Enhancing tree selection for future urban environments

Dr Andrew Hirons

URBAN PLANT LAB

University Centre Myerscough


August 12 2022


THE Sun
MAY IN 'NO' TO NO DEAL
DON'T MISS OUT
HOLS FROM £9.50
QUEEN OLIVIA'S OSCAR BRAVO
RECORD-BREAKING SUNSHINE
FABRUARY
20°C
UK has hottest winter day ever


THE Sun
WHEN MEG MET HARRY'S PALS
HOLS FROM £9.50
IT'S SUPER SCORCHIO!
UK will be one of world's warmest spots
41°
Beaches full as offices & schools shut
HOTTER THAN THE SAHARA
...AND INDIA...AND PAKISTAN...AND ALGERIA...AND ETHIOPIA...


DAILY STAR
FADI NICKED
Barry girl dies at 33
FREE INSIDE
YOUR GAMES & GADGETS PULLOUT
Hottest day in Britain EVER
Workers told: Stay at home
Gritters stop roads melting
39C
RECORD BAKER


Is this the end of the movie star?
You love her so much right now! The top tracks by Kelis – ranked
The Guardian
Fears for NHS patient data after cyber-attack
Drought alert: new rules on way as climate crisis bites
Unions warn on cost of living crisis


DAILY Mirror
£10 off No7
EXCLUSIVE
Gemma: If Penny can do it, so can I
NATIONAL EMERGENCY
MELTDOWN
First ever red alert on deadly heatwave issued
Extreme Heat
41C scorcher to close roads and stop trains
NHS braced for casualties, schools to shut
30
30
38
37
41


70p
i
The Big Breakfast is back!
No new measures to help with cost of living
Heatwave UK: drought may last months


70p
i
Day of reckoning for Truss and Mordaunt
Earth sends a warning
Dark truths about motherhood

“If you can see me weep”

A 'hunger stone' on the bank of the Elbe River in the Decin, Czech Republic. (Michal Cizek/AFP/Getty Images)

The consequences...

More than 12,000 trees planted across a city have died because they were not watered enough during the summer heatwave.

Gloucester City Council announced in February that it would plant 12,800 saplings across the city as part of its aim to become carbon neutral.

Councillors have since been told that 95% of them - about 12,100 - have died.

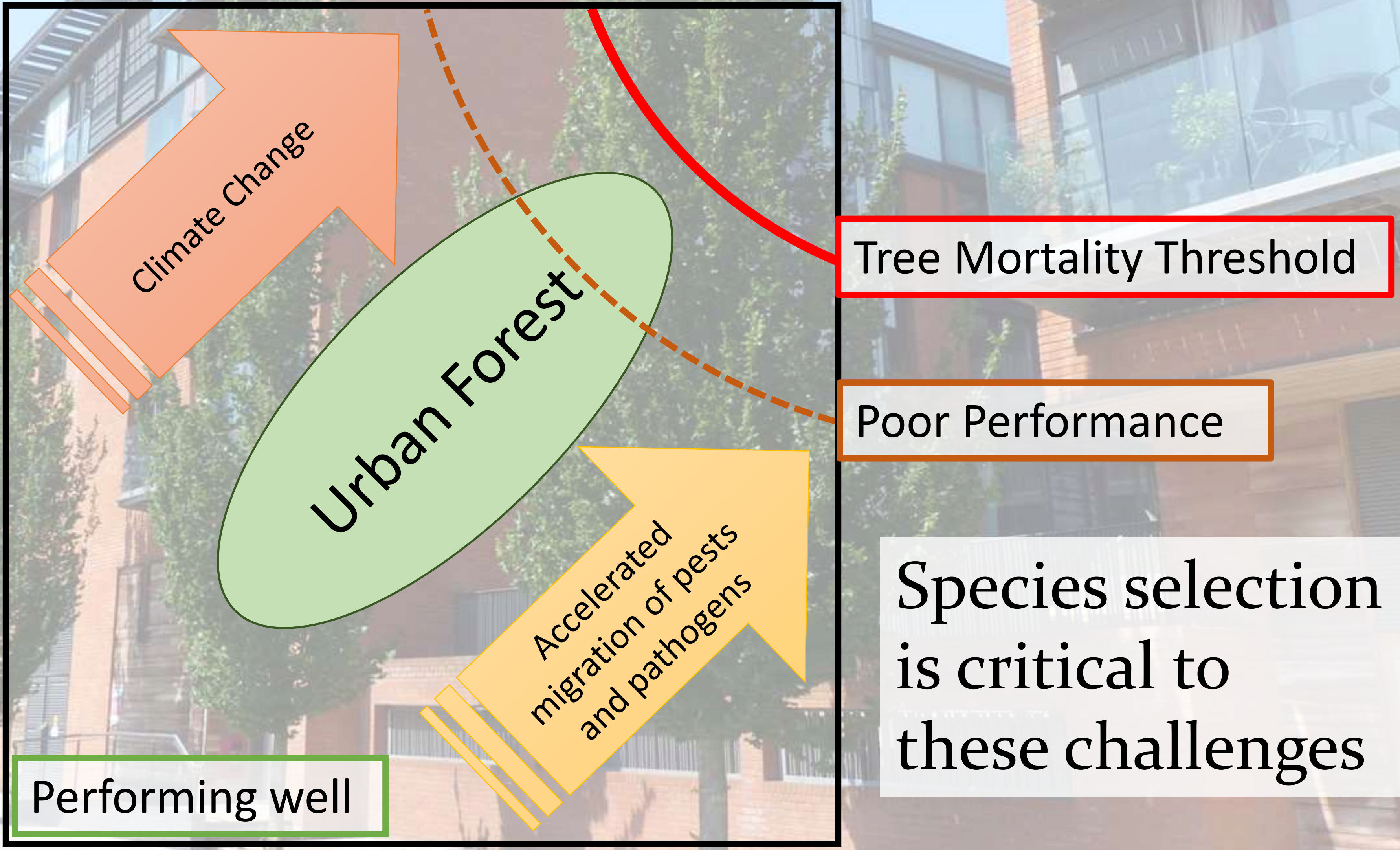
The council blamed the trees' demise on the "unprecedented" hot and dry weather.

