Transpiration by Crape Myrtle Cultivars Surrounded by Mulch, Soil, and Turfgrass Surfaces

Jayne M. Zajicek¹ and J.L. Heilman²

Texas A&M University, College Station, TX 77843-2123

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Abstract. A study was conducted to explore how surface materials, including pine bark mulch, bare soil, and turfgrass, affect water use of diverse cultivars (dwarf weeping, dwarf upright, standard weeping, and standard upright) of crape myrtle (*Lagerstroemia indica* L.). Daily water use was measured gravimetrically, and instantaneous rates of sap flow were measured using heat balance stem flow gauges. Plants of all cultivars surrounded by the mulched surface lost 0.63 to 1.25 kg·m⁻²·day⁻¹ more water than plants on the soil surface and 0.83 to 1.09 kg·m⁻²·day⁻¹ more than plants surrounded by turf. The surface temperature of the mulch was higher than that of the other surfaces, resulting in greater fluxes of longwave radiation from the surface. Because of the greater energy load, plants on the mulched surface had higher leaf temperatures and higher leaf-air vapor pressure deficits (VPD) throughout the day. Plants on the mulched area also had higher stomatal conductances during most of the day compared with those on bare soil and turfgrass surfaces.

The role of vegetation in the urban environment, not only from an aesthetic stand-

point but also as a modifier of the urban climate, is gaining more attention as the discipline of urban horticulture evolves. Plant water loss is one issue facing urban horticulturists because water use for maintenance of landscape vegetation accounts for a large portion of the total water used in urban environments.

Plant transpiration is controlled principally by the physical environment. Temporary water deficits can occur whenever leaf transpiration fluxes exceed the rate of water uptake from the soil (Hinkley et al., 1978). At the microsite level, radiation loads on a tree crown might be increased because of thermal energy reflection and reradiation from buildings and surfaces. These environmental factors can increase leaf temperatures and leaf-air vapor pressure deficits (VPD), thereby increasing leaf transpirational fluxes (Whitlow and Bassuk, 1987). Heilman et al. (1989)

found that longwave radiation emitted from building walls was a major factor affecting plant water use. Water use was highest for plants adjacent to east- and west-facing walls. They also found that wind speed and, thus, convective transport of water vapor and heat in the shrubs were reduced by the building.

It is widely assumed that plant water deficits cause reductions in stomatal aperture either when a threshold level of water deficit is reached or progressively (Cowan, 1977;

Fig. 1. Surface temperatures (A), air temperatures (B), and leaf-air vapor pressure deficits (C) as affected by surface material: (▲) mulched, (△) soil, and (○) turf, 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.

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¹Assistant Professor, Dept. of Horticultural Sciences.

²Associate Professor, Dept. of Soil and Crop Sciences.

Fig. 2. Sap flow per unit leaf area of four cultivars of crape myrtle as affected by surface material: (▲) mulched, (△) soil, and (○) turf, for one representative day.

Fig. 3. Daily water use per unit leaf area of four cultivars of crape myrtle as affected by surface material: (▲) mulched, (△) soil, and (○) turf, for the week 17-23 Aug. 1989. Each point is the mean of three replications per surface treatment. Vertical bars represent SE of the mean.

Hall et al., 1976; Hsiao, 1973). Plant species appear to vary in their response to urban conditions. Potts and Herrington (1982) reported that in environments where water loss was driven to excess by advection of sensible heat from surrounding man-made surfaces, honeylocust [*Gleditsia triacanthos* (or var.) *f. inermis* Willd.] was not able to adequately regulate water loss through stomatal control. Green ash [*Fraxinus pennsylvanica* (Borkh.) Sarg.] also maintained high transpiration rates despite relatively low midday water potentials compared with littleleaf linden (*Tilia cordata* Mill.) trees (Whitlow and Bassuk, 1988).

This study was designed to evaluate how energy transport from soil, turfgrass, and mulched surfaces affects transpiration of diverse cultivars of crape myrtle.

The study was conducted from 10 July-24 Aug. 1989, at the Texas A&M Univ. Turfgrass Field Laboratory in College Station (30.4°N, 96.2°W). Holes lined with alu-

minum cylinders, 26 cm in diameter, were prepared to house 11.3-liter pots, 12 each surrounded by bare soil, bermudagrass (*Cynodon dactylon* L.), or bare soil covered with 8 cm of pine bark mulch. Pine bark mulch particles measured 0.6 to 0.9 cm and were spread just to the edge of the holes. The holes were spaced 1.2 m apart in 9.6 × 3.6 m beds. The turfgrass plot was surrounded by additional turfgrass, and the bare soil and mulched plots were surrounded by additional bare soil. The bermudagrass was irrigated by sprinklers daily at sunset and maintained at a cutting height of 0.03 m.

