Leaf vessel length and leaf-stem connections: Structure of water transport pathways in woody plants

Muhammad Ali, Lhea Domondon, Sara Ortiz, Fernando Tenorio, Tagacy Valdez

Graduate mentor: Danica Bergin

Faculty mentor: Dr. Anna L. Jacobsen

SURE Program 2022

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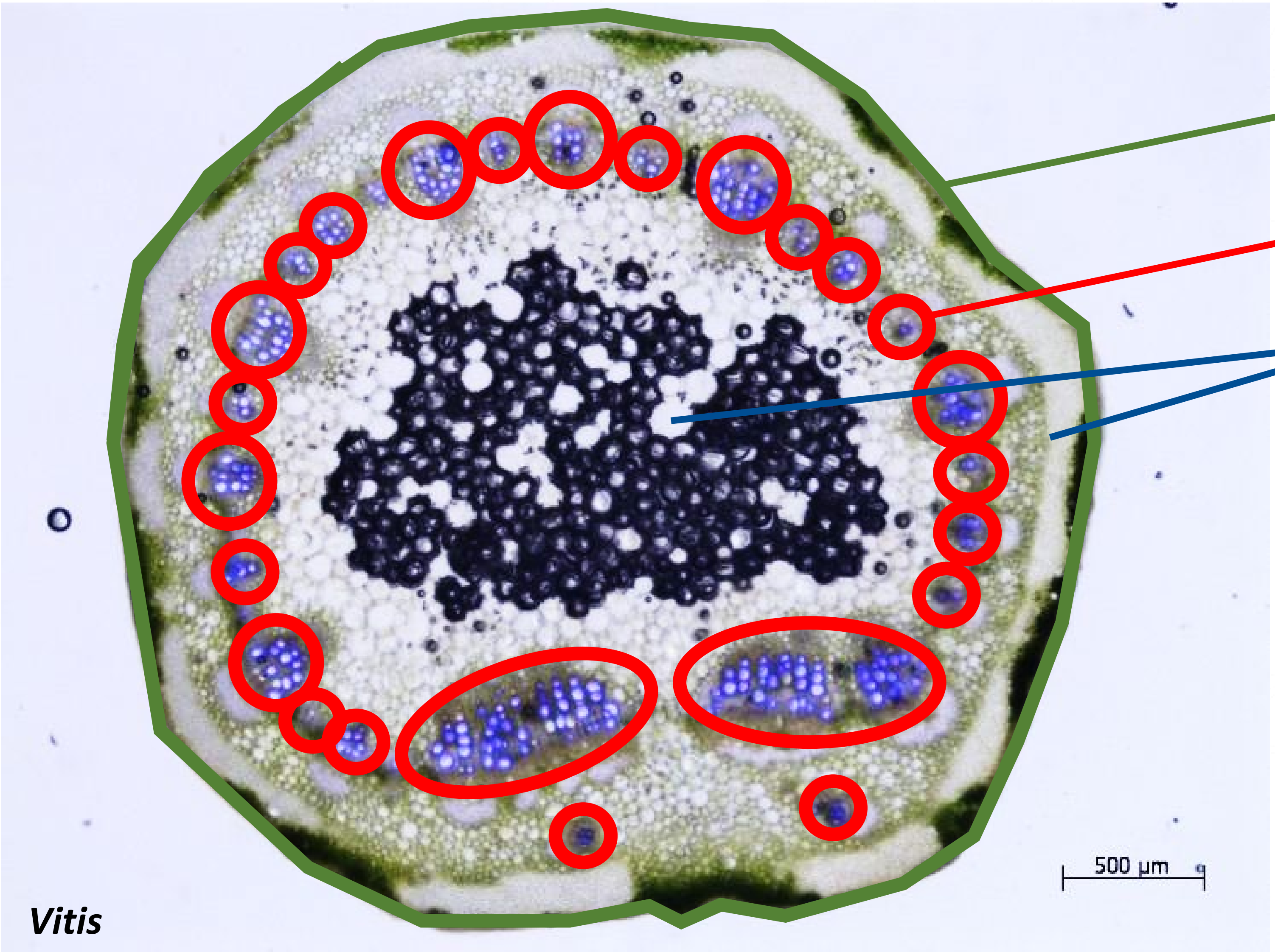
Plant Tissue Systems: Leaf Morphology



Dermal Tissue System
(epidermis)

Vascular Tissue System
(xylem and phloem tissues)

Ground Tissue System
(several types of simple tissues)

Photo credit: Jacobsen lab members, SURE 2022

Xylem: The water transport tissue within plants

Why were we interested in studying xylem vessels in leaves?

- Transpiration (water loss from leaves) and photosynthesis are important leaf functions.
- Xylem vessels supply water to leaves to support transpiration, photosynthesis, and growth.
- There are no published data of leaf vessel length in woody plants. No one has looked at this before! (New to science!)

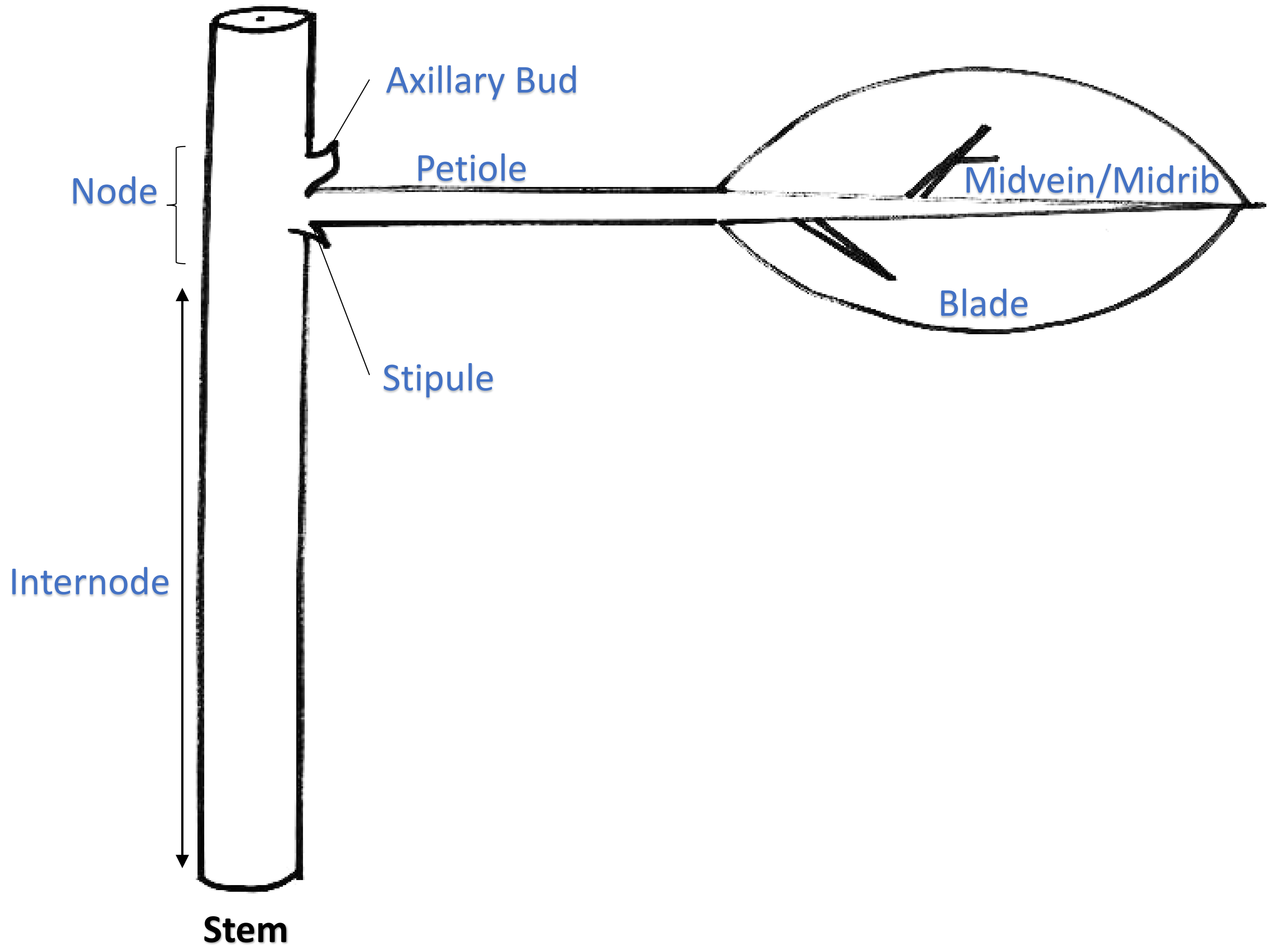
Vessel elements (cells) within the xylem connect to form multi-cellular pipes, termed **vessels**, that transport water throughout the plant body.