Lack of aftercare kills 12,000 trees planted in Gloucester

2 days ago

Climate change

Strategic challenges for the urban forest



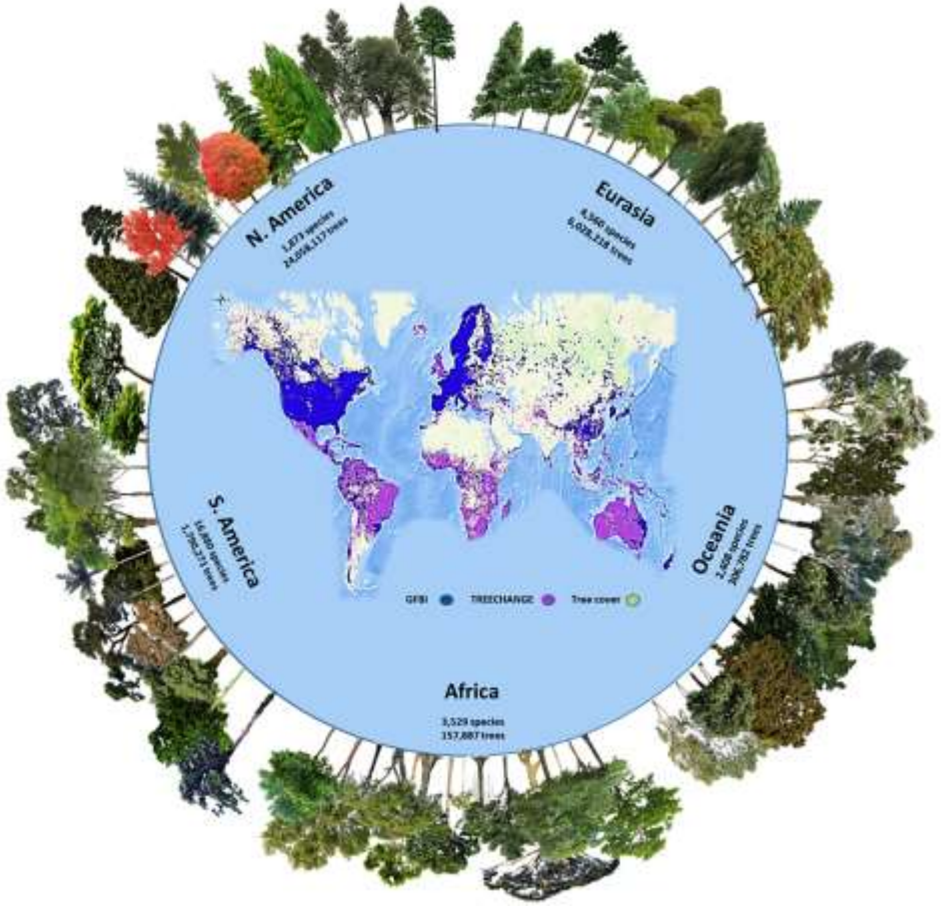
Species selection is critical to these challenges

