Cell Wall Undulation As Light Proxy In *Cercidiphyllum Japonicum* Leaves

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Introduction

- Light environment affects leaf morphology from the whole blade down to the individual cells, and fossil leaf morphology is used as a proxy for light in reconstructing ancient ecosystems.
- Leaf light exposure can reflect forest canopy structure and is a confounding variable in stomatal pCO_2 reconstruction.
- Constraining the morphological variability driven by light environment in modern plants allows for more accurate interpretation of fossil data.
- This study investigates the epidermal cell and whole-leaf morphology of of sun and shade leaves from a *Cercidiphyllum japonicum* tree, with particular focus on cell wall undulation index (UI), a metric used as a proxy for light environment in paleoecological studies.[1,2]

Methods

Two sets of leaves were collected from a weeping katsura tree on the southwest corner of the Norris University Center at Northwestern University (pictured far right).

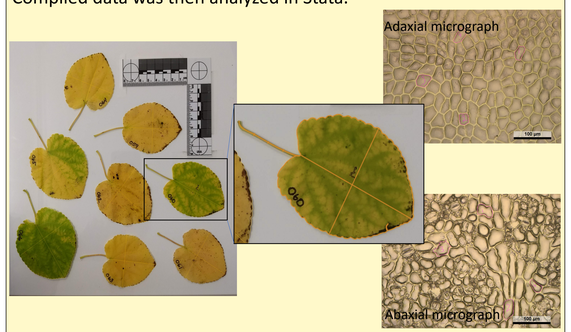
- Set 1: Sun, shade, and litter before senescence - 50 leaves each
- Set 2: Sun and shade collected weekly (3 each) from soon after budburst to before senescence.

Leaves were photographed flat with a scale, then cuticle peels were taken from a central point both sides (adaxial- top, abaxial- bottom) and photographed with a light microscope.

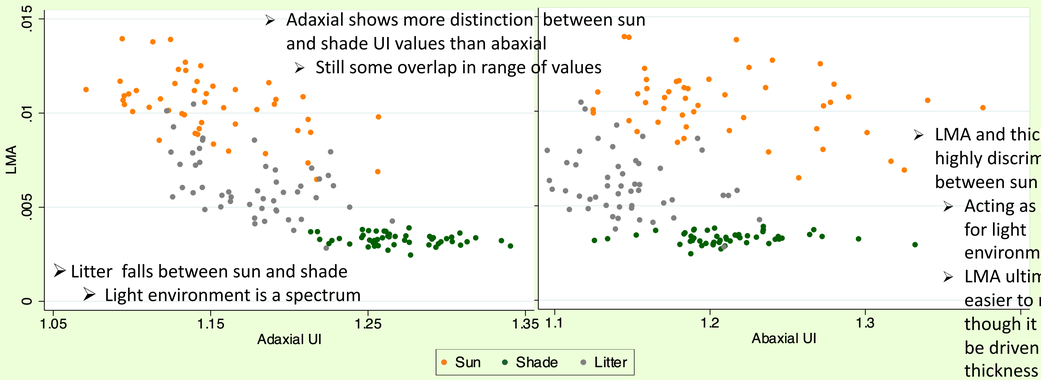
Both whole-leaf photos and micrographs were measured in Image J, compiled, and used to calculate UI and leaf mass per area (LMA).

- $UI = {}^{C_e}/_{C_O}$, where C_e= cell circumference and C_o= circumference of a circle with equivalent area to the cell.[3]
- LMA = leaf blade mass (g)/blade area (cm^2)

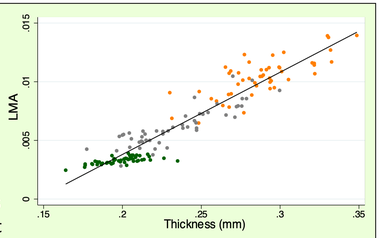
Compiled data was then analyzed in Stata.



Set 1: 2018 Mature Leaves



- Adaxial shows more distinction between sun and shade UI values than abaxial
  - Still some overlap in range of values
- Litter falls between sun and shade
  - Light environment is a spectrum

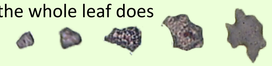


- LMA and thickness highly discriminant between sun and shade
  - Acting as a stand in for light environment
  - LMA ultimately easier to measure, though it seems to be driven by thickness

	Det. Shade	Det. Sun	Total
Leaves w/ light environment classified by Abaxial UI			
True Shade	21 (42%)	29 (58%)	50
True Sun	20 (40.82%)	29 (59.18%)	49
Total	41 (41.41%)	58 (58.59%)	99
Leaves w/ light environment classified by Adaxial UI			
True Shade	50 (100%)	0	50
True Sun	6 (12.24%)	43 (87.76%)	49
Total	56 (56.57%)	43 (43.43%)	99