"Accurate measurement of the length of vessels is laborious…consequently **our basic knowledge of vessel length is less detailed than that of many other components of xylem anatomy** and hydraulic architecture.
"We hope that this discussion will draw the attention of future studies to this **often-neglected dimension**." (Comstock and Sperry 2000)

Comstock, J.P. and Sperry, J. S., 2000. Theoretical considerations of optimal conduit length for water transport in vascular plants. *The New Phytologist*, 148(2), pp. 195-218.

Photo credit: Jacobsen

Parts of a leaf

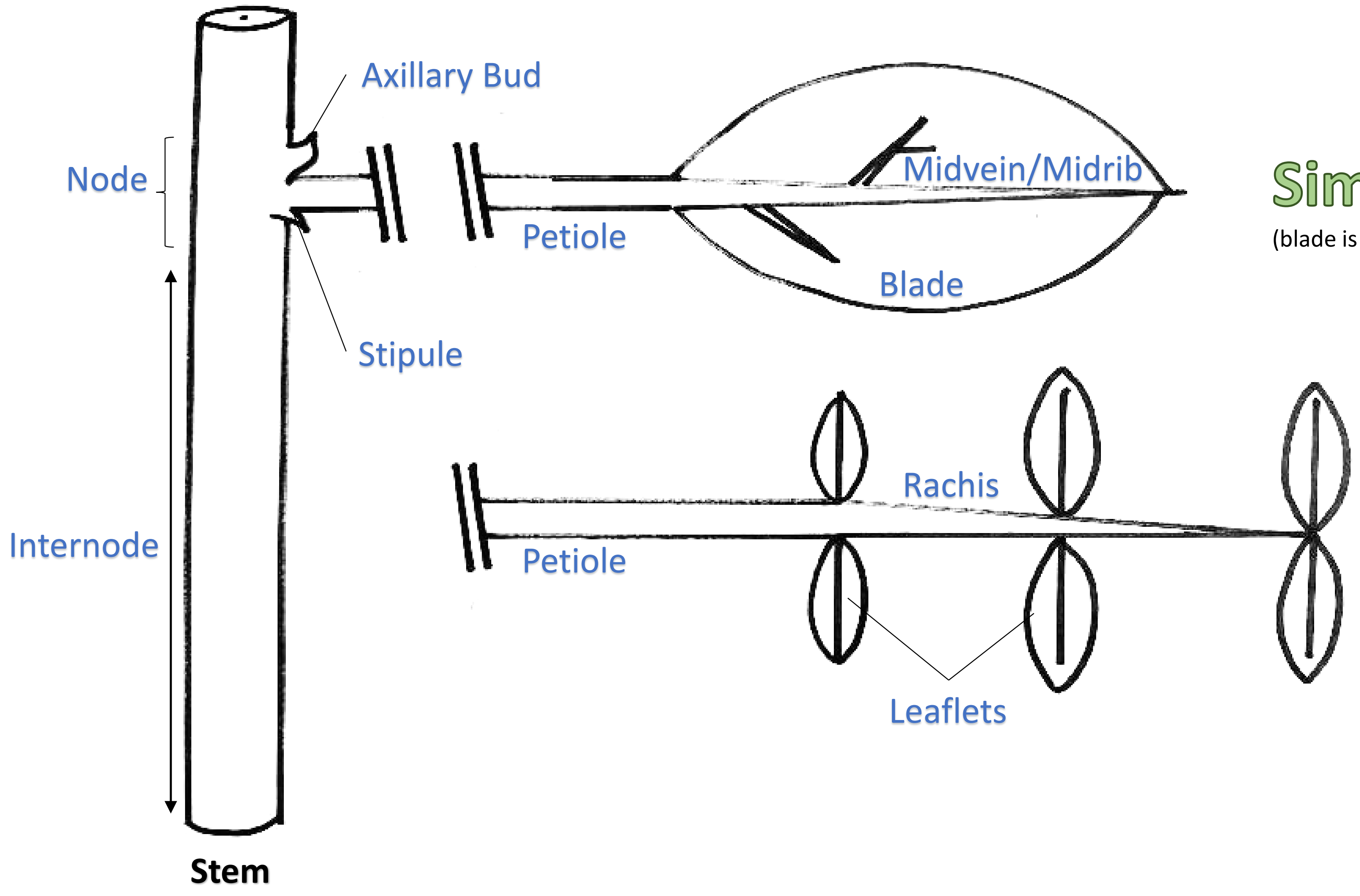


Simple Leaf

(blade is 'entire')

Image credit: Jacobsen

Parts of a leaf



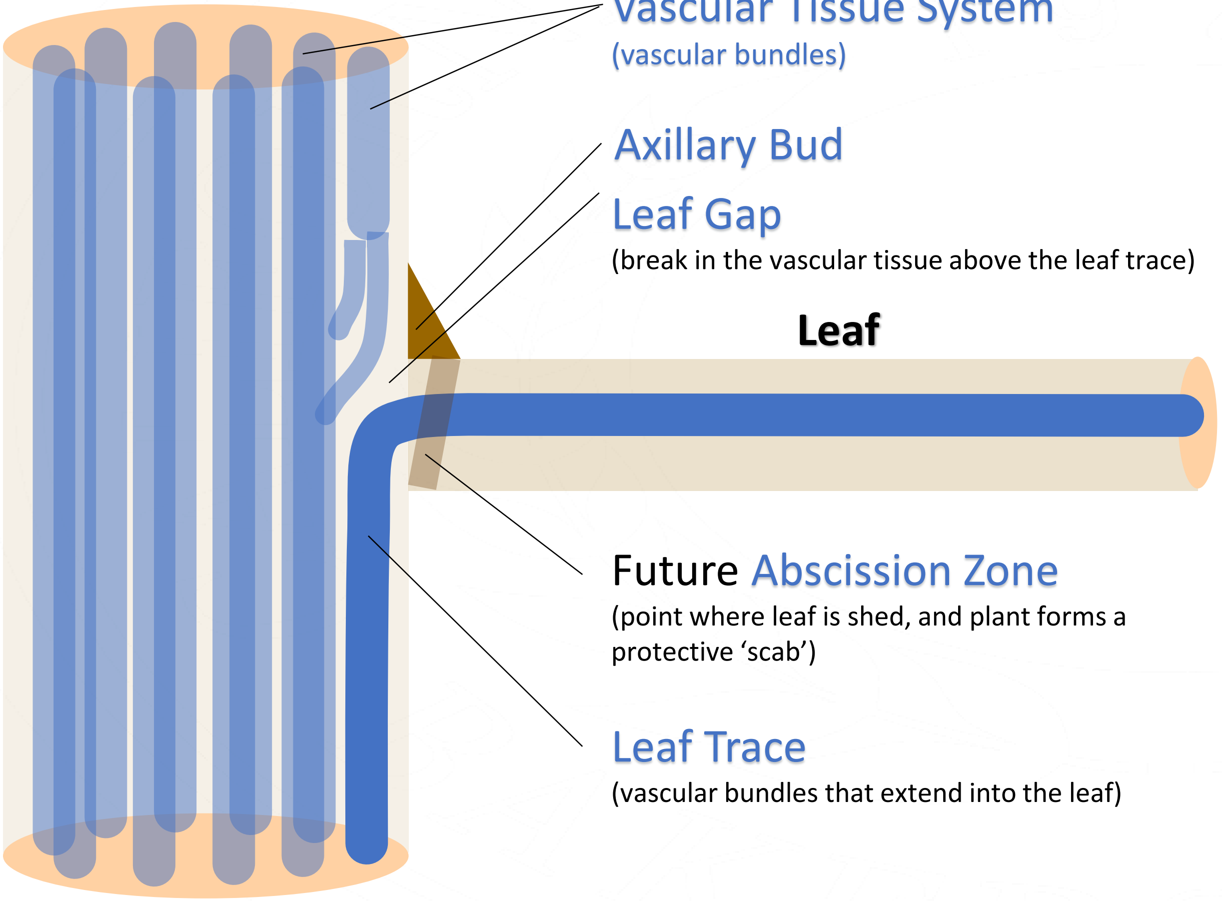
Simple Leaf
(blade is 'entire')

