THE RELATIVE WATER DEMAND OF FIVE URBAN TREE SPECIES

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Abstract. The relative water demand (RWD) of container-grown seedlings of red maple, green ash, Washington hawthorn, honeylocust and flowering crabapple was determined for the period mid-May through August by comparing water consumption values and potential evapotranspiration rates with growth rates. While RWD for red maple was high, actual water consumption based on changes in plant size (water use index, WUI) was quite low, indicating efficient use of available moisture. RWD for green ash was high, but WUI was also high indicating relative inefficiency in utilizing available water resources. RWD values for Washington hawthorn, honeylocust and flowering crabapple were all lower than those for maple or ash, while WUI values for these species were intermediate between maple and ash. In general, growth rate was not correlated with RWD. However, actual water consumption rates did correlate well with potential evapotranspiration as determined by the Thornthwaite equation.

Plant moisture, and the onset of plant-water stress caused by water deficits, is generally recognized as the principal limiting factor controlling the growth of urban trees (1). Efficient utilization of available moisture supplies is critical to the successful establishment of newly planted trees, and supplemental irrigation is often required to ensure the survial of these plantings in the urban landscape. In light of recently reported water shortages and increased governmental restrictions on agricultural water use (5,8,9), arborists must have adequate information to effectively and prudently manage existing water resources. While some data have been published on the irrigation requirements of container-grown ornamental plants under nursery conditions (4,6), there is a lack of information on the water requirements of urban tree species, especially during periods of peak water demand.

The present study was undertaken to determine the relative water requirements of five container-grown tree species commonly planted in the urban environment. Potential evapotranspiration rates were also measured and compared with the average irrigation requirements for each species. From these comparisons it was possible to determine whether or not potential evapotranspiration might be a useful indicator for estimating consumptive water use for these urban species.

Material and Methods

Dormant 2-yr-old seedlings of red maple (Acer rubrum), green ash (*Fraxinus pennsylvanica*), Washington hawthorn (*Crategus phaenopyrum*), honeylocust (*Gleditsia triacanthos*) and flowering crabapple (*Malus sargentii*) were planted in commercial potting medium (Metro-Mix 300) in 15-cm (6-in) diam plastic containers and placed out-of-doors on raised benches under a plastic-covered lathhouse with 25% shade [21.4 +/- 10.6 C (70.5 +/- 19.5 F); 55 +/- 26% RH]. At the time of full leaf expansion (mid-May), the experiment was begun by hand-watering 15 seedlings of each species twice weekly with 550 ml (approx. 0.5 qt) of water, a quantity sufficient to uniformly wet the potting media in each container to field capacity. Retained moisture was determined 2 hr after each watering by subtracting the volume of leachate collected in plastic saucers placed under each container. The amount of retained water measured over a one month period was considered equivalent to the average irrigation demand (AID) for each species.

Changes in plant size were determined by measuring height, stem diameter, and average canopy diameter (2 measurements) for each seedling at the beginning of the study and again at 2-week intervals thereafter for the duration of the experiment (June through August). These values were summed to obtain a size index (SI) for each species. To ensure that nutrients were provided in adequate amounts, all seedlings were fertilized monthly with 550 ml of a commercial fertilizer solution containing 200 ppm each of nitrogen, phosphoric acid and soluble potash.

To determine the consumptive water use for each species, the technique described by Fitzpatrick (3) was utilized to measure relative water demand, RWD. This measurement was obtained by dividing cumulative AID values for each species by potential evapotranspiration, ETp. Evapotranspiration, the process by which leaf surfaces may lose water to the atmosphere at a rate unlimited by available moisture supplies, was calculated by the Thornthwaite method (2). By comparing monthly ETp and cumulative AID values, it was possible to determine if ETp might be a useful indicator of water consumption rates for the species used in these experiments. An estimate of water use efficency (termed here water use index, WUI) was also obtained by dividing changes in plant size into total AID for each species.

