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**EDUCATION**

**University of Vermont**

*Ph.D. in Botany awarded 5/08*

Burlington, VT

**Wake Forest University**

*M.S. in Biology awarded 12/03*

Winston-Salem, NC

**Wake Forest University**

*B.S. in Biology awarded 5/02*

Winston-Salem, NC

**WORK EXPERIENCE**

**Yale University, School of Forestry & Environmental Studies**

7/2021 to present, *Professor of Physiological Plant Ecology*

7/2019 to 2021, *Associate Professor of Physiological Plant Ecology*

7/2014 to 7/2019, *Assistant Professor of Physiological Plant Ecology*

**University of Florida Citrus Research & Education Center**

7/2012 to 7/2014, *Assistant Professor of Horticultural Science*

**University of California, Santa Cruz, Department of Ecology & Evolutionary Biology**

12/2011 to 7/2012, *Postdoctoral Scholar*

**University of California, Davis, Department of Viticulture & Enology**

10/2008 to 12/2011, *Postdoctoral Scholar*

**University of Vermont, Department of Plant Biology**

9/2008 to 10/2008, *Lecturer*

## PUBLICATIONS

### PEER-REVIEWED JOURNAL ARTICLES

\* = Postdoc Co-author Supervised by Brodersen

‡ = Graduate Student Co-author Supervised by Brodersen

† = Undergraduate Co-author Supervised by Brodersen

§ = Recommended for *Faculty of 1000*

89. Borsuk A<sup>‡</sup>, Roddy A, Thérroux-Rancourt G, Brodersen C (2022) Structural organization of the spongy mesophyll. *New Phytologist* (In Press)
88. Trueba S<sup>\*</sup>, Thérroux-Rancourt G, Earles J, Buckley T, Love D, Johnson D, Brodersen C (2021) The 3D construction of leaves is coordinated with water use efficiency in conifers. *New Phytologist* (In Press)
87. Prats K<sup>‡</sup>, Brodersen C (2021) Desiccation and rehydration dynamics in the epiphytic resurrection fern *Pleopeltis polypodioides*. *Plant Physiology* (In Press)
86. Furze M<sup>\*</sup>, Wainwright D, Hugget B, Knipfer T, McElrone A, Brodersen C (2021) Ecologically driven selection of nonstructural carbohydrate storage in oak trees. *New Phytologist* (In Press)
85. Brodribb T, Brodersen C, Carriqui M, Tonet V, Rodriguez Dominguez C, McAdam S (2021) Linking xylem network failure with leaf tissue death. *New Phytologist* (In Press)
84. Fanton Borges AC<sup>‡</sup> and Brodersen C (2021) Hydraulic consequences of enzymatic breakdown of grapevine pit membranes. *Plant Physiology* (In Press)
83. Brodersen C (2021) By the narrowest of margins: Nano-scale modification of pit membranes and the fate of plants during drought. A Commentary on: “Intervessel pit membrane thickness best explains variation in embolism resistance amongst stems of *Arabidopsis thaliana* accessions”. *Annals of Botany* (In Press)
82. Wason J<sup>\*</sup>, Bouda M<sup>‡</sup>, Lee E, McElrone A, Phillips R, Shackel K, Matthews M, Brodersen C (2021) Xylem network connectivity and embolism spread in grapevine (*Vitis vinifera* L.). *Plant Physiology* (In Press)
81. Thérroux-Rancourt G, Roddy A<sup>\*</sup>, Earles M<sup>\*</sup>, Gilbert M, Zwieniecki M, Boyce C, Tholen D, McElrone A, Simonin K, Brodersen C (2021) Maximum CO<sub>2</sub> diffusion inside leaves is limited by the scaling of cell size and genome size. *Proceedings of the Royal Society B* (In press)
80. Singhal S, Roddy A<sup>\*</sup>, DiVittorio C, Sanchez-Amaya A, Henriquez C, Brodersen C, Fehlberg S, Zapata F (2021) Diversification, disparification, and hybridization in the desert shrubs *Encelia*. *New Phytologist* (In Press)
79. McElrone A, Manuck C, Brodersen C, Patakas A, Pearsall K, Williams L (2021) Functional hydraulic sectoring in grapevines as evidenced by sap flow, dye infusion, leaf removal, and microCT, *AoB PLANTS*, plab003, <https://doi.org/10.1093/aobpla/plab003>
78. Albuquerque C, Scoffoni C, Brodersen C, Buckley T, Sack L, McElrone A (2020) Coordinated decline of leaf hydraulic and stomatal conductances under drought is not linked to leaf xylem embolism for different grapevine cultivars, *Journal of Experimental Botany*, Volume 71, Issue 22, Pages 7286–7300, <https://doi.org/10.1093/jxb/eraa392>
77. DiVittorio C, Singhal S, Roddy A, Zapata F, Ackerly D, Baldwin B, Brodersen C, Búrquez A, Fine P, Flores M, Solis E, Morales-Villavicencio J, Morales-Arce D, Kyhos D (2020) Natural selection maintains species despite frequent hybridization in the desert shrub *Encelia*. *Proceedings of the National Academy of Sciences* 117 (52) 33373-33383; DOI:10.1073/pnas.2001337117
76. Prats K<sup>‡</sup>, Brodersen C. (2020) Seasonal coordination of leaf hydraulics and gas exchange in a wintergreen fern. *Annals of Botany Plants* (In Press)