Compound Leaf
(blade is 'divided')

Image credit: Jacobsen

Leaf-stem connections

Stem



Vascular Tissue System
(vascular bundles)

Axillary Bud

Leaf Gap
(break in the vascular tissue above the leaf trace)

Future Abscission Zone
(point where leaf is shed, and plant forms a protective 'scab')

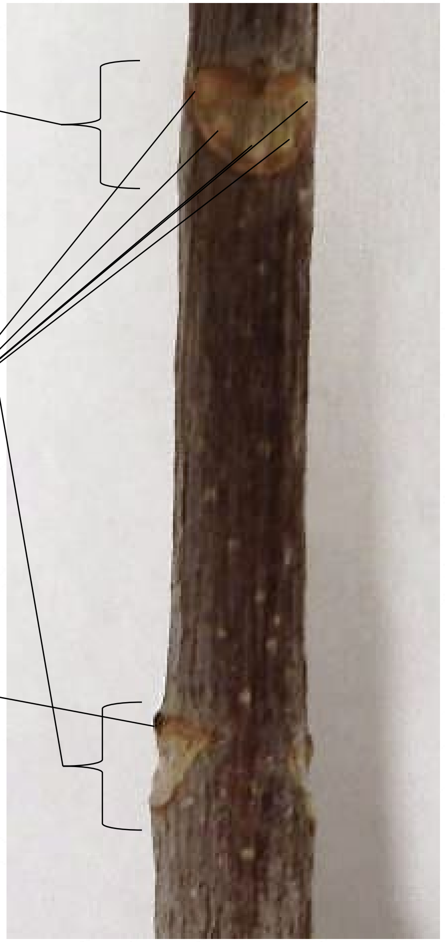
Leaf Trace
(vascular bundles that extend into the leaf)

Leaf Abscission (Leaf shedding)

Leaf Scar
(location from which a leaf has been abscised)

Bundle Scars
(vascular bundles, aka leaf traces, that formerly extended into a leaf)

Axillary Bud



Node
(stem region with leaf connections)

Internode
(region of stem between where leaves emerge)

Node

Image credit: Jacobsen

Leaf-stem connections

"The study of water-conducting tissues in these [abscission] zones is sorely neglected despite their possible role as safety devices or flow-resistance barriers along the water delivery pathway." (André *et al.* 1999)

André, J.P., Catesson, A.M. and Liberman, M., 1999. Characters and origin of vessels with heterogenous structure in leaf and flower abscission zones. *Canadian Journal of Botany*, *77*(2), pp.253-261.

Our research questions:

Q1: Do bigger leaves have longer vessels?

Q2: Does vessel length differ between simple and compound leaves?

Q3: Are vessels open from the petiole into the stem through the abscission zone?

Methods

- 1 species for Q1 (12 samples); 9 species for Q2; 8 species for Q3
- Branches from 6 individuals per species examined (Q2 & Q3)
- Samples collected from on and near campus, mostly from the CSUB Environmental Studies Area (ESA)

Scientific name	Common name	Family	Leaf structure	Growth habit
Ceratonia siliqua L.	Carob Tree	Fabacaeae	Compound	Tree
Heteromeles arbutifolia (Lind.) M. Roemer	Toyon; Hollywood; Christmas Berry	Rosaceae	Compound	Shrub
Juglans californica S. Watson	Southern California Black Walnut	Juglandaceae	Compound	Shrub
Magnolia grandiflora L.	Southern Magnolia	Magnoliaceae	Simple	Tree
Malosma laurina (Nutt.) Nutt. ex Abrams	Laurel Sumac	Anacardiaceae	Simple	Shrub
Populus balsamifera L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook.) Brayshaw	Cottonwood	Salicaceae	Simple	Tree
Quercus rubra L.	Nothern Red Oak	Fagaceae	Simple	Tree
Sambucus nigra L.	Elderberry	Caprifoliaceae	Compound	Shrub
Vitis vinifera L. 'Glenora'	Grapevine	Vitaceae	Simple	Liana

Methods

- All branches collected at pre-dawn to ensure hydration
- Water potentials were measured using a pressure chamber

Photo credit: Jacobsen lab members, SURE 2022

Methods

- Selected and measured leaves (1 leaf per branch)
- Prepared stems and leaves for injection (cut under water from plant and fit with a grommet and tubing)
- Wrapped leaves in wet towels and plastic bags to keep moist

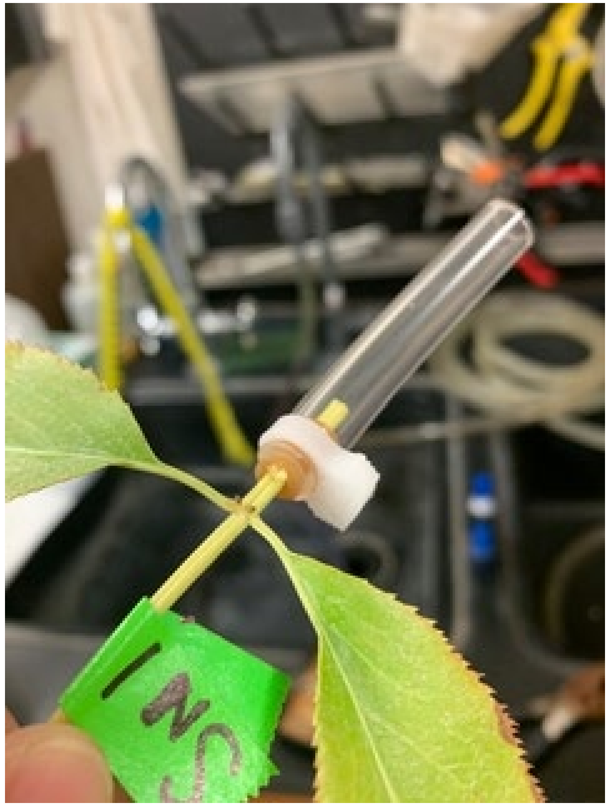
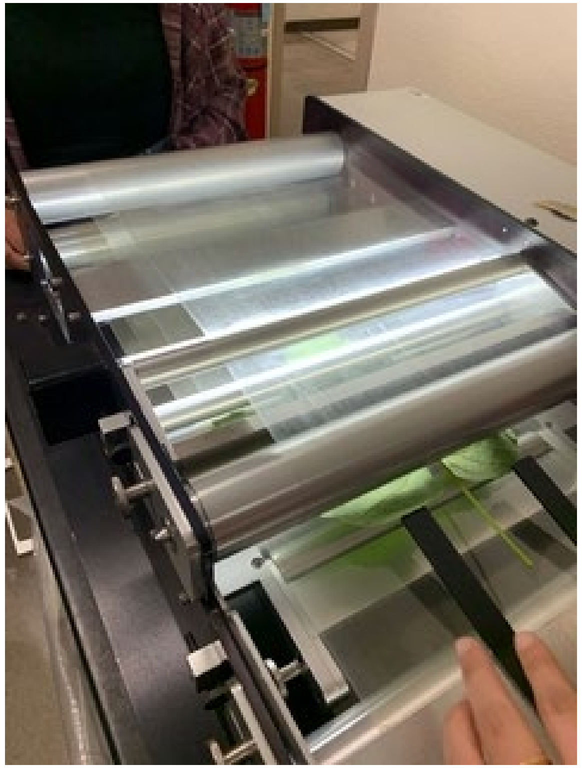


