Cooling capacity of urban trees exposed to thermal stress

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Background

Urban heat islands pose a major threat to human and environmental health, requiring city managers to develop strategies to mitigate the effects of excess heat. Urban vegetation is known for mitigating some of these threats by cooling the local surroundings through shade and evapotranspiration. However, choosing the appropriate tree species remains a challenge, as urban planners have little information on species' cooling capacities (i.e., shade intensity and area, water use).

Objectives

We quantified the species-specific cooling effect of 14 tree species (native and exotic) commonly found in Phoenix, AZ, USA. Specifically:

1) How does plant water loss (stomatal conductance, *gsw*) and transpiration, *Et*) vary across urban tree species (native vs. exotic)?
2) How did these parameters change from spring to summer, when temperatures regularly exceed 40 °C?

Methods

Research Site: Desert Botanical Garden, Phoenix, AZ, USA

Temporal extent: April-July, 2021. Measurements taken 4-5 days at the end of each month

Sample plants: 14 species chosen based on Maricopa County Urban Tree Selection Criteria list.

- 15-gal potted plants from local nurseries irrigated daily (once in spring, twice in summer). Four plants per species

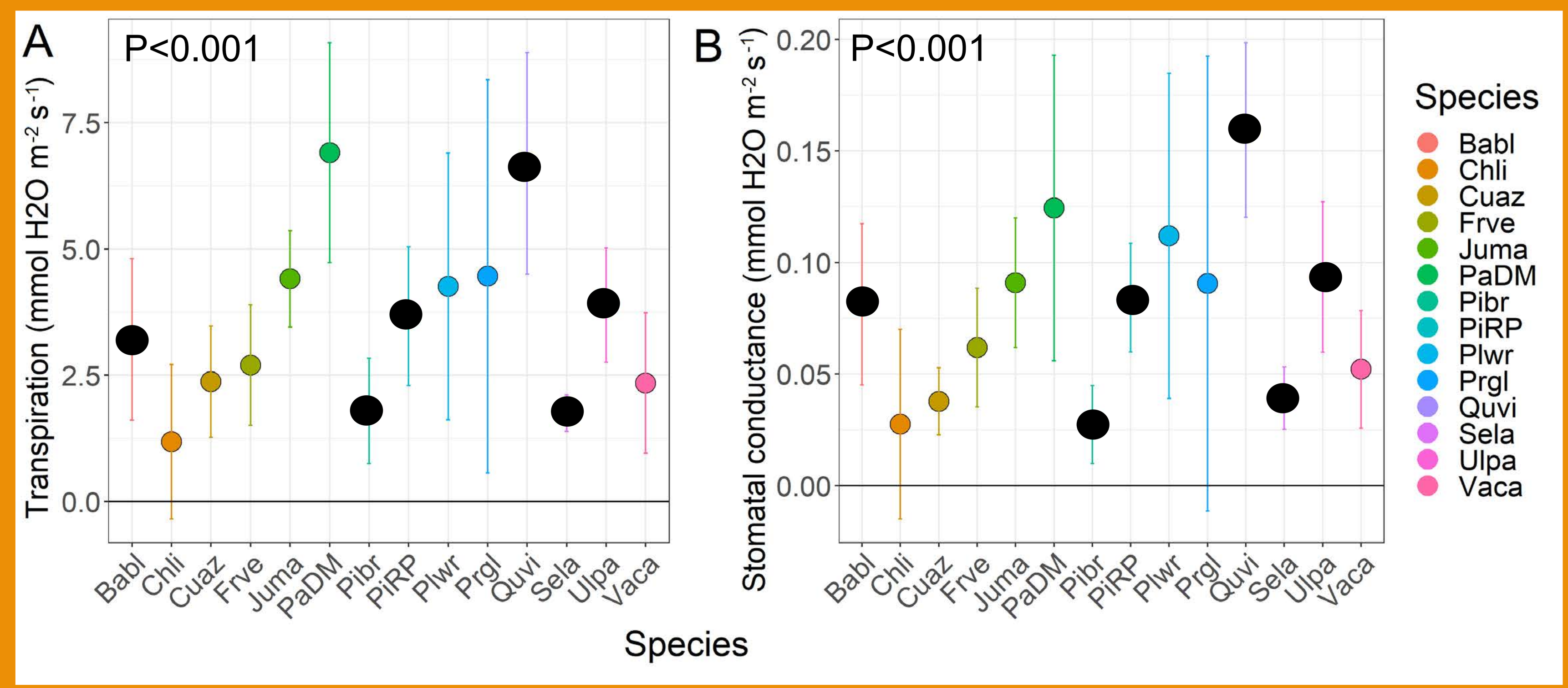
Measurements:

- *Diurnal gas exchange*: porometer (LI600), and photosynthesis system (LI6400) for small leaves and needles → 4 leaves per plant
- *Thermal*: thermal IR sensor, FLIR One phone camera
- *Weather*: nearby HOBO weather station
- *Plant traits:* LMA, LDMC, thermal damage, canopy area and volume

1 Description of sampled plants and percentage difference in stomatal conductance (Δgsw) and transpiration (ΔEt) from spring (April-May) to summer (June-July).