75. Albuquerque C, Scoffoni C, Brodersen C, Buckley T, Sack L, McElrone A (2020) Coordinated decline of leaf hydraulic and stomatal conductances under drought is not linked to leaf xylem embolism for different grapevine cultivars. *Journal of Experimental Botany* (In Press)
74. Johnson K, Brodersen C, Cairns-Murphy M, Choat B, Brodribb T (2020) Xylem embolism spreads by single-conduit events in three dry forest angiosperm trees. *Plant Physiology* (In Press; DOI: <https://doi.org/10.1104/pp.20.00464>)
73. Th  roux-Rancourt G, Jenkins M, Brodersen C, McElrone A, Forrestel E, Earles M (2020) Digitally reconstructing leaves in 3D using X-ray microCT and machine learning. *Applications in Plant Science* (In press)
72. Miller M, Roddy A\*, Brodersen C, McElrone A, Johnson D (2020) Anatomical responses to desiccation in emergent conifer seedlings. *American Journal of Botany* (In Press)
71. Schreel J, Leroux O, Goossens W, Brodersen C, Rubinstein A, Steppe K (2020) Identifying the pathways for foliar water uptake in beech (*Fagus sylvatica* L.): a major role for trichomes. *The Plant Journal* (In Press; doi: 10.1111/tpj.14770)
70. Cuneo I, Barrios-Masias F, Knipfer T, Uretsky J, Reyes C, Lenain P, Brodersen C, Walker A, McElrone A (2020) Differences in grapevine rootstock sensitivity and recovery from drought are linked to fine root cortical lacunae and root time function. *New Phytologist* (In Press; doi: 10.1111/nph.16542)
69. Bouda M\*, Windt C, McElrone J, Brodersen C (2019) In vivo pressure gradient heterogeneity increases flow contribution of small diameter vessels in grapevine. *Nature Communications* 10, 5645 doi:10.1038/s41467-019-13673-6
68. Brodersen C, Germino M, Johnson D, Reinhardt K, Smith WK, Resler L, Bader M, Sala A, Kueppers L, Broll G, Cairns D, Holtmeier F, Wieser G (2019) Seedling survival at timberlines are critical to conifer mountain forest elevation and extent. *Frontiers in Forests and Global Change* (doi.org/10.3389/ffgc.2019.00009)
67. Roddy A\*, Th  roux-Rancourt G, Abb   T, Benedetti J, Brodersen C, Castro M, Castro S, Gilbride A, Jensen B, Jiang G, Perkins J, Perkins S, Loureiro J, Syed Z, Thompson A, Kuebbing S, Simonin K (2019) The scaling of genome size and cell size limits the maximum rates of photosynthesis with implications for ecological strategies. *International Journal of Plant Sciences*, DOI: 10.1086/706186
66. North G, Brinton E, Browne M, Gillman M, Roddy A\*, Kho T, Want E, Fung V, Brodersen C (2019) Hydraulic conductance, resistance, and resilience: how leaves of a tropical epiphyte respond to drought. *American Journal of Botany* 106(7): 943–957; <https://doi.org/10.1002/ajb2.1323>
65. Roddy A\*, Jiang G-F, Cao K-F, Simonin K, Brodersen C (2019) Hydraulic traits are more diverse in flowers than in leaves. *New Phytologist* 223: 193-203. doi:[10.1111/nph.15749](https://doi.org/10.1111/nph.15749)
64. Knipfer T, Reyes C, Earles J\*, Berry Z, Johnson D, Brodersen C, McElrone A (2019) Spatiotemporal coupling of vessel cavitation and discharge of stored xylem water in a tree sapling. *Plant Physiology* 179(4): 1658–1668; doi.org/10.1104/pp.18.01303
63. Wason J\*, Brodersen C, Huggett B (2019) The functional implications of tracheary connections across growth rings in four northern hardwood trees. *Annals of Botany* 124, Issue 2, 24 July 2019, Pages 297–306, <https://doi.org/10.1093/aob/mcz076>
62. Brodersen C, Roddy A\*, Wason J\*, McElrone J (2019) Functional status of xylem through time. *Annual Review of Plant Biology* 70, 407-433; DOI: [10.1146/annurev-arplant-050718-100455](https://doi.org/10.1146/annurev-arplant-050718-100455)
61. Borsuk A‡, Brodersen C (2019) The spatial distribution of chlorophyll in leaves. *Plant Physiology* 180 (3) 1406-1417; DOI:10.1104/pp.19.00094
60. Prats K‡, Ashton M, Brodersen C (2019) Dry season influence on *Quercus suber* L. leaf traits in the Iberian Peninsula. *American Journal of Botany* 106(5): 656–666; doi:10.1002/ajb2.1280
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58. Alfaress S, Brodersen C, Ammar E, Rogers M, Killiny (2019) Laser surgery reveals the biomechanical and chemical signaling functions of aphid siphunculi (cornicles). *PLoS ONE* 13(10): e0204984; DOI: 10.1371/journal.pone.0204984
57. Choat B, Brodribb T, Brodersen C, Duursma R, López R, Medlyn B (2018) Triggers of tree mortality under drought. *Nature* 558: 531-539; DOI: 10.1038/s41586-018-0240-x<sup>s</sup>
56. Earles J\*, Thérroux-Rancourt G, Roddy A\*, Gilbert M, McElrone A, Brodersen C (2018) Beyond porosity: 3D leaf intercellular airspace traits that impact mesophyll conductance. *Plant Physiology* 178 (1) 148-162; DOI: 10.1104/pp.18.00550
55. Bouda M\*, Brodersen C, Saiers J (2018) Whole root system water conductance responds to both axial and radial traits and network topology over natural range of trait variation. *Journal of Theoretical Biology* 456, 49-61; DOI: 10.1016/j.jtbi.2018.07.033
54. Knipfer K, Barrios-Masias F, Cuneo I, Bouda M\*, Albuquerque C, Brodersen C, Kluepfel D, McElrone A. (2018) Variations in drought-induced embolism susceptibility across walnut species are related to vessel size, connectivity, and pit characteristics. *Tree Physiology* 38(8),1180–1192; DOI: [10.1093/treephys/tpy049](https://doi.org/10.1093/treephys/tpy049)
53. Earles J\*, Knipfer T, Tixier A, Orozco J, Reyes C, Zwieniecki M, Brodersen C, McElrone A (2018) In-vivo quantification of plant starch reserves at micrometer resolution using X-ray microCT imaging and machine learning. *New Phytologist* 218: 1260-1269; DOI:10.1111/nph.15068
52. Wason J\*, Anstreicher K†, Stephansky N†, Huggett B, Brodersen C (2018) Hydraulic safety margins and air-seeding thresholds in roots, trunks, branches, and petioles of four northern hardwood trees. *New Phytologist* 219: 77-88; DOI: 10.1111/nph.15135
51. Roddy A\*, Simonin K, McCulloh K, Brodersen C, Dawson T (2018) Water relations of *Calycanthus* flowers: hydraulic conductance, capacitance, and embolism resistance. *Plant, Cell & Environment* 2018: 1-13; DOI: 10.1111/pce.13205
50. Cuneo I, Knipfer T, Mandal P, Brodersen C, McElrone A (2018) Water uptake can occur through woody portions of roots and facilitates localized embolism repair in grapevine. *New Phytologist* 218(2): 506-516; DOI: 10.1111/nph.15032
49. Brodersen C, Knipfer T, McElrone A (2018) In vivo visualization of the final stages of xylem vessel refilling in grapevine (*Vitis vinifera*) stems. *New Phytologist* 217: 117-126; DOI: 10.1111/nph.14811
48. Wason J\*, Huggett B, Brodersen C. (2017) MicroCT imaging as a tool to study vessel endings in situ. *American Journal of Botany* 104(9): 1424-1430; DOI: 10.3732/ajb.1700199
47. Knipfer T, Cuneo I, Earles J\*, Reyes C, Brodersen C, McElrone A. (2017) Storage compartments for capillary water rarely refill in intact Woody plant. *Plant Physiology* 175(4): 1649-1660 DOI: 10.1104/pp.17.01133
46. Thérroux-Rancourt G, Earles J\*, Gilbert M, Zwieniecki M, Boyce C, McElrone A, Brodersen C (2017) The bias of a 2D view: Comparing 2D and 3D mesophyll surface area estimates using noninvasive imaging. *New Phytologist* 215(4): 1609-1622; DOI: 10.1111/nph.14687
45. Earles J\*, Thérroux-Rancourt G, Gilbert M, McElrone A, Brodersen C (2017) Excess diffuse light absorption in the upper mesophyll limits CO<sub>2</sub> drawdown and depresses photosynthesis. *Plant Physiology* 174: 1082-1096; DOI: 10.1104/pp.17.00223
44. Scoffoni C, Albuquerque C, Brodersen C, Townes S, John G, Bartlett M, Buckley T, McElrone A, Sack L (2017) Outside-xylem vulnerability, not xylem embolism, controls leaf hydraulic decline during dehydration. *Plant Physiology* 173: 1197-1210; DOI: 10.1104/pp.16.01643
43. Morris H, Brodersen C, Schwarze F, Jansen S (2016) The parenchyma of secondary xylem and its critical role in tree defense against fungal decay in relation to the CODIT model. *Frontiers in Plant Science* 7: 1665; DOI: 10.3389/fpls.2016.01665
42. Scoffoni C, Albuquerque C, Brodersen C, Townes S, John G, Cochard H, Buckley T, McElrone A, Sack L (2016) Leaf vein xylem conduit diameter influences susceptibility to embolism and hydraulic decline. *New Phytologist* 213(3): 1076-1092; DOI: 10.1111/nph.14256