Photo credit: Jacobsen lab members, SURE 2022

Methods

- Injected with silicone containing UV stain for 24 hours (using 50 kPa pressure) and left to cure for 72 hours (method described in Sperry *et al*. 2005)
- Measured leaf area, leaf length, and petiole length (distance from cut petiole to stem = ‘distance x’)



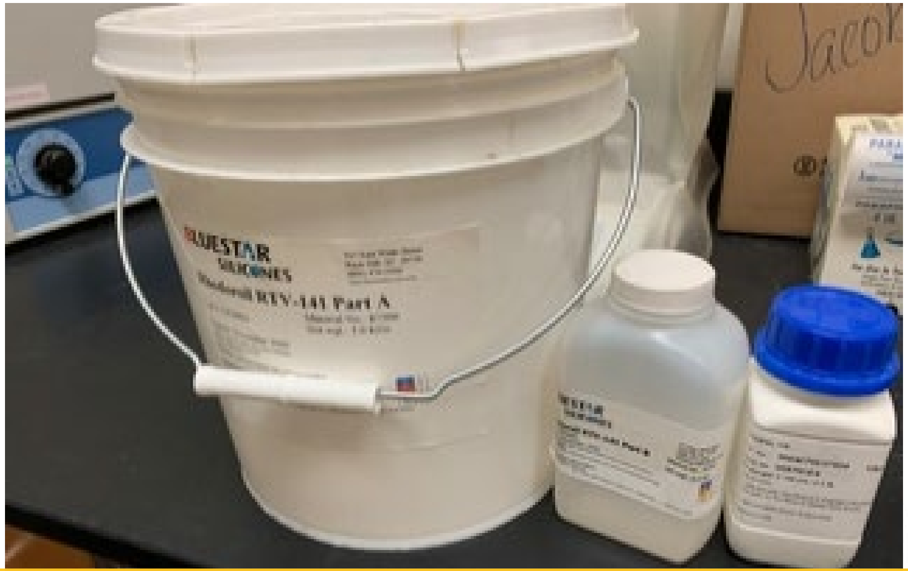


Photo credit: Jacobsen lab members, SURE 2022

Methods

- Prepared slides for serial cross-sections of leaves; Sectioned stems at node just below petiole insertion
- Photographed cross-sections with microscope and UV fluorescence
- Counted number of filled vessels in each section
- Distance from injection point and number of filled vessels used to calculate vessel length distribution

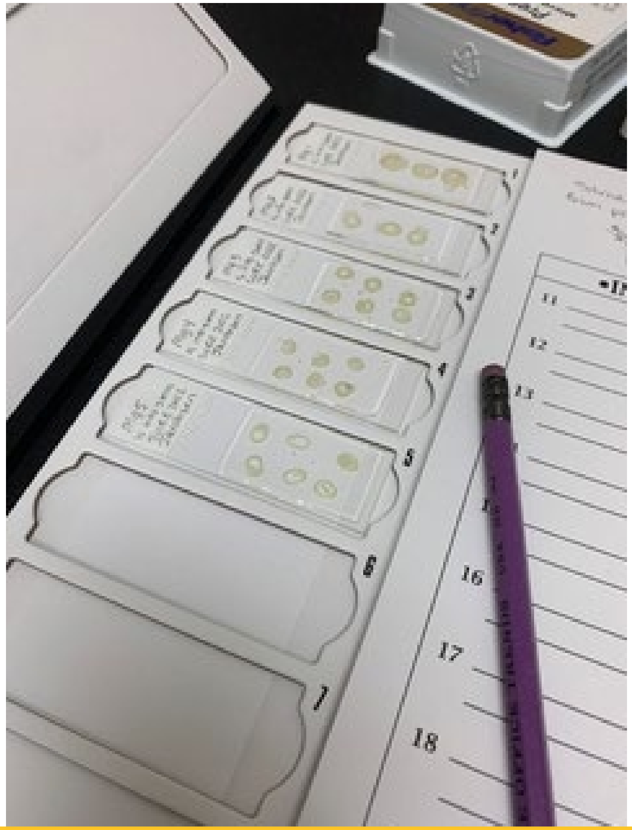
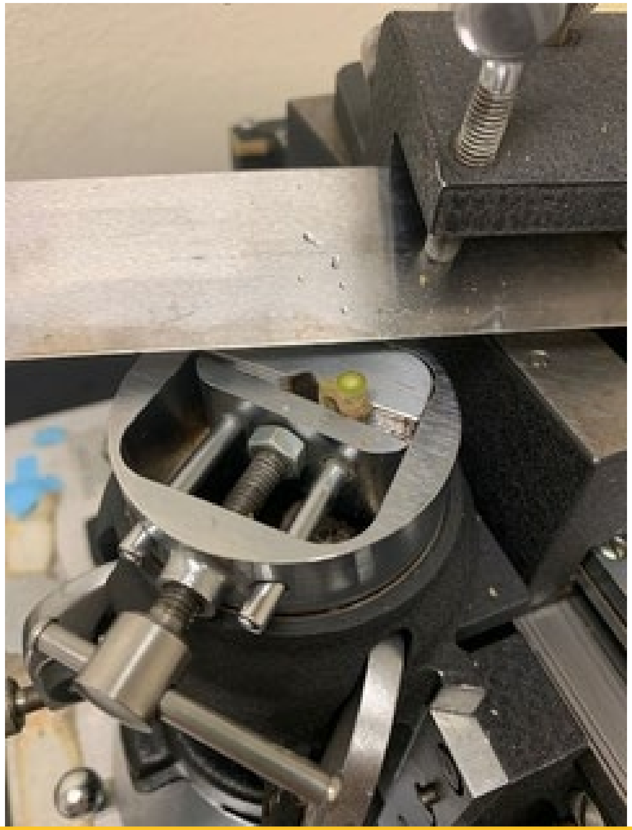




Photo credit: Jacobsen lab members, SURE 2022

Results: Leaf vessel length injections were successful!