Code	Species	Common Name	Origin	Δgsw	ΔEt
Babl	*Bauhinia blakeana*	Hong Kong Orchid tree	Exotic	24%	52%
Chli	*Chilopsis linearis*	Desert willow	Native	75%	84%
Cuar	*Cupressus arizonica*	Arizona cypress	Native	42%	49%
Frve	*Fraxinus velutina*	Arizona ash	Native	24%	46%
Juma	*Juglans major*	Arizona walnut	Native	-8%	-1%
PaDM	*Parkinsonia x 'Desert Museum'*	Palo verde	Native	31%	26%
Pibr	*Pinus brutia*	Eldarica pine	Exotic	61%	62%
PiRP	*Pistacia x 'Red Push'*	Chinese pistache	Exotic	9%	34%
Plwr	*Platanus wrightii*	Arizona sycamore	Native	-62%	-5%
Prgl	*Prosopis glandulosa*	Honey mesquite	Native	63%	64%
Quvi	*Quercus virginiana*	Live oak	Exotic to AZ	-26%	15%
Sela	*Searsia lancea*	African sumac	Exotic	-26%	15%
Ulpa	*Ulmus parvifolia*	Chinese elm	Exotic	-21%	19%
Vaca	*Vauquelinia californica*	California rosewood	Native	-23%	21%

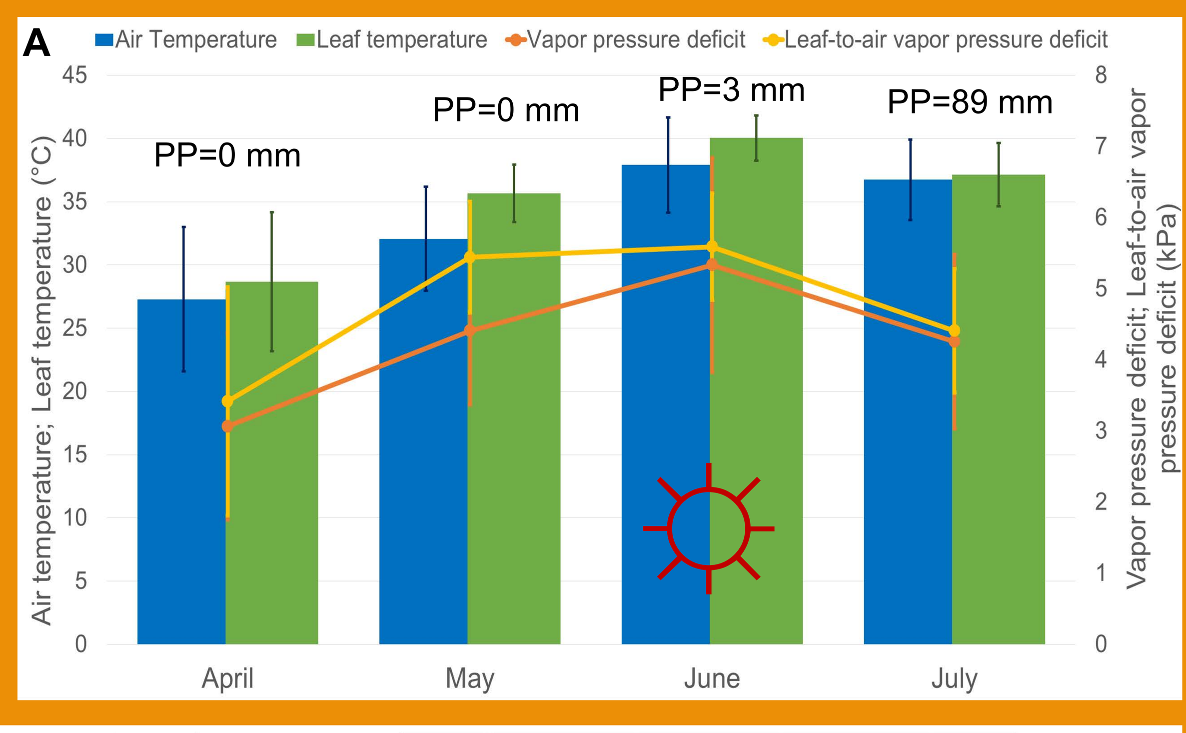
2 Average transpiration (A) and stomatal conductance (B) per species. Solid black enlarged points indicate exotic species.