41. Cueno I, Knipfer T, Brodersen C, McElrone A (2016) Mechanical failure of fine root cortical cells initiates plant hydraulic decline during drought. *Plant Physiology* 172(3): 1669-1678; DOI: 10.1104/pp.16.00923
40. Roddy A\*, Brodersen C, Dawson T (2016) Hydraulic conductance and the maintenance of water balance in flowers. *Plant, Cell & Environment* 39(10): 2123-2132; DOI: 10.1111/pce.1276139
39. Knipfer T, Cuneo I, Brodersen C, McElrone A (2016) In-situ visualization of the dynamics in xylem embolism formation and removal in the absence of root pressure: A study on excised grapevine stems. *Plant Physiology* 171(2): 1024-36; DOI: 10.1104/pp.1600136
38. Sack L, Ball M, Brodersen C, Davis S, Des Marais D, Donovan L, Givnish T, Hacke U, Huxman T, Jansen S, et al. (2016) Plant hydraulics as a central hub integrating plant and ecosystem function: meeting report for “Emerging Frontiers in Plant Hydraulics” (Washington, DC, May 2015). *Plant, Cell & Environment* 39(9): 2085-2094; DOI: 10.1111/pce.12732
37. Brodersen C & Roddy A\* (2016) New frontiers in the three-dimensional visualization of plant structure and function. Invited “On the Nature of Things” commentary for the *American Journal of Botany* 103(2): 184-188; DOI: 10.3732/ajb.1500532
36. Etxeberria E, Gonzalez P, ‡Borges A, Brodersen C (2016) The use of laser light to enhance the uptake of foliar-applied substances into citrus (*Citrus sinensis*) leaves. *Applications in Plant Science* 4(1): 1500106; DOI: 10.3732/aaps.1500106
35. Hochberg U, Albuquerque C, Rachmilevitch S, Cochard H, David-Schwartz R, Brodersen C, McElrone A, Windt C. (2016) Grapevine petioles are more sensitive to drought induced embolism than stems: evidence from in vivo MRI and microCT observations of hydraulic vulnerability segmentation. *Plant, Cell & Environment* 39(9): 1886-1894; DOI: 10.1111/pce.12688
34. Brodersen C, Rico C, Guenni O, Pittermann J (2016) Embolism spread in the primary xylem of *Polystichum munitum*: implications for water transport during seasonal drought. *Plant, Cell & Environment* 39(2): 338-346; DOI: 10.1111/pce.12618
33. Etxeberria E, Gonzalez P, Brodersen C (2015) Evidence for alternative pathways of CLas movement in citrus trees. *Journal of the Florida State Horticultural Society* 128: 2015
32. Brodersen C (2015) Finding support for theoretical tradeoffs in xylem structure and function. *New Phytologist* 209(1): 8-10; DOI:10.1111/nph.13763
31. Earles J\*, Sperling O, Silva L, McElrone A, Brodersen C, North M, Zwieniecki M (2015) Bark water uptake promotes localized hydraulic recovery in coastal redwood crown. *Plant, Cell & Environment* 39(2): 320-8; DOI: 10.1111/pce.12612
30. Knipfer T, Brodersen C, Zedan A, Kluepfel D, McElrone A (2015) Patterns of drought-induced embolism formation and spread in living walnut saplings visualized using x-ray microtomography. *Tree Physiology* 35(7): 744-755; DOI: 10.1093/treephys/tpv040
29. Torres-Ruiz J, Jansen S, Choat B, McElrone A, Cochard H, Brodribb T, Badel E, Burrett R, Bouche P, Brodersen C, Li S, Morris H, and Delzon S. (2015) Direct X-Ray Microtomography Observation Confirms the Induction of Embolism upon Xylem Cutting under Tension. *Plant Physiology* 167(1): 40-43; DOI: 10.1104/pp.114.249706
28. Choat B, Brodersen C, McElrone A (2015) Synchrotron x-ray microtomography of xylem embolism in *Sequoia sempervirens* saplings during cycles of drought and recovery. *New Phytologist* 205(3): 1095-1105; DOI: 10.1111/nph.13110
27. Knipfer T, Eustis A, Brodersen C, Walker A, McElrone A (2015) Grapevine species from varied native habitats exhibit differences in embolism formation/repair associated with leaf gas exchange and root pressure. *Plant, Cell & Environment* 38(8): 1503-1513; DOI: 10.1111/pce.12497
26. Brodersen C, Jansen S, Choat B, Rico C, & Pittermann J (2014) Cavitation resistance in seedless vascular plants: the structure and function of interconduit pit membranes. *Plant Physiology* 165(2): 895-904; DOI: 10.1104/pp.113.226522
25. Brodersen C, Narciso C, Reed M, & Etxeberria E (2014) Phloem production in Huanglongbing-affected citrus trees. *HortScience* 49(1): 59-64

