DESIGN AND TESTING OF URBAN LANDSCAPES FOR WATER CONSERVATION

by Jayne M. Zajicek

Abstract. *Studies were conducted to provide information* on water use by woody ornamentals and how it is affected by plant selection, the urban environment and landscape management practices. Study 1 evaluated water relations of containerized native versus non-native woody ornamentals. Study 2 explored how energy transport from bare soil, turfgrass, and pine-bark mulched surfaces affect transpiration of crape myrtle. Study 3 quantified the effect of pruning and chemical growth regulation using uniconazole on water use of hibiscus. The investigations provided information which indicated that it may be possible through more innovative designs and better management practices to reduce total landscape irrigation by 80%.

Competition among agricultural, industrial, and urban users for limited water resources is increasing dramatically, while the outlook for increasing supplies is dim. In urban areas, about 60% of the peak water demand in the summertime is the result of irrigation of landscapes and 50% of that water is inefficiently applied. On an annual basis, about 30% of the water used is for landscape maintenance. Landscape plantings have traditionally been designed using aesthetic criteria with minimal consideration given to water requirements. Only recently has water conservation been a goal of landscape design throughout the United States due to lengthy droughts, depletion of water tables, water rationing and poor water quality.

Unfortunately, landscape design has been proceeding with limited information on plant water requirements, urban environment effects on water use and the effects of landscape management practices on water conservation. This paper summarizes several different research projects which begin to address the above problems. The results of these projects will help to formulate guidelines that would allow landscape architects and designers to design water conserving landscapes and landscape managers to maintain these landscapes utilizing practices that would conserve water without deterring from the aesthetics of the landscape.

Methods and Materials

Plant Water Requirements. Optimal water and nutrient requirements for literally hundreds of ornamental species with diverse cultural requirements are largely unknown. The objective of this study was to determine water relations of native versus nonnative plants under optimal conditions. Seven species of woody ornamental plants [salvia (*Salvia gregii*), anisacanthus (*Anisacanthus wrightii*), wax myrtle (*Myrica cerifera*), yaupon holly (*Ilex vomitoria*), euonymus (*Euonymus kiautschovica* 'Manhattan'), Sandankwa viburnum (*Viburnum suspensum*), and southern magnolia (*Magnolia grandiflora*)] were planted in 3.8 l containers containing a mix of 4 composted pine bark:1 sand (v/v) amended with 3.7 kg/m^3 18N-6P-12K, 3kg/m^3 gypsum and dolomitic limestone and 7.2 g/m^3 fritted trace elements. Plants were established for 10 weeks prior to the start of the experiment. Plants were maintained under well-watered conditions and covered with polyethylene plastic to prevent evaporation. The study consisted of 2-day cycles beginning when plants were hydrated and ending when plants were rehydrated two days later. Leaf water potential and transpiration were determined in addition to whole plant transpiration which was determined gravimetrically. Upon completion of the experiment, plants were harvested and leaf area was determined.

Urban Environment, Mulch Study. In cities, plants must contend with environments significantly different than rural areas. Air temperatures are higher, windspeed and humidity lower. To develop and evaluate water management strategies, it is important to understand how the urban environment affects water use by vegetation. This study was designed to evaluate how energy transport from soil, turfgrass, and mulched surfaces affects transpiration of diverse cultivars of crape myrtle (*Lagerstroemia indica*). One year old plants of crape myrtle were used including four different cultivars ('Hope', dwarf-weeping; 'Seminole', standard-weeping; 'Victor', dwarf-upright; and 'Carolina Beauty', standard-upright). Plants were planted in 11.3 l pots containing a mix of 2 fritted clay:1 peat-lite mix (v/v). Pots were inserted in holes lined with aluminum cylinders in one of three treatments including; bare soil, bermudagrass (*Cynodon dactylon*), or bare soil covered with 8 cm of pine bark mulch. Plants were removed from the holes and watered daily. Pots were covered with plastic and aluminum foil to prevent evaporation and minimize effects of radiation on surface temperatures. Whole plant transpiration was determined daily by weighing the pots. In addition, sap flow rates were recorded using stem flow gauges (1,4,5). Stomatal conductance, and surface, plant and air temperatures were recorded at regular intervals. At the termination of the study, total leaf area of each plant was determined.

