Tree Species Selection for Urban Environments – Translating Science to Practice

Dr Andrew Hirons, ahirons@myerscough.ac.uk


Tree Species Selection for Green Infrastructure
A Guide for Specifiers
Version: 20.06.2018
Written by:
Dr Andrew Hirons & Dr Henrik Sjöman
Primary Project Funder
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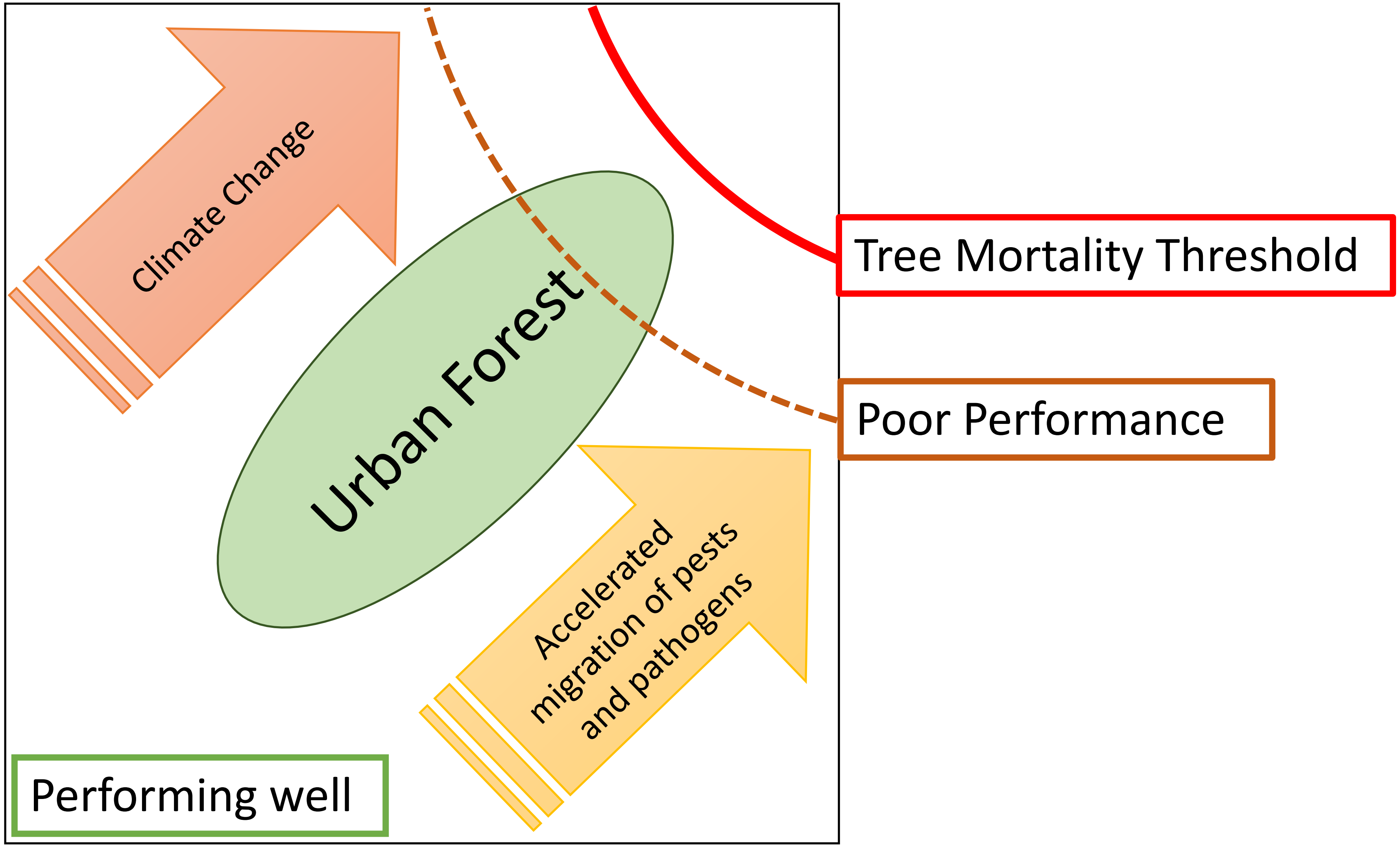
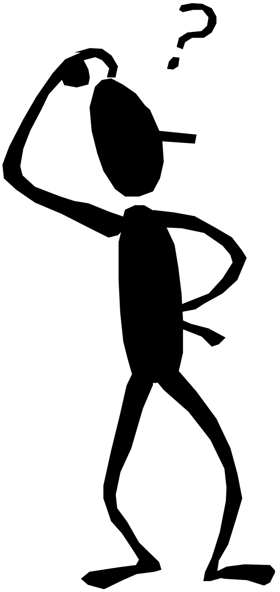
Strategic challenges for the urban forest





How do we currently select trees?

Do you currently source guidance from:

	Always	Mostly	Sometimes	Never
Dendrological literature	9%	20%	54%	16%
Online selection tools	3%	17%	58%	22%
Tree nursery catalogues	12%	48%	38%	1%
Recommendations from a tree nursery	4%	18%	67%	10%

Tree Nursery Catalogues dominated species selection decisions across all major professional groups (Landscape Architects, Arboricultural Consultants, Local Authority Officers).

Other sources of important to selection decisions

- 37% identify ‘experience’ as being important to selection
- Only 4% mention that they visit nurseries or botanical collections.

“Many of the nursery catalogues offer conflicting advice”

“Never depend on nursery catalogues alone”

“Hard technical information is very difficult to come by with nursery information often being very superficial and based on aesthetic features.”

Magnolia ‘Caerhays surprise’

Focusing the priorities of selection guidance

Ranking of characteristics that are most important for your tree selection decisions:

1. Potential mature tree size and form
2. Environmental tolerance – Drought most important
3. Suitability to planting site soil
4. Susceptibility to pests and diseases
5. Future maintenance requirements
6. Aesthetic qualities
7. Leaf phenology
8. Native vs. non-native
9. Cost of material
10. Leaf form

Other notable mentions:

- Salt and pollution tolerance
- Conflict potential
- Wildlife and ecological value

Quercus castaneifolia, RBG Kew

A Need for Guidance…

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Introduction

The Tree Profiles

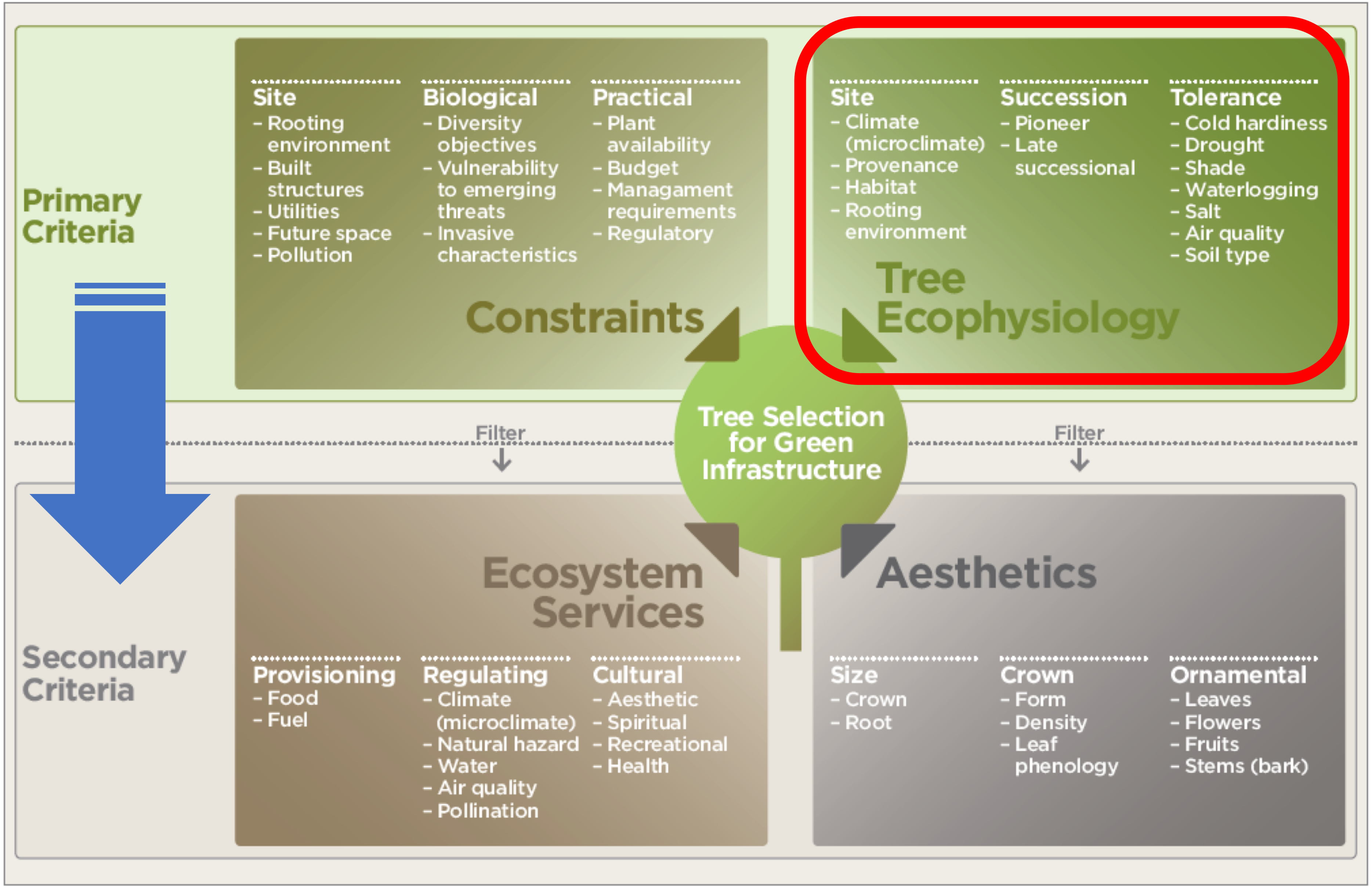


Figure from: Hirons and Sjöman (2018)

Thriving or Surviving?

Photo credit:
Duncan Slater

Site – Climate, habitat and provenance

- UK – Temperate oceanic climate (Cfb)

i. Mean temperature of the coldest month > 0 ^{o}C

ii. Four months with a mean temperature > 10 ^{o}C

iii. Warm summer (warmest month mean <22^{o}C)

iv. No pronounced dry season

- We also adopt trees from adjacent climates

The importance of tree succession

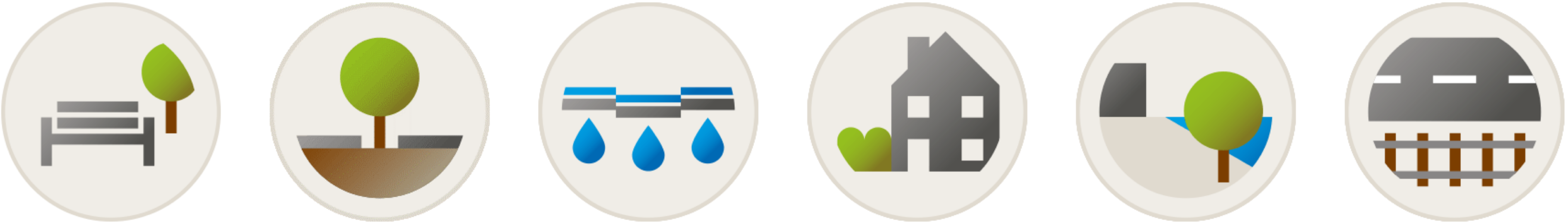
Figure from: Hirons and Sjöman 2018

Figure from: Sjöman *et al.* 2017

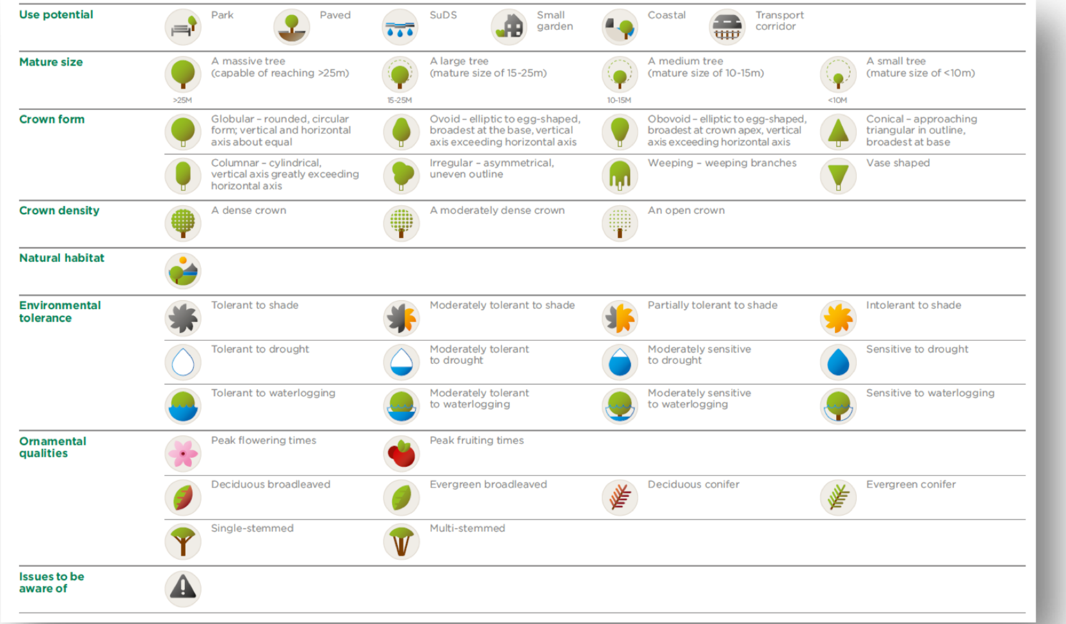
Sucessional status can be vital to establishment