24. Johnson D, Brodersen C, Reed M, Domec J-C, & Jackson R (2014) Contrasting hydraulic architecture and function in deep and shallow roots of tree species from a semi-arid habitat. *Annals of Botany* 113(4): 617-627; DOI: 10.1093/aob/mct294
23. Brodersen C (2013) Visualizing wood anatomy in three dimensions with high-resolution X-ray microtomography ( $\mu$ CT) — a review. *IWA Journal* 34(4): 408-424; DOI: 10.1163/22941932-00000033
22. Pittermann J, Brodersen C, & Watkins J (2013) The physiological resilience of fern sporophytes and gametophytes: advances in water relations offer new insights into an old lineage. *Frontiers In Plant Science* 5: 285; DOI: 10.3389/fpls.2013.00285
21. Lee E, Matthews M, McElrone A, Phillips R, Shackel K, & Brodersen C (2013) Analysis of HRCT-derived xylem network reveals reverse flow in some vessels. *Journal of Theoretical Biology* 333: 146-155; DOI: 10.1016/j.jtbi.2013.05.021
20. McElrone A, Choat B, Gambetta G, & Brodersen C (2013) Water uptake and transport in vascular plants. *Nature Education Knowledge* 4(5): 6
19. Brodersen C & McElrone A (2013) Maintenance of xylem network transport capacity: a review of embolism repair in vascular plants. *Frontiers In Plant Science* 4: 108; DOI: 10.3389/fpls.2013.00108
18. Brodersen C (2013) Visualizing water transport in roots: advanced imaging tools for an expanding field. *Plant and Soil* 366: 29-32; DOI: 10.1007/s11104-013-1657-5
17. McElrone A, Choat B, Parkinson D, MacDowell A, & Brodersen C (2013) Utilization of high resolution computed tomography to visualize the three dimensional structure and function of plant vasculature. *Journal of Visualized Experiments*. (74) e50162; DOI:10.3791/50162
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15. Brodersen C, Choat B, Chatelet D, Shackel K, Matthews M, & McElrone A. (2013) Xylem vessel relays contribute to radial connectivity in grapevine stems (*Vitis vinifera* and *V. arizonica*). *American Journal of Botany* 100(2): 314-321; DOI: 10.3732/ajb.1100606
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5. Brodersen C, Vogelmann T, Williams W, & Gorton H (2008) A new paradigm in leaf-level photosynthesis: Direct and diffuse light are not equal. *Plant, Cell & Environment* 31(1): 159-164; DOI: 10.1111/j.1365-3040.2007.01751.x
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2. Johnson D, Smith W, Vogelmann T, & Brodersen C (2005) Leaf architecture and direction of incident light influence mesophyll fluorescence profiles. *American Journal of Botany* 92(9): 1425-1431; DOI: 10.3732/ajb.92.9.1425
1. Smith W, Brodersen C, Hancock T, & Johnson D (2004) Integrated plant temperature measurement using heat-sensitive paint and colour image analysis. *Functional Ecology* 18(1): 148-153; DOI: 10.1111/j.1365-2435.2004.00814.x

#### BOOK CHAPTERS

1. Ashton M, Brodersen C (2019) A restoration agenda for native forests. Contributed chapter to *Better Planet* resulting from the Yale Environmental Dialogue. Yale University Press
2. Pittermann J, Watkins E, Cary K, Schuettpelz E, Brodersen C, Smith A, Baer A (2015) The Structure and Function of Xylem in Seed-Free Vascular Plants: An Evolutionary Perspective. In *Functional and Ecological Xylem Anatomy*, Springer International Publishing. DOI: 10.1007/978-3-319-15783-2\_1

#### PATENTS

1. Patent No. 9,763,440; issued September 19, 2017  
 “Colored clays for agricultural and other industrial applications”  
 Moudgil BM (U. of Florida), Musella S (U. of Florida), Etxeberria E (U. of Florida), Rogers M (U. of Florida), Brodersen C, Sharma P (U. of Florida)  
 Serial No. 62/199,020; Filed 7/30/2015

#### FUNDED GRANTS AND GIFTS

- 2020-2025 *Gift from Howard Newman '69 to Yale YSE*  
 “Yale-Salk Foundation Collaboration - Harnessing Plants Initiative”  
 PI: Craig Brodersen  
 Collaborators: Joanne Chory (Salk), Joseph Noel (Salk), Wolfgang Busch (Salk)
- 2020-2022 *National Science Foundation* (NSF# 2029756)  
 “Biological self assembly: Tissue mechanics of the spongy mesophyll in flowers”  
 PI: O’Hern (Yale)  
 Co-PIs: Brodersen C; Roddy A (Florida International University)

2020-2022 *National Science Foundation* (NSF# 1950498)

“The critical importance of diverse leaf ‘hairstyles’: Integrative quantification of anatomy, function, evolution and ecology of trichomes”

PI: Sack L (UCLA)

Co-PIs: Brodersen C; Mooney K (UC Irvine); Buckley T (UC Davis); Beaulieu J (U. of Arkansas)

2020-2022, *CT Sea Grant*

“Sea-level rise, storm surge, and salt marsh migration”

PI: Anisfeld S (Yale)

Co-PI: Brodersen C

2019-2021, *University of Tasmania Visiting Scholarship*

PI: Brodersen C, collaborator Brodribb T (U. of Tasmania)

2019-2021, *National Science Foundation* (NSF# 1838327)

“RoL: FELS: EAGER: Simple scaling rules that define how genome size constrains metabolism: a test among photosynthetic pathways”

PI: Simonin K (SFSU)

Co-PIs: Rohlfs R (SFSU); Roy S (SFSU), Brodersen C, Roddy A (F&ES Postdoc)

2018-2019, *Yale University Rosenkranz Grant for Pedagogical Advancement*

“3D Glasses and X-ray Vision: New Tools for Integrating Teaching and Research in the Classroom”

PI: Brodersen C, collaborator Wason J (F&ES Postdoc)

2018-2021, *Lawrence Berkeley National Laboratory Advanced Light Source* (ALS# 09763) 10% of available beamtime for 3 years on beamline 8.3.2 X-ray micro-computed tomography instrument.