Landscape Management Practices, Growth Regulator Study. Landscape management practices also have a major influence on growth and survival of ornamentals in the harsh conditions of the urban landscape. Control of growth has long been an important factor in the management of trees and shrubs. This has been traditionally accomplished by mechanical pruning, but recently the use of growth regulating chemicals has gained acceptance. The effects of these practices on tree or shrub water use will become increasingly important in the future. The major objective of this study was to quantify the effect of two plant growth-regulation methods, pruning and the growth-regulating chemical uniconazole, on water use of hibiscus (*Hibiscus rosa-sinensis*). Hibiscus plants were grown in 7.6 l pots filled with fritted clay. The treatments were pruning, uniconazole, and a control. Uniconazole was applied as a drench at 3.0 mg a.i. in 400 ml water/pot. Plants of the pruned treatment were allowed to grow until the branches became undesirably long at which time new growth was removed from all actively growing terminals. During the experiment, plants in each treatment were maintained at well-watered conditions except for several dry down cycles. Pots were covered with plastic and plant water use was obtained by weighing the pots daily. Transpiration rates were measured in addition to leaf water potential at regular intervals. At termination, leaf area for each plant was determined.

Results and Discussion

Plant Water Requirements. Under nondrought conditions, two of the native species, salvia and wax myrtle, had the highest whole plant transpiration using two to three times more water per leaf area compared to the other species (Table 1). The introduced species, viburnum, magnolia and euonymus, had the lowest whole plant transpiration (Table 1). Myrica and anisacanthus generally had the highest leaf transpiration rates at the beginning of the cycle, and all three native species including myrica had greater transpiration rates than the introduced species at the end of the 2 day cycle (Table 2). Establishment of non-water stressed baselines of selected woody plant species is a key to measuring and interpreting plant water stress. By analyzing the components of growth under non-limiting conditions, it may be possible to predict which species would be most sensitive to water deficit under reduced irrigation. In this study, salvia had the highest whole plant transpiration and very high transpiration rates which would indicate that it would be one of the least drought resistant of the

Table 1. Whole plant transpiration (E) of seven landscape species under non-drought conditions.[z]

Species	E ($mg/m^2/s$)	E ($mg/m^2/s$)
Salvia	48a[y]	36a
Anisacanthus	26c	18cd
Myrica	34d	25b
Ilex	27d	21bc
Euonymus	20cd	16d
Viburnum	11e	10e
Magnolia	17de	15d

[z] At the beginning of each 2-day cycle, plants were watered to container capacity.
[y] Mean separation within columns by Duncan's multiple range test, 5% level.

Table 2. Leaf diffusion resistance (r) and transpiration (T) of seven landscape species under non-drought conditions during cycle 1.[z]

Species	AM Day 1 r (s/cm)	AM Day 1 T (µg/cm²/s)	PM Day 2 r (s/cm)	PM Day 2 T (µg/cm²/s)
Salvia	2.1cd[y]	5.7b	1.8c	10.4ab
Anisacanthus	1.4d	9.4a	1.7c	11.4a
Myrica	1.6d	10.2a	2.1c	8.7bc
Ilex	—	—	—	—
Euonymus	2.5bc	7.1b	3.3a	6.1d
Viburnum	2.9b	6.8b	3.3a	6.2d
Magnolia	3.6a	6.2b	2.7b	7.5cd

[z] At the beginning of each 2-day cycle, plants were watered to container capacity.
[y] Mean separation within columns by Duncan's multiple range test, 5% level.

species tested. Unfortunately, results from studies on plants in containers do not always indicate how plants will react in landscape situations. Containerized crape myrtle is drought susceptible, but adapts well to drought in the landscape with a more extensive root system (2). This study only begins to address the water use issue, and additional studies are needed that test these species in actual landscape situations.