Photo credit:
Henrik Sjöman

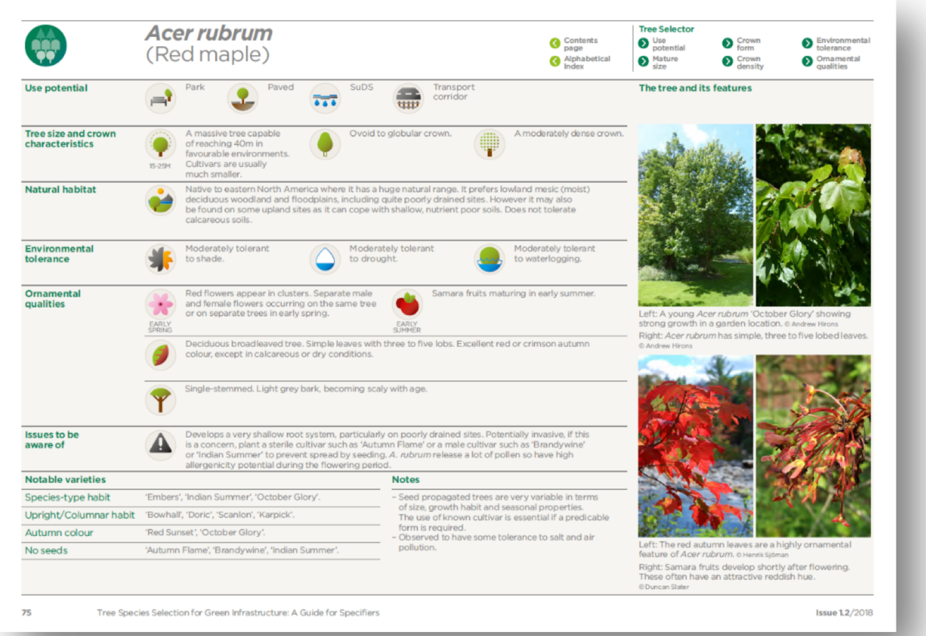
The Profiles



Park | Paved | SuDS | Small Garden | Coastal | Transport Corridor



Use potential	Park; Paved	SuDS; Small garden	Coastal; Transport corridor	
Mature size	A massive tree (capable of reaching >25m) >25M	A large tree (mature size of 15-25m) 15-25M	A medium tree (mature size of 10-15m) 10-15M	A small tree (mature size of <10m) <10M
Crown form	Globular – rounded, circular form; vertical and horizontal axis about equal	Ovoid – elliptic to egg-shaped, broadest at the base, vertical axis exceeding horizontal axis	Obovoid – elliptic to egg-shaped, broadest at crown apex, vertical axis exceeding horizontal axis	Conical – approaching triangular in outline, broadest at base
	Columnar – cylindrical, vertical axis greatly exceeding horizontal axis	Irregular – asymmetrical, uneven outline	Weeping – weeping branches	Vase shaped
Crown density	A dense crown	A moderately dense crown	An open crown	
Natural habitat				
Environmental tolerance	Tolerant to shade	Moderately tolerant to shade	Partially tolerant to shade	Intolerant to shade
	Tolerant to drought	Moderately tolerant to drought	Moderately sensitive to drought	Sensitive to drought
	Tolerant to waterlogging	Moderately tolerant to waterlogging	Moderately sensitive to waterlogging	Sensitive to waterlogging
Ornamental qualities	Peak flowering times	Peak fruiting times		
	Deciduous broadleaved	Evergreen broadleaved	Deciduous conifer	Evergreen conifer
	Single-stemmed	Multi-stemmed		
Issues to be aware of				



Acer rubrum
(Red maple)

Contents page
Alphabetical Index

Tree Selector
Use potential | Mature size | Crown form | Crown density | Environmental tolerance | Ornamental qualities

Use potential — Park; Paved; SuDS; Transport corridor

Tree size and crown characteristics — 15-25M A massive tree capable of reaching 40m in favourable environments. Cultivars are usually much smaller. | Ovoid to globular crown. | A moderately dense crown.

Natural habitat — Native to eastern North America where it has a huge natural range. It prefers lowland mesic (moist) deciduous woodland and floodplains, including quite poorly drained sites. However it may also be found on some upland sites as it can cope with shallow, nutrient poor soils. Does not tolerate calcareous soils.

Environmental tolerance — Moderately tolerant to shade. | Moderately tolerant to drought. | Moderately tolerant to waterlogging.

Ornamental qualities — EARLY SPRING Red flowers appear in clusters. Separate male and female flowers occurring on the same tree or on separate trees in early spring. | EARLY SUMMER Samara fruits maturing in early summer.

Deciduous broadleaved tree. Simple leaves with three to five lobs. Excellent red or crimson autumn colour, except in calcareous or dry conditions.

Single-stemmed. Light grey bark, becoming scaly with age.

Issues to be aware of — Develops a very shallow root system, particularly on poorly drained sites. Potentially invasive, if this is a concern, plant a sterile cultivar such as 'Autumn Flame' or a male cultivar such as 'Brandywine' or 'Indian Summer' to prevent spread by seeding. *A. rubrum* release a lot of pollen so have high allergenicity potential during the flowering period.

Notable varieties	
Species-type habit	'Embers', 'Indian Summer', 'October Glory'.
Upright/Columnar habit	'Bowhall', 'Doric', 'Scanlon', 'Karpick'.
Autumn colour	'Red Sunset', 'October Glory'.
No seeds	'Autumn Flame', 'Brandywine', 'Indian Summer'.

Notes
- Seed propagated trees are very variable in terms of size, growth habit and seasonal properties. The use of known cultivar is essential if a predicable form is required.
- Observed to have some tolerance to salt and air pollution.

The tree and its features

Left: A young *Acer rubrum* 'October Glory' showing strong growth in a garden location. © Andrew Hirons
Right: *Acer rubrum* has simple, three to five lobed leaves. © Andrew Hirons

Left: The red autumn leaves are a highly ornamental feature of *Acer rubrum*. © Henrik Sjöman
Right: Samara fruits develop shortly after flowering. These often have an attractive reddish hue. © Duncan Slater

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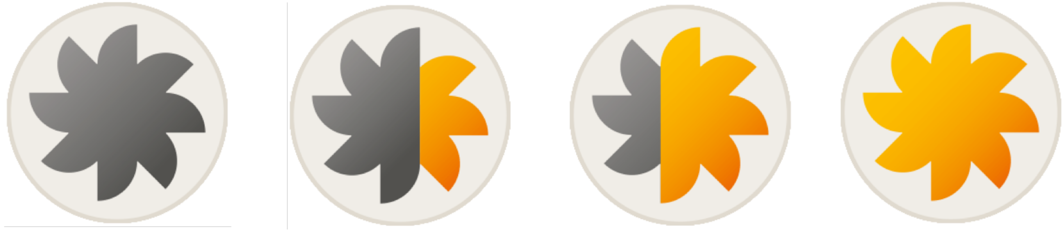
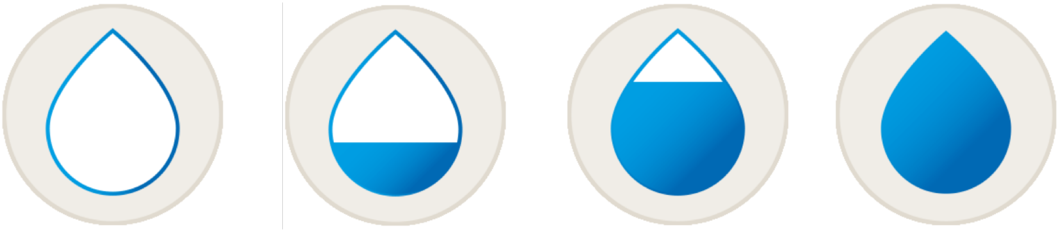
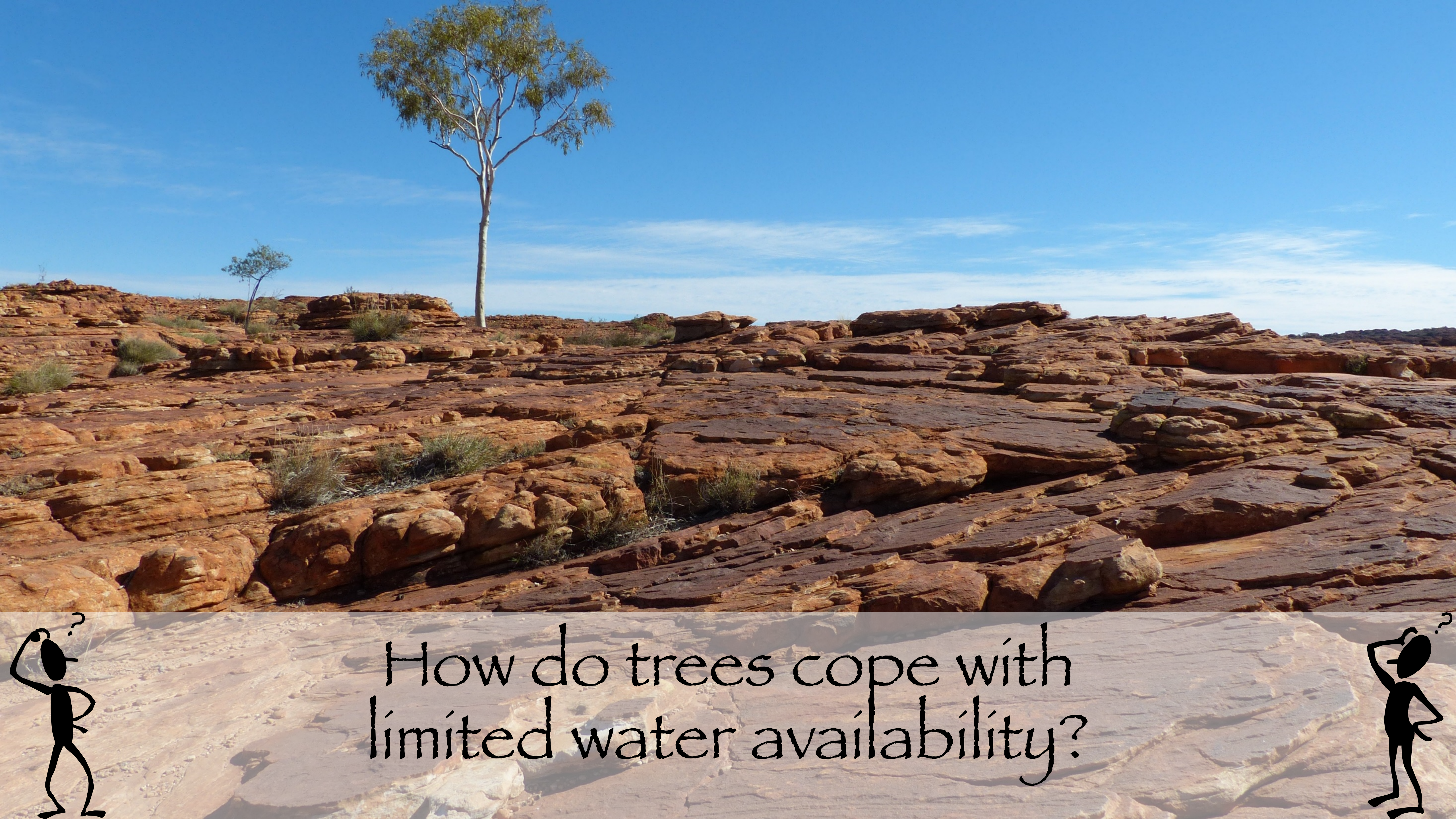
Environmental tolerance

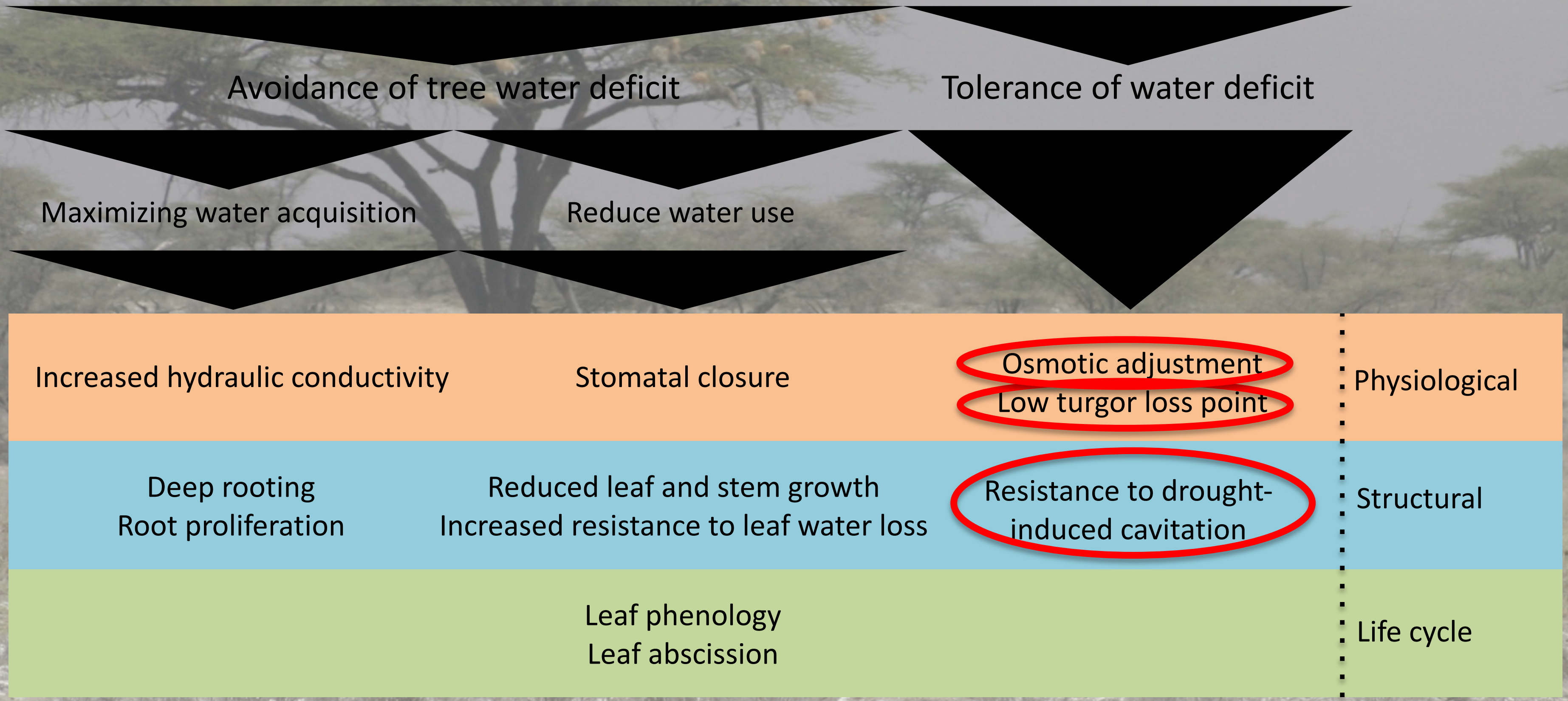


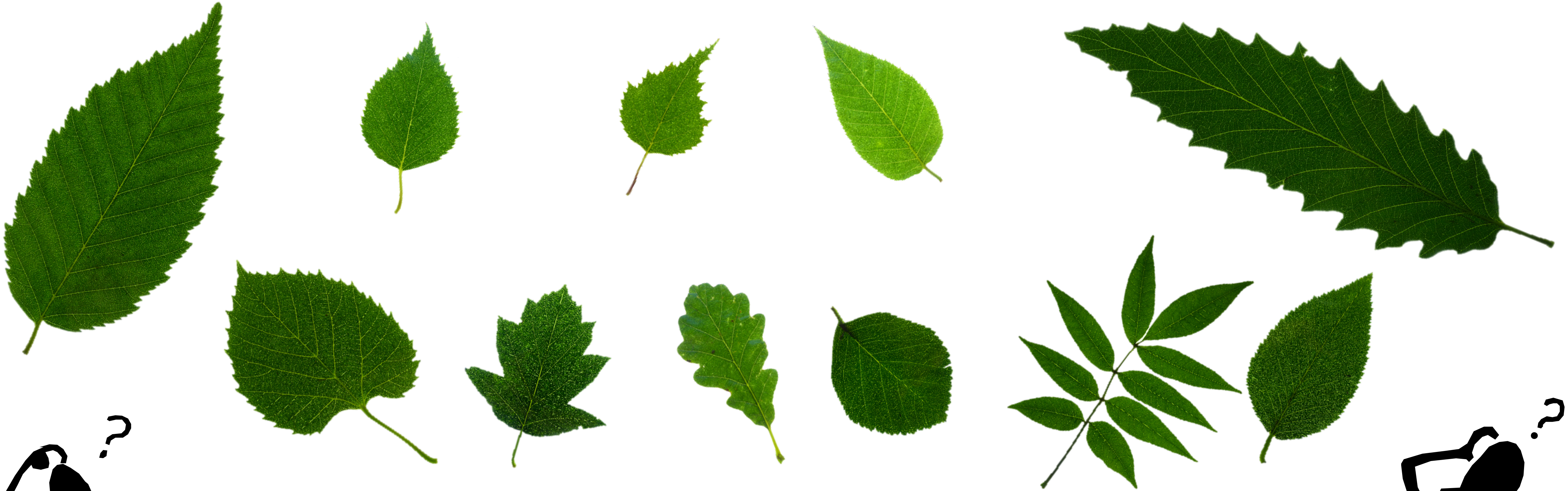


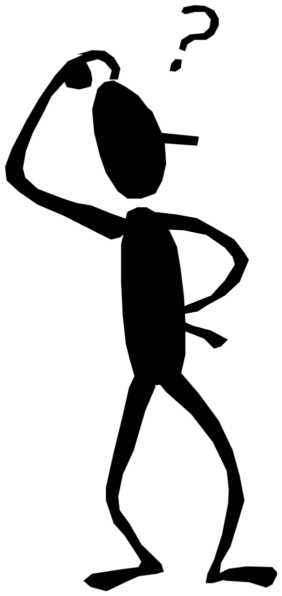
Shade	12%	26%	44%	18%
Drought	20%	33%	37%	10%
Waterlogging	1%	11%	25%	63%


How do trees cope with
limited water availability?