Results and Discussion

Based on cumulative average irrigation demand, expressed in this study as total AID, water consumption over the 12-week experimental period was greatest for red maple and significantly less for Washington hawthorne, honeylocust and flowering crabapple (Table 1). In terms of total water requirements, there were no significant differences between red maple and green ash or between green ash and Washington hawthorne. For all species tested the greatest demand for water occurred in July, a situation that reflects meteorological conditions conducive to high transpiration rates and the subsequent need to replenish depleted plant-moisture supplies. This assumption is supported, at least in part, by the high ETp value for July (11.4) compared to the values for June (10.6) and August (10.3).

Table 1. Average irrigation demand (AID) of five container-grown urban tree species.

Species	AID (liters/container)[z]				Chi-sq.[y]
	June	July	Aug.	Total	
Red maple	4.3a	5.7a	5.3a	15.3a	.26
Green ash	4.4a	5.5ab	4.7b	14.6ab	.03
W. hawthorn	3.5b	5.0bc	4.9ab	13.4b	.30
Honeylocust	3.0c	4.7c	4.5b	12.2c	.31
Fl.crabapple	3.2bc	3.9d	3.5c	10.6d	.02

z Each value represents the mean of 15 seedlings. AID determined by subtracting the volume of leachate collected from the volume of water applied per seedling. Mean values in a column followed by the same letter are not significantly different, LSD 0.05.

y Chi-square comparison of AID distribution with potential evapotranspiration (ETp), df=2. All values non-significant. ETp calculations for June, July and August were 10.6, 11.4 and 10.3, respectively, as computed by the Thornthwaite equation.

Monthly ETp values computed by the Thornthwaite method were compared with monthly distribution of AID for each species using the chi-square test (Table 1). The Thornthwaite equation utilizes air temperature as an index of the energy available for evapotranspiration, and assumes that this temperature is correlated with the effects of net radiation on the evapotranspiration process. The absence of any significant difference between monthly ETp distribution and AID distribution in these experiments suggests that ETp calculations would be useful in making estimates of water consumption rates for these particular species. This would seem to be especially true for green ash and flowering crabapple, where the correlation between AID and ETp was very close. Similar correlations have been published by Fitzpatrick (3) for various container-grown ornamentals and by Roberts and Schnipke (7) for a number of Acer species.

The relationship between AID and plant growth was investigated by comparing changes in the SI for each species at the beginning and again at the end of the experiment. Red maple, which consumed the most water, exhibited the largest increase in SI, while flowering crabapple, which used the least amount of water, showed a significantly smaller increase in SI (Table 2). Washington hawthorn and honeylocust were intermediate between maple and crabapple but followed the same pattern of water consumption vs SI. Green ash, however, while consuming a considerable quantity of water [AID = 14.6 liters (approx. 3.8 gal)], showed the smallest increase in size [SI = 25.4 cm (10 inches)]. These data suggest that green ash is not as efficient in utilizing available moisture supplies for vegetative growth as compared to the remaining species included in this study. Although their research dealt with established trees, it is interesting to note that Whitlow et al (10) reported that urban plantings of green ash in New York City transpired at higher rates and sustained more negative water potentials (i.e. higher water deficits) than did littleleaf linden plantings under similar conditions.

To measure the quantity of water consumed per unit of growth, WUI values (Table 2) were calculated for each species by dividing changes in SI into total AID. WUI values for maple, hawthorn, honeylocust and crabapple ranged from 184 to 207, while WUI for green ash was 574, some 2.5 to 3 times higher. While WUI values for maple, hawthorn, honeylocust and crabapple were statistically similar, overall growth for three of these species was statistically different, suggesting that vegetative growth in this study was influenced by factors other than water availability alone.

When the average amount of water consumed by each species is considered along with changes in plant size (SI per month), it is possible to categorize the species used in this study as either fast growing (red maple), slow growing (green ash and flowering crabapple) or moderate growing (Washington hawthorn and honeylocust). Red maple (fast growing) had a RWD of 476, while flowering crabapple (slow growing) had a RWD of only 326, significantly less (Table 2). Washington hawthorne and honeylocust (moderately growing) exhibited RWD values intermediate between those for maple and crabapple. However, green ash, a slower growing species based on changes in the SI per month, exhibited a relatively high RWD indicating, as previously noted, ineffectual use of available moisture for vegetative growth. Fitzpatrick (3) has reported a close relationship between growth rate and RWD for numerous ornamentals, and his studies also show occasional exceptions such as we observed with green ash.