Urban Environment, Mulch Study. Water loss of crape myrtle was significantly affected by surface materials (8). Plants of all cultivars surrounded by the mulched surface used 0.63 to 1.25 kg/m²/day more water than plants surrounded by soil and 0.83 to 1.09 kg/m²/day more water than plants on turf. Plants on the soil used an average of 0.20 kg/m²/day more water than plants on turf.

Highest sap flow rates occurred from 1000 to 1300 h on the mulched surface for all cultivars (Fig. 1). However, by midafternoon, flow rates in plants on the mulched surface equaled or were less than flow rates in plants on the soil and turf surfaces for three out of the four cultivars.

The mulched surface was warmer by 0900 h and remained warmer throughout the day than the other surfaces. For example, on 23 Aug 1989, the

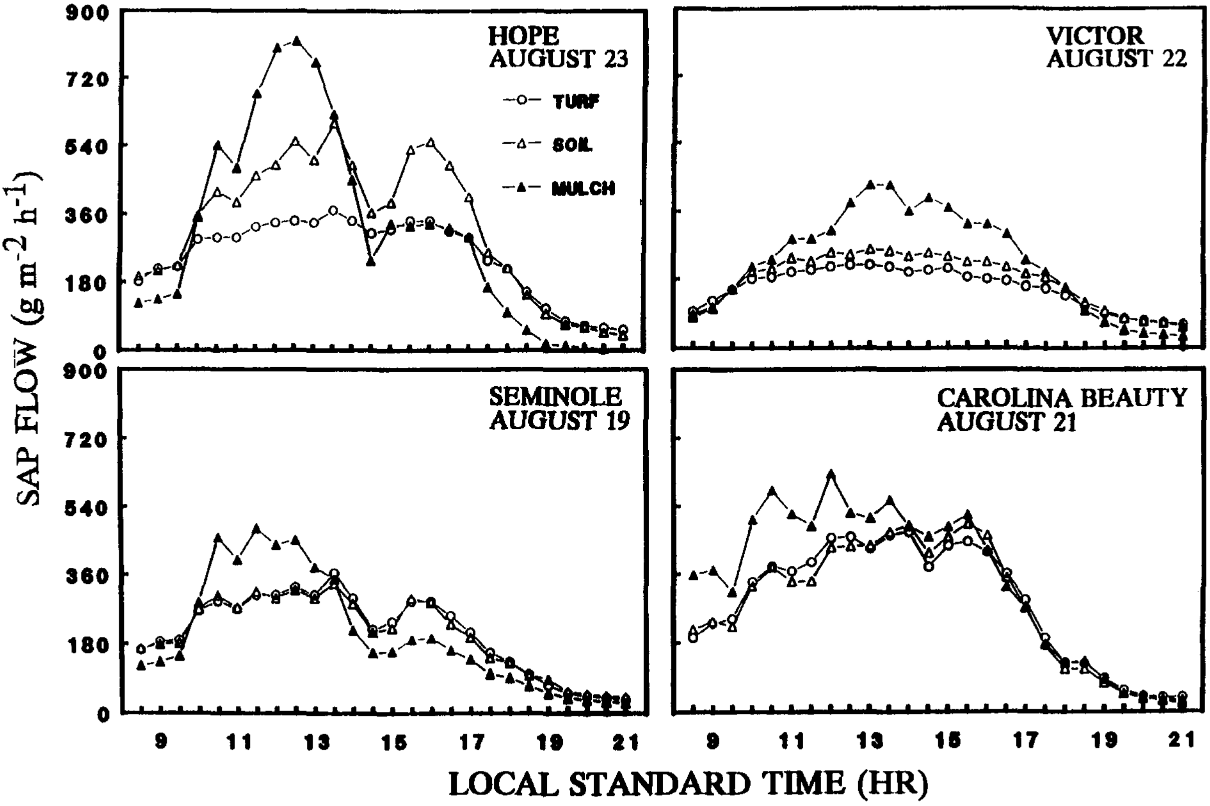

Figure 1. Sap flow per unit leaf area of four cultivars of crape myrtle as affected by surface material.