“Utilizing synchrotron X-ray micro-computed tomography to study structural and physiological responses of plants to environmental stress”

PI: Brodersen C

Co-PI: McElrone A (UC Davis)

2017-2020, *National Science Foundation* (IOS# 1656610)

“Conifer leaf anatomy determines hydraulic functioning”

Co-PIs: Brodersen C, Johnson D (U. of Idaho)

2016-2019, *Yale Institute for Biospheric Studies*

“Hydraulic and biomechanical tradeoffs in the evolution and diversification of angiosperm flowers”

PI: Brodersen C, collaborators: Roddy A (Yale F&ES postdoc), Venkadensan M (Yale MEMS)

2016-2017, *National Science Foundation* (IOS# 1637194)

“Meeting: Reconciling Methodological Discrepancies in the Measurement of Hydraulic Vulnerability to Embolism: August 13-21, 2016 Berkeley, CA & August 6-11, 2017 Portland, OR”

PI: Johnson D, Organizing Committee: Brodersen C, McElrone A, Choat B, Berry Z, Knipfer T, Smith D.

2016-2019, *National Science Foundation* (IOS# 1557917)

“Structure and function of whole-tree 3D xylem networks in response to past, present, and future drought”

PI: Brodersen C, Co-PI: Huggett B (Bates College)

2015-2018 *Lawrence Berkeley National Laboratory Advanced Light Source* 10% of available beamtime



for 3 years on beamline 8.3.2 X-ray micro-computed tomography instrument.  
“Utilizing micro-tomography to study the water transport mechanisms responsible for plant survival”  
PI: Brodersen C  
Co-PI: McElrone A (UC Davis)

2014-2016, *Citrus Research & Development Foundation*  
“Determining the contents of citrus phloem sap and its directional movement throughout the year”  
PI: Etxeberria E (U. of Florida), Co-PI: Brodersen C, Killiny N (U. of Florida)

2014-2015, *Citrus Research & Development Foundation*  
“Optical and physical deterrent for preventing ACP vector attack on citrus.”  
PI: Sharma P (U. of Florida), Co-PI: Brodersen C, Rogers M (U. of Florida), Etxeberria E (U. of Florida)

2014-2016, *USDA Specialty Crops Research Initiative*  
“Mechanism and control of citrus preharvest drop related to HLB disease.”  
PI: Albrigo G (U. of Florida), Co-PI: Brodersen C, Grosser J (U. of Florida), Wang N (U. of Florida)

2013-2015, *Citrus Research & Development Foundation*  
“Are there declines in hydraulic conductivity and drought tolerance associated with HLB?”  
PI: Brodersen C, Co-PI: Gruber B (U. of Florida), Brlansky R (U. of Florida), Schumann A (U. of Florida)

2013-2015, *Citrus Research & Development Foundation*  
“Identification of potential pathways for the spread of HLB through citrus vascular systems.”  
PI: Brodersen C, Co-PI: Etxeberria E (U. of Florida)

2013-2015, *Lawrence Berkeley National Laboratory Advanced Light Source* 10% of available beamtime for 3 years on beamline 8.3.2 X-ray micro-computed tomography instrument.  
“Utilizing micro-tomography to study the water transport mechanisms responsible for plant survival”  
PI: Brodersen C  
Co-PI: McElrone AJ (UC Davis)

2012, *National Magnetic Field Laboratory*  
“NMR imaging of drought-induced vessel blockage and restoration of hydraulic conductivity in citrus and blueberry plants”  
PI: Brodersen C

2012, *Lawrence Berkeley National Laboratory Advanced Light Source*  
“3D vascular structure of citrus and blueberry wood and its relevance to pathogen isolation.”  
PI: Brodersen C  
Co-PI: Olmstead J (U. of Florida)

2012, *Lawrence Berkeley National Laboratory Advanced Light Source*  
Characterizing the dynamics of embolism spread across four diverse functional plant groups.  
PI: Brodersen C  
Co-PI: Pittermann J (UC Santa Cruz)

2011, *Lawrence Berkeley National Laboratory Advanced Light Source*  
Persistent and resilient: xylem function in relation to drought stress in ferns  
PI: Brodersen C

Co-PI: Pittermann J (UC Santa Cruz)

2010, *American Viticulture Foundation*

High Definition Time-Lapse Videos of Grapevine Development.

PI: Matthews M (UC Davis)

2010, *Lawrence Berkeley National Laboratory Advanced Light Source*

“Study of the 3D vascular structure of grapevine and its relevance to nutrient supply and pathogen isolation.”

PI: Brodersen C

Co-PIs: Choat B (U. Western Sydney), McElrone A (UC Davis), Phillips R (UC Davis), Shackel K (UC Davis), & Matthews M (UC Davis)

2009, *UC Davis Nuclear Magnetic Resonance Facility*

“NMR Imaging of drought induced embolism and repair in *Vitis vinifera*”

PI: Brodersen C

Co-PI Matthews M (UC Davis)

2009, *Lawrence Berkeley National Laboratory Advanced Light Source*

Study of the 3D vascular structure of grapevine and its relevance to nutrient supply and pathogen isolation.