About 73,000 tree species globally

The number of tree species on Earth

Roberto Cazzolla Gatti[a,b,c], Peter B. Reich[d,e,f,1], Javier G. P. Gamarra[g], Tom Crowther[h], Cang Hui[i,j], Albert Morera[k,l], Jean-Francois Bastin[m], Sergio de-Miguel[k,l], Gert-Jan Nabuurs[n], Jens-Christian Svenning[o,p], Josep M. Serra-Diaz[q], Cory Merow[r], Brian Enquist[s], Maria Kamenetsky[t], Junho Lee[u], Jun Zhu[v], Jinyun Fang[w], Douglass F. Jacobs[a], Bryan Pijanowski[a], Arindam Banerjee[x], Robert A. Giaquinto[y], Giorgio Alberti[z,aa], Angelica Maria Almeyda Zambrano[bb], Esteban Alvarez-Davila[cc], Alejandro Araujo-Murakami[dd], Valerio Avitabile[ee], Gerardo A. Aymard[ff,gg], Radomir Balazy[hh], Chris Baraloto[ii], Jorcely G. Barroso[jj], Meredith L. Bastian[kk,ll], Philippe Birnbaum[mm,nn], Robert Bitariho[oo], Jan Bogaert[m], Frans Bongers[n], Olivier Bouriaud[pp], Pedro H. S. Brancalion[qq], Francis Q. Brearley[rr], Eben North Broadbent[ss], Filippo Bussotti[tt], Wendeson Castro da Silva[uu,vv], Ricardo Gomes César[qq], Goran Češljar[ww], Víctor Chama Moscoso[xx], Han Y. H. Chen[yy], Emil Cienciala[zz,aaa], Connie J. Clark[bbb], David A. Coomes[ccc], Selvadurai Dayanandan[ddd], Mathieu Decuyper[eee,fff], Laura E. Dee[ggg], Jhon Del Aguila Pasquel[hhh], Géraldine Derroire[iii], Marie Noel Kamdem Djuikouo[jjj], Tran Van Do[kkk], Jiri Dolezal[lll,mmm], Ilija D. Đorđević[ww], Julien Engel[nnn], Tom M. Fayle[ooo], Ted R. Feldpausch[ppp], Jonas K. Fridman[qqq], David J. Harris[rrr], Andreas Hemp[sss], Geerten Hengeveld[ttt], Bruno Herault[uuu,vvv,www], Martin Herold[xxx,yyy], Thomas Ibanez[zzz,aaaa], Andrzej M. Jagodzinski[bbbb], Bogdan Jaroszewicz[cccc], Kathryn J. Jeffery[dddd], Vivian Kvist Johannsen[eeee], Tommaso Jucker[ffff], Ahto Kangur[gggg], Victor N. Karminov[hhhh], Kuswata Kartawinata[iiii,jjjj], Deborah K. Kennard[kkkk], Sebastian Kepfer-Rojas[llll], Gunnar Keppel[mmmm], Mohammed Latif Khan[nnnn], Pramod Kumar Khare[oooo], Timothy J. Kileen[pppp], Hyun Seok Kim[qqqq,rrrr,ssss,tttt], Henn Korjus[gggg], Amit Kumar[uuuu], Ashwani Kumar[vvvv], Diana Laarmann[gggg], Nicolas Labrière[wwww], Mait Lang[gggg,xxxx], Simon L. Lewis[yyyy,zzzz], Natalia Lukina[hhhh], Brian S. Maitner[aaaaa], Yadvinder Malhi[bbbbb], Andrew R. Marshall[ccccc,ddddd], Olga V. Martynenko[eeeee], Abel L. Monteagudo Mendoza[fffff], Petr V. Ontikov[ggggg], Edgar Ortiz-Malavasi[hhhhh], Nadir C. Pallqui Camacho[iiiii], Alain Paquette[jjjjj], Minjee Park[a], Narayanaswamy Parthasarathy[kkkkk], Pablo Luis Peri[lllll], Pascal Petronelli[mmmmm], Sebastian Pfautsch[nnnnn], Oliver L. Phillips[yyyy], Nicolas Picard[g,ooooo], Daniel Piotto[ppppp], Lourens Poorter[n], John R. Poulsen[bbb], Hans Pretzsch[qqqqq], Hirma Ramírez-Angulo[rrrrr], Zorayda Restrepo Correa[sssss], Mirco Rodeghiero[ttttt,uuuuu], Rocío Del Pilar Rojas Gonzáles[vvvvv], Samir G. Rolim[wwwww], Francesco Rovero[xxxxx,yyyyy], Ervan Rutishauser[zzzzz], Purabi Saikia[aaaaaa], Christian Salas-Eljatib[bbbbbb,cccccc,dddddd], Dmitry Schepaschenko[eeeeee,ffffff], Michael Scherer-Lorenzen[gggggg], Vladimír Šebeň[hhhhhh], Marcos Silveira[iiiiii], Ferry Slik[jjjjjj], Bonaventure Sonké[kkkkkk], Alexandre F. Souza[llllll], Krzysztof Jan Stereńczak[mmmmmm], Miroslav Svoboda[nnnnnn], Hermann Taedoumg[oooooo,pppppp], Nadja Tchebakova[eeeeee], John Terborgh[qqqqqq,rrrrrr], Elena Tikhonova[hhhh], Armando Torres-Lezama[ssssss], Fons van der Plas[tttttt], Rodolfo Vásquez[vvvvv], Helder Viana[uuuuuu,vvvvvv], Alexander C. Vibrans[wwwwww], Emilio Vilanova[xxxxxx], Vincent A. Vos[yyyyyy], Hua-Feng Wang[zzzzzz], Bertil Westerlund[aaaaaaa], Lee J. T. White[bbbbbbb,ccccccc,ddddddd], Susan K. Wiser[eeeeeee], Tomasz Zawiła-Niedźwiecki[fffffff], Lise Zemagho[kkkkkk], Zhi-Xin Zhu[ggggggg], Irié C. Zo-Bi[hhhhhhh], and Jingjing Liang[a,1]

ECOLOGY



Cazzolla Gatti *et al.,* (2022) *PNAS* Vol. 119 No. 6

How do we improve selection decisions?