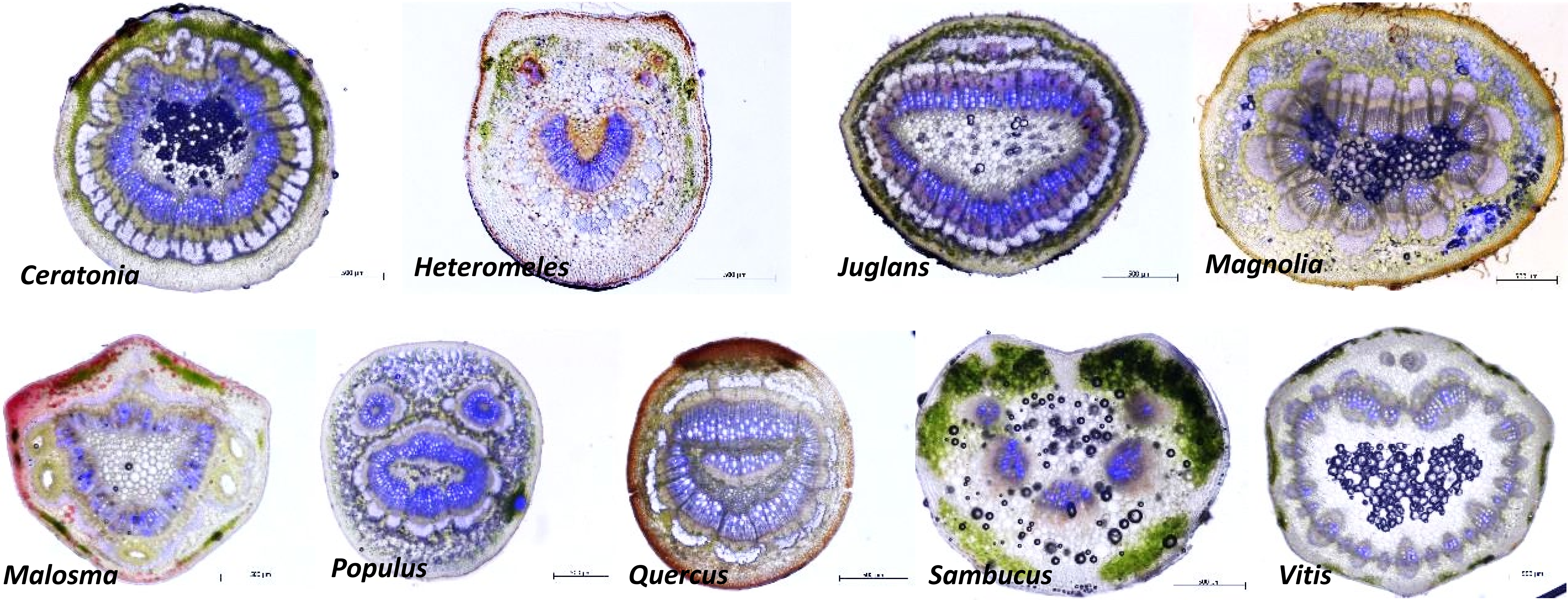
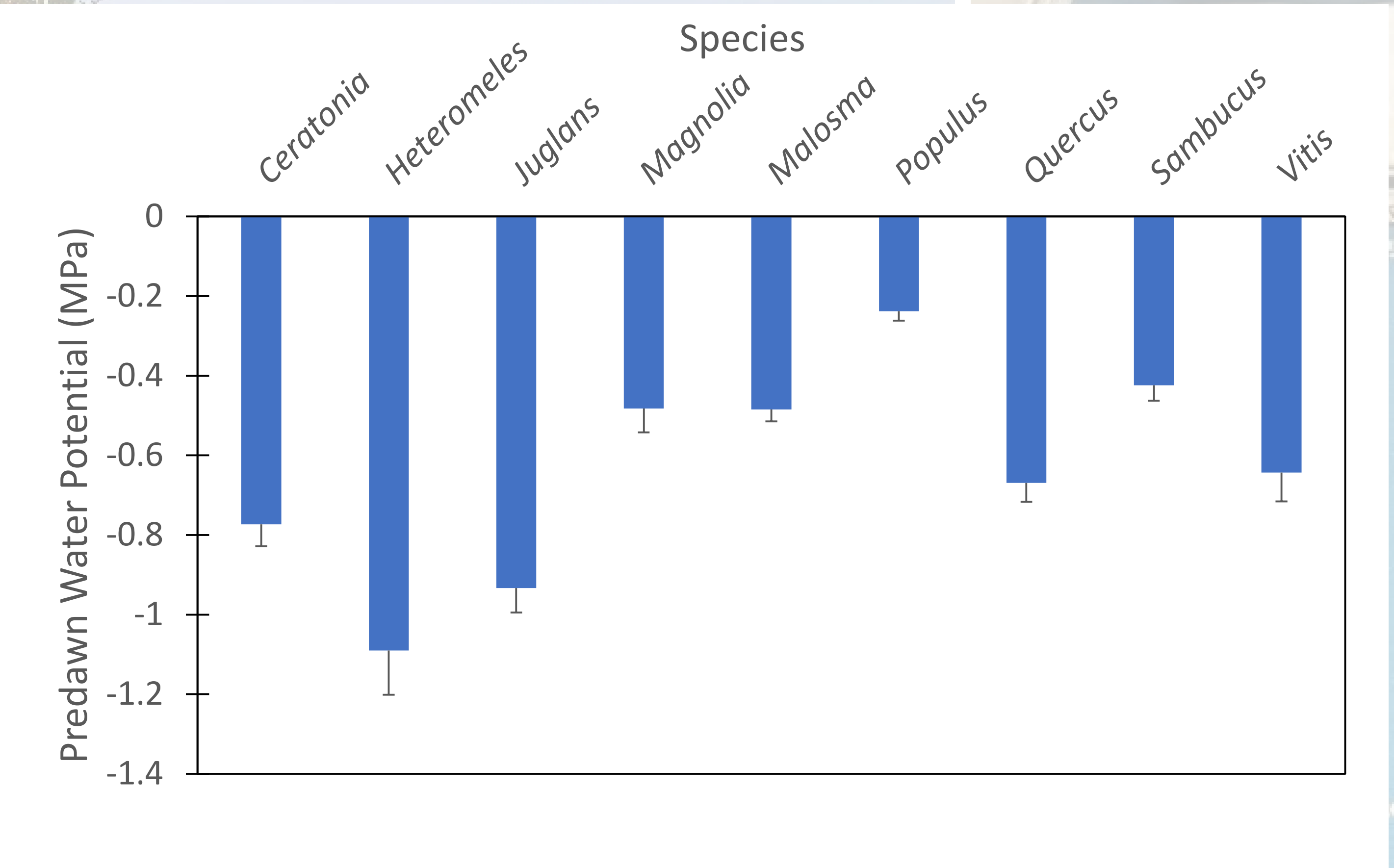