PI: Brodersen C

Co-PIs: Choat B (U. Western Sydney), McElrone A (UC Davis), Phillips R (UC Davis), Shackel K (UC Davis), & Matthews M (UC Davis)

## TEACHING

### CHRONOLOGICAL LIST OF ALL COURSES TAUGHT AT YALE

Spring 2021

YSE 652 Wood: Structure & Function (Course director; 13 enrolled)

Fall 2021

YSE 679 Plant Ecophysiology (12 enrolled)

Spring 2021

YSE 652 Wood: Structure & Function (Course director; 8 enrolled)

EVST 191 Trees: Environmental Biology & Global Significance (Course director; 19 enrolled)

Fall 2020

YSE 679 Plant Ecophysiology (21 enrolled)

Spring 2019

YSE 652 Wood: Structure & Function (Course director; 8 enrolled)

EVST 191 Trees: Environmental Biology & Global Significance (Course director; 93 enrolled)

E&EB 145 Plants & People (Linda Puth Course Director; 1 Guest Lecture)

Fall 2018

YSE 679 Plant Ecophysiology (Course director; 8 enrolled)  
YSE 679L Plant Ecophysiology Lab (Course director; 8 enrolled)

Spring 2018

YSE 652 Wood: Structure & Function (Course director; 5 enrolled)  
EVST 191 Trees: Environmental Biology & Global Significance (Course director; 104 enrolled)  
YSE 3072 MESC/MFS Research Thesis (Course director; 2 enrolled)  
YSE 646 Foundations: Agriculture & Environment (Steve Wood & Mark Bradford Course Directors;  
1 Guest Lecture)  
E&EB 145 Plants & People (Linda Puth Course Director; 1 Guest Lecture)

Fall 2017

YSE 998 Fern Ecophysiology (Course director; 1 enrolled)  
YSE 679 Plant Ecophysiology (Course director; 15 enrolled)  
YSE 679L Plant Ecophysiology Lab (Course director; 12 enrolled)  
YSE 3072 MESC/MFS Research Thesis (Course director; 1 enrolled)

Spring 2017 (Junior Faculty Fellowship Teaching Leave)

YSE 998 Readings in Ecophysiology (Course director; 1 enrolled)  
YSE 1072 Independent Study (Course director; 1 enrolled)  
YSE 3072 (MESC/MFS Research Thesis (Course director; 1 enrolled)  
E&EB 145 Plants & People (Linda Puth Course Director; 1 Guest Lecture)

Fall 2016 (Junior Faculty Fellowship Teaching Leave)

Spring 2016

YSE 652 Wood: Structure & Function (Course director; 8 enrolled)  
YSE 1072 Independent Study (Course director; 1 enrolled)

Fall 2015

YSE 690a Plant Hydraulics (Course director; 10 enrolled)  
EVST191/ YSE 691a Trees: Environmental Biology & Global Significance (Course director; 109  
enrolled)  
YSE 1072 Independent Study (Course director; 1 enrolled)  
YSE 2072 Master's project (Course director; 2 enrolled)

Spring 2015

EVST191 Trees: Environmental Biology & Global Significance (Course director; 14 enrolled)

Fall 2014

YSE 690a Plant Hydraulics (Course director; 10 enrolled)

SERVICE

ADVISING

CURRENT GRADUATE STUDENTS AND POSTDOCTORAL SCHOLARS

Postdoctoral Advisor for Haoran Zhou, Leila Fletcher, Martin Bouda

Doctoral Advisor for YSE Ph.D. Students: Kyra Prats, Aleca Borsuk, Joseph Zailaa

#### FORMER GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS

Postdoctoral Advisor for:

Dr. Morgan Furze (Current Position: Postdoctoral student, UC Davis)  
Dr. Adam Roddy (Current Position: Assistant Professor, Florida International University)  
Dr. Elizabeth Clark (Current Position: Postdoctoral Student, UC Berkeley)  
Dr. Santiago Trueba (Current Position: Postdoctoral Student, INRA France)  
Dr. Jay Wason (Current position: Assistant Professor, University of Maine)  
Dr. J. Mason Earles (Current position: Apple Computer Co.; 3D Data Analyst)  
Dr. Martin Bouda (Current position: Postdoctoral Scientist, Czech Academy of Sciences)

Doctoral Advisor for:

Dr. Ana Fanton (Current position: Postdoctoral student, U. Bordeaux)

#### YSE MASTER'S ADVISEES:

Michael Maier (2020)  
Mary Schoell (2020; co-advisor with Anisfeld)  
Aleca Borsuk (2019; Current position: YSE Ph.D. Program)  
Cameron Musser (2018; Current position: US Forest Service)  
Jenny Katz (2019, MFS)  
Javier Gonzalez Rodrigo (2019, MEM)

#### YALE COLLEGE ACADEMIC ADVISEES

Max Teirstein (Saybrook College, 2021)  
Victoria Lim (Saybrook College, 2021)  
Ally Soong (Jonathan Edwards College, 2021)  
Tommy Martin (Silliman College, 2021)

#### Doctoral Committee Member:

Andrew Muehleisen, Yale YSE (Advisor: Dr. Liza Comita)  
Jeroen Schreel, University of Ghent (Advisor: Dr. Kathy Steppe)  
Gerard Sapes, University of Montana (Advisor: Dr. Anna Sala)

#### YSE SERVICE

Master's Program Committee (2020 to present)  
Internal Community and Inclusiveness Committee (2016 to present)  
Yale Myers Forest Research Committee (2018 to present)  
Doctoral Program Committee (2015, 2018)  
Ph.D. Dissertation Reader, Thomas James, 2015 (Chair: Ashton)  
Ph.D. Dissertation Reader, Martin Bouda, 2017 (Chair: Saiers)  
Ph.D. Dissertation Reader, Andrew Muehleisen, 2020 (Chair: Comita)  
Western Silviculture Field Trip Faculty Representative (2018)

#### YALE UNIVERSITY COMMITTEE SERVICE

Yale Biological Safety Committee (2021 to Present)  
Advisory Committee Member: Yale Poorvu Center for Teaching and Learning (September 2018-September 2020)

## YALE UNIVERSITY ART GALLERY (YUAG) AND PEABODY MUSEUM CONTRIBUTIONS

Provided species identification for herbarium selections from Albert Bierstadt's ca. 1873 *Yosemite Valley* painting, and coordinated YSE contribution of a 11.5' redwood tree radius as part of the YUAG installation *Yosemite: Exploring the Incomparable Valley* 2016-2017  
YUAG Contact: Mark Mitchell

Provided species identification and historical dating of a Juniper beam from the Native American Pollock Ruin dwelling near Gila, New Mexico (2016)  
Anthropology Contact: Dr. William Gardner

Provided species identification for a wood fragment from a 17<sup>th</sup> Century musket stock to be repatriated to a Native American burial site in Alabama (2015)  
Anthropology Contact: Erin Gredell

## YALE COLLEGE UNDERGRADUATE STUDENT INDEPENDENT STUDY ADVISEES

Madeleine Marino, Pierson College (Independent Study)  
Eamon Haberlein, Berkeley College (Independent Study)  
Chainey Boroski, Silliman College (Senior Thesis; Currently in Ph.D. program at Duke University)

## YALE COLLEGE UNDERGRADUATE STUDENT RESEARCH MENTORING

Katherine Anstreicher, Branford College, participated in the NSF REU program at Harvard Forest as part of Dr. Brodersen's NSF grant during the summer of 2016 and continued to work in the lab during the 2017 and 2018 academic year.