- Ecological theory
- Ecophysiological strategies
- Trait based assessment
- Biogeographical data analysis

How do trees cope with limited water availability?

Adaptations to limited water availability

Avoidance of tree water deficit		Tolerance of water deficit	
Maximizing water acquisition	Reduce water use		
Increased hydraulic conductivity	Stomatal closure	Osmotic adjustment Low turgor loss point	Physiological
Deep rooting Root proliferation	Reduced leaf and stem growth Increased resistance to leaf water loss	Resistance to drought-induced cavitation	Structural
	Leaf phenology Leaf abscission		Life cycle

Hirons and Thomas 2018

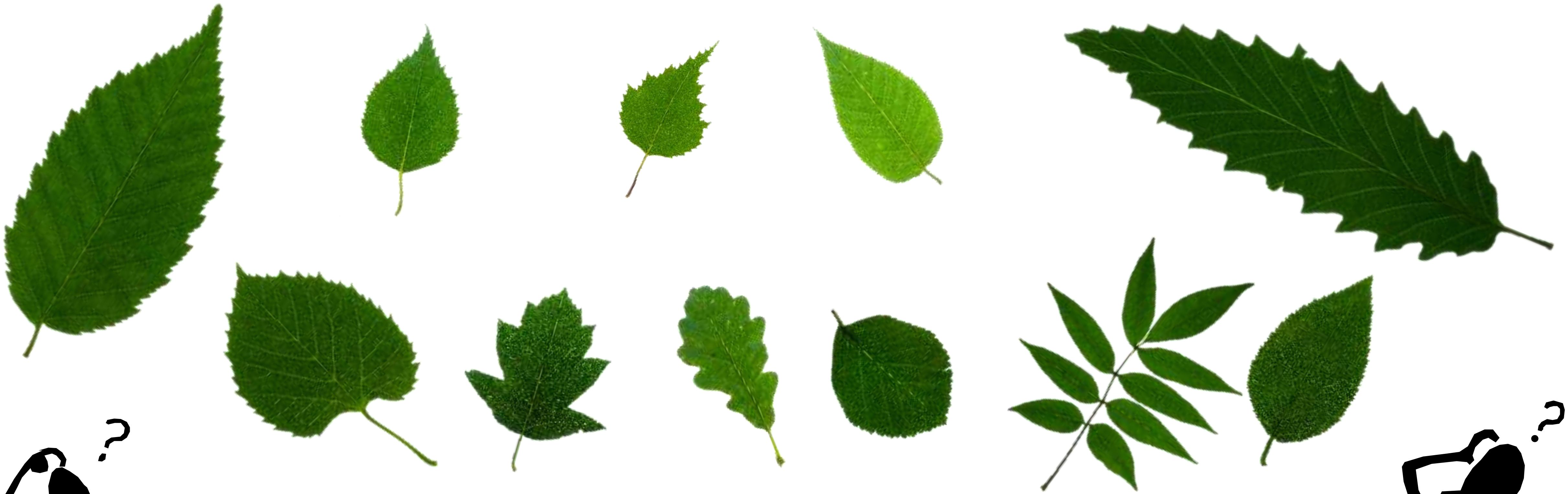
Avoid 'avoiders' for the challenging sites

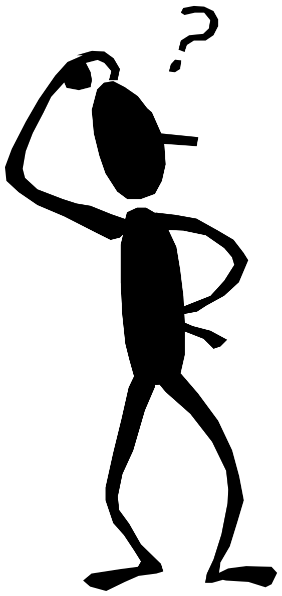
Tilia x euchlora

Betula utilis

Drought tolerant trees have an inherent resilience to water deficits

- Able to extract water from the soil for longer during a drying cycle
- Maintain physiological activity for longer
  - Carbon gain
  - Transpiration > Evaporative cooling
- Will perform better as landscape trees on challenging sites





How can we select for drought tolerance?

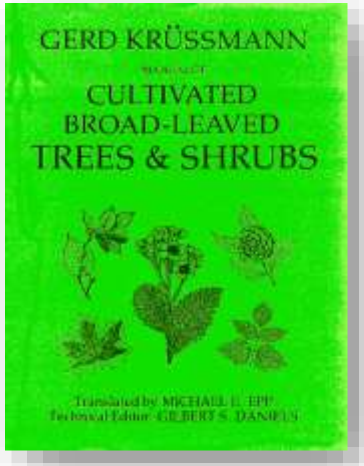

PLANTS OF CHINA
WOODY SHRUBS AND TREES
STADSTRÄDSLEXIKON
TRÄD I URBANA LANDSKAP
PLANT ECOLOGY
Tree Statics and Tree Inspection
TREES FOR AMERICAN GARDENS
Trees for All Seasons
Wurzelatlas
Trees of Western North America
Trees of Eastern North America
STEPPES
Trees & Shrubs
JONES Plants and Microclimate
Forest Giants of the Pacific Coast
Marschner's Mineral Nutrition of Higher Plants
ENCYCLOPEDIA OF TREES & SHRUBS
TREES
New Trees
Kew
The Secret Life of Trees
Ladders to Heaven
TREE GUIDE
TREES & SHRUBS HARDY IN THE BRITISH ISLES
W.J. BEAN
JOHN MURRAY
ECOSYSTEMS OF THE WORLD
7
6
10
15
Flint
LANDSCAPE PLANTS FOR EASTERN NORTH AMERICA
NATIVE TREES
TREES FOR THE SMALL GARDEN
LANDSCAPE PLANTS OF ARABIA
JULIAN LEE
G