Table 2. Growth, relative demand, and water-use index of five container-grown urban tree species.[z]

Species	Change in size index[y] (cm)	Relative water demand[x] (RWD)	Water use index[w] (WUI)
Red maple	83.7a	476a	184b
Green ash	25.4d	452ab	574a
W. hawthorn	68.5b	416b	195b
Honeylocust	60.6bc	375c	200b
Fl. crabapple	50.8c	326d	207b

z Each value represents the mean of 15 seedlings. Mean values in a column followed by the same letter are not significantly different, LSD 0.05.
y Change in size index calculated by subtracting initial size [sum of height, stem diameter, and average canopy diameter (2 measurements)] from final size.
x RWD calculated by dividing total monthly evapotranspiration, ETp, into total AID, in ml (Table 1).
w WUI calculated by dividing total water consumption, in ml, by changes in the size index.

The use of water consumption data such as those recorded in this study need to be considered in conjunction with other management decisions such as species selection, site characteristics, and any regulatory water-use constraints. If soil moisture resources tend to be limited because of occasional droughts, arborists may want to consider faster growing species where new plantings are likely to become established before drought becomes a problem. If, on the other hand, irrigation water is restricted on a routine basis, it may be more desirable to select a slower growing species, since these plantings would have lower RWD and, thus, would tolerate less water over the establishment period. These data might also be useful in the selection and maintenance of species to be planted in above-ground containers where water availability may be limited because of container size and/or inadequate supplies of natural precipitation.

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Résumé. La demande relative en eau de semis en pot d'érable rouge, de frêne de Pennsylvanie, d'aubépine de Washington, de févier inerme et de pommetier était évaluée pour la période de la mi-mai à août en comparant les valeurs de consommation en eau et les taux d'évapotranspiration potentielle avec les taux de croissance. Tandis que la demande en eau pour l'érable rouge était élevée, la consommation actuelle en eau, basée sur les changements dans les dimensions de la plante (index d'utilisation en eau), était plutôt basse indiquant dès lors une utilisation efficiente de l'humidité disponible. La demande relative en eau du frêne de Pennsylvanie était élevée, mais l'index d'utilisation en eau l'était aussi ce qui indique une consommation inefficace de l'eau. La demande relative en eau pour l'aubépine de Washington, le févier inerme et le pommetier était pour tous plus basse que celle pour l'érable ou le frêne, alors que les valeurs de l'index d'utilisation en eau pour ces espèces étaient intermédiaires entre celles de l'érable et du frêne. En général, le taux de croissance n'était pas nécessairement correlé avec la demande relative en eau; néanmoins, les taux de consommation actuelle en eau étaient bien correlés avec l'évapotranspiration potentielle tel que déterminé par l'équation de Thornthwaite.

Zusammenfassung. Die relative Wassernachfrage (RDW) von in Kontainern gezogenen Sämlingen von Rotahorn, Grüner Esche, Weißdorn, Gleditschie und blühendem Holzapfel wurde für die Periode von Mitte Mai bis August bestimmt, indem die Wasserverbrauchswerte und die potentielle Evapotranspirationsrate mit den Wachstumsraten verglichen wurden. Während der RWD für Rotahorn hoch war, so war doch der tatsächliche Wasserverbrauch, basierend auf den Änderungen der Pflanzengröße (Wasserverbrauch-Index - WUI) sehr niedrig, was einen effizieten Verbrauch der vorhandenen Feuchtigkeit zeigt. Der RWD für Grüne Esche war hoch, aber der WUI ebenso, was einen ineffezienten Wasserverbrauch anzeigt. Die RWD-Werte für Weißdorn, Gleditschie und Holzapfel waren alle niedriger, als für Ahorn und Esche. Allgemein war die Wachstumsrate nicht korreliert mit dem RWD-Wert. Trotzdem korrelierte die Wasserverbrauchsrate mit der potentiellen Evapotranspiration, wie es die Thornthwaite Gleichung beschreibt.