Caroline Schlutius, Saybrook College, works with Dr. Carla Staver (Yale EEB) and has worked in my lab on wood anatomy related to Dr. Staver's research on savannah ecophysiology.

## SAYBROOK COLLEGE CONTRIBUTIONS

Saybrook Resident Fellow	2014-2015
Saybrook Fellow	2014 to Present
Rhodes and Marshall Scholarship Mock Interview Coordinator	2015
Saybrook Fellowship Committee	2015

## HARVARD FOREST NSF REU PROGRAM MENTOR 2015, 2016, 2018

Julia Fisher (Bates College), Nathan Stephansky (Bates College), Katherine Anstreicher (Yale University), Ruth van Kampen (Bates College), Katja Diaz-Granados (Harvard University)

## PROFESSIONAL ACTIVITIES

### EDITORIAL POSITIONS

Associate Editor for the *American Journal of Botany* 2018-Present

### JOURNAL REVIEWER

*American Journal of Botany; Biological Invasions; Functional Ecology; IAWA Journal; Journal of Experimental Botany; Journal of Plant Research; Nature, New Phytologist; Photosynthetica; Plant, Cell, & Environment; Plant Physiology; Plant Science; Proceedings of the National Academy of Science; Tree Physiology; Trees: Structure & Function*

#### CONFERENCE ORGANIZER

Co-organized a conference at the Oak Spring Garden Foundation in 2017 to bring together experts in the field to develop a new interdisciplinary theoretical framework for studying flower physiology and evolution.

#### PRESENTATIONS

- Brodersen C (2020) Emergent honeycomb topology of the leaf spongy mesophyll. Invited seminar at the Department of Plant Biology, University of Tasmania.
- Brodersen C (2019) A multi-method approach for studying leaf optics and the effect of diffuse vs. direct light on photosynthesis. Invited seminar at Université de Fribourg Adolphe Merkle Institute.
- Brodersen C (2019) *The role of surface tension in the formation, spread, and removal of gas bubbles in the xylem of plants*. Invited seminar at ETH Zurich, Switzerland.
- Brodersen C (2019) *How to build a leaf: New insights into plant structure and function from the inside out with X-ray imaging*. Invited seminar at the Ithaca College Department of Biology.
- Brodersen C (2018) *How to build a leaf: New insights into plant structure and function from the inside out with X-ray imaging*. Invited seminar at the University of Minnesota-Duluth.
- Brodersen C (2018) *How to build a leaf: New insights into plant structure and function from the inside out with X-ray imaging*. Yale YSE Seminar, New Haven, CT
- Brodersen C, Wason J, Huggett B (2018) *Modeling xylem network performance and vulnerability curves with microCT-derived connectivity parameters*. Botanical Society of American Conference, Rochester, MN
- Brodersen C, Wason J, Huggett B (2018) *Modeling xylem network performance and vulnerability curves with microCT-derived connectivity parameters*. Multiscale Vascular Plant Biology Gordon Research Conference, Mt. Snow, VT.
- Brodersen C (2018) *Using microCT imaging to study the vulnerability of plant vascular systems to drought and pathogens* DANFIX/3D Imaging Center Users Meeting, Copenhagen, Denmark
- Brodersen C (2018) *The 3D Leaf: Mapping the pathways of water and CO<sub>2</sub> movement inside leaves that links plants to the atmosphere*. YIBS Friday Seminar. New Haven, CT.
- Brodersen C (2017) *3D X-ray imaging as a complementary tool for studying plant structure and function*. Harvard University Arnold Arboretum, Boston, MA.
- Brodersen C (2017) *Using microCT imaging to study the vulnerability of plant vascular systems to drought and pathogens*. Connecticut Agricultural Experiment Station Seminar Series, New Haven, CT.
- Brodersen C (2016) *Insights into three-dimensional organization of plant vascular networks from X-ray microCT*. Gordon Research Conference “Multiscale Plant Vascular Biology”, Sunday River, ME.
- Brodersen C (2016) *New methods for predicting the future of New England Forests*. Yale Myers Summer Seminar Series. Eastford, CT.
- Brodersen C (2016) *Visualizing wood anatomy and xylem function in 3D*. University of Illinois Urbana-Champaign Plant Biology Seminar. Urbana-Champaign, IL.
- Brodersen C (2015) *Visualizing wood anatomy and xylem function in 3D: new insights into the structure and function of plant vascular systems*. Yale University Molecular, Cell, Developmental Biology Botany Seminar Series. New Haven, CT.

- Brodersen C (2015) *Non-invasive imaging tools for studying plant hydraulics*. Emerging frontiers in Plant Hydraulics NSF-funded Workshop. Washington, DC.
- Brodersen C (2015) *Understanding the plumbing of plants with new non-destructive imaging tools*. Saybrook College Fellow's Seminar Series hosted by Saybrook Master Dr. Paul Hudak. New Haven, CT.
- Brodersen C, McElrone A, Choat B, Knipfer T (2015) *Assessing drought-induced cavitation in vivo with synchrotron microCT across species*. Poster presentation at the International workshop on plant hydraulics techniques. Ulm, Germany.
- Brodersen C (2014) *Visualizing wood anatomy and xylem function in 3D: new insights into the structure and function of plant vascular systems*. University of Connecticut EEB Department Seminar Series. Storrs, CT.
- Brodersen C (2014) *Visualizing wood anatomy and xylem function in 3D: new insights into the structure and function of plant vascular systems*. Wake Forest University Department of Biology Seminar Series. Winston-Salem, NC.
- Brodersen C (2013) *Visualizing wood anatomy and xylem function in 3D: new insights into the structure and function of plant vascular systems*. Harvard University Herbaria Seminar Series. Cambridge, MA.
- Brodersen C (2013) *Phloem anatomy of citrus trees: is there lateral movement?* Florida Citrus Grower's Institute. Avon Park, FL.
- Brodersen C (2013) *Xylem network connectivity and the spread of drought-induced embolism*. International Symposium on Wood Structure in Plant Biology and Ecology. Naples, Italy.
- Brodersen C, Jansen S, Choat B, Pittermann J (2012) *Cavitation resistance in the primary xylem of ferns and fern allies*. Ecological Society of America. Portland, OR.
- Brodersen C (2011) *3D xylem organization and the spread of xylem-dwelling pathogens and drought induced embolism*. University of Florida Department of Horticulture. Gainesville, FL.
- Brodersen C (2011) *The dynamics of embolism repair in xylem: in vivo visualizations using High Resolution Computed Tomography*. Smith College Department of Biology. Northampton, MA
- Brodersen CR (2010) *Dynamics of embolism repair in grapevine: in vivo visualizations using high resolution computed tomography*. American Society of Plant Biologists Conference. Montreal, Canada
- Brodersen C (2010) *Functional hydraulic sectoriality in grapevine*. Poster presentation at the American Society of Plant Biologists Conference, Montreal, Canada
- Brodersen C (2009) *Mapping 3D xylem networks in Vitis vinifera using high resolution computed tomography*. Poster presentation at the Botanical Society of America Conference. Snowbird, UT.
- Brodersen C & Vogelmann TC (2008) *Do directional changes in light affect absorption profiles?* Poster presentation at the Botanical Society of America Conference. Vancouver, BC.