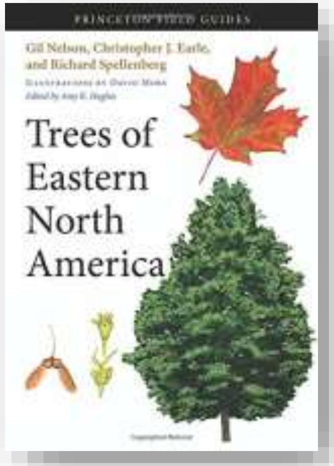
Male flower of *Acer negundo* (Duncan Slater)

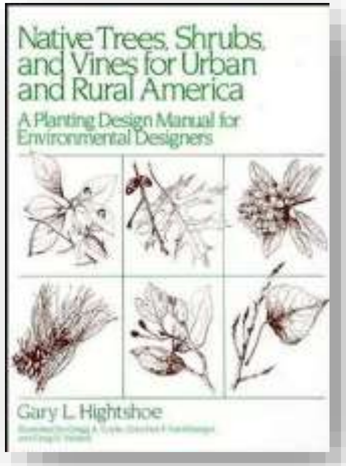
Advice from literature…

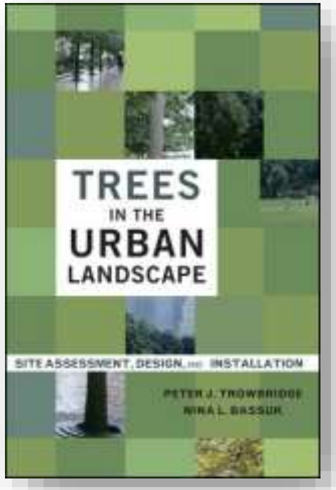
Acer negundo

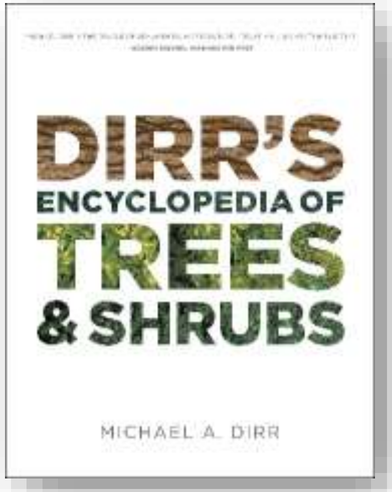
- Useful for sandy, dry to sterile soil (Krüssmann 1982)
- Drought tolerant (Stoecklein 2001)
- Its native habitat is along streams and ponds (Grimm 2002)
- Native in moist habitats but performs well also in poor, wet, or dry habitats (Dirr 2009)
- Very heat and drought tolerant (Hightshoe 1988)
- Grows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

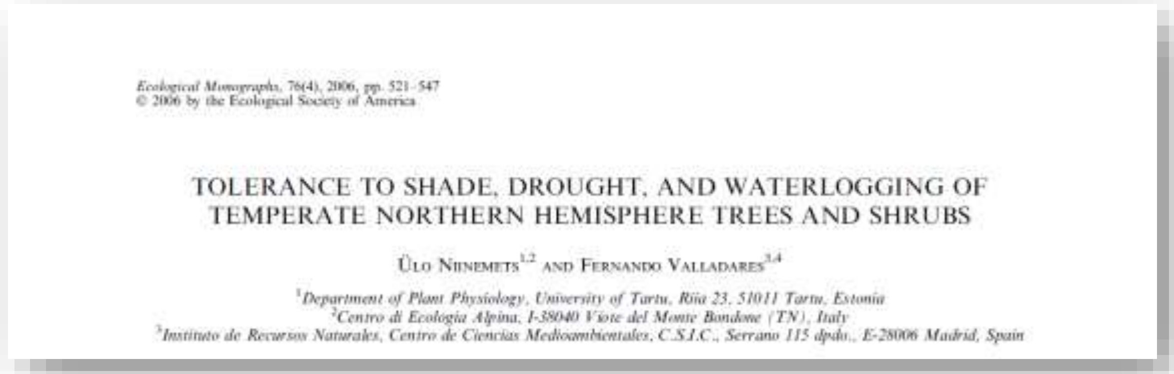












Ecological Monographs, 76(4), 2006, pp. 521–547
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TOLERANCE TO SHADE, DROUGHT, AND WATERLOGGING OF TEMPERATE NORTHERN HEMISPHERE TREES AND SHRUBS

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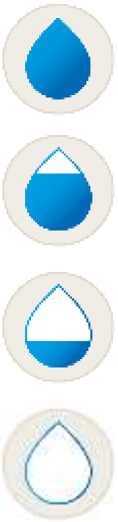
Drought Tolerance Index



Scale ranking	Annual precipita (m	Distri		Soil water tial (MPa)	Duration of dry period
1					A few days
2				-0.8	A few weeks
3	4			-0.8 to -1.5	Up to a month
4	300-400	20-25%	0.5:0.8	-1 -3	Two to three months
5	<300	>25%	<0.5	< -3	More than three months

But, does survival equal performance in our urban landscapes?