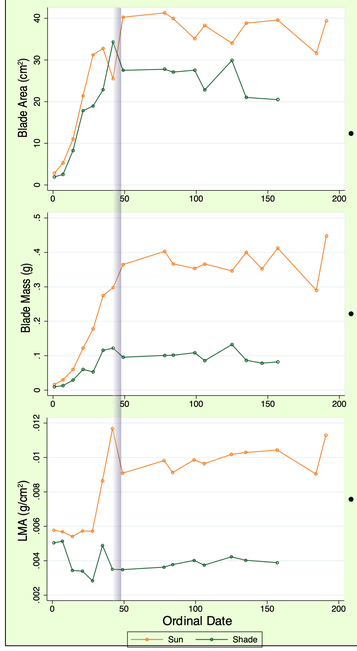
Set 2: Time Series, 2019

- Whole leaves reach maturity ~42-49 days after budburst
  - Sun and shade start at the same place for whole-leaf dimensions
  - Sun leaves overall have larger area, more massive, higher LMA, growing at a faster rate than shade
- Epidermal cells reach maturity ~28-35 days after budburst
  - Also start in the same place and end at the same time, but shade leaves seem to have larger, more sinuous epidermal cells
  - Shade cells growing at a faster rate than sun
  - Distinct separation between light environments
- Central epidermal cells seem to reach maturity before the whole leaf does

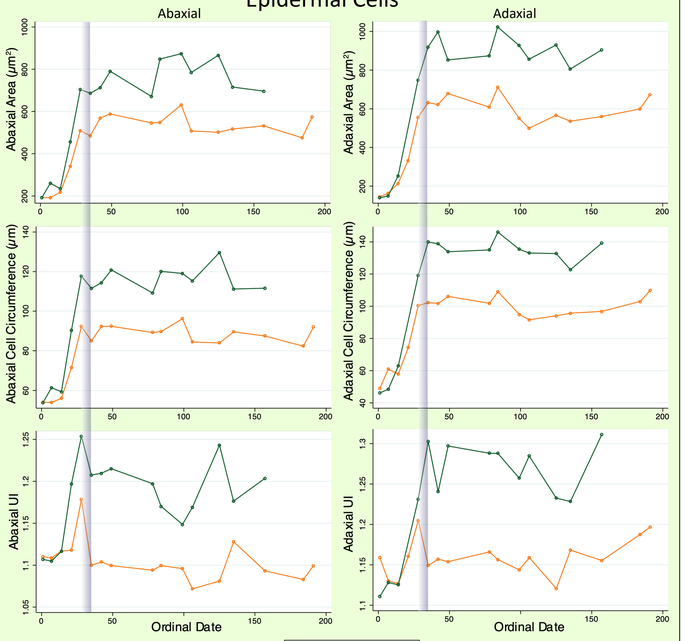


Top: Growth series of the whole-leaf samples
Bottom: Growth series of shade-leaf adaxial epidermal cells

Whole-Leaf



Epidermal Cells



Questions

1. Does UI correlate to light environment in *C. japonicum*? Does it correlate on both abaxial and adaxial sides?
2. When is cell shape set? Does it set at the same time on both sides of the leaf? Does it set at the same time as other parameters?
3. Do the differences in timing of UI development account for the differences between sun and shade leaves? Can this tell us anything about the driving mechanisms behind undulation?

The subject in question: a weeping variety of C. japonicum

Conclusions

- LMA and adaxial UI have considerably strong correlations to light environment in *C. Japonicum,* making adaxial UI a fair candidate for a light proxy in fossil study.
- The overlap in values between sun and shade UI values suggest more conservative ranges be used for separating out fossils.
- The quicker rate of growth apparent in shade leaves supports the theory that undulation is driven by the need for structural support in faster growing cells.[4]
- Central epidermal cells reaching their final shape and size before the whole leaf is consistent with current literature, which suggests most new cell growth occurs from the petiole and base of the major vein and is not uniform across the leaf.[5]

Possible Future Studies

- A lateral study of *C. japonicum* development to see how/if these patterns differ year to year
- Study of a larger sample of *C. japonicum* specimens to see if these trends are consistent across the species or endemic to one tree
- Direct comparison with other light proxies, like Carbon isotope composition in both mature and developmental trends [6]

References

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3 Kürschner, W. M, **1997**. *Review of Palaeobotany and Palyntology* 96, no. 1: 1-30.
4 Sapala, A. et al., **2018.** *eLife,* 7:e32794.
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6 Farquhar, G. D. et al., **1989**, *Annual Review of Plant Biology* 40, no.1: 503-537

Acknowledgements

Many thanks to the Office of Undergraduate Research at Northwestern University, especially Peter Civetta and Tori Larsen for their guidance in, and the Chicago Botanic Garden, particularly Pat Herendeen and Nyree Zerega for facilitating the use of the research facilities. This poster is part of an honors thesis (Julia's) in the Program in Environmental Sciences, and she would like to thank Patricia Beddows for her guidance and Rosemary Bush for her mentorship throughout this whole process.