).

Finally, much is generally said about vandalism of plants in cities however, our experiences on the streets of New York point to damage done by cars, trucks, bicyc es and urban construction as occurring much more frequently and with more severe consequences than the breaking of twigs by people. Trees are planted close to curbs where the lower branches of a tree and bark on the trunk are regularly injured by overzealous motorists.

Field Study - Preliminary Findings

During the summers of 1983, 1984 and 1985, Cornell's Urban Horticulture Institute studied the street trees on Columbus Avenue in Manhattan's Upper West Side. The broad objective of the study was to investigate the inner city street tree environment over the course of the growing season and to determine the effects of exposure and tree species on the amount of water consumed. This study was one of very few to address the question of water use by urban trees in a real, non-laboratory environment and the first ever conducted in New York City.

Although the full three years of data are still being analyzed, preliminary findings indicate several examples of stressful environmental conditions. Portable weather sensing equipment measuring air temperature, relative humidity and solar radiation were set up on the east and west sides of Columbus Avenue at a height of between three and four meters from the ground at the same level as the middle branches of the tree's canopy. Data were automatically collected by a Campbell data logger. The environmental measurements for the east and west sides of the street were taken directly opposite one another, separated across the street by approximately 17 meters. Building heights on either side of the street were comparable with five stories per side.

Tilia _cordata_ 'Greenspire' and _Fraxinus pennsylvanica_ 'Marshalls Seedless' were the two cultivars studied. All twenty trees in the study were standard 2½ inch (6.4 cm)caliper balled and burlapped trees planted in the spring of 1982 into 1.5 m^2 tree pits.

By looking at the data from one sampling period in August, 1983, many striking patterns can be seen. Figure 1 shows the solar radiation patterns for the east and west sides of the street. Data points represent the mean of readings taken every ten seconds within each thirty minute period. On the west side, solar radiation increased quickly after 9:30 a.m. dipped slightly at mid-day as a cloud passed over and then diminished rapidly after 4:00 p.m. The east side's pattern was similar except for a longer period of shade in the morning; radiation increasing rapidly only after 11:OO a.m. If Columbus Avenue were a true north-south running street, the light patterns of east and west would be mirror images of each other. However, as Columbus is skewed more toward a northeast-southwest orientation, the west side receives more direct sunlight.

Figures 2 and 3 show the air temperature and relative humidity patterns of the east and west sides of the street for those same days in August. Air temperature on the west side of the street reached a high of 42°C (107°F) around mid-day while relative humidity dropped to a low of 10% at the same time. On the east side of the street, the air temperature reached a high of 32°C (89°F) while relative humidity fell to between 10% and 12%. Interestingly, the official high temperature for both of those days was 30°C (86°F) taken at the official weather station in Central Park just a few blocks away. Moreover, the official low relative humidity was reported as 40% for those same days. These differences between the official weather report and the actual environment around street trees were not wholly unexpected; however, the magnitude of difference was striking, especially between the west side of the street compared to both the east side and the official report.

On both sides of the street, the air temperature rose higher and the relative humidity fell lower than the official report indicated, creating a much higher atmospheric evaporative demand on the trees. In fact, the conditions recorded for the west side of the street would be more likely to be found in the desert southwest than in a maritime northeastern city.

To investigate why these environmental conditions occurred, we took the temperatures of surfaces surrounding the trees such as asphalt, car tops, and building facades using an infra-red thermometer, at one or two hour intervals throughout the day. Again, examining the west side of the street in August we see in Fig. 4 that car tops reached a high temperature of approximately 55°C (131°F) as did that of asphalt. However, by comparing the heat gain and loss patterns for asphalt and car tops with the solar radiation pattern for that day (Fig. 1), we can see that while car tops mirror solar radiation and heat up when the sun is out, their low mass allows them to cool down extremely rapidly after direct solar radiation is removed. Asphalt heats up slightly more slowly in response to solar radiation but being of high mass, loses its heat slowly to the atmosphere and in doing so heats the air long after the sun has gone behind the building. At 8:00 p.m. the asphalt temperature is still approximately 33°C (91°F), creating a longer warm period for street trees than would be experienced by trees growing surrounded by grassy or vegetated areas. Figure 4 also shows that brick building facades contributed to the heat load on urban tree leaves.

Of the two species that were tested on Columbus Avenue, Tilia cordata appeared to transpire less but over a longer period of time than Fraxinus pennsylvanica which transpired rapidly only during the period of highest light. These apparent species differences need further investigation to ascertain whether such strategies may be exploited to select for more urban tolerant trees.