Adaptations to limited water availability







How can we select for drought tolerance?


PLANTS OF CHINA
THE TREES OF SONORA, MEXICO
WOODY SHRUBS AND TREES
OAKS OF CALIFORNIA
Oaks in the Urban Landscape
TREASURY of TREES
STADSTRÄDSLEXIKON
TRÄD I URBANA LANDSKAP
FOREST TREES OF THE PACIFIC SLOPE
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URBAN TREE MANAGEMENT
Tree Statics and Tree Inspection
trees for Society and the Environment
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MAPLES
Hawthorns and Medlars
Physiological Ecology of Tropical Plants
Trees for All Seasons
BROADLEAVED EVERGREENS FOR TEMPERATE CLIMATES
SEAN HOGAN
TREES in CANADA
Wurzelatlas
mitteleuropäischer Waldbäume und Sträucher
Flowering Cherries
The Urban Forest
Trees of Western North America
Trees of Eastern North America
Routledge Handbook of Urban Forestry
STEPPES
TREES for gardens, orchards and permaculture
MARTIN CRAWFORD
Trees & Shrubs
JONES
Plants and Microclimate
TREES IN URBAN DESIGN
Forest Giants of the Pacific Coast
Marschner's Mineral Nutrition of Higher Plants
DIRR'S ENCYCLOPEDIA OF TREES & SHRUBS
KRÜSSMANN
MANUAL OF CULTIVATED BROAD-LEAVED TREES & SHRUBS
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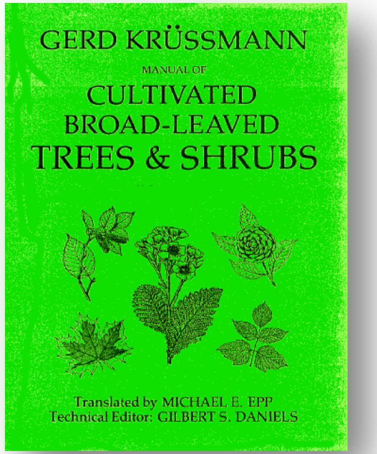
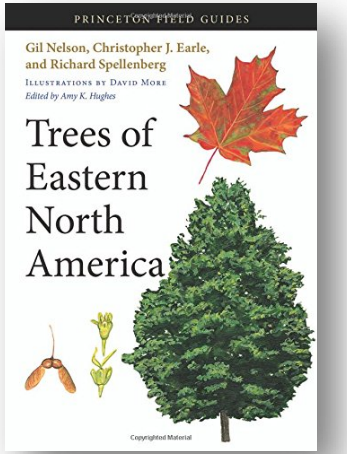
TREES FOR THE SMALL GARDEN
EAGLE'S
LANDSCAPE PLANTS OF ARABIA
JULIAN LEE

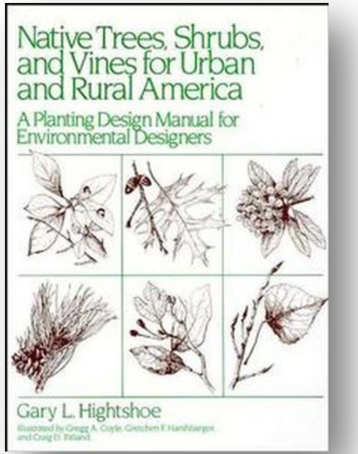
Advice from literature…

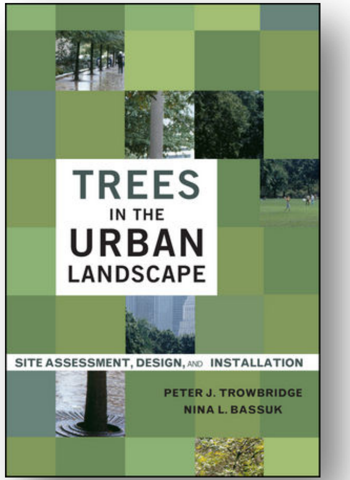
Acer negundo

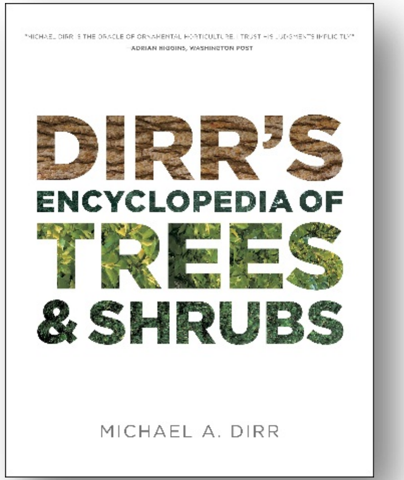
- Useful for sandy, dry to sterile soil (Krüssmann 1982)
- Drought tolerant (Stoecklein 2001)
- Its native habitat is along streams and ponds (Grimm 2002)
- Native in moist habitats but perform well also in poor, wet, or dry habitats (Dirr 2009)
- Very heat and drought tolerant (Hightshoe 1988)
- Grows along shores of permanent bodies of water (Krüssmann, 1986)
- Like humid areas (Beaulieu 2003)
- Grows along stream banks, flood plains, swamps (Nelson et al. 2014)

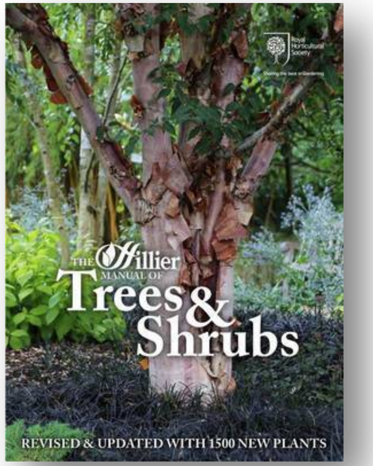












Avoid 'avoiders' for the challenging sites

Alnus hirsuta

Betula utilis

Improving selection decisions (in relation to drought tolerance)

- Trait based assessment
  - A quantifiable characteristic that reveals something of the tree's 'personality'
- Turgor loss point (permanent wilting point) (Ψ_{P0})
- Water potential at 50% loss of hydraulic conductivity (Ψ_{50})

Underpinning Science

- Leaf turgor loss point can be used as a universal measure of physiological drought tolerance that is quantifiable and measurable

ECOLOGY LETTERS

Ecology Letters, (2012) 15: 393–405 doi: 10.1111/j.1461-0248.2012.01751.x

IDEA AND PERSPECTIVE

The determinants of leaf turgor loss point and prediction of drought tolerance of species and biomes: a global meta-analysis

Megan K. Bartlett, Christine Scoffoni and Lawren Sack*
Department of Ecology and Evolution, University of California Los Angeles, 621 Charles E. Young Drive South, Los Angeles, California 90095, USA

*Correspondence:
E-mail: lawrensack@ucla.edu

Abstract
Increasing drought is one of the most critical challenges facing species and ecosystems worldwide, and improved theory and practices are needed for quantification of species tolerances. Leaf water potential at turgor loss, or wilting (π_{tlp}), is classically recognised as a major physiological determinant of plant water stress response. However, the cellular basis of π_{tlp} and its importance for predicting ecological drought tolerance have been controversial. A meta-analysis of 317 species from 72 studies showed that π_{tlp} was strongly correlated with water availability within and across biomes, indicating power for anticipating drought responses. We derived new equations giving both π_{tlp} and relative water content at turgor loss point (RWC_{tlp}) as explicit functions of osmotic potential at full turgor (π_o) and bulk modulus of elasticity (ε). Sensitivity analyses and meta-analyses showed that π_o is the major driver of π_{tlp}. In contrast, ε plays no direct role in driving drought tolerance within or across species, but sclerophylly and elastic adjustments act to maintain RWC_{tlp}, preventing cell dehydration, and additionally protect against nutrient, mechanical and herbivory stresses independent of drought tolerance. These findings clarify biogeographic trends and the underlying basis of drought tolerance parameters with applications in comparative assessments of species and ecosystems worldwide.

Keywords
Biogeography, biomes, climate, plant hydraulics, plant traits.

Ecology Letters (2012) 15: 393–405

Prunus avium – Early July 2018

Underpinning Science

- Assess osmotic potential at full turgor in leaf discs based on Bartlett *et al.* (2012) and subsequent meta-analysis
- Apply regression equation to determine leaf water potential at turgor loss
- Rank species in terms of their physiological drought tolerance

Methods in Ecology and Evolution

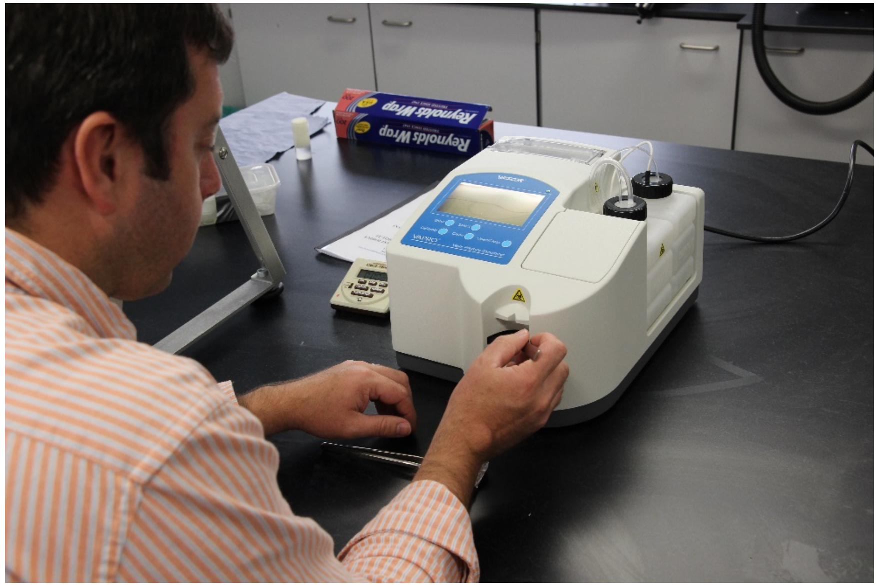
British Ecological Society

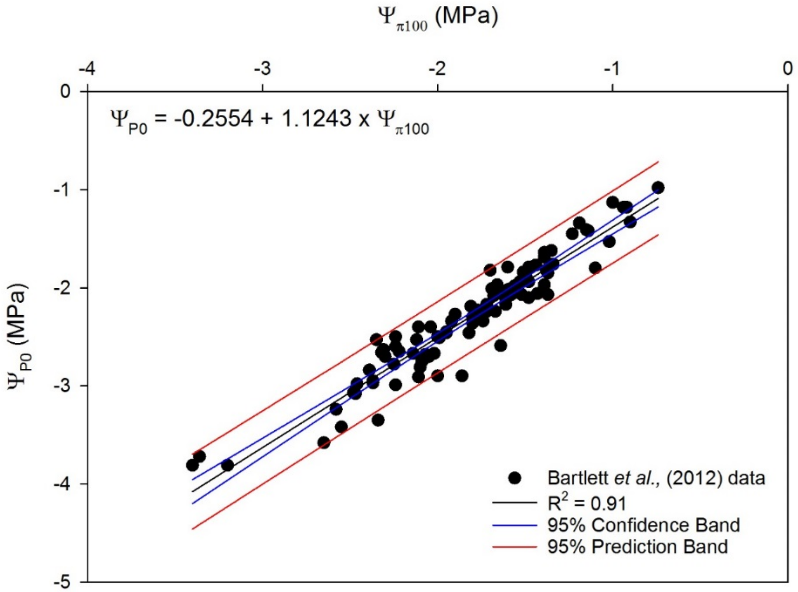
Methods in Ecology and Evolution 2012, 3, 880–888 doi: 10.1111/j.2041-210X.2012.00230.x

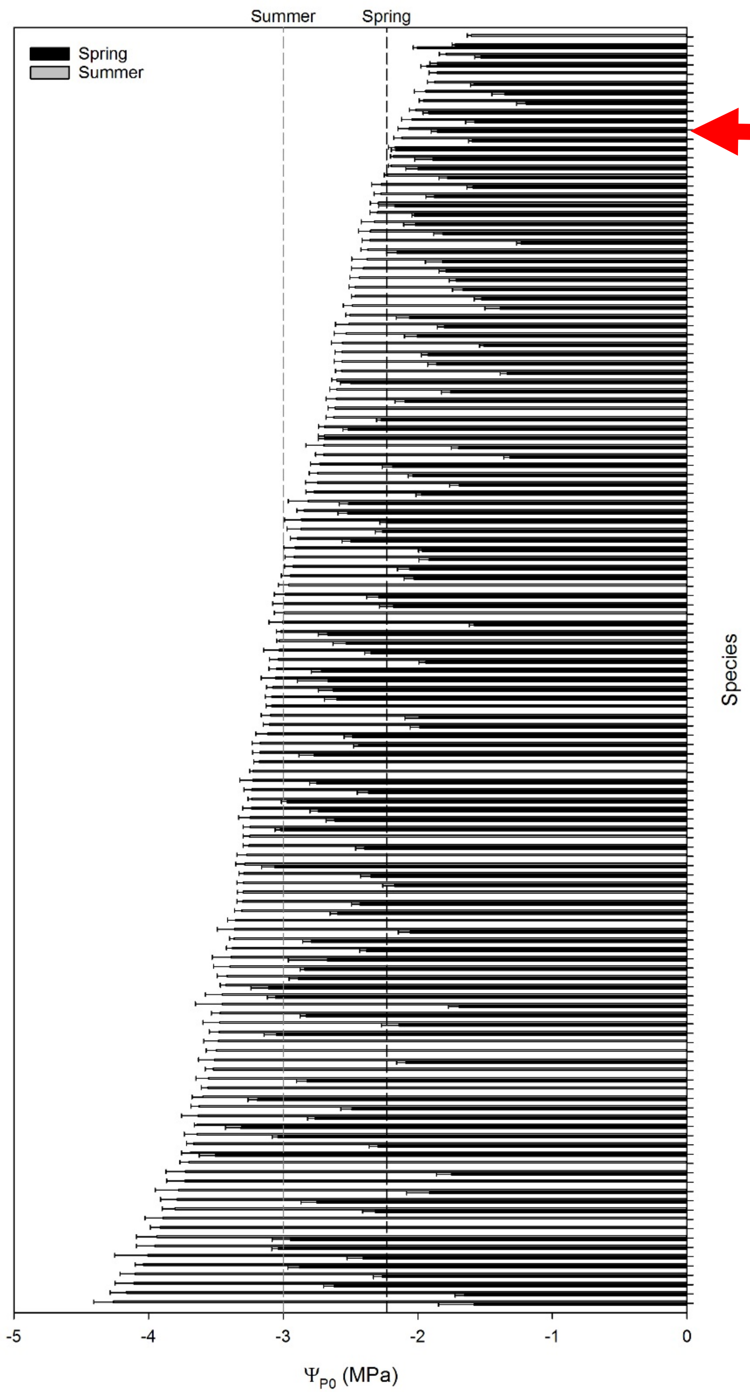
Rapid determination of comparative drought tolerance traits: using an osmometer to predict turgor loss point