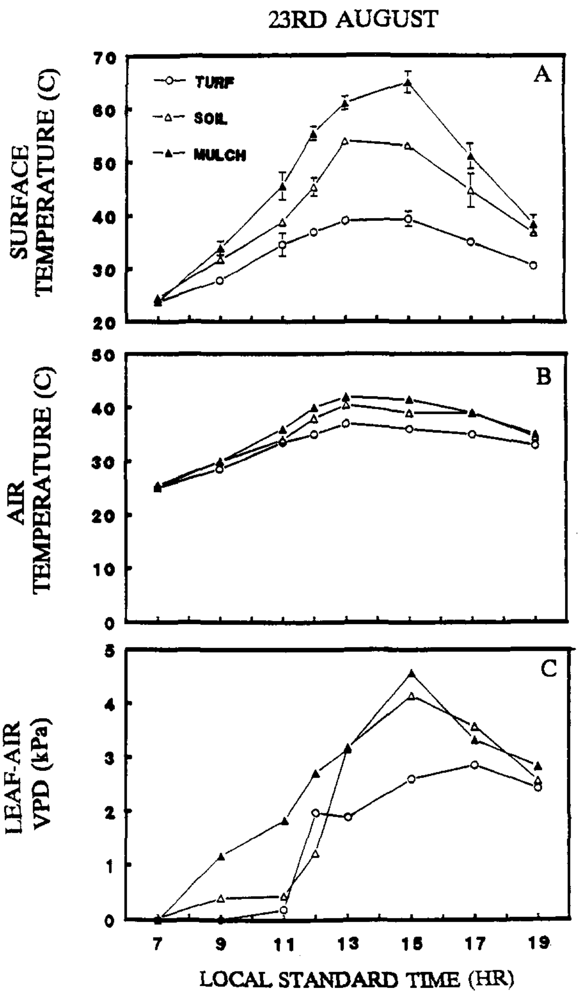

Figure 2. Surface temperatures (A), air temperatures (B), and leaf-air vapor pressure deficits (C) as affected by surface material on 23 Aug. 1989. Only measurements replicated in this figure were surface temperatures (A). Each point is the mean of five replications per surface treatment. Vertical bars represent SE of the mean. SE is smaller than symbol when error bar is not shown.

maximum for the mulched surface was 65C compared with 55C and 39C for the bare soil and turfgrass surfaces, respectively (Fig. 2A). Air temperatures over the mulched surface reached a maximum of 42C compared with 40C on the soil and 37C on the turfgrass (Fig. 2B). Leaf-air vapor pressure deficits were generally higher over the mulch (Fig. 2C) with VPDs for all three surfaces reaching a maximum at midafternoon. In the afternoon, plants on the mulched surface were 2 to 4C warmer than plants on soil and turfgrass.

Plants surrounded by mulch consistently had higher stomatal conductances during midmorning than those on turf and soil (Table 3). Stomatal conductance decreased in the afternoon for all cultivars on all surfaces, but the largest decrease was recorded for plants on the mulch.

Energy balance interactions between plants and the surface had a sizeable effect on plant transpiration in this study. On the mulched area, sensible heat and longwave radiation from the surface increased plant temperatures, and thus, leaf-air VPDs and transpiration above those surrounded by the other surfaces. Higher stomatal conductance in the morning for plants on the mulched surfaces appeared to be caused by higher surface and air temperatures and increased leaf-air VPDs.

Many advantages of using organic mulches have been reported, including reduction of water evaporation and buffering of soil temperatures (3,7). Results from this study indicate that mulches might increase plant transpiration under well-

Table 3. Mid-morning and mid-afternoon stomatal conductance rates for crape myrtle cultivars on mulched, soil and turf surfaces on 23 August, 1989.