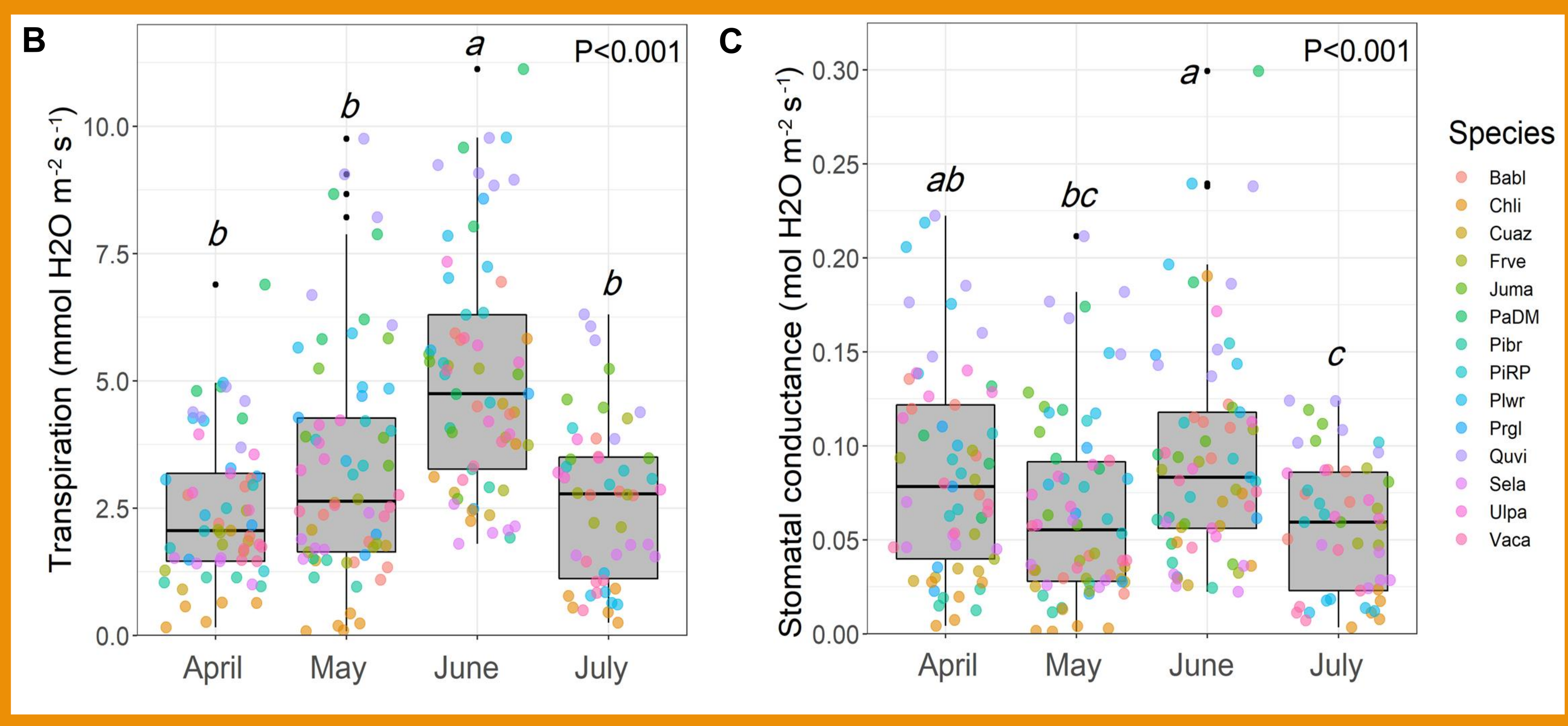


3 Climatic (A) and plant water use (B-C) variation across measurement months. Letters indicate significant differences (α=0.05) of transpiration and stomatal conductance between months.

☼ 8-day heatwave (13-20 June, 2021)