Photo credit: Jacobsen lab members, SURE 2022

Results: Sampled plants were relatively hydrated



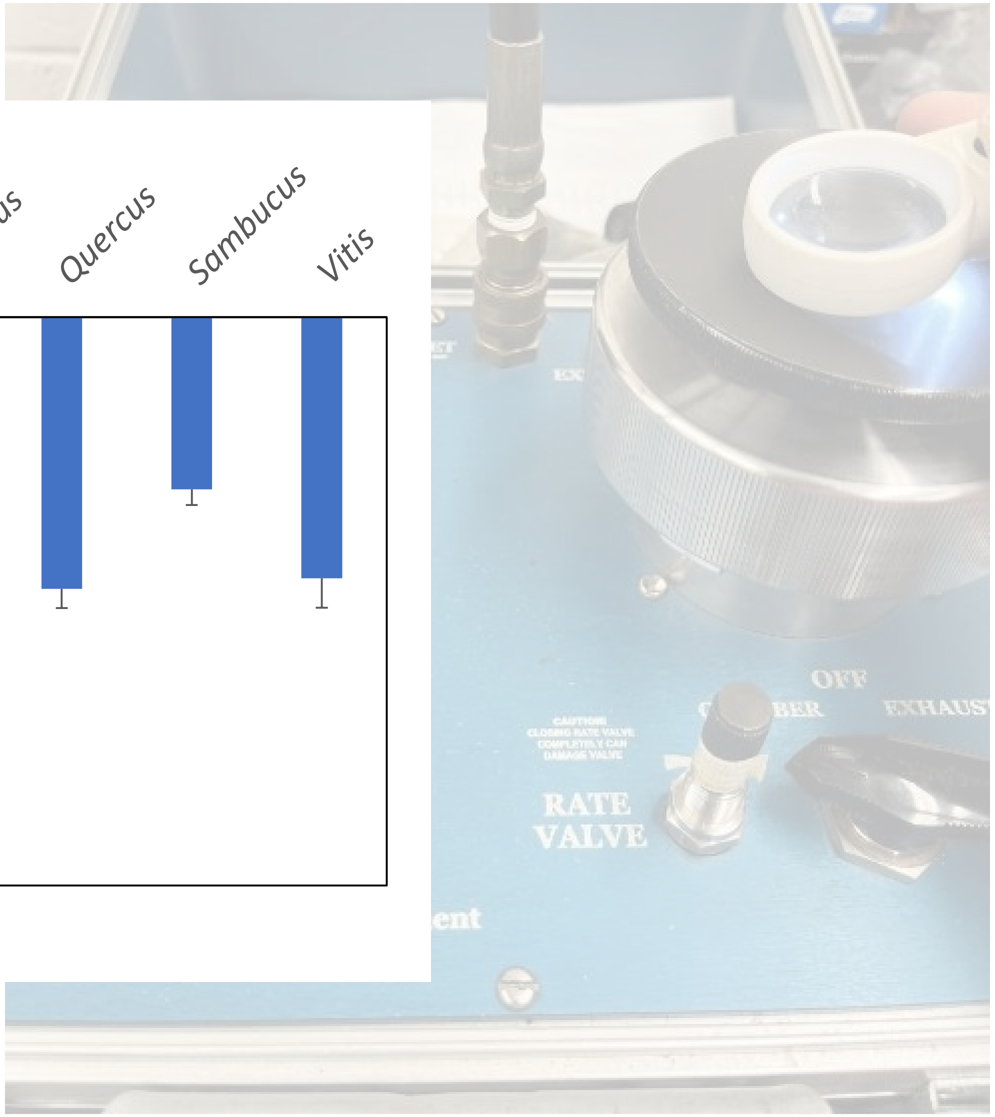


Photo credit: Jacobsen lab members, SURE 2022

Results: Q1 (leaf size and vessel length)

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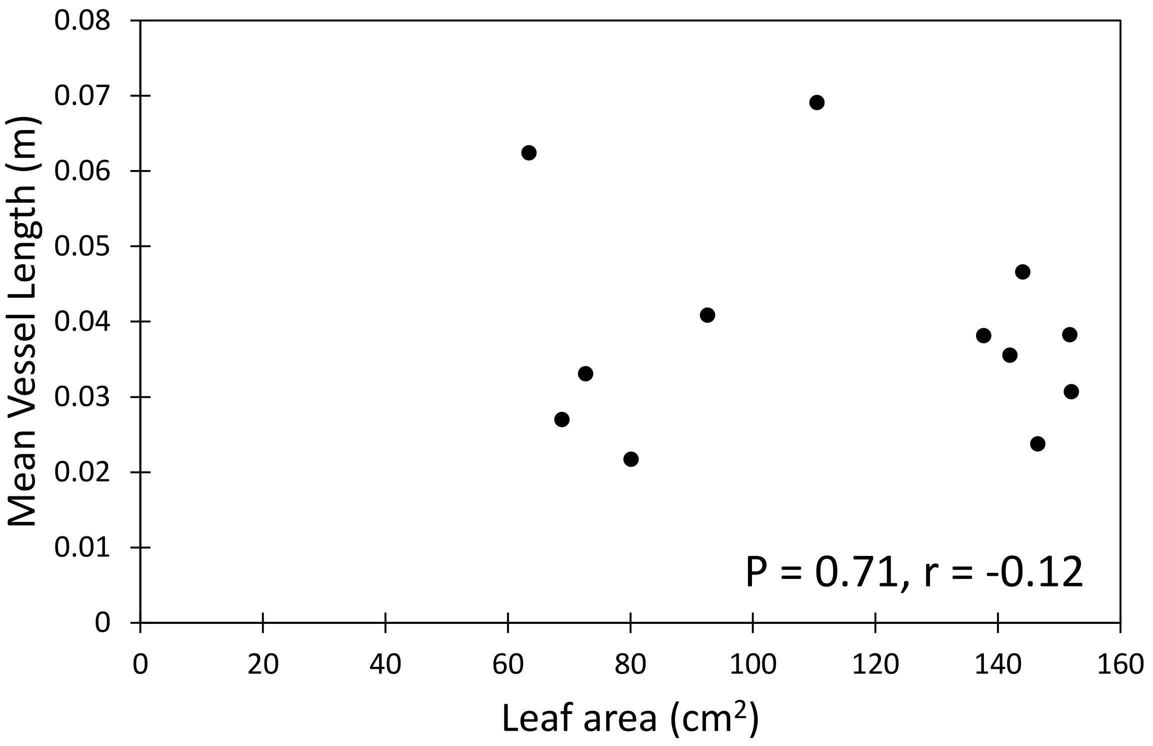

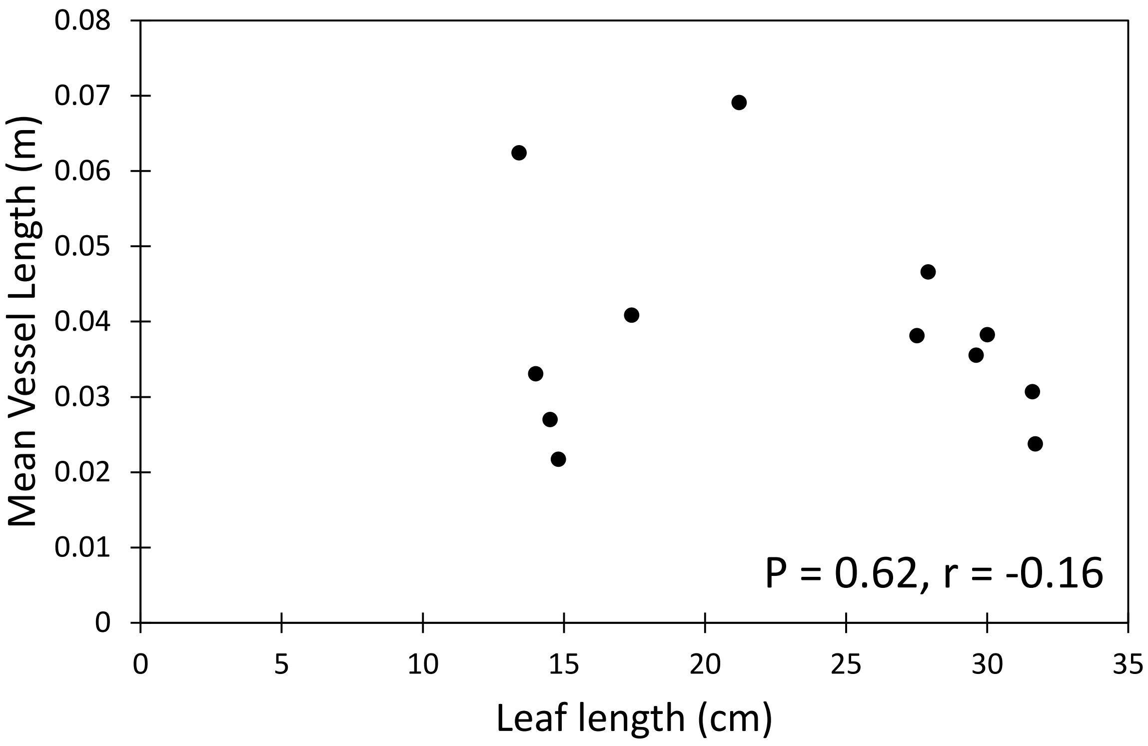

Photo credit: Jacobsen lab members, SURE 2022

Results: Q2 (Simple v. Compound leaves)