One-year-old plants (stem diameters ranging from 12 to 20 mm, depending on cultivar) of crape myrtle were used. Nine each of four cultivars including 'Hope' (dwarf-weeping, average height 20 cm), 'Seminole' (standard-weeping, average height 30 cm), 'Victor' (dwarf-upright, average height 35 cm), and 'Carolina Beauty' (standard-upright, average height 65 cm) were planted in

11.3-liter pots containing a mix of 2 fritted clay : 1, Redi-earth peat-lite (v/v) (Grace-Sierra, Fogelsville, Pa.). One-third each of the pots (three of each cultivar) were inserted into the aluminum cylinders in the bare soil, in the turfgrass, and in the mulched plot in a completely randomized design. Pots were buried so that the tops were flush with the surface. Plants were removed from the holes and watered to saturation daily at sunset. Pots were allowed to drain to container capacity to help leach out salts and then reinserted into the holes. Plants were fertilized weekly with Peters Peat-lite Special (15N-16P-17X) (Grace-Sierra) at 400 mg N/liter. The pots were covered with white plastic to prevent evaporation and with aluminum foil to minimize effects of radiation on surface temperatures.

Whole-plant transpiration was determined gravimetrically by weighing the plants daily with a Mettler PM16 balance accurate to 0.1 g (Mettler Institute, Highstown, N.J.). In addition, sap flow rates were recorded for two 2-day intervals, for each cultivar on each surface, using the heat-balance technique (Sakuratani, 1981). Sap flow gauges were constructed in our laboratory according to the design of Baker and Van Bavel (1987), using the wiring configuration of Steinberg and Van Bavel (1990). Plants designated for sap flow measurements (one plant per cultivar per surface treatment) were placed side-by-side on the turfgrass on 16 Aug. 1989, and daily water use was measured in each plant under the same environmental conditions. Water use rates per unit leaf area over 24 h were similar for all three plants of each cultivar, the ranges ($\text{kg} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$) being: 'Hope', 4.63 to 4.79; 'Seminole', 3.32 to 3.47; 'Victor', 3.55 to 3.67; and 'Carolina Beauty', 3.72 to 3.88. These results are consistent with results for *Ligustrum japonicum* (Thunb.) reported by Heilman and Ham (1990). Because there were not enough gauges to use on all cultivars at one time, sap flow for each cultivar was measured on consecutive days. Gauges were attached to the stem between the soil surface and the lowest branch and covered with a polyethylene rain shield to prevent water from causing an electrical short in the gauge heaters. Additional foam insulation was attached above and below each gauge where space permitted. Gauges, rain shield, and insulation were wrapped in aluminum foil to minimize effects of radiation on the heat balance of the stems. The power applied to the stems was 0.2 W. Gauges were interrogated every 15 sec by a CR21X micrologger (Campbell Scientific, Logan, Utah); and the signals averaged every 15 min. Detailed discussions of the heat balance method are given by Baker and Van Bavel (1987) and Ham and Heilman (1990). Water loss was expressed on a unit leaf area basis to reduce plant-to-plant variability caused by differences in leaf area (Heilman and Ham, 1990).

Stomatal conductance was measured with a LI-1600 Steady State porometer (LI-COR, Lincoln, Neb.) midmorning and midafternoon on selected days. Measurements were

Table 1. Midmorning and midafternoon stomatal and conductance rates for crape myrtle cultivars surrounded by mulched, soil, and turf surfaces on 23 Aug. 1989.

Cultivar and surface	Stomatal conductance (mmol·m ⁻² ·s ⁻¹)	
	1030 HR	1400 HR
Hope		
Turf ^a	22.5 ± 0.32	19.8 ± 0.64
Soil	27.6 ± 0.62	18.4 ± 0.77
Mulch	45.6 ± 0.63	21.5 ± 0.60
Victor		
Turf	15.8 ± 0.67	11.6 ± 0.58
Soil	14.5 ± 0.72	13.1 ± 0.58
Mulch	26.5 ± 0.84	19.6 ± 0.78
Seminole		
Turf	15.5 ± 0.72	13.8 ± 0.46
Soil	17.7 ± 0.61	15.9 ± 0.44
Mulch	24.0 ± 0.58	15.8 ± 0.64
Carolina Beauty		
Turf	14.2 ± 0.35	13.5 ± 0.35
Soil	16.7 ± 0.38	13.3 ± 0.43
Mulch	20.5 ± 0.23	14.7 ± 0.47

^aData are means ± SE (n = 6).

made on the first two fully expanded leaves per plant on three plants per cultivar per treatment. Surface and plant temperatures (Fig. 1) were measured at regular intervals during daylight hours with a hand-held infrared radiometer pointed directly down on top of the surface or plant canopy (Model 110, Everest Interscience, Tustin, Calif.). Plant canopies were dense enough to ensure that only the plants were in view of the infrared thermometer. Vapor pressure and air temperature 20 cm above each surface material were recorded at regular intervals with a wet/dry bulb psychrometer. Leaf vapor pressures were calculated using the measurements of plant temperature. At the termination of the study, total leaf area of each plant was measured with a LI-COR area meter (Model LI-3000).