Megan K. Bartlett[1]*, Christine Scoffoni[1], Rico Ardy[1], Ya Zhang[2], Shanwen Sun[2], Kunfang Cao[2] and Lawren Sack[1]

[1]*Department of Ecology and Evolution, University of California Los Angeles, 621 Charles E. Young Drive South, Los Angeles, CA 90095, USA; and* [2]*Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan 666303, China*







Aesculus flava

Photo courtesy of Henrik Sjöman

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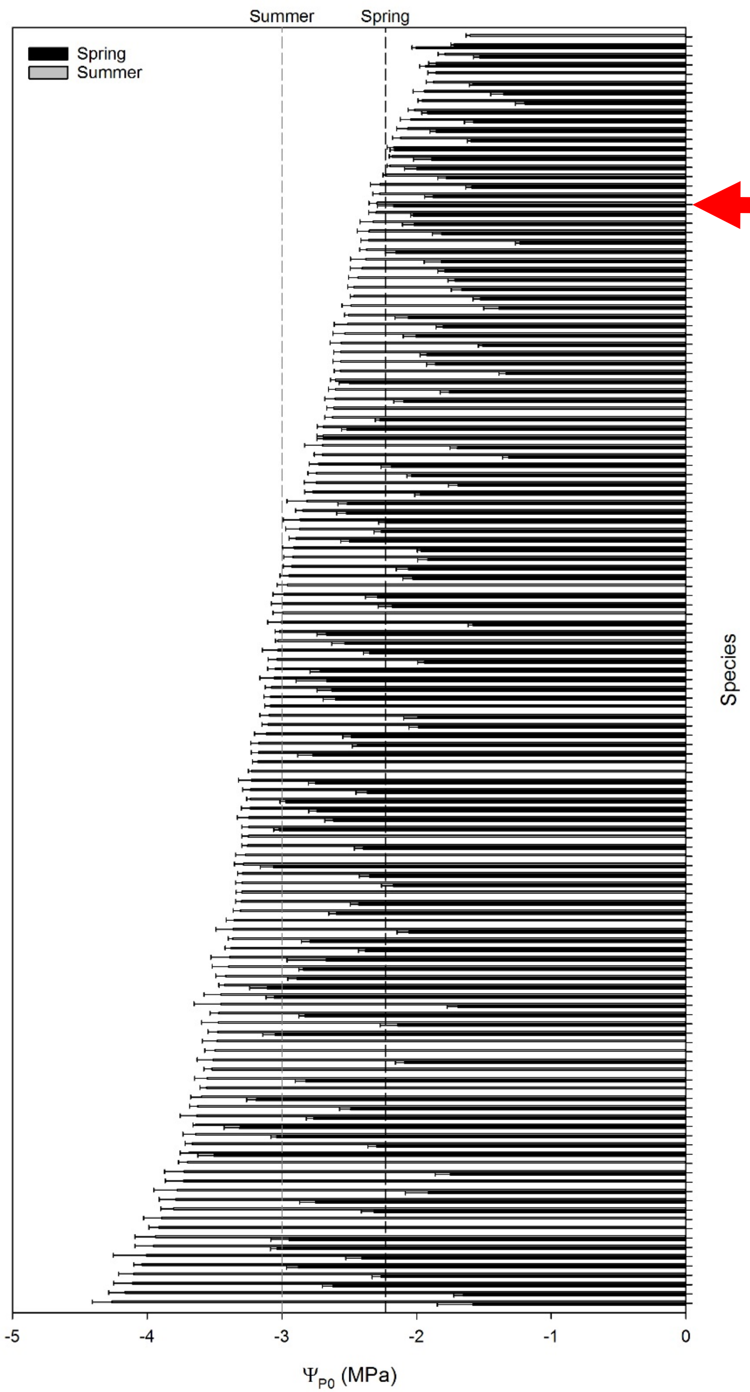
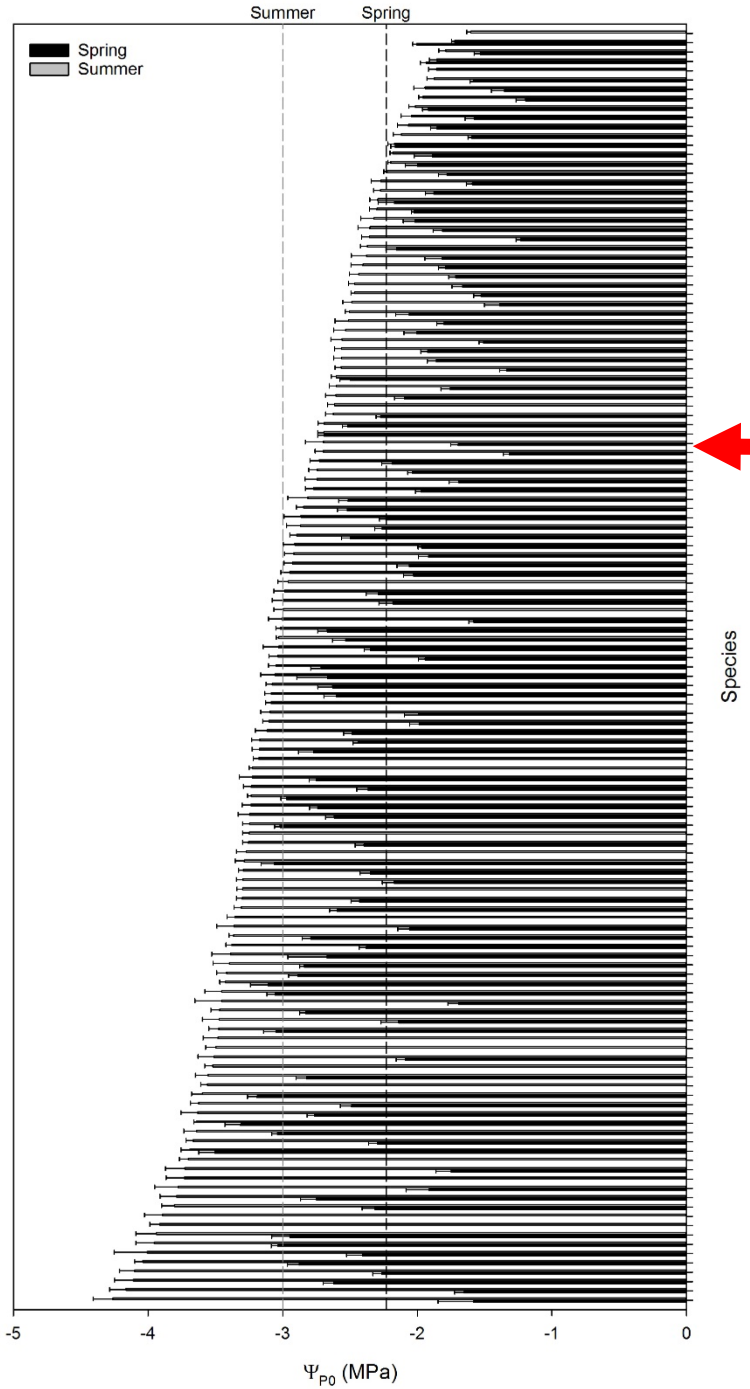