#### OTHER PRESENTATIONS (presenter underlined)

- Borges A, Brodersen C (2018) *Implications of xylem-dwelling bacterium spread on grapevine water transport*. Multiscale Vascular Plant Biology Gordon Research Conference, Mt. Snow, VT.
- Wason J, Huggett B, Brodersen C (2018) *Using 3D data and virtual reality to teach xylem anatomy*. Multiscale Vascular Plant Biology Gordon Research Conference, Mt. Snow, VT.
- Huggett B, Wason J, Brodersen C (2018) *The functional implications of the presence or absence of intervessel connections across growth rings of four northern hardwood trees*. Multiscale Vascular Plant Biology Gordon Research Conference, Mt. Snow, VT.
- Wason J, Huggett B, Brodersen C (2018) *Intervessel connections across growth rings in xylem of northern hardwood trees*. Harvard Forest Ecology Symposium
- Wason J, Brodersen C (2018) *Three-dimensional teaching: Using virtual reality and 3D-printed models in the classroom*. CIRTL Leaders Meeting Showcase at the Yale Center for Teaching and Learning

- Roddy A, Dawson T, Brodersen C. Hydraulic tradeoffs in the diversification of angiosperm flowers. 3rd Xylem International Meeting, Bordeaux, France (September 2017).
- Roddy A and Brodersen C. Hydraulic tradeoffs in the evolution and diversification of angiosperm flowers. Stomata: Evolution, Development, and Evolution, 12th Annual Plant Biology Symposium, Arnold Arboretum of Harvard University (May 2017).
- Roddy A, Guilliams C, Dawson T, Brodersen C. The macroevolution of floral hydraulic traits and strategies for maintaining turgor. XIX International Botanical Congress, Shenzhen, China (July 2017).
- Théroux-Rancourt G, Earles JM, Gilbert M, Zwieniecki M, Boyce K, McElrone A, Brodersen C. “Angiosperms evolved a higher mesophyll surface area per volume to maximize gas exchange surface under a low CO<sub>2</sub> world.” Ecological Society of America Conference, (August 2017).
- North G, Browne M, Brinton E, Gillman M, Kho T, Roddy A, Brodersen C. “Leaf hydraulic conductance and resilience for a tank bromeliad to drying and rewetting. Ecological Society of America Conference (August 2017).
- Berry Z et al. “A comparison of micro-CT imaging and excised segment methods to measure xylem embolism using a relatively long-vesseled species, *Castanea dentata*”. Ecological Society of America Conference, (August 2017).
- Wason J, Anstreicher K, Stephansky N, Huggett B, Brodersen C. “Hydraulic safety margins in roots, trunks, branches and petioles of northern hardwood trees”. Northeast Regional American Society of Plant Biologists Conference, (April 2017).
- Wason J, Anstreicher K, Stephansky N, Huggett B, Brodersen C. “New England Forests and the 2016 Drought: Hydraulic safety margins and physiological tipping points of four hardwood tree species”. 33rd Annual Yale School of Forestry and Environmental Studies Research Conference, (April 2017).
- Wason J, Anstreicher K, Stephansky N, Huggett B, Brodersen C. “Hydraulic safety margins in roots, trunks, branches and petioles of northern hardwood trees”. Harvard Forest Ecology Symposium, (March 2017).
- Riley ML, Roddy AB, Brodersen C, Johnson DM (2016) *A comparison of vascular development and desiccation in stems of very young Pseudotsuga menziesii and Pinus ponderosa*. Poster presentation at the Ecological Society of America Meeting. Ft. Lauderdale, FL.
- Todorovic-Jones AJ, Ashton MA, Brodersen C, Berlyn GP, Thadani R (2016) *Ecophysiological responses to climate change in banj oak (Quercus leucotrichophora)*. Poster presentation at the Ecological Society of America Meeting. Ft. Lauderdale, FL.
- Pittermann J, Baer A, Brodersen C, Burns E, Watkins J, Wheeler J (2016) *Water transport in seed-free vascular plants: a macro-evolutionary perspective*. Botanical Society of America Conference. Savannah, GA.
- Brodersen C, Narciso C, Reed M, Etteberria E (2014) *Seasonal production of phloem tissue in HLB-Affected trees*. Botanical Society of America Conference. Boise, ID.
- Etteberria E and Brodersen C (2014) *Seasonal production of phloem tissue in HLB-affected citrus trees*. American Society of Horticultural Science, Palm Desert, CA.
- Etteberria E, Brodersen C. Florida State Horticultural Society, Sarasota, FL – Oral presentation: *Seasonal production of phloem tissue in HLB-affected citrus trees*.
- Pittermann J, Brodersen C, Watkins J (2013) *Sporophytes, gametophytes, and the symplast connection: evolutionary implications for water relations in ferns*. Botanical Society of America, New Orleans, LA
- Shackel KA et al. (2012) Invited Keynote Address, German Society of Plant Nutrition, Bonn University – *What HR-CT imaging can teach us about xylem structure and function*.
- Vogelmann TC & Brodersen C (2010) *Leaf tissue optics under direct and diffuse light: The problem and instrumentation to solve it*. Poster presentation at the American Society for Photobiology Conference, Providence, RI.