Global irradiance, air temperature, humidity, and wind speed and direction were measured 1.5 m above the soil surface at a portable weather station located on the turf plot. Temperature and humidity were measured with a shielded, aspirated probe (Model CSI 207, Campbell Scientific), and global irradiance was measured with a LI-COR Model LI-200SCZ pyranometer. Meteorological sensors were connected to a CR21X micrologger (Campbell Scientific). Weather data were recorded at 10-sec intervals and averaged every 30 min.

An analysis of variance procedure was performed on all replicated data of the 3 × 4 factorial.

Weather conditions during the study were characterized by partly cloudy skies (global irradiance of 20 to 24 MJ·m⁻²·day⁻¹), high temperatures (maximum 35 to 37°C, minimum 23 to 25°C), moderate wind speeds (2 to 4 m·s⁻¹), and 67% to 70% relative humidity.

There was no significant interaction between cultivars and surface materials for plant water loss. However, water loss of crape myrtle was significantly affected by surface materials ($P = 0.001$) and plant cultivar

($P = 0.001$). Plants of all cultivars surrounded by mulched surface used 0.63 to 1.25 kg·m⁻²·day⁻¹ more water than plants surrounded by soil and 0.83 to 1.09 kg·m⁻²·day⁻¹ more water than plants on turf. Plants on the soil used an average of 0.20 kg·m⁻²·day⁻¹ more water than plants on turf.

Highest sap flow rates occurred from 1000 to 1300 HR on the mulched surface for all cultivars (Fig. 2). 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 HR and remained warmer throughout the day than the other surfaces (Fig. 1A). For example, on 23 Aug. 1989, the maximum for the mulched surface was 65°C compared with 55°C and 39°C for the bare soil and turfgrass surfaces, respectively (Fig. 1A). Maximum longwave exitances were 741, 649, and 541 W·m⁻² for the mulched, bare soil, and turfgrass surfaces, respectively. Turfgrass temperatures were lower than those of the other surfaces, probably due to latent heat of vaporization during transpiration of the grass. Air temperatures over the mulched surface reached a maximum of 42°C compared with 40°C on the soil and 37°C on the turfgrass (Fig. 1B), indicating a higher sensible heat flux from the mulch.

Leaf-air vapor pressure deficits were generally higher over the mulch (Fig. 1C) with VPDs for all three surfaces reaching a maximum at midafternoon. In the afternoon, plants on the mulched surface were 2 to 4°C 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 1). Stomatal conductance decreased in the afternoon for all cultivars on all surfaces, but the largest decrease was recorded for plants on mulch.

Differences were also apparent in water use among crape myrtle cultivars. 'Hope' (dwarf, weeping) used more water per unit leaf area throughout the study than the other cultivars (Fig. 3). 'Hope' had, on the average, more leaves per plant (1220), with the smallest average area per leaf (2.03 cm²) compared with the others ('Victor', 902 leaves, 3.08 cm²/leaf, 'Seminole', 452 leaves, 9.69 cm²; and 'Carolina Beauty', 1037 leaves, 4.26 cm²). 'Hope' also had the highest stomatal conductance throughout the study (Table 1).

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. Ham et al. (1991) found that at partial canopy cover, sensible heat generated by a dry soil surface accounted for as much as 21% of the daily water use of cotton. They also found that longwave radiation from soil contributed >450 W·m⁻² to the radiation balance of the cotton near midday.

Higher stomatal conductance in the morning for plants on the mulched area compared with plants on the other surfaces appeared to be caused by higher surface and air temperatures and increased leaf-air VPDs. Hofstra and Hesketh (1969) and Drake et al. (1970) reported a marked increase in stomatal conductance with increased air temperatures to 36°C under well-watered conditions, as was the case in our study. Turner et al. (1984) and Woledge et al. (1989) found that transpiration in many woody species increased initially with an increase in VPD but decreased when subjected to higher VPDs. This reversal may be one explanation for the sharp decline in sap flow of plants on the mulch at midafternoon where surface temperatures reached 65°C and leaf-air VPDs were ≈ 4.6 kPa.

Canopy architecture and leaf size also influenced water loss of crape myrtle. 'Hope', the dwarf, weeping cultivar, lost more water per unit leaf area and had higher transpirational fluxes than the others throughout the study. The smaller leaves of 'Hope' would be expected to provide low boundary layer resistances to the diffusion of heat and water vapor. The fact that 'Hope' is a weeping cultivar may help to explain the higher transpiration rates due to increased interception of radiation from the surface materials.

Many advantages of using organic mulches have been reported, including reduction of water evaporation with increased moisture levels under mulched vs. nonmulched soil (Kolb et al., 1983) and buffering of soil temperatures (Unger, 1978). Results from this study indicate that mulches might increase plant transpiration under well-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.

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