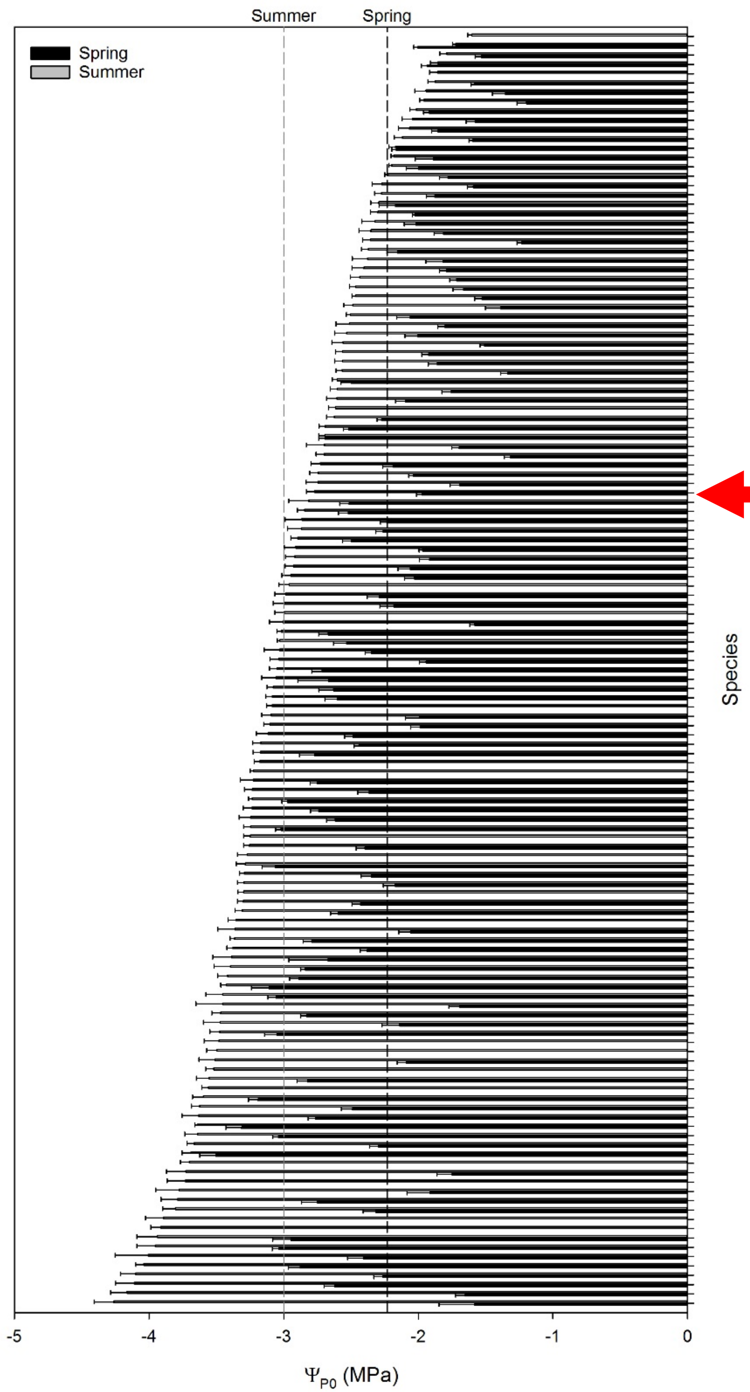
Magnolia kobus

Photo courtesy of Henrik Sjöman



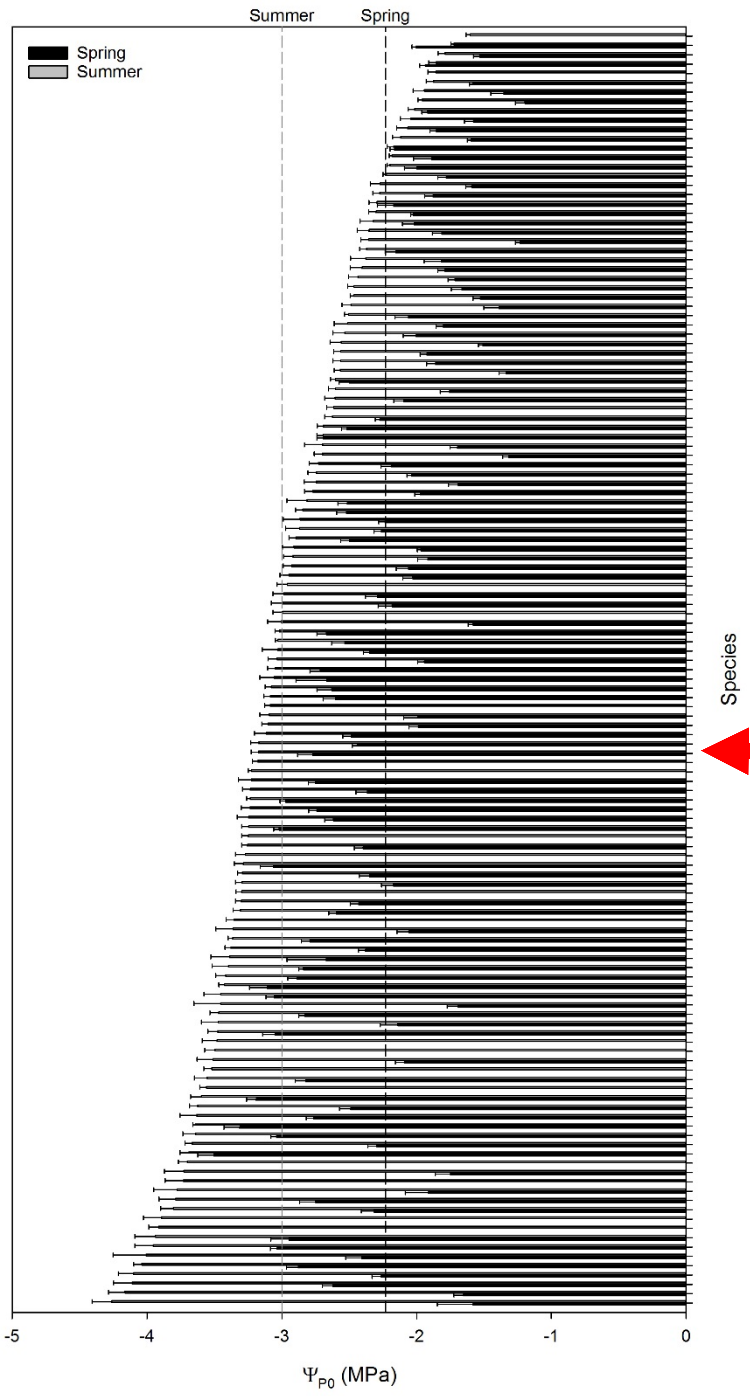
Cercidiphyllum japonicum

Photo courtesy of Henrik Sjöman



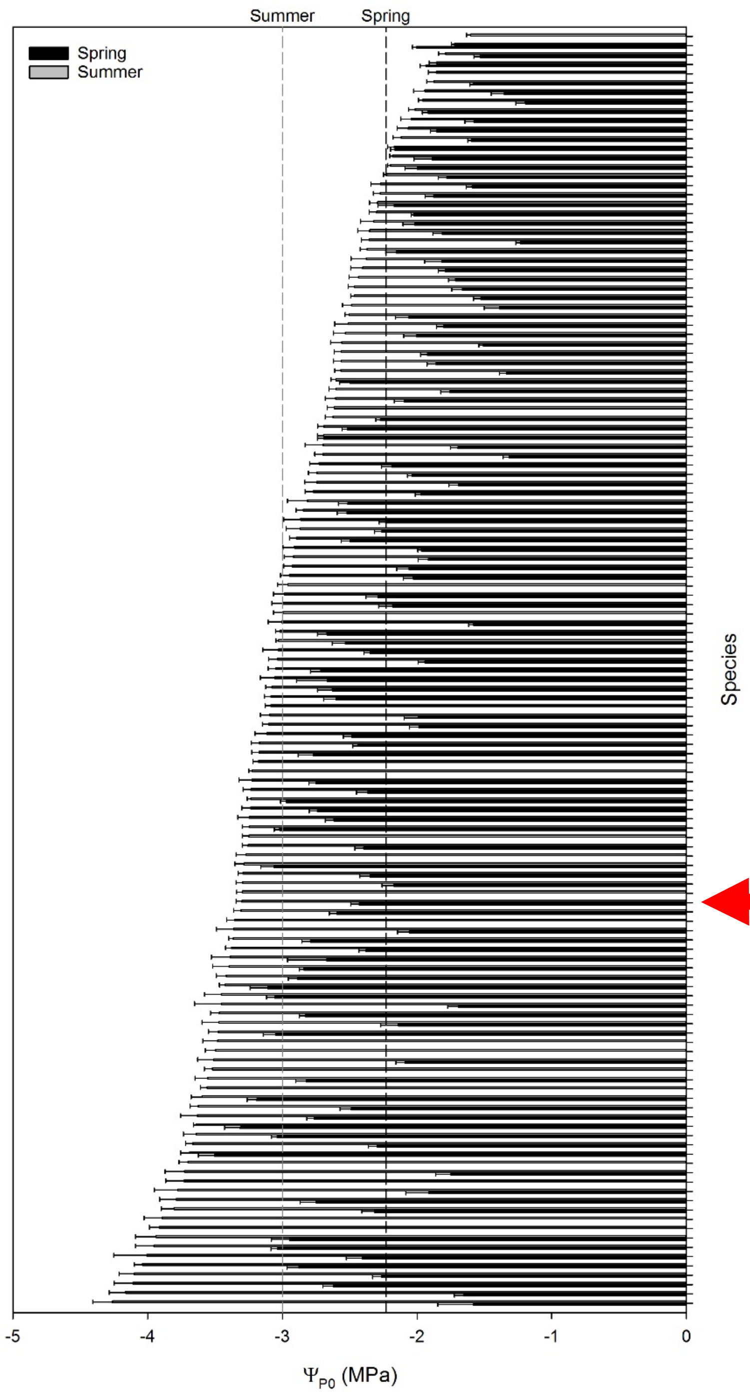
Liriodendron tulipifera

Photo courtesy of Henrik Sjöman



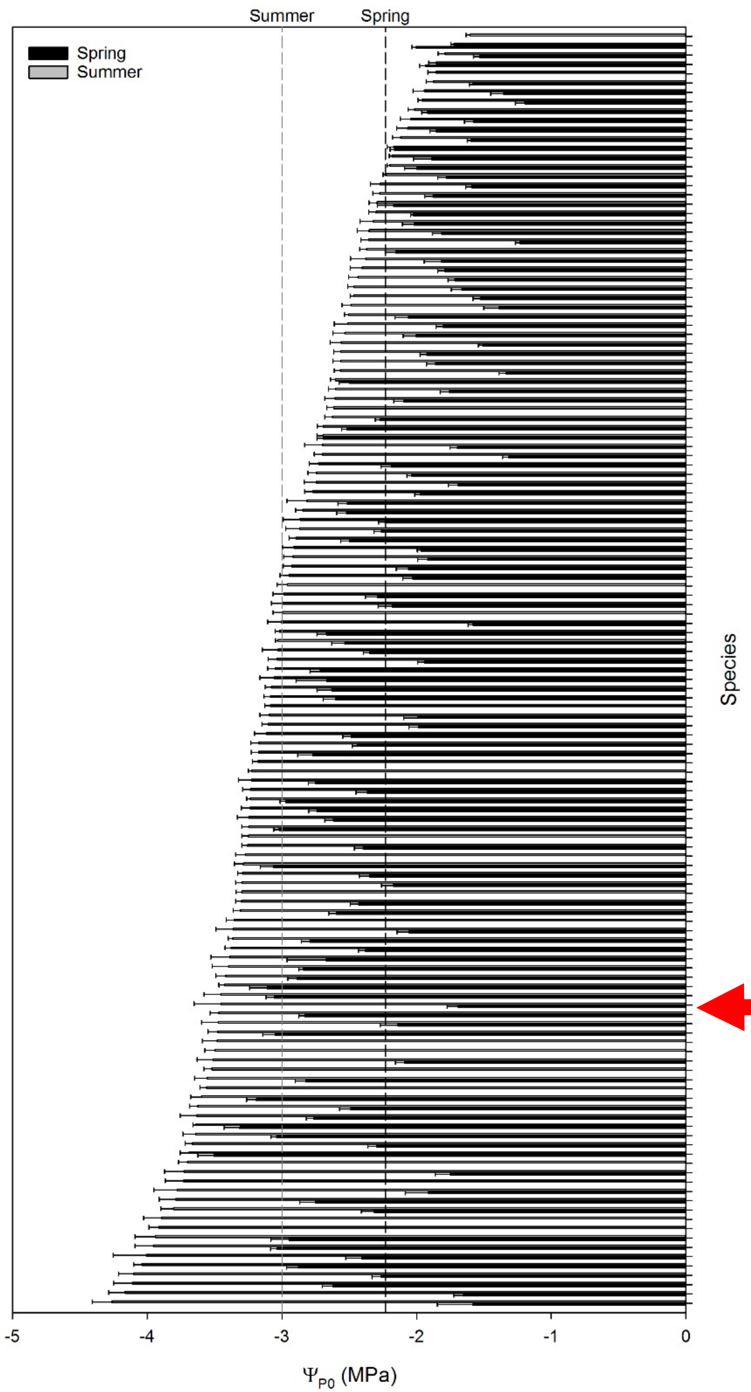
Corylus colurna

Photo courtesy of Henrik Sjöman



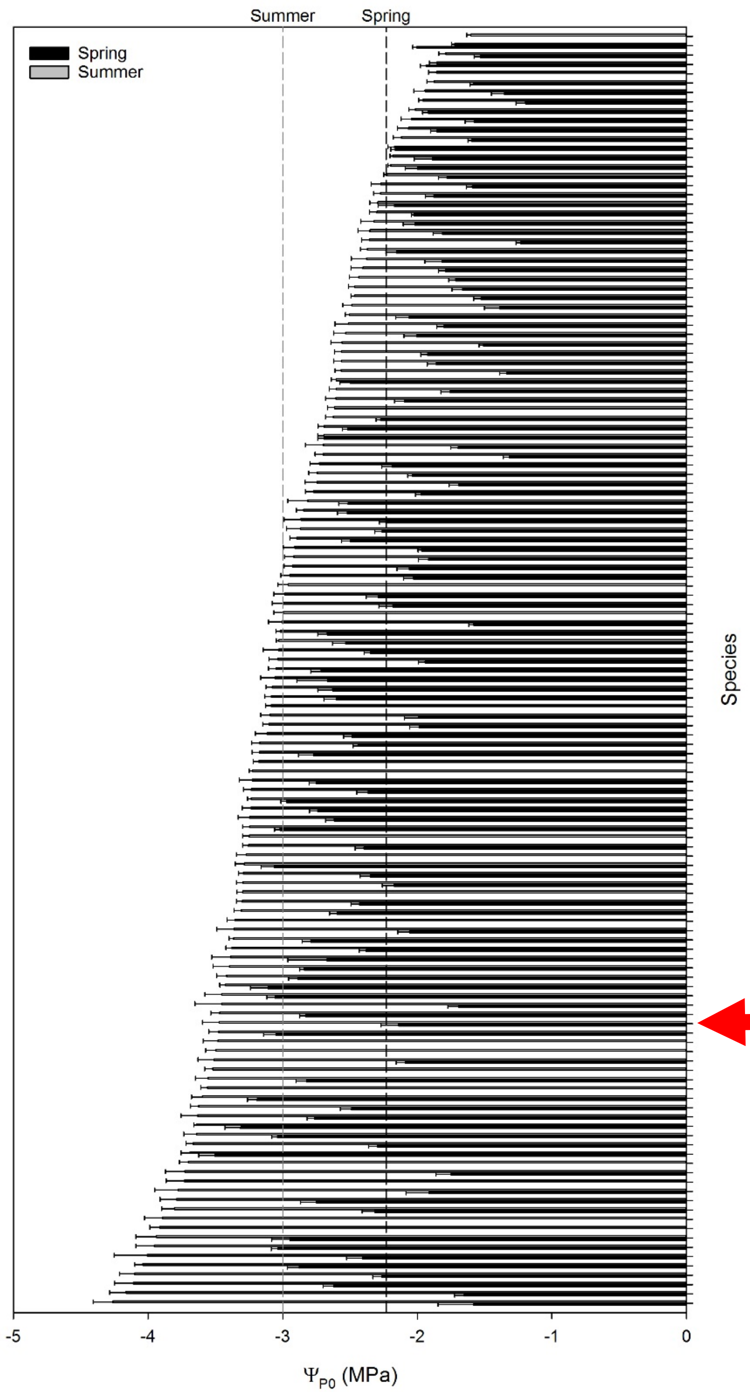
Tilia tomentosa

Photo courtesy of Henrik Sjöman



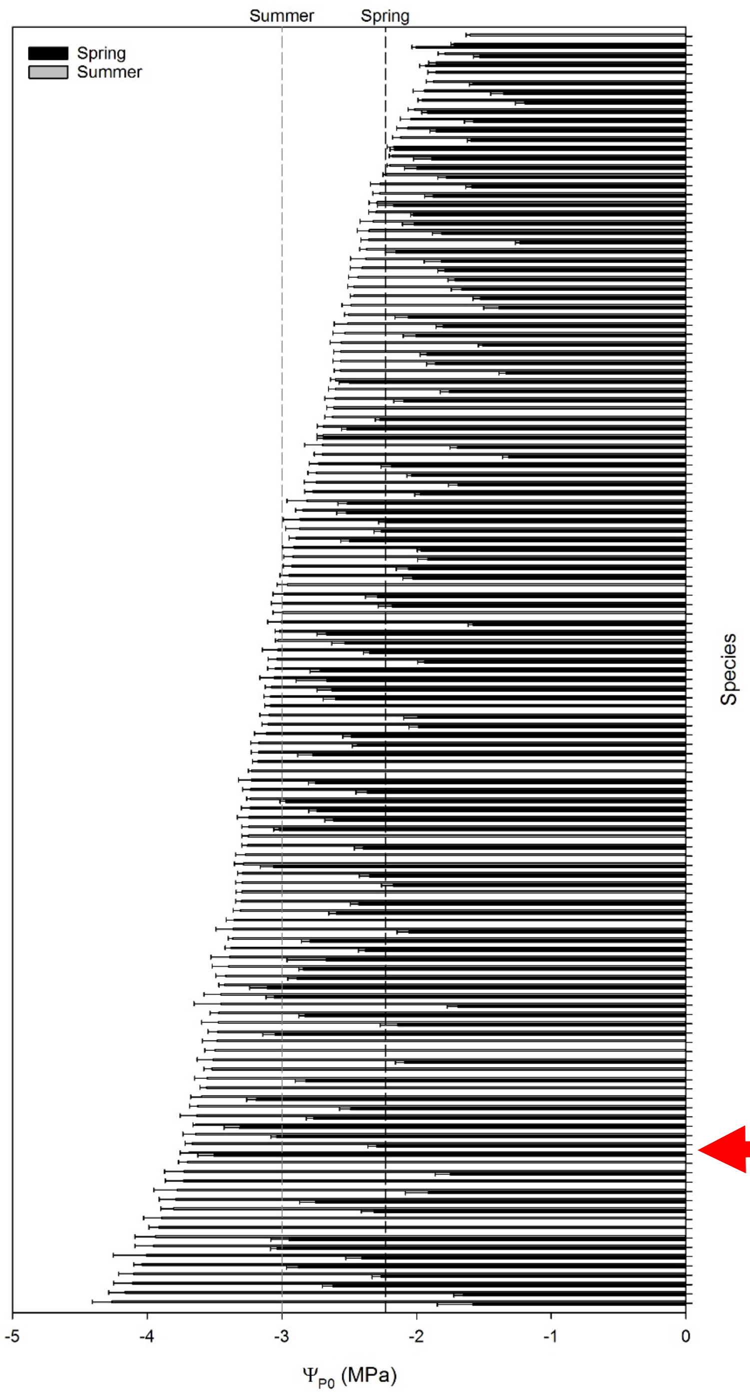
Prunus sargentii

Photo courtesy of Henrik Sjöman