Possible Solutions

Although our inner city street trees experience a variety of diverse environment stresses, there appear to be two viable approaches to solving the problem of their early mortality. 1. Select trees which are more tolerant of stressful conditions. The traditional approach of choosing a tree only for form and seasonal interest must broaden to inc ude drought, salt, heat and other stress tolerances where appropriate. Screening and selection schemes now underway will eventually give the city forester better choices for city plantings. Also, collecting plant material originating in stressful habitats such as seashores or floodplains may provide other alternatives.

2. Within the bounds of reality, change the way in which trees are planted on our city streets. Where individual street trees are still the preferred planting design, we must widen and provide drainage in these pits to allow for greater water and oxygen infiltration. Continuous horizontal soil columns between pits are better yet and allow for greater lateral root access to water, nutrients and oxygen than would be available in traditional containerized pits. If porous paving materials could also be used between these continuous tree pits, then the area that roots could explore would be vastly expanded.

Grouped plantings in slightly raised planting beds offer a still better alternative to tree pit planting. Grouped trees would share a common, large soil mass which could intercept adequate rainfall. The raised lip of the planting bed could act as a barrier to salt water run off in the winter and spring. Trees planted in groups would mutually shade each other from the heat and wind of the street environment while allowing for a greater esthetic impact caused by the massing of trees, shrubs and ground covers. Finally, these less formal plantings could utilize tree species now commonly thought of as unsuitable to street tree planting because they don't have the required 'lollypop' shape, i.e. one trunk with symmetrical branches on top. Many of these so-called 'weedy' species such as Ailanthus altissima Elaeagnus angustifolia, Morus alba and Maclura pomifera to name a few may be better able to withstand environmental stress than our commonly planted street trees.

By understanding the limitations of the street environment in terms of the tree's physiological needs and by being willing and imaginative in the ways in which we plant trees, we can begin a renaissance in the greening our urban centers.

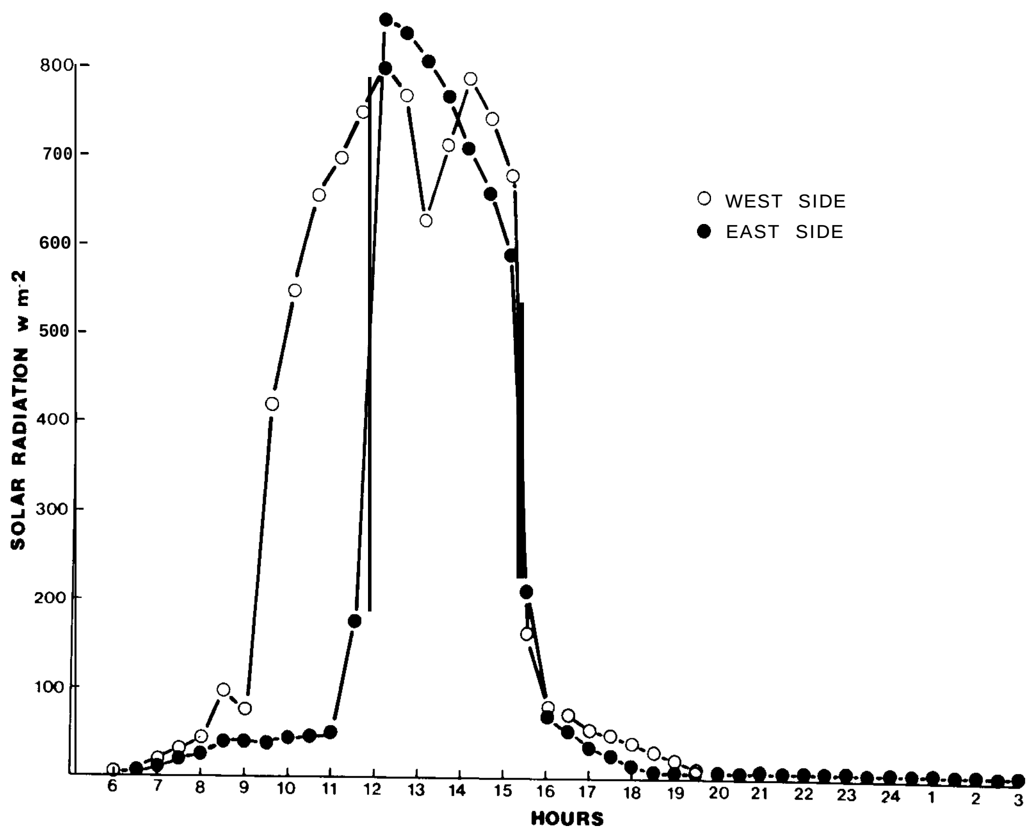

Figure 1. Diurnal solar radiation patterns for the east (August 15, 1983) and west sides (August 16, 1983) of Columbus Avenue, New York City.