Cultivar and surface treatment	Stomatal conductance ($mmol/m^2/s$) 10:30 am	2:00pm
Hope		
Turf[z]	22.5±0.3	19.8±0.6
Soil	27.6±0.6	18.4±0.8
Mulch	45.6±0.6	21.5±0.6
Victor		
Turf	15.8±0.7	11.6±0.6
Soil	14.5±0.7	13.1±0.6
Mulch	26.5±0.8	19.6±0.8
Seminole		
Turf	15.5±0.7	13.8±0.5
Soil	17.7±0.6	15.9±0.4
Mulch	24.0±0.6	15.8±0.6
Carolina Beauty		
Turf	14.2±0.4	13.5±0.4
Soil	16.7±0.4	13.3±0.4
Mulch	20.5±0.2	14.7±0.5

[z] Data are means ± SE (n=6)

watered conditions. In cases where water is limited, the savings in water due to the reduction in evaporation by mulching may offset this increase in transpiration, but further research is needed to verify this conclusion.

Landscape Management Practices, Growth Regulator Study. Reduction in water use in chemically treated hibiscus plants was found to be both morphological and physiological (6). At termination, leaf area of regulated plants averaged approximately 4170 cm^2 compared to 6940 cm^2 for pruned plants and 7320 cm^2 for control plants. About 14 days after application of the growth regulator, daily water use of growth regulated plants decreased below that of control and pruned plants, a difference that became more pronounced with time (Fig. 3). The daily water use of pruned plants before pruning was similar to that of control plants. After pruning, (CDN 129), water use of the pruned plants was significantly lower than that of control plants for approximately 20 days, but thereafter it was similar for the two treatments. Total water use of growth regulated plants was significantly lower than that of control or pruned plants for the entire 51-day experiment. Plants in the growth regulated treatment used 33% less water than control plants. Near the end of the experiment, when daily plant water use was normalized on a leaf-area basis, control plants lost more water per day than pruned or growth regulated plants.

Throughout the 51-day experiment, individual leaf transpiration rates of plants in the growth regulated treatment were generally reduced below those of the control and pruned plants (Fig. 4). The water potential of leaves from the growth regulated treatment was 0.3 to 0.5 MPa higher than that of leaves from the control or pruned treatments for most of the experiment. Lower leaf transpiration rates in growth regulated plants show that uniconazole had a direct effect on the water relations of hibiscus. Lower stomatal density was found in growth regulated leaves which may have contributed to the change in leaf transpiration. The reduced water use of growth regulated plants may confer a greater ability to withstand periods of drought in a landscape setting by slowing depletion of soil moisture. These plants may also require fewer water resources than pruned plants during nursery production.

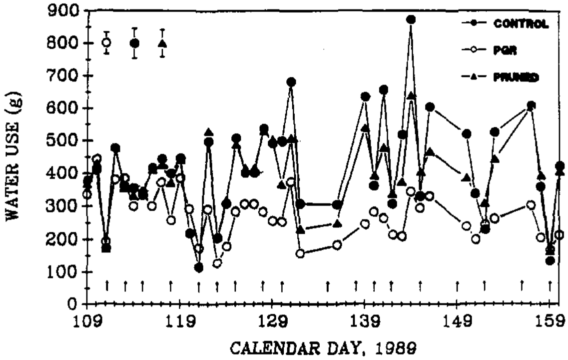

Figure 3. Daily water use of hibiscus plants in a control, uniconazole, and pruning treatment. Pruning was done on CDN 129. Vertical bars indicate average standard deviation (n=5). Arrows denote irrigations after 1600 h.

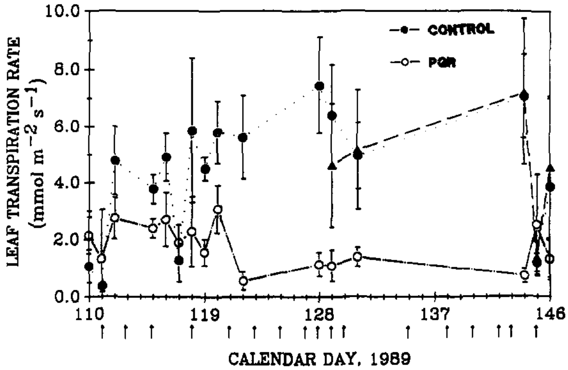

Figure 4. Midday pattern of leaf transpiration for hibiscus plants in control, uniconazole, and pruning treatments. Symbols represent the means from three or more plants and six or more measurements per treatment ± 1 SD. Data were collected between 1300 and 1530 h.