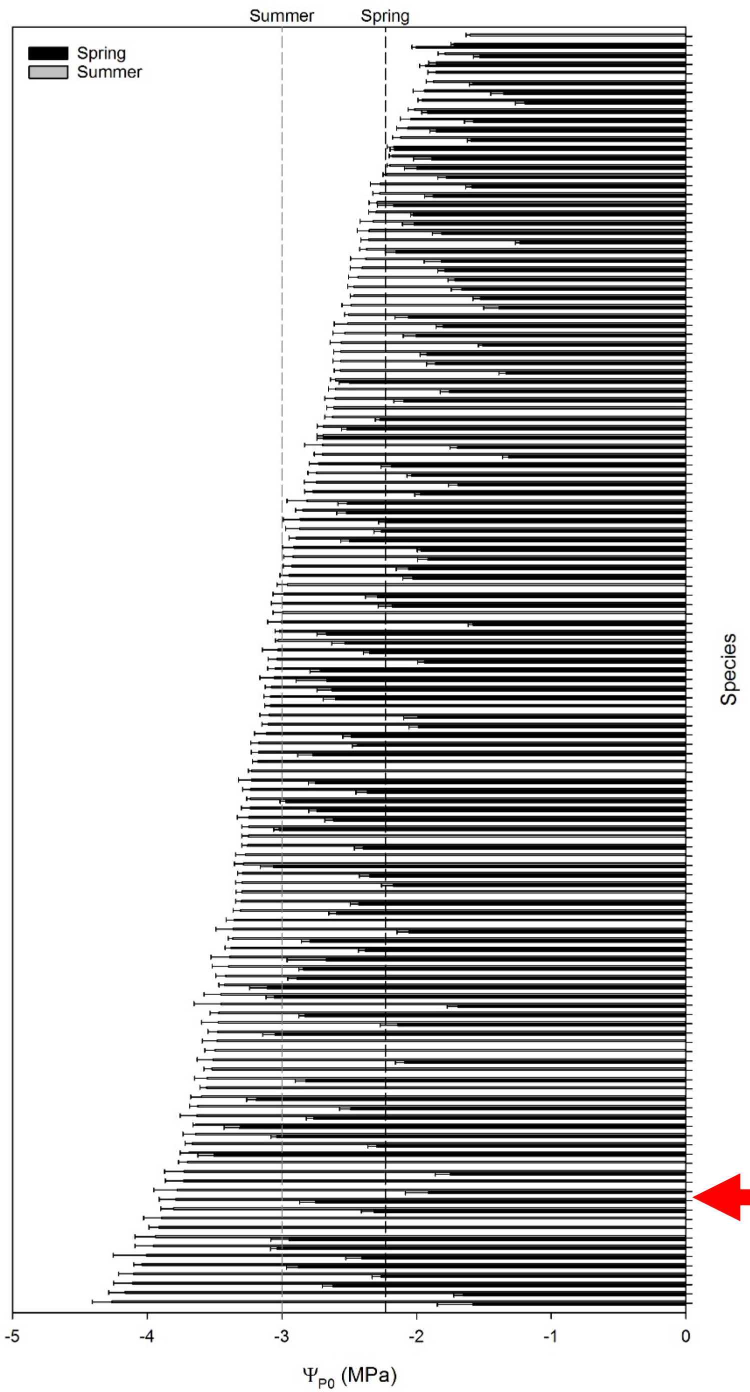
Acer x zoeschense

Photo courtesy of Henrik Sjöman



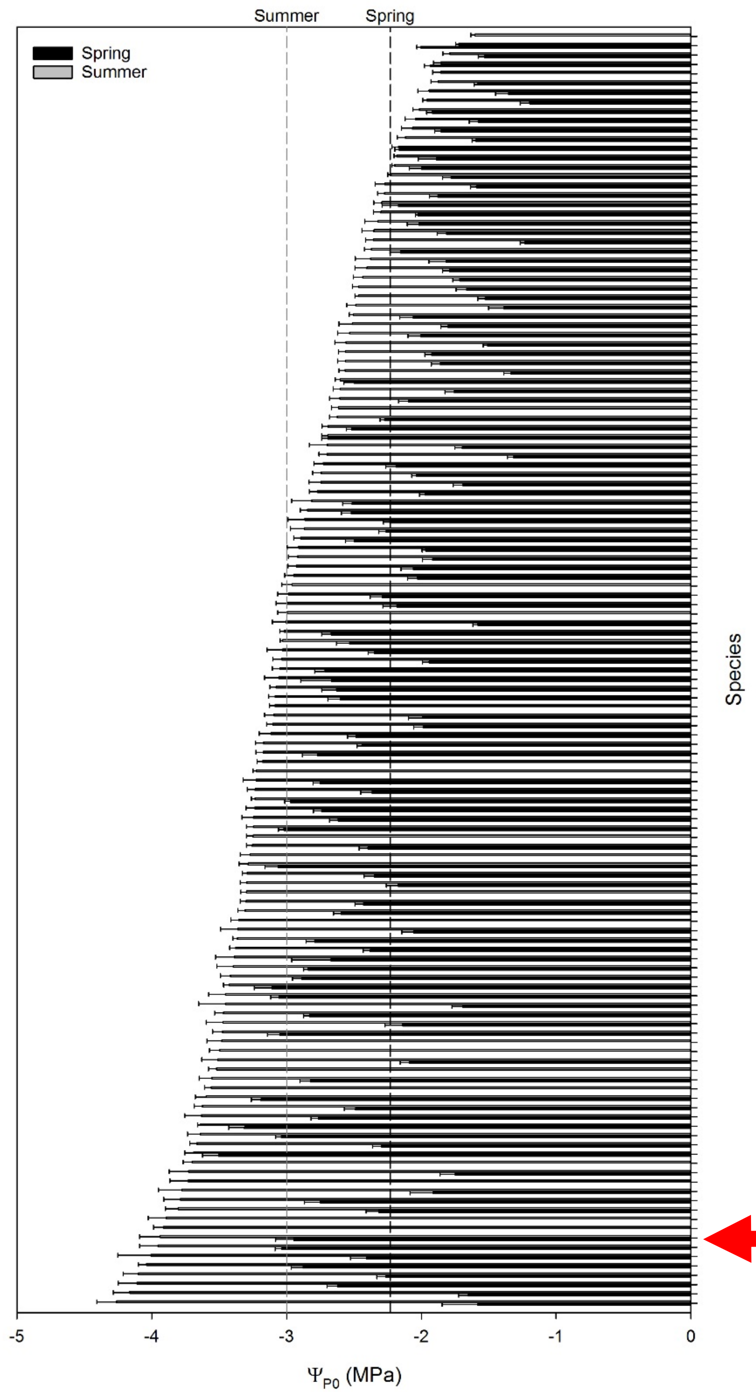
Eucommia ulmoides

Photo courtesy of Henrik Sjöman



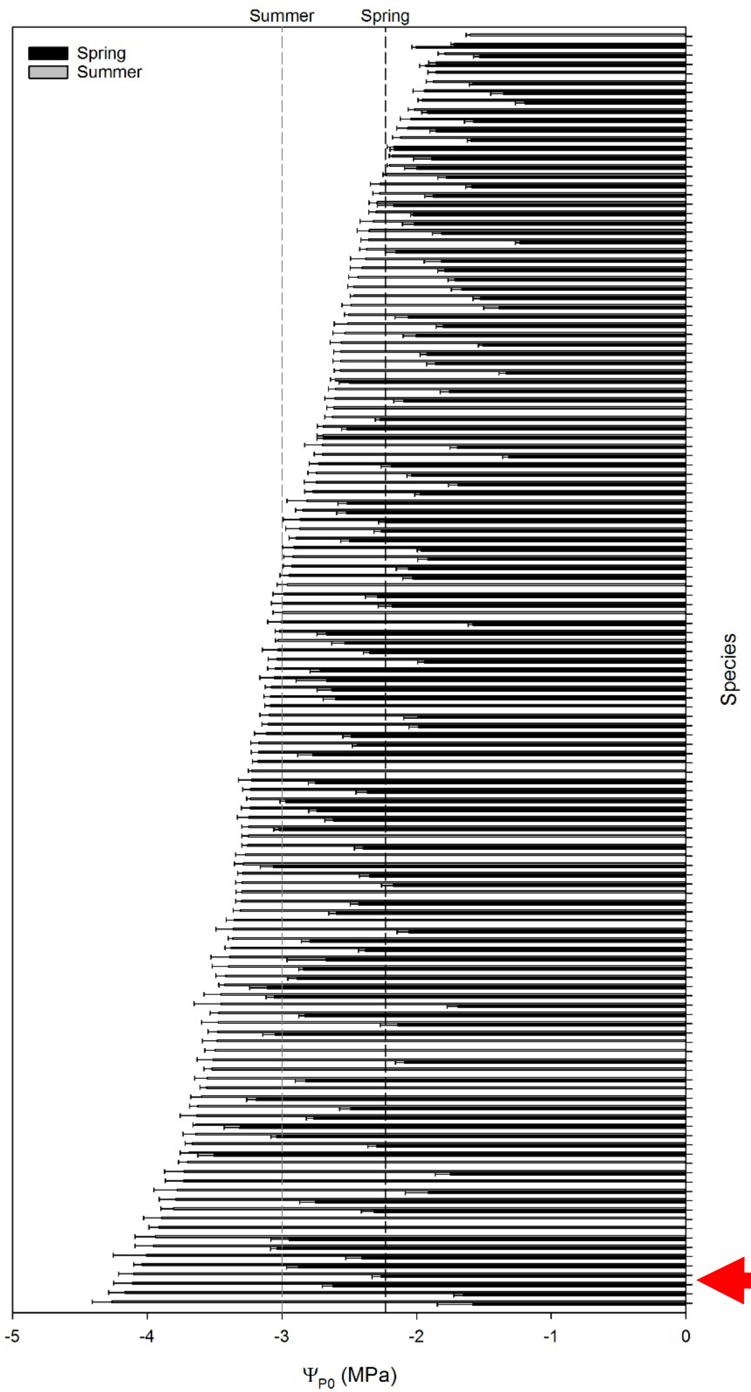
Quercus cerris

Photo courtesy of Henrik Sjöman



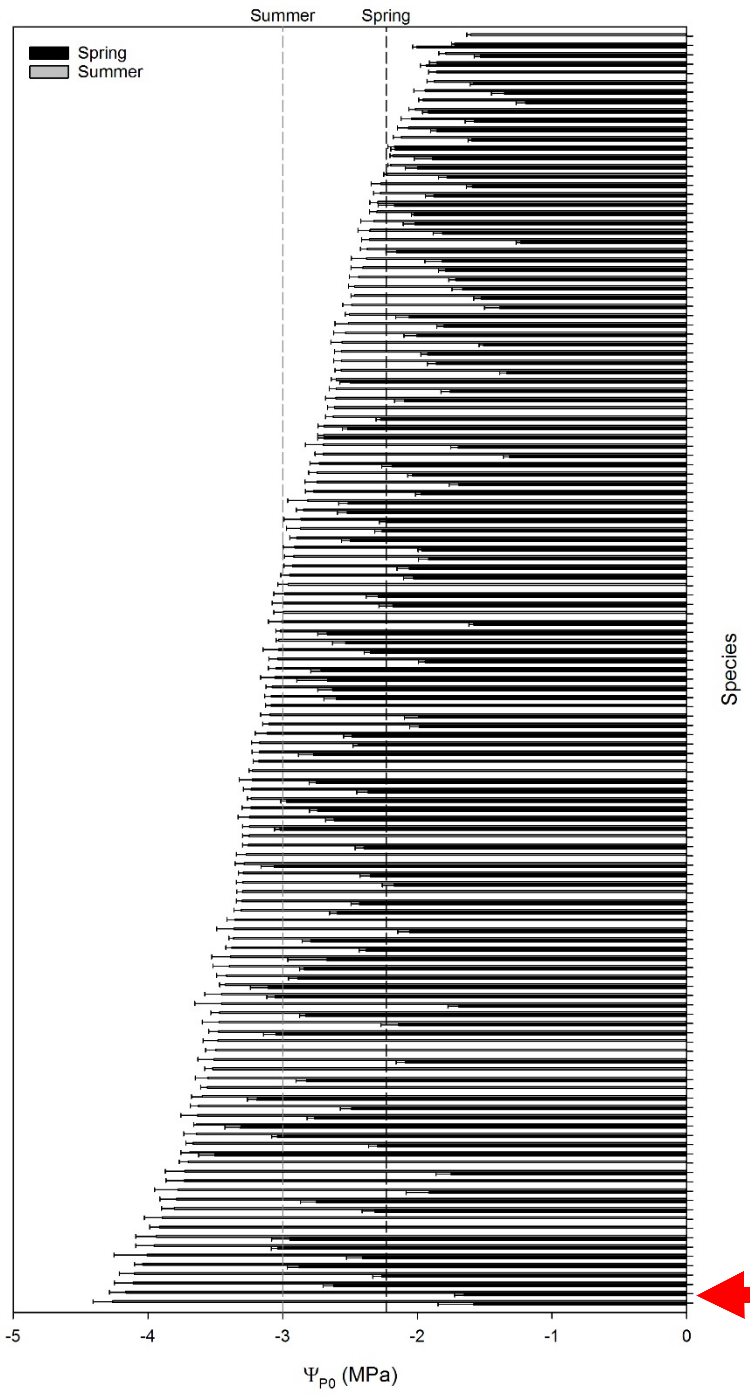
Pinus nigra

Photo courtesy of Henrik Sjöman



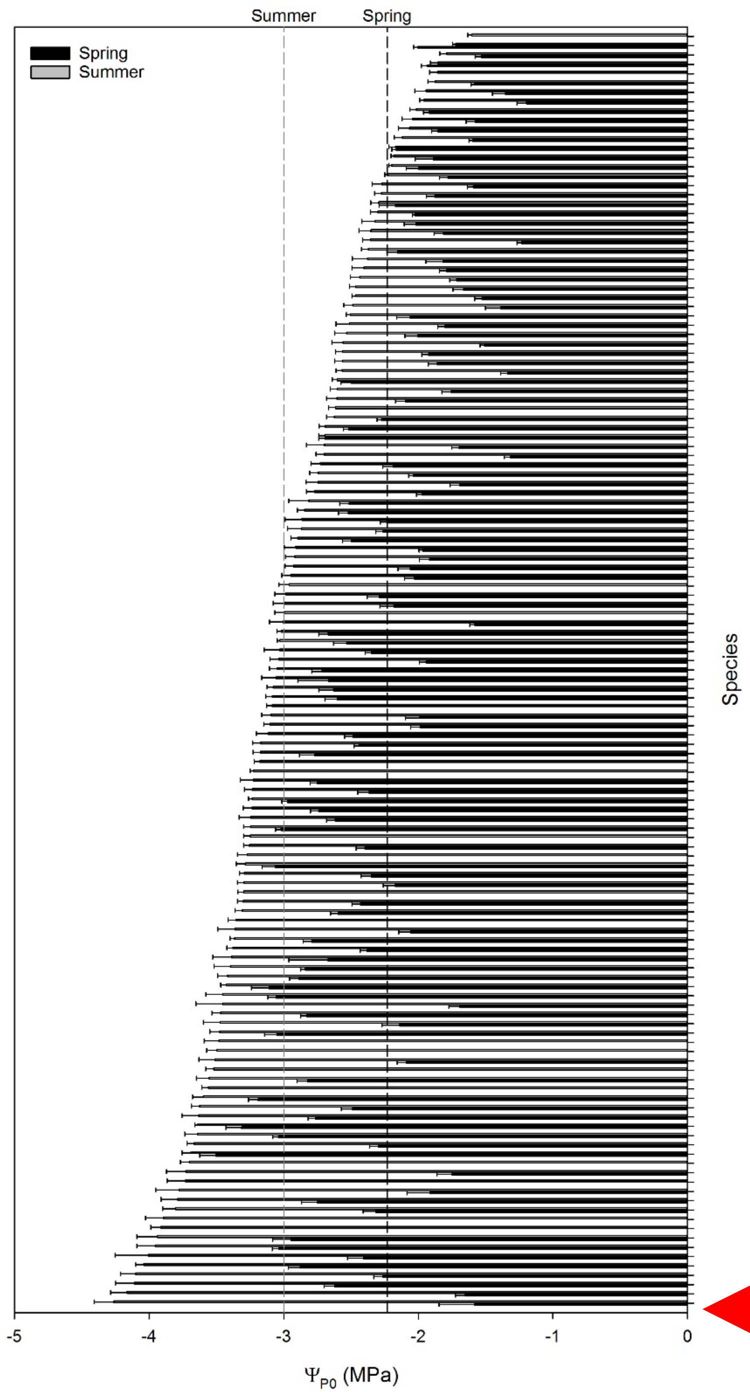
Ginkgo biloba

Photo courtesy of Henrik Sjöman



Syringa reticulata

Photo courtesy of Henrik Sjöman



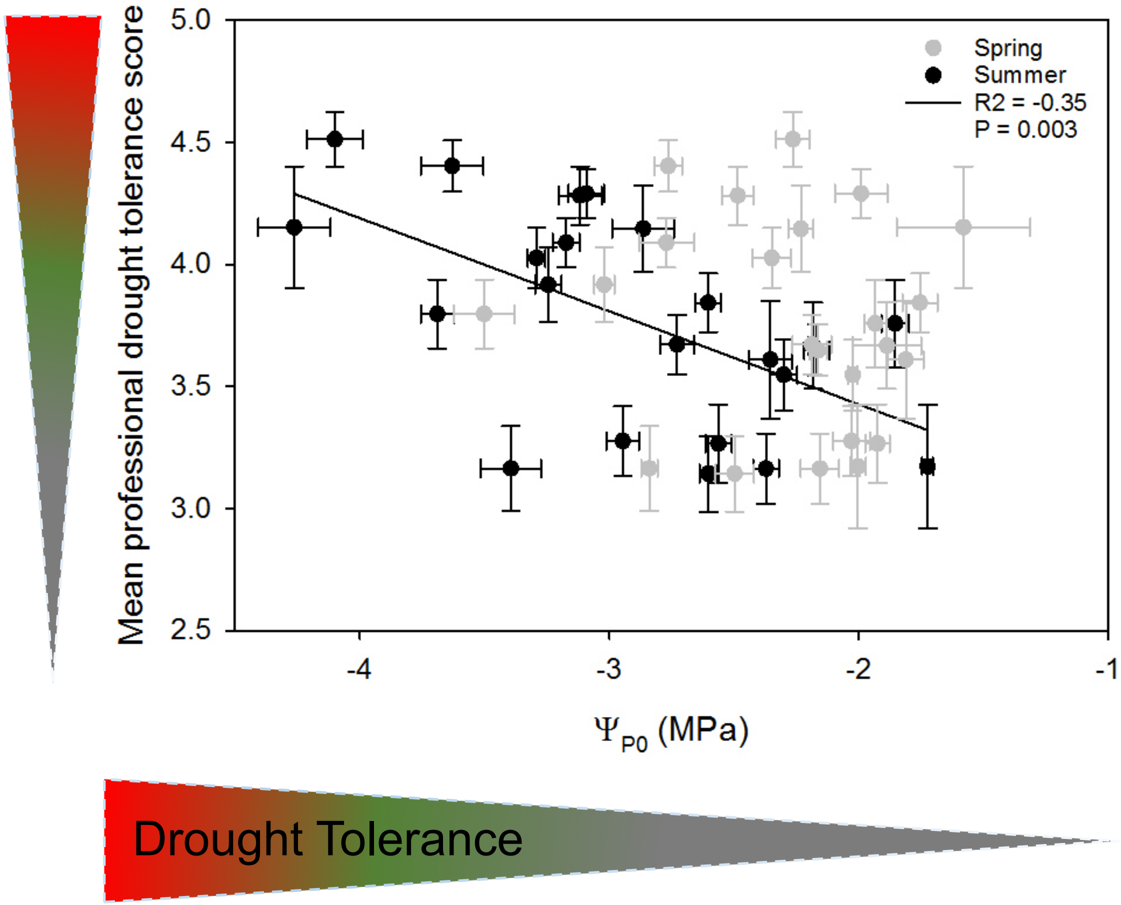
Koelreuteria paniculata Photo courtesy of Henrik Sjöman