Adapted from: Niinemets and Valladares 2006

Using plant traits – leaf turgor loss

- 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

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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 (p_{tlp}), is classically recognised as a major physiological determinant of plant water stress response. However, the cellular basis of p_{tlp} and its importance for predicting ecological drought tolerance have been controversial. A meta-analysis of 317 species from 72 studies showed that p_{tlp} was strongly correlated with water availability within and across biomes, indicating power for anticipating drought responses. We derived new equations giving both p_{tlp} and relative water content at turgor loss point (RWC_{tlp}) as explicit functions of osmotic potential at full turgor (p_o) and bulk modulus of elasticity (e). Sensitivity analyses and meta-analyses showed that p_o is the major driver of p_{tlp}. In contrast, e 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.

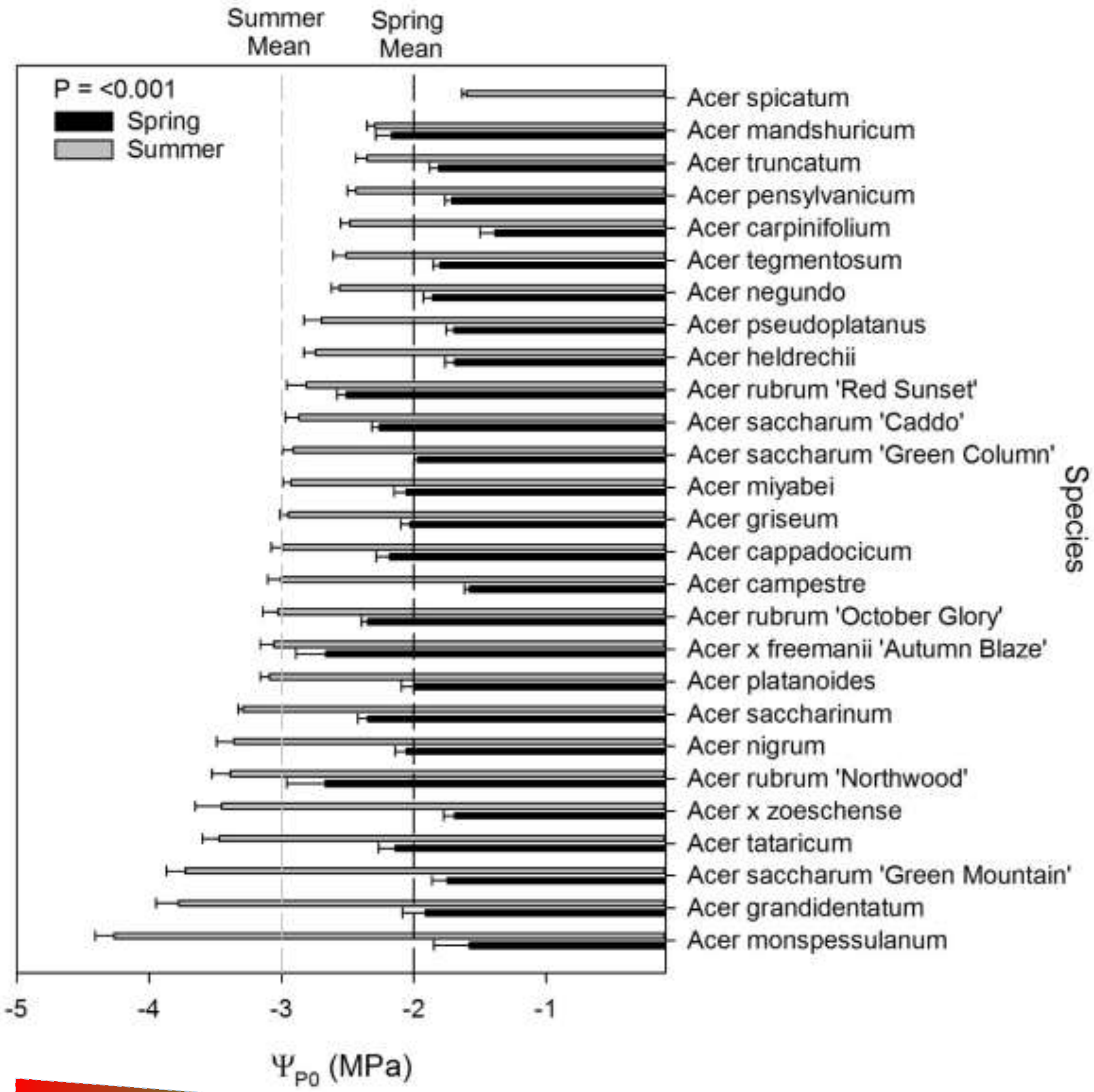
Ecology Letters (2012) 15: 393–405

Drought tolerance in *Acer*




University Centre Myerscough

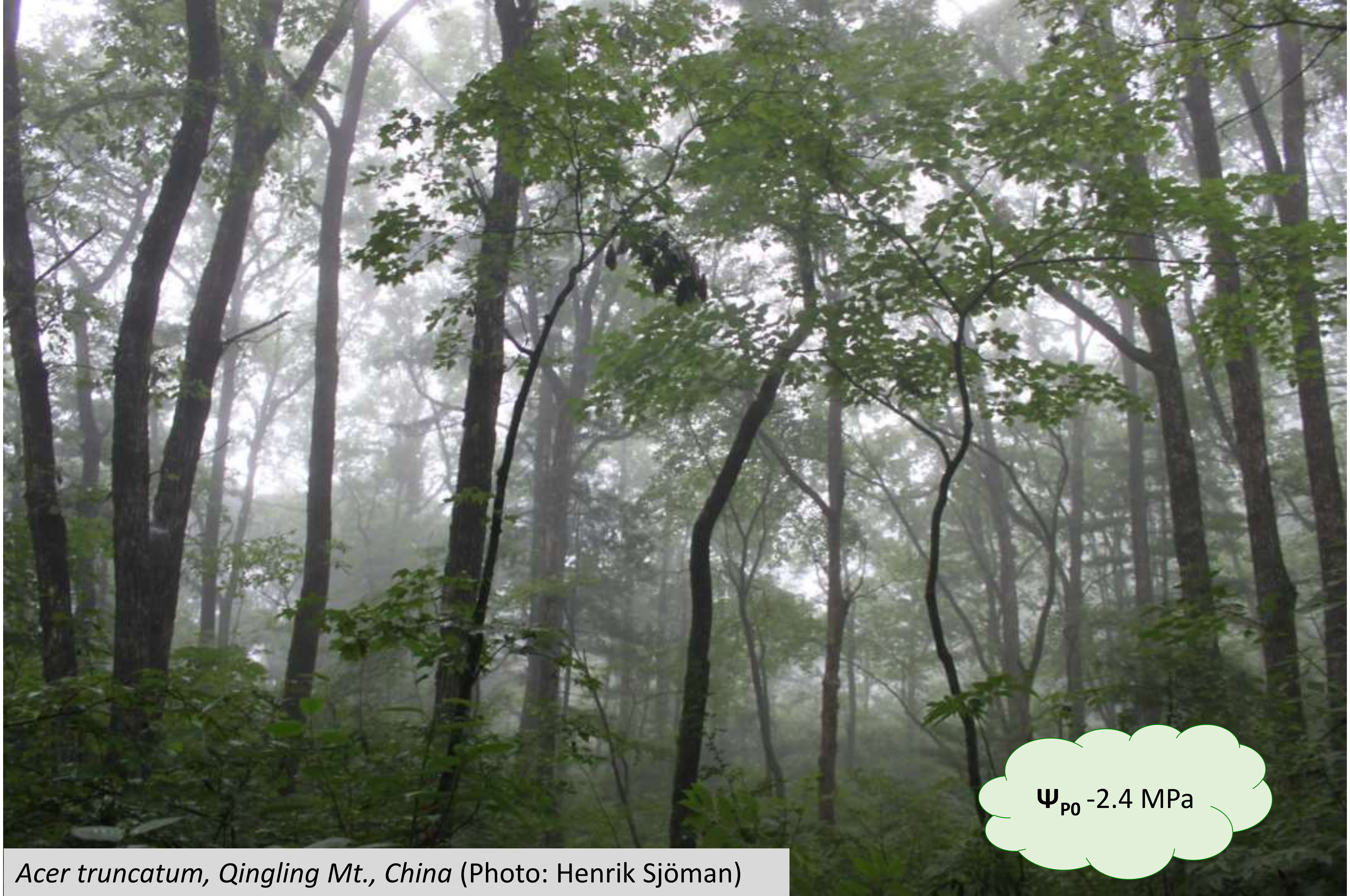
SLU



Drought tolerance

Sjöman, Hirons and Bassuk (2015)