Maximum T_{air}>45 °C, Maximum VPD=8.5-10.5 kPa

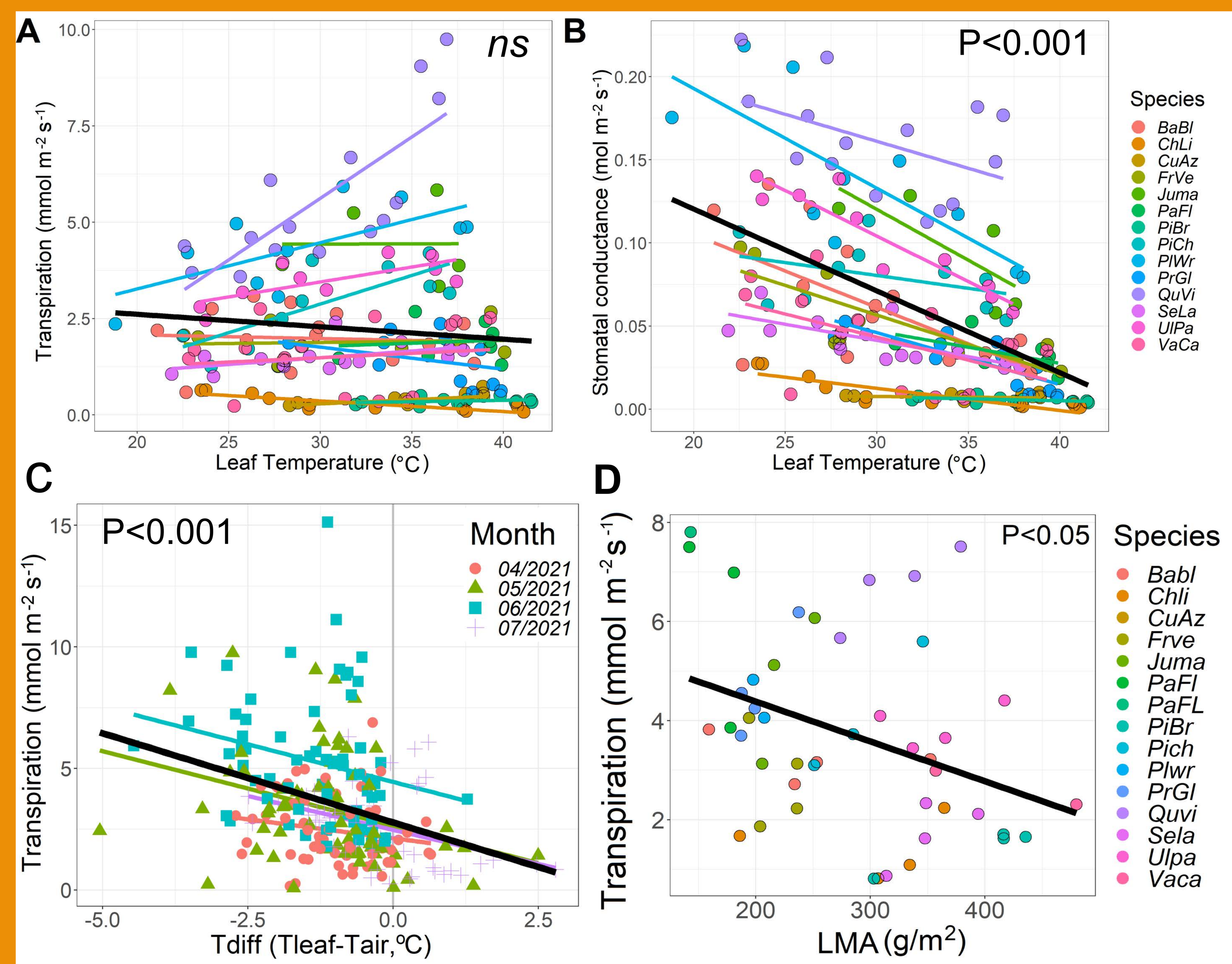




Results

- *Et* rates increased 33% from spring to summer; and *gsw* increased 12%.
- Mean *gsw* was negatively affected by both VPDleaf and Tleaf. Mean *Et* kept constant (ns), with exception to negative response to VPDleaf during June/2021.
- Wide range of *Et* rates reflects different strategies that each species adopt to cope with heat (evaporative cooling vs. stomatal suppression).
- Mean *Et* and *gsw* (marginally) were both negatively correlated only to LMA. Relationship to LMA was strongest during the summer months.
- Tdiff became mostly positive in July/2021 after the heatwave, suggesting stomatal closure from hydraulic failure or leaf thermal damage. Highest Tdiff was in June/2021 indicating that stomatal regulation was focused on evaporatively cooling the canopy and surroundings.

4 Effects of leaf temperature on transpiration (A) and stomatal conductance (B) across species; effects of temperature difference (Tdiff) on transpiration (similar to gsw) across months (C); relationship to leaf mass per area (D).



Conclusions

- *Pinus eldarica, Cupressus arizonica, Chilopsis linearis, Searsia lancea,* and *Fraxinus velutina* were the most "cooling efficient" trees for Phoenix landscaping → *provide intermediate-full shade across seasons, relative to water use under arid conditions.*
- Highly drought-tolerant plants used the most water and partially dropped leaves during the summer (*Quercus*, *Parkinsonia*, and *Prosopis*).
- *In progress:* NDVI variation across seasons and species; leaf water use upscaled to whole-canopy.

Acknowledgements

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☼ ***Next steps:*** I will be starting my lab as an Assistant Professor at Univ of Utah in July/2023. Please reach out t if you are interested in collaborating in future projects related to this work.