University Centre Myerscough

Applying data to guidance

- Highly significant differences in species turgor loss point.
- Data is consistent with what we would expect based on the trees' natural habit
- Excellent promise as a tool to guide species selection in the future

Based on your experience, categorise the following species according to their tolerance to drought.

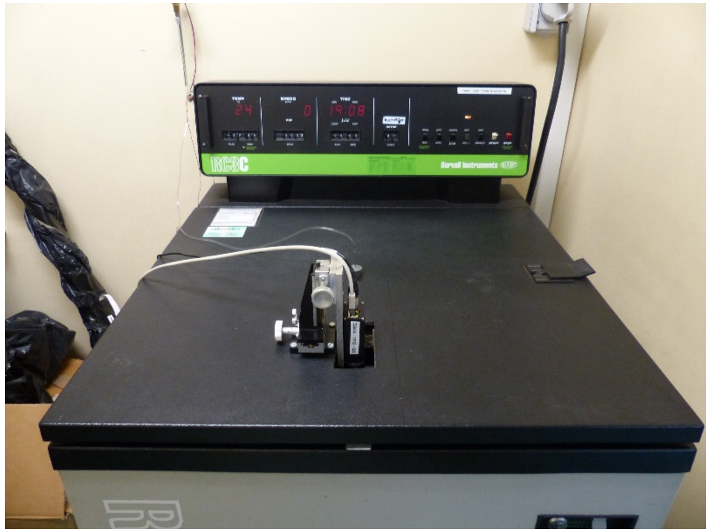


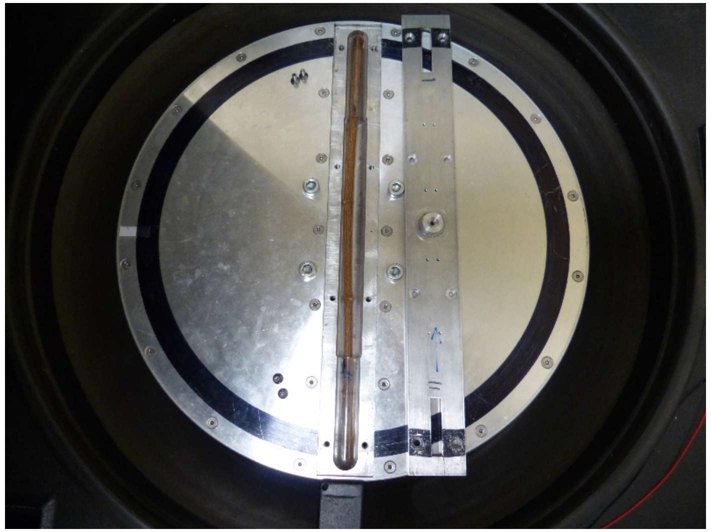
	Very sensitive to drought	Sensitive to drought	Moderately sensitive to drought	Moderately tolerant to drought	Tolerant to drought	Very tolerant to drought
Acer griseum						
Acer monspessulanum						
Acer platanoides						

- Highly significant relationship between practitioners experience of a tree's drought tolerance and summer turgor loss.

Sjöman, H. Hirons, A.D. and Bassuk, N.L – Accepted – *Urban Ecosystems*

Assessing Vulnerability Curves





Research Report

Herbaceous Angiosperms Are Not More Vulnerable to Drought-Induced Embolism Than Angiosperm Trees[1][OPEN]

Frederic Lens*, Catherine Picon-Cochard, Chloé E.L. Delmas, Constant Signarbieux, Alexandre Buttler, Hervé Cochard, Steven Jansen, Thibaud Chauvin, Larissa Chacon Doria, Marcelino del Arco, and Sylvain Delzon

Naturalis Biodiversity Center, Leiden University, 2300RA Leiden, The Netherlands (F.L., L.C.D.); INRA UR874 Grassland Ecosystem Research, F-63039 Clermont-Ferrand cedex 2, France (C.P.-C.); UMR SAVE, INRA, BSA, Université de Bordeaux, 33882 Villenave d'Ornon, France (C.E.L.D.); School of Architecture, Civil and Environmental Engineering (ENAC), Ecole Polytechnique Fédérale de Lausanne (EPFL), Ecological Systems Laboratory (ECOS), Station 2, 1015 Lausanne, Switzerland (C.S., A.B.); Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Site Lausanne, Station 2, 1015 Lausanne, Switzerland (C.S., A.B.); PIAF, INRA, Université Clermont Auvergne, 63100 Clermont-Ferrand, France (H.C., T.C.); Institute of Systematic Botany and Ecology, Ulm University, D-89081 Ulm, Germany (S.J.); AGPF, INRA Orléans, 45166 Olivet cedex, France (T.C.); Department of Plant Biology (Botany), La Laguna University, 38071 La Laguna, Tenerife, Spain (M.d.A.); and BIOGECO INRA, Université de Bordeaux, 33610 Cestas, France (S.D.)

ORCID IDs: 0000-0002-5001-0149 (F.L.); 0000-0001-7728-8936 (C.P.-C.); 0000-0001-7780-5366 (C.S.); 0000-0002-2727-7072 (H.C.); 0000-0002-4476-5334 (S.J.); 0000-0003-3442-1711 (S.D.).

The water transport pipeline in herbs is assumed to be more vulnerable to drought than in trees due to the formation of frequent embolisms (gas bubbles), which could be removed by the occurrence of root pressure, especially in grasses. Here, we studied hydraulic failure in herbaceous angiosperms by measuring the pressure inducing 50% loss of hydraulic conductance (P_{50}) in stems of 26 species, mainly European grasses (Poaceae). Our measurements show a large range in P_{50} from −0.5 to −7.5 MPa, which overlaps with 94% of the woody angiosperm species in a worldwide, published data set and which strongly correlates with an aridity index. Moreover, the P_{50} values obtained were substantially more negative than the midday water potentials for five grass species monitored throughout the entire growing season, suggesting that embolism formation and repair are not routine and mainly occur under water deficits. These results show that both herbs and trees share the ability to withstand very negative water potentials without considerable embolism formation in their xylem conduits during drought stress. In addition, structure-function trade-offs in grass stems reveal that more resistant species are more lignified, which was confirmed for herbaceous and closely related woody species of the daisy group (Asteraceae). Our findings could imply that herbs with more lignified stems will become more abundant in future grasslands under more frequent and severe droughts, potentially resulting in lower forage digestibility.

Terrestrial biomes provide numerous ecosystem services to humans, such as biodiversity refuges, forage supply, carbon sequestration, and associated atmospheric feedback (Bonan, 2008). Drought frequency and severity are predicted to increase across various ecosystems (Dai, 2013), and its impact on the fate of terrestrial biomes has aroused great concern for stakeholders over the past decade. For instance, worldwide forest declines have been associated with drought events (Allen et al., 2010), and the sustainability of grasslands, one of the most important agro-ecosystems representing 26% of the world land area, is threatened due to increasing aridity in the light of climate change (Tubiello et al., 2007; Brookshire and Weaver, 2015). Since the maintenance of grasslands is of prime importance for livestock, and several of the most valuable crops are grasses, herbaceous species deserve more attention from a hydraulic point of view to understand how they will cope with shifts in precipitation and temperature patterns.

During water deficit, hydraulic failure in trees has been put forward as one of the primary causes of forest decline (Anderegg et al., 2015, 2016). Drought exacerbates the negative pressure inside the water conducting cells, making the liquid xylem sap more metastable,

[1] This project was funded by the Climagie Project within the Metaprogramme Adaptation of Agriculture and Forests to Climate Change (AAFCC) of the French National Institute for Agriculture Research (INRA) and by the program "Investments for the Future" (ANR-10-EQPX-16 and XYLOFOREST) from the French National Agency for Research. The Swiss contribution was part of the project GrassAlt, funded by the Swiss National Science Foundation (SNF CR31I3_156282/1). F.L. received support from the Alberta Mennega Foundation.

* Address correspondence to frederic.lens@naturalis.nl.

The author responsible for distribution of materials integral to the findings presented in this article in accordance with the policy described in the Instructions for Authors (www.plantphysiol.org) is: Frederic Lens (frederic.lens@naturalis.nl).

F.L., H.C., and S.D. designed research; F.L., C.P.-C., C.S., A.B., S.J., T.C., L.C.D., and M.D.A. performed experiments; C.E.L.D., H.C., and S.D. analyzed data; F.L. wrote the article with contributions from all the authors.

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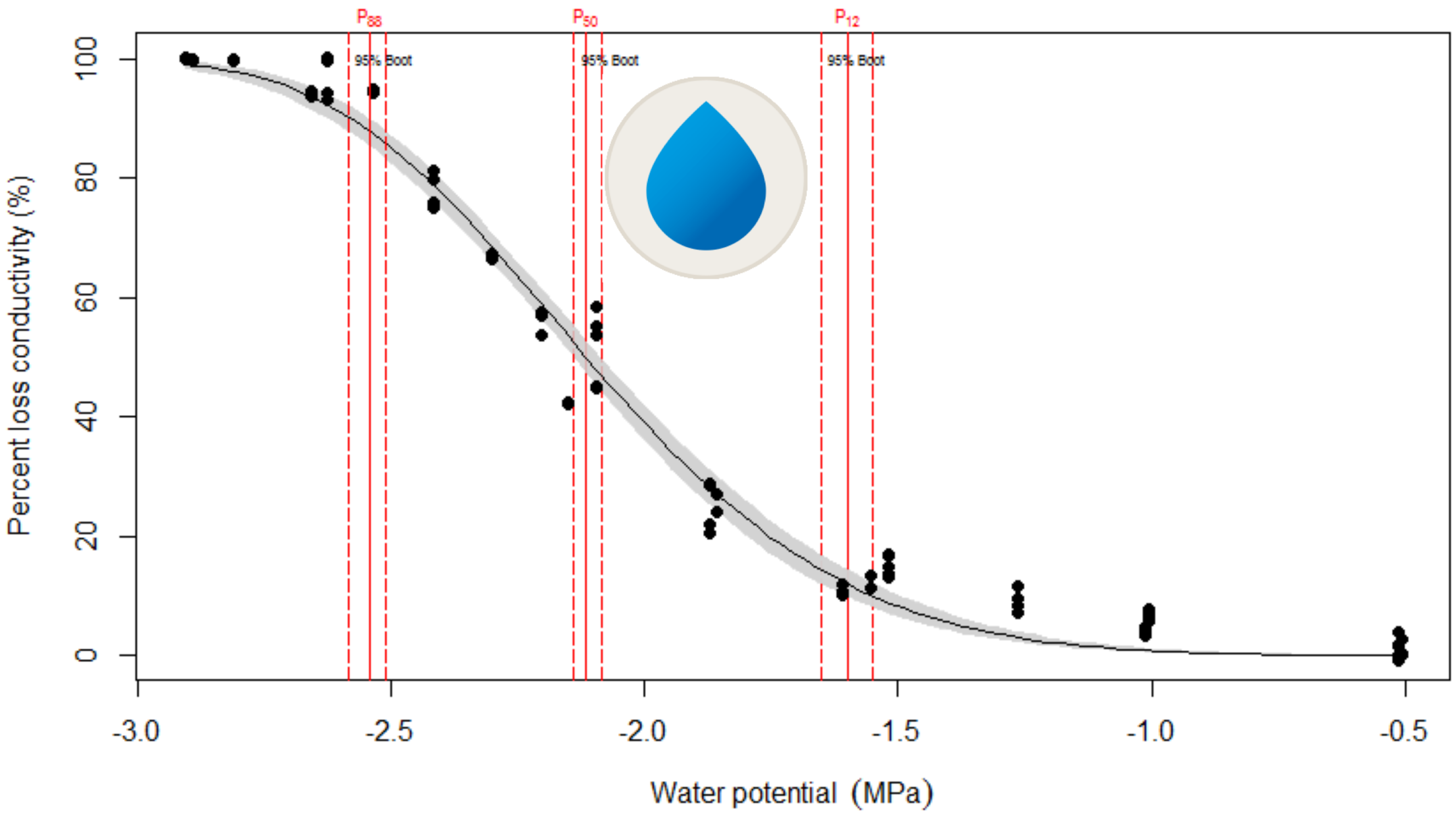
www.plantphysiol.org/cgi/doi/10.1104/pp.16.00829