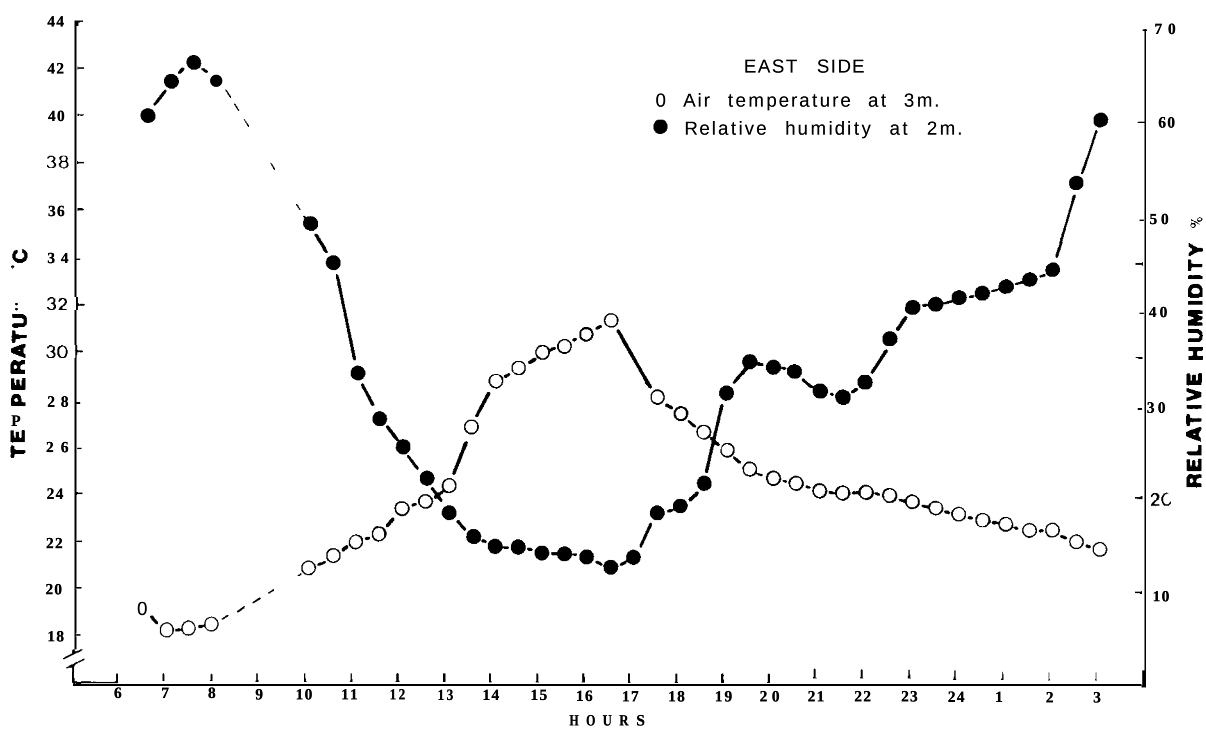

Figure 2. Diurnal air temperature and relative humidity for the east side of Columbus Avenue, New York City on August 15, 1983.