Acer spicatum, NY, USA

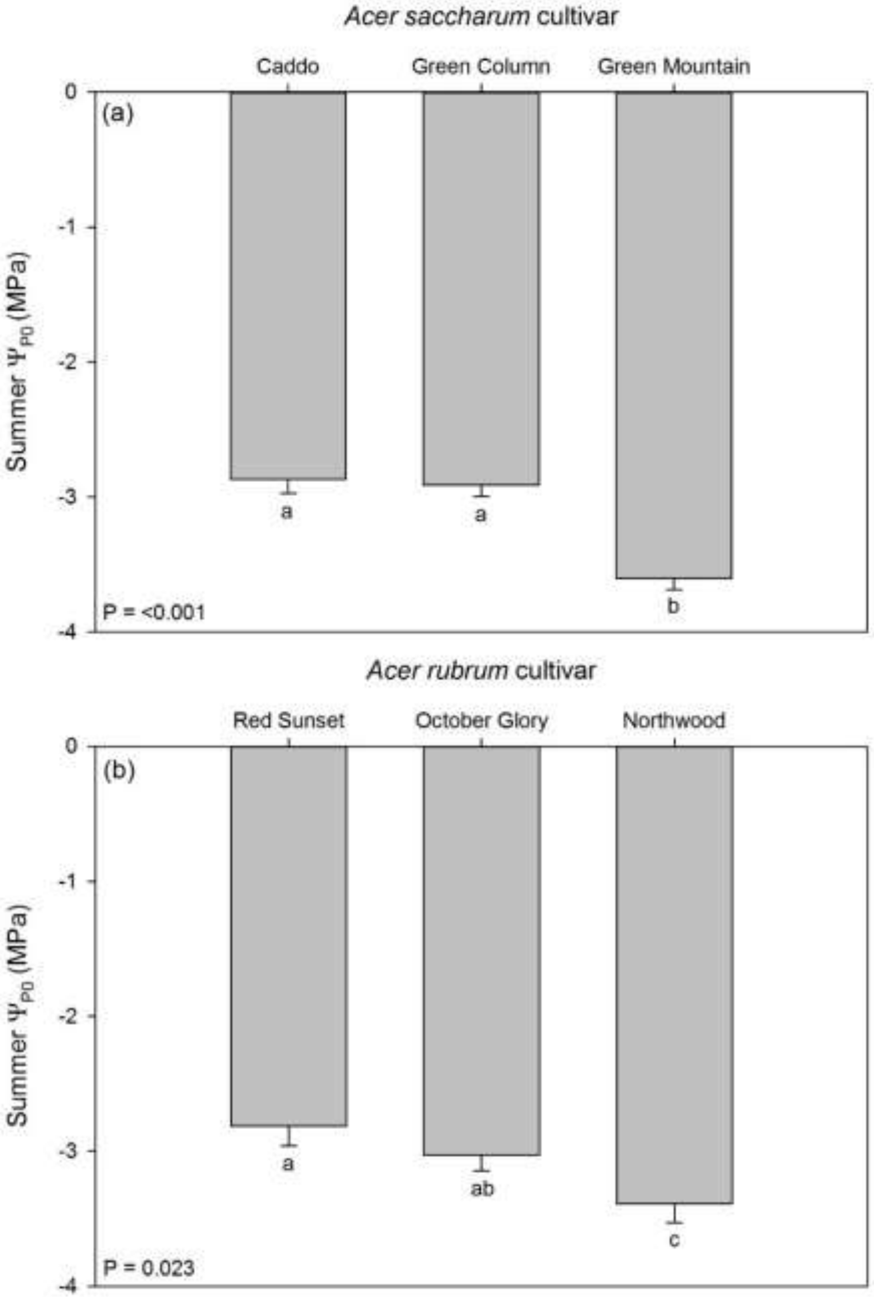


Acer truncatum, Qingling Mt., China (Photo: Henrik Sjöman)

Acer tataricum & Quercus pubescens, Steppe Forest in Eastern Romania. (Photo: Henrik Sjöman)

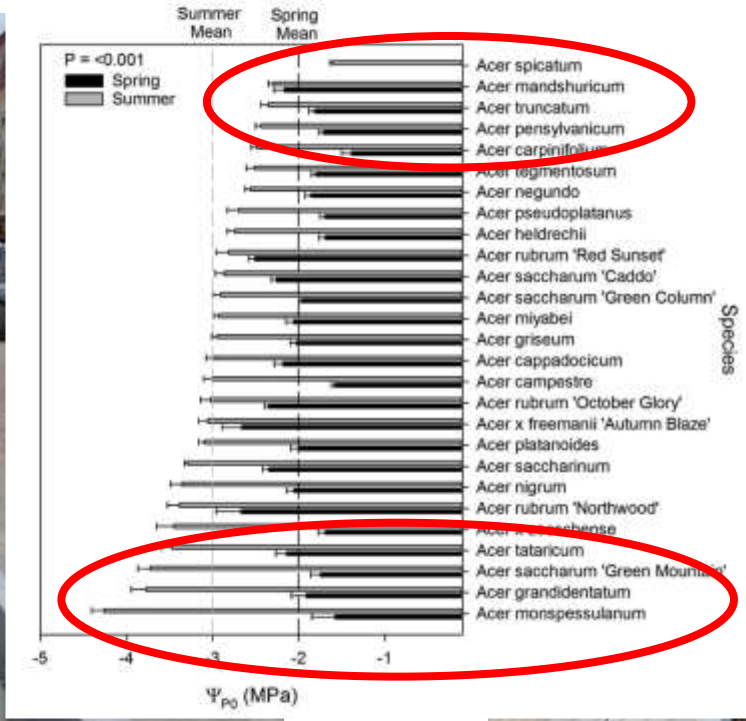
Acer grandidentatum, Utah, USA (Photo: Henrik Sjöman)