Vulnerability of amenity trees to embolism



Cercidiphyllum japonicum

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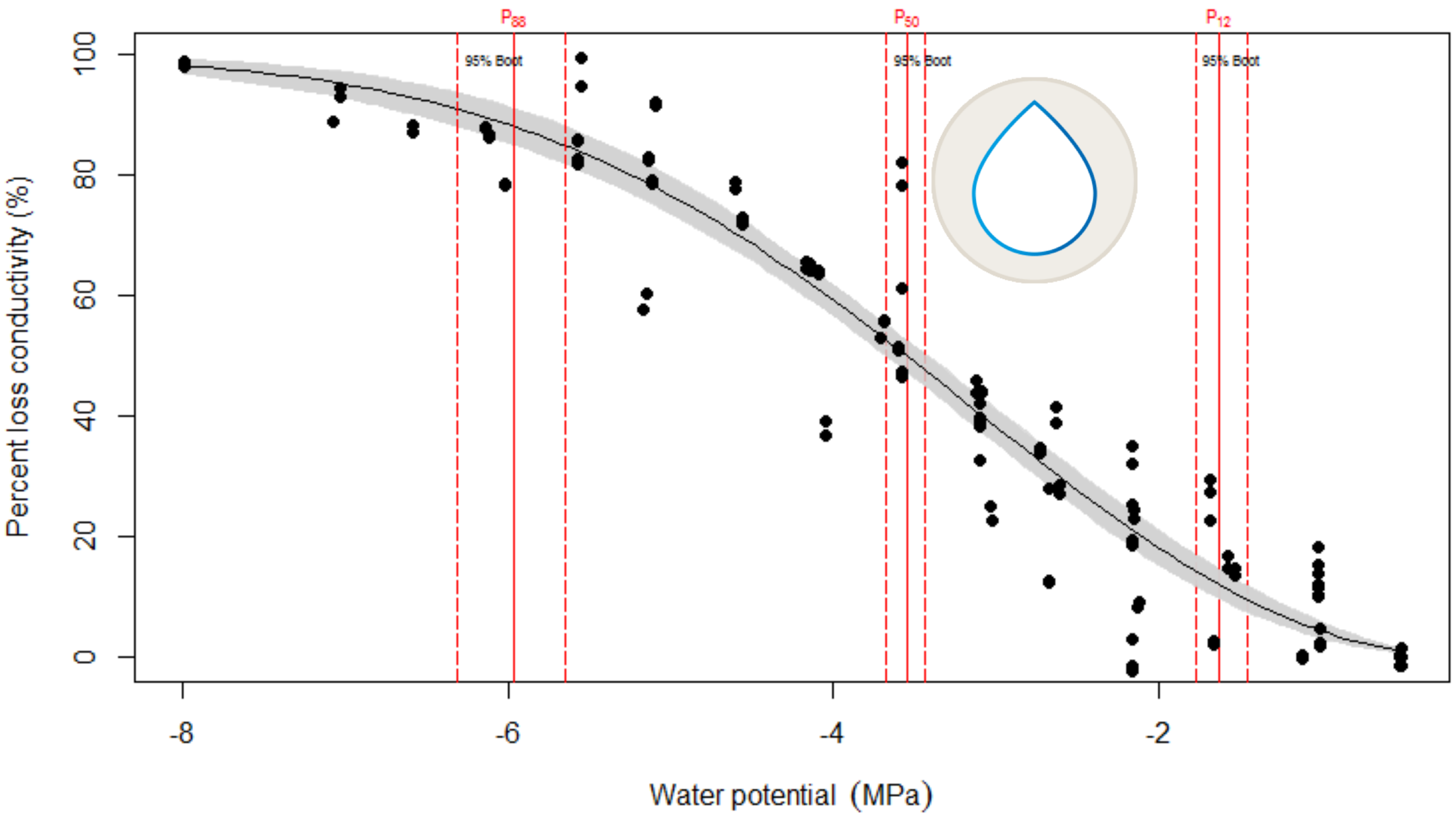
Vulnerability of amenity trees to embolism



Eucommia ulmoides

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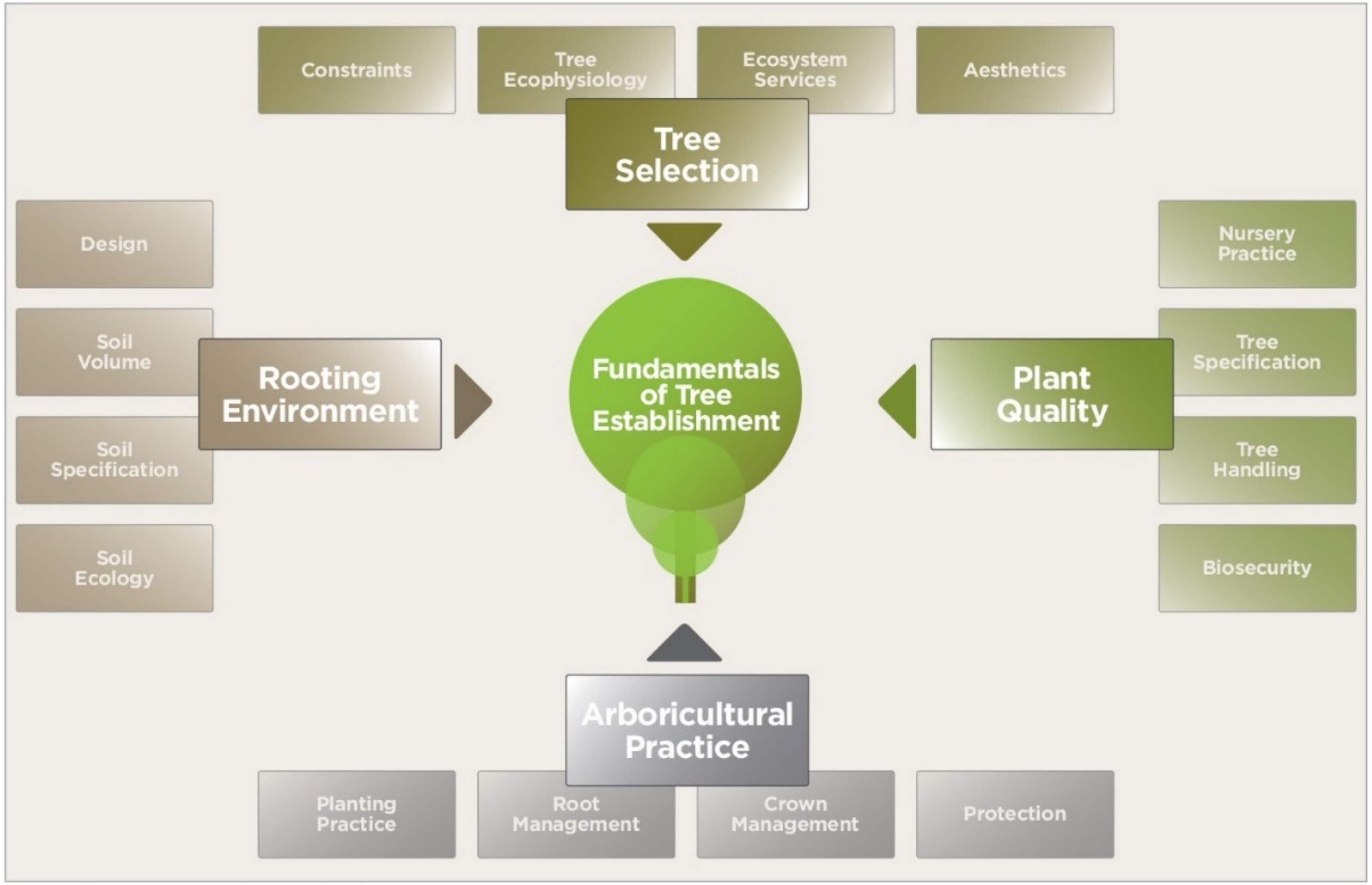
Consequences of high PLC

Appropriate tree selection does not secure tree establishment!



Adapted from: Hirons and Percival 2012

Figure from: Hirons and Sjöman (2018)

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A Guide for Specifiers

Issue 1.2/2018

Written by:
Dr Andrew Hirons and Dr Henrik Sjöman

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Primary Project Funder
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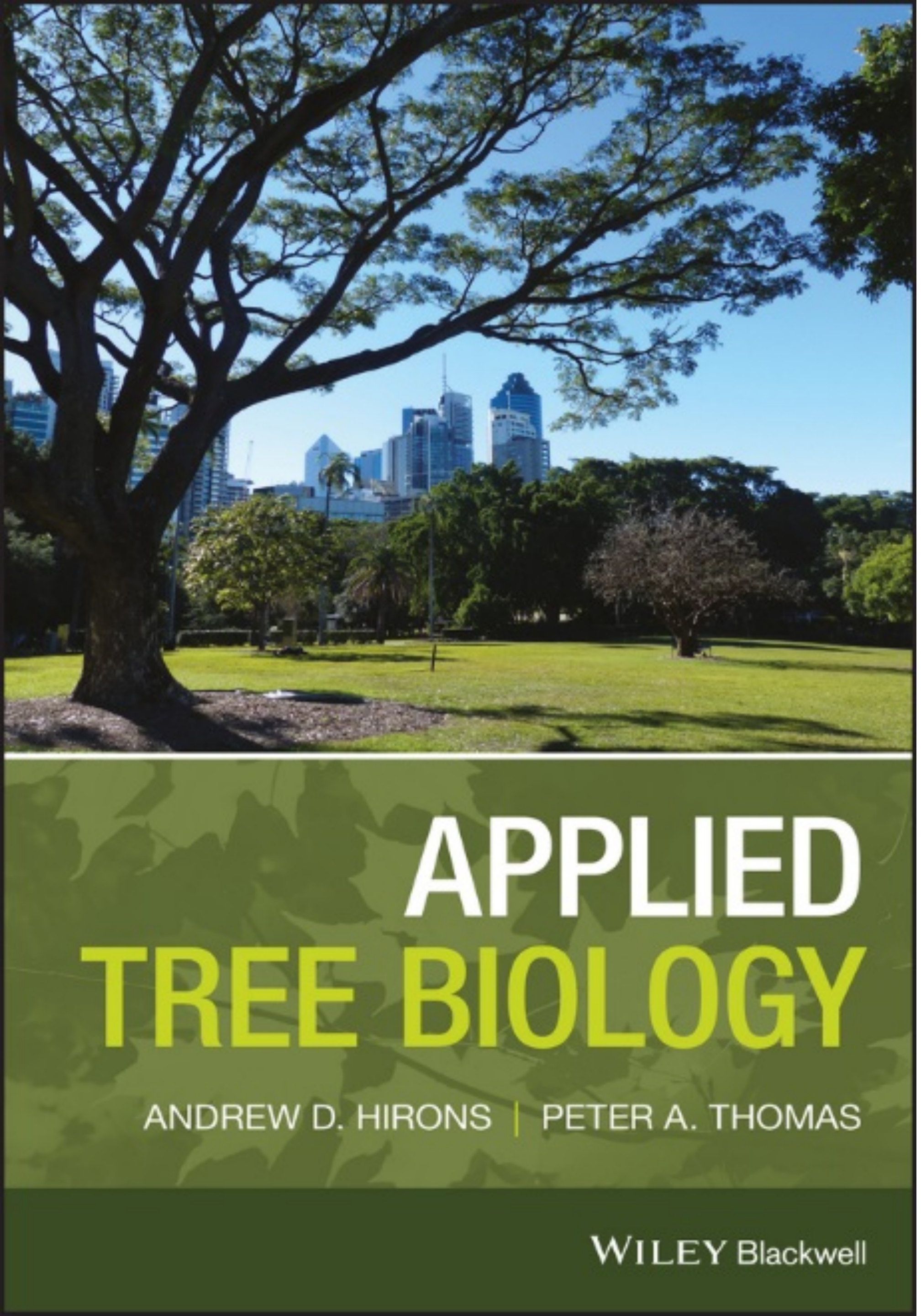

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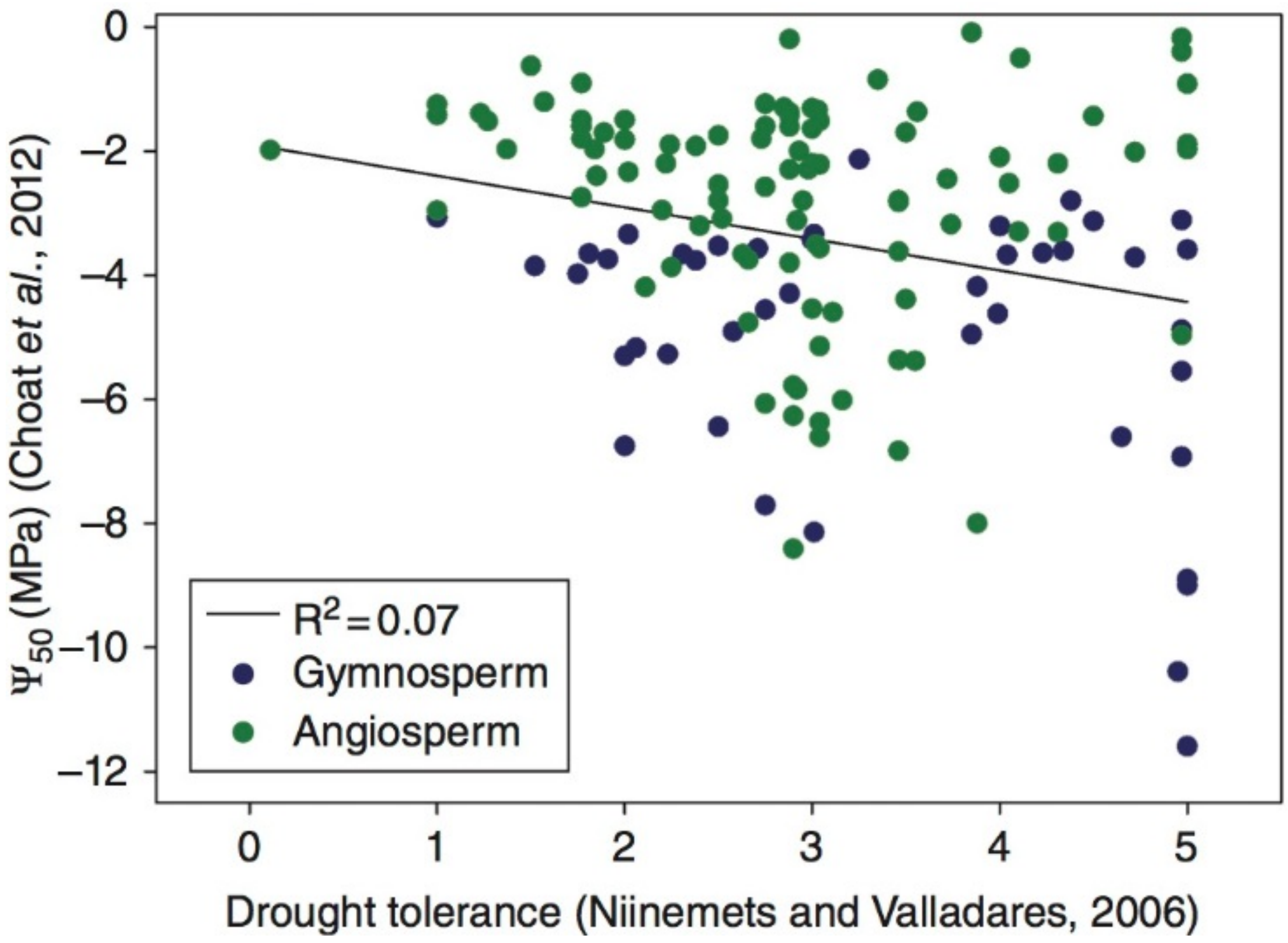
•*I saw your talk at ecobuild and have been anticipating this ever since, it's fantastic. Congratulations of making such an empowering, practical, and hopefully change enabling tool.*
•*Congratulations on the production of the new Tree Species Selection Guide - a wonderful piece of work which I imagine will be hugely useful across the country. I'm very impressed with the linked, browsable PDF document which is a technique I will look into.*
•*I have just been reading your tree selection guide and it is excellent. As a life long tree lover, qualified horticulturalist, and part-time garden designer, this is the best reference work I have come across. Thank you very much for all the care you and your colleagues have put into its preparation.*
•*This looks very useful- my congratulations to you and all concerned. I have already put it to use, as a double check on species selection in a current project.*



Hirons and Thomas (2018)