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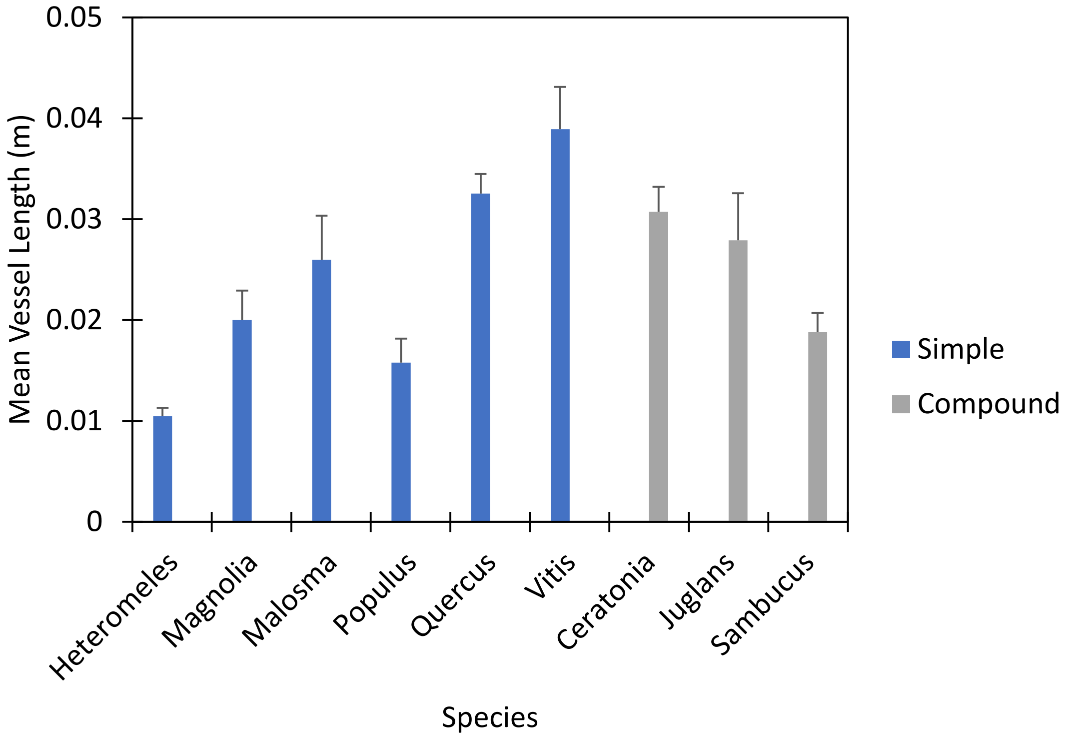
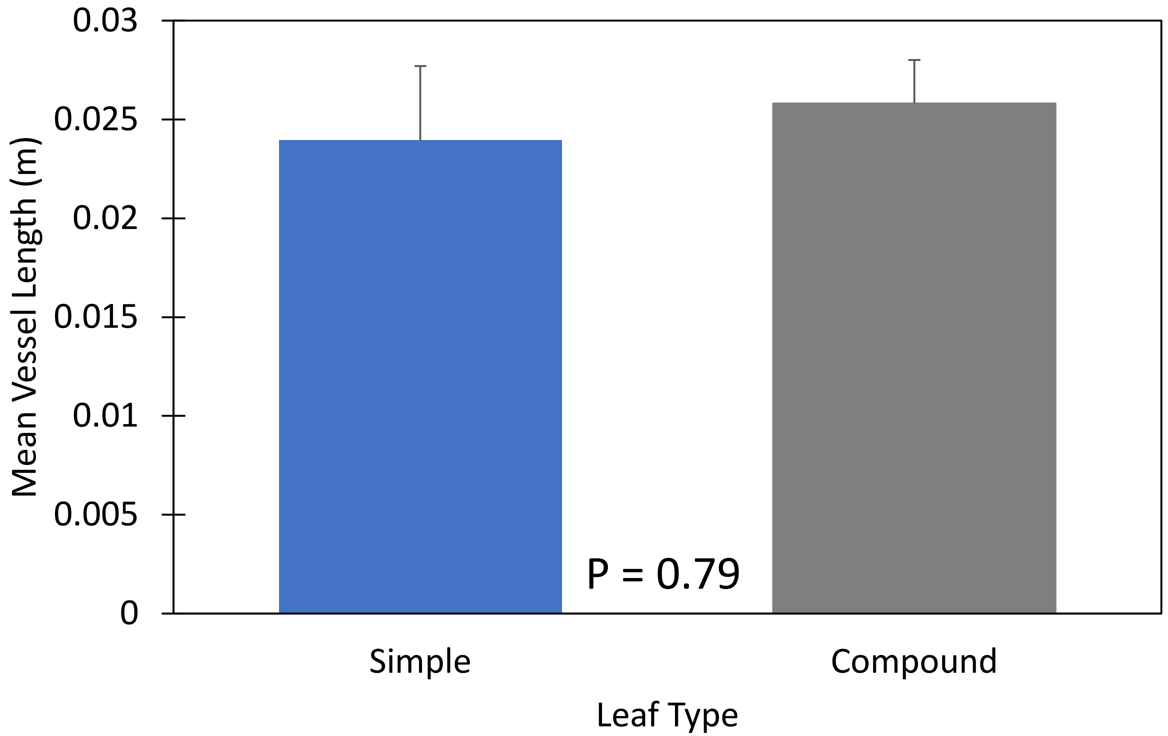
Results: Q2 (Simple v. Compound leaves)

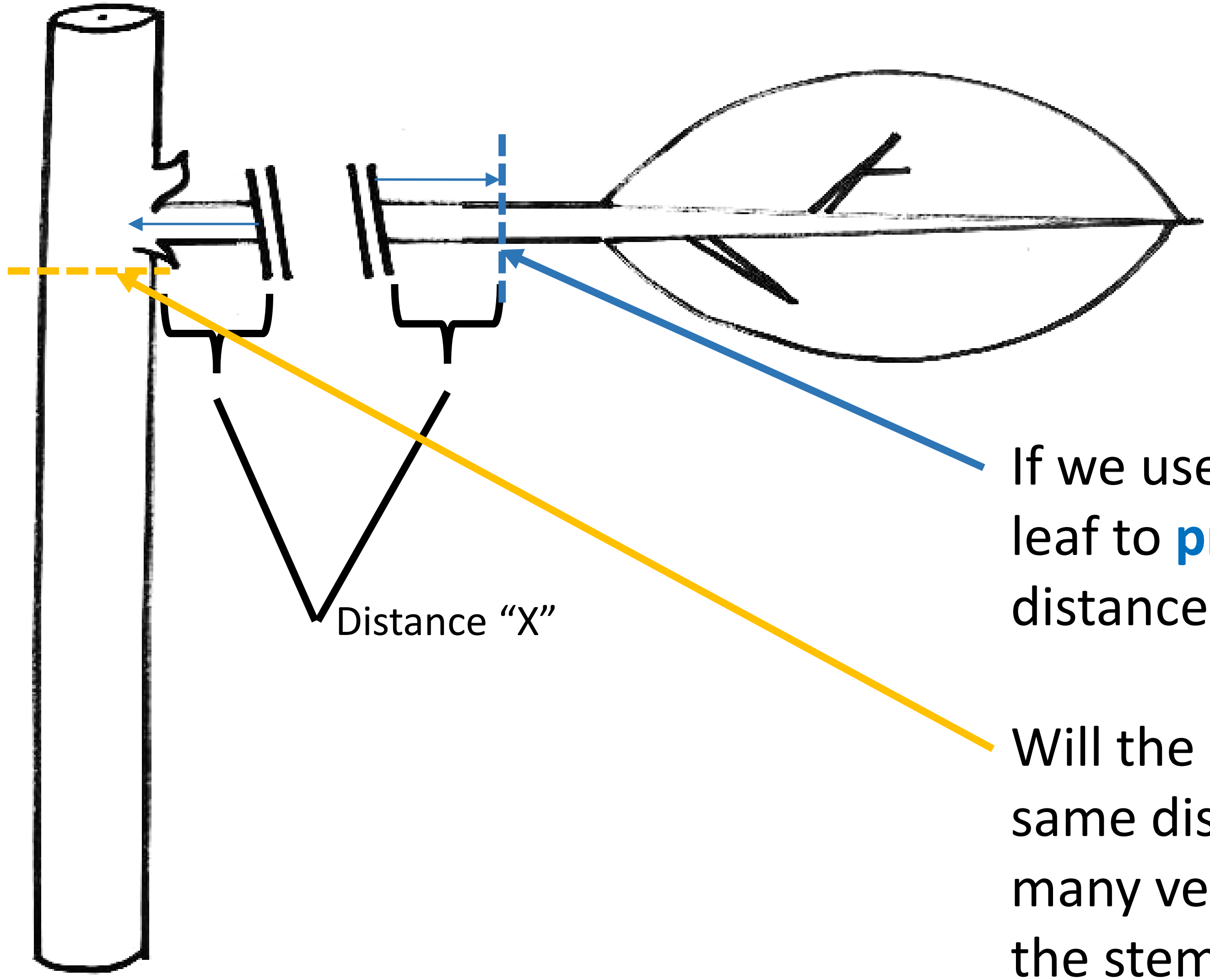
No difference in vessel length between simple versus compound leaves.
All leaves displayed very short vessel lengths compared to data reported in the literature for stems.