Summary

The above research begins to provide information that will allow commercial firms to design and maintain landscapes that will conserve water and reduce contamination, yet maintain acceptable levels of comfort and be aesthetically pleasing. In both rural and urban municipalities the need for reduced water demands is paramount. Through scientific investigation providing information aiding in more innovative designs and better management practices, it may be possible for municipalities to reduce total landscape irrigation by 80%. This represents a tremendous economic savings, plus the preservation of the current water supply and reduction of environmental contamination.

Literature Cited

1. Baker, J.M. and C.H.M. van Bavel. 1987. *Measurement of mass flow of water in the stems of herbaceous plants.* Plant Cell Environ. 10:777-782.
2. Davies, F.T., Jr. and Y. Castro-Jimenez. 1989. *Water relations of Lagerstroemia indica grown in amended media under drought stress.* Scientia Hortic. 41:97-104.
3. Kolb, W., T. Schwarz, and R. Trunk. 1983. *Comparison of cost and effectiveness of different mulch materials applied to planted areas.* Sportsattenbau. 2:56-72.
4. Sakuratani, T. 1981. *A heat balance method for measuring water flux in the stem of intact plants.* J. Agr. Meteorol. 37:9-17.
5. Steinberg, S.L., C.H.M. van Bavel, and M.J. McFarland. 1990. *Improved sap flow gauge for woody plants.* Agron. J. 82:851-854.
6. Steinberg, S.L., J.M. Zajicek, and M.J. McFarland. 1991. *Water relations of hibiscus following pruning or chemical growth regulation.* J. Amer. Soc. Hort. Sci. 116:465-470.
7. Unger, P.W. 1978. *Straw mulch effects on soil temperature and sorghum germination and growth.* Agron. J. 709:858-864.
8. Zajicek, J.M. and J.L. Heilman. 1991. *Transpiration of crape myrtle cultivars surrounded by mulch, soil, and turfgrass surfaces.* HortScience. 26:1207-1210.

Associate Professor
Department of Horticultural Sciences
Texas A&M University
College Station, Texas 77843-2133.

Résumé. Des études furent réalisées afin de procurer de l'information pertinente sur l'utilisation de l'eau par les végétaux ligneux ornementaux et sur la manière dont elle est affectée par la sélection végétale, l'environnement urbain et les pratiques d'aménagement paysager. La première étude évaluait les relations de l'eau avec des végétaux ligneux ornamentaux indigènes cultivés en contenant par comparaison à d'autres non indigènes. L'étude numéro deux explorait la manière dont le transport d'énergie affectait la transpiration du lilas d'été (*Lagerstroemia indica*) dans les cas où la surface était à nue, gazonnée et recouverte d'un paillis d'écorces de pin. La troisième étude quantifiait l'effet de l'élagage et de l'uniconazole comme régulateur de croissance sur l'utilisation de l'eau chez l'hibiscus. Les recherches ont fourni de l'information qui indiquait qu'il est possible, avec des designs plus innovateurs et de meilleures pratiques d'aménagement, de réduire de 80% le total des besoins en irrigation des parterres.

Zusammenfassung. Es wurden Studien durchgeführt über den Wasserverbrauch von Ziergehölzen und die Auswirkungen von Pflanzenauswahl, städtischer Umwelt und Plfegepraktiken. Studie 1 beurteilte den Wasserhaushalt von einheimischen Ziergehölzen in Containern gegenüber fremländischen Ziergehölzen. In studie 2 wurde untersucht, wie der Wärmetransport von offener Erde, Rasenstücken und Oberflächen mit Rindenmulch die transpiration der Trauerflormyrthe beeinträchtigen. Studie 3 quantifizierte die Wirkung des Astens und der chemischen Wachstumsregulation unter Verwendung von Uniconazole bezüglich des Wasserverbrauchs von Hibiscus. Die Untersuchungen deuteten daraufhin, daß durch innovative Ertwürfe und bessere Pflegepraktiken die gesamte Landschaftsbewässerung zu 80% vermindert werden kann.