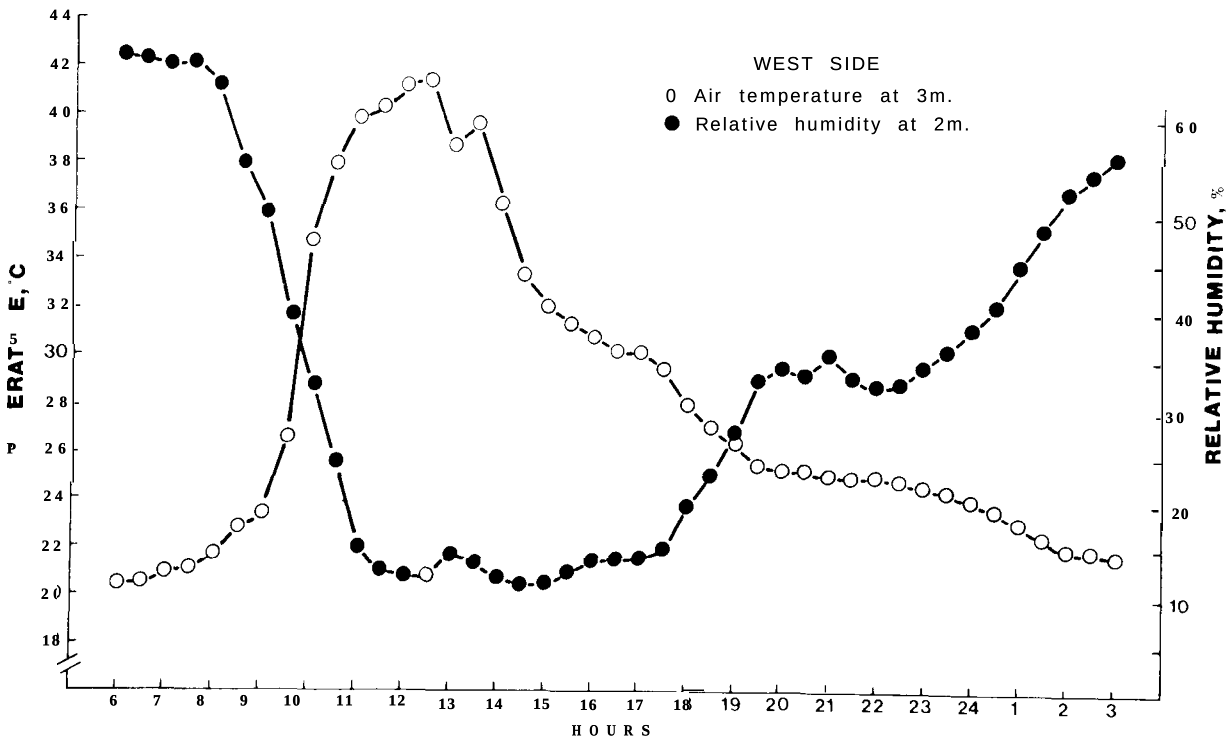

Figure 3. Diurnal air temperature and relative humidity for the west side of Columbus Avenue, New York City on August 16, 1983.

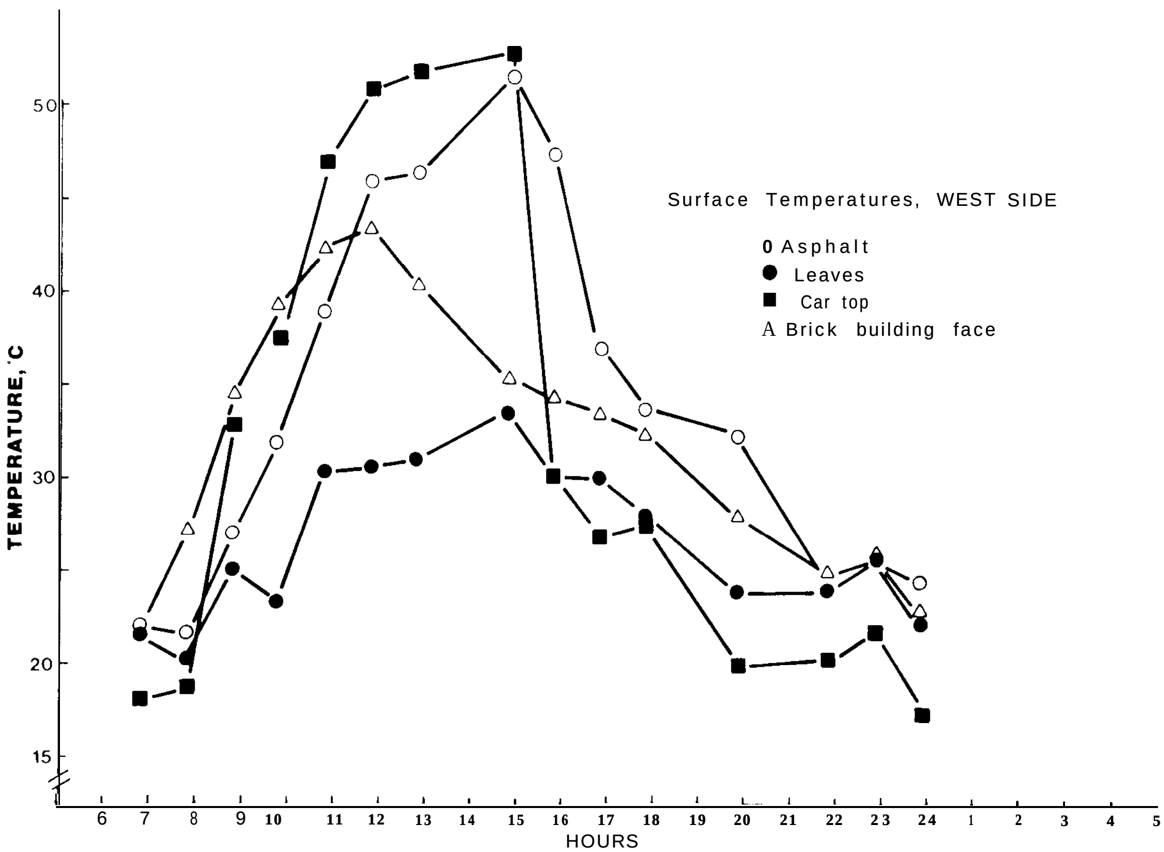

Figure 4. Diurnal surface temperatures on the west side of Columbus Avenue, New York City on August 16, 1983.