STEMS: Vessel lengths of 0.061 m ± 0.005 (shrubs) and 0.096 m ± 0.016 (trees) (Jacobsen *et al.* 2012)
LEAVES: Vessel length of 0.025 m ± 0.003 (our data)





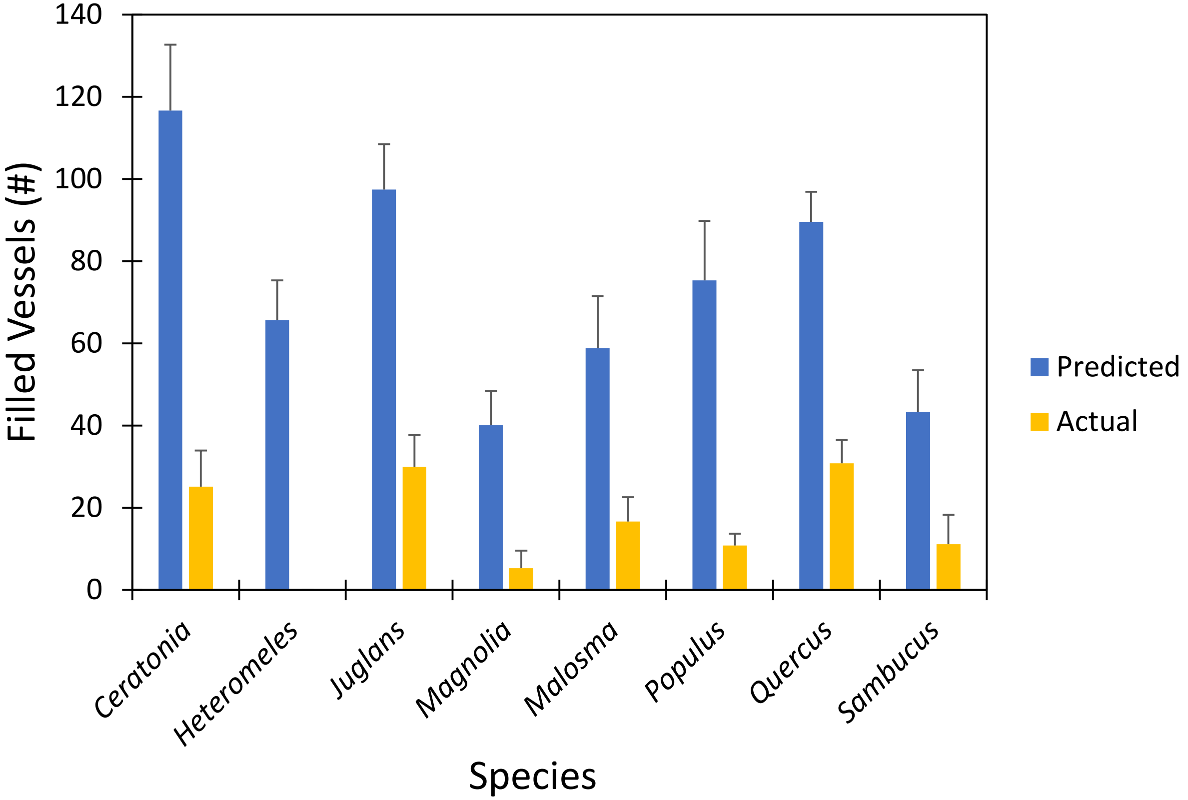
Results: Q3 (leaf-stem connections)

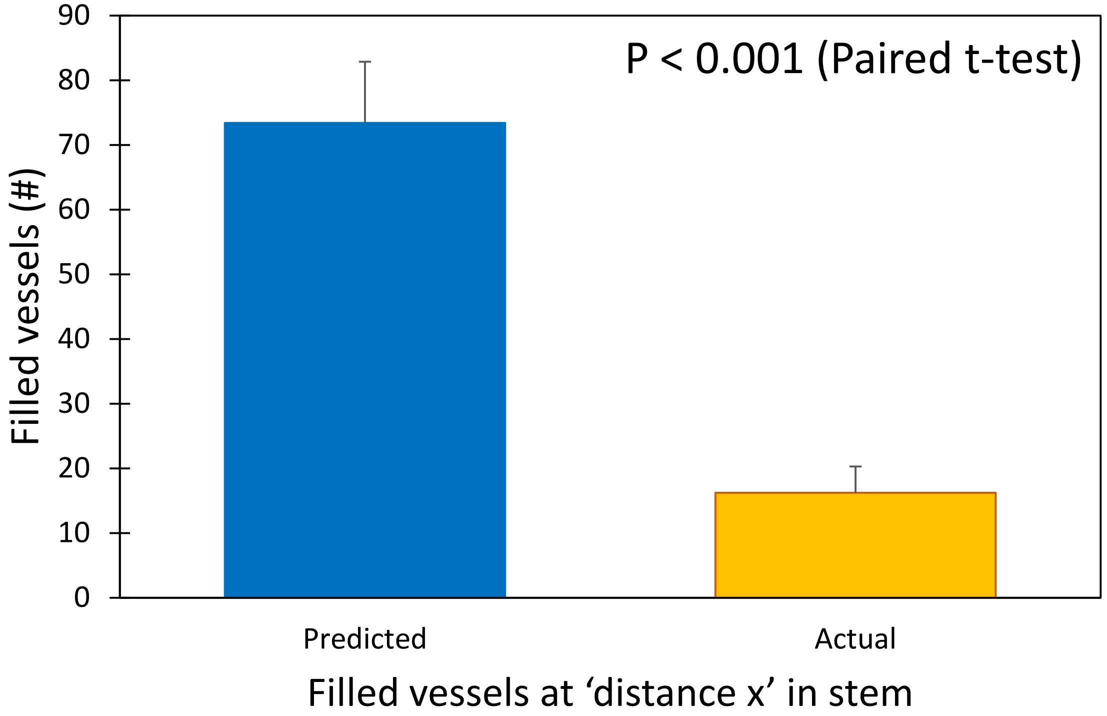


If we use the vessel length distribution of the leaf to **predict** the number of filled vessels "x" distance from the injection…

Will the same number be **actually** filled at the same distance in the stem direction (i.e., how many vessels will be 'open' from the leaf into the stem)?

Results: Q3 (leaf-stem connections)





Few vessels were open from leaves into the stem.

The leaf-stem junction is likely a large hydraulic barrier, because most vessels are 'closed'.

For this junction, the vessel length distribution is not homogenous or symmetrical. Both of these features are assumed within vessel length calculations—this means we may need to alter how we are calculating leaf vessel lengths.

Summary & Conclusions

- Vessel length in plants has been relatively little studied.
- We examined vessel length in the leaves of woody tree and shrub species. This hasn't been previously measured.
- Vessels in leaves were quite short (much shorter than those reported for stems).
- Leaf form (compound v. simple) and leaf size didn't impact vessel length.
- Vessel endings appeared with greater frequency (fewer filled vessels) than predicted in the stem-leaf junction. This could be important in leaf shedding (abscission).
- Vessel endings in the stem-leaf junction may also add hydraulic transport resistance and limit water transport into leaves. This is an interesting area of further study.

Photo credit: Jacobsen lab members, SURE 2022

Jacobsen Lab SURE 2022: Fernando Tenorio, Muhammad Ali, Lhea Domondon, Tagacy Valdez, Sara Ortiz, Graduate mentor: Danica Bergin, Faculty mentor: Dr. Anna L. Jacobsen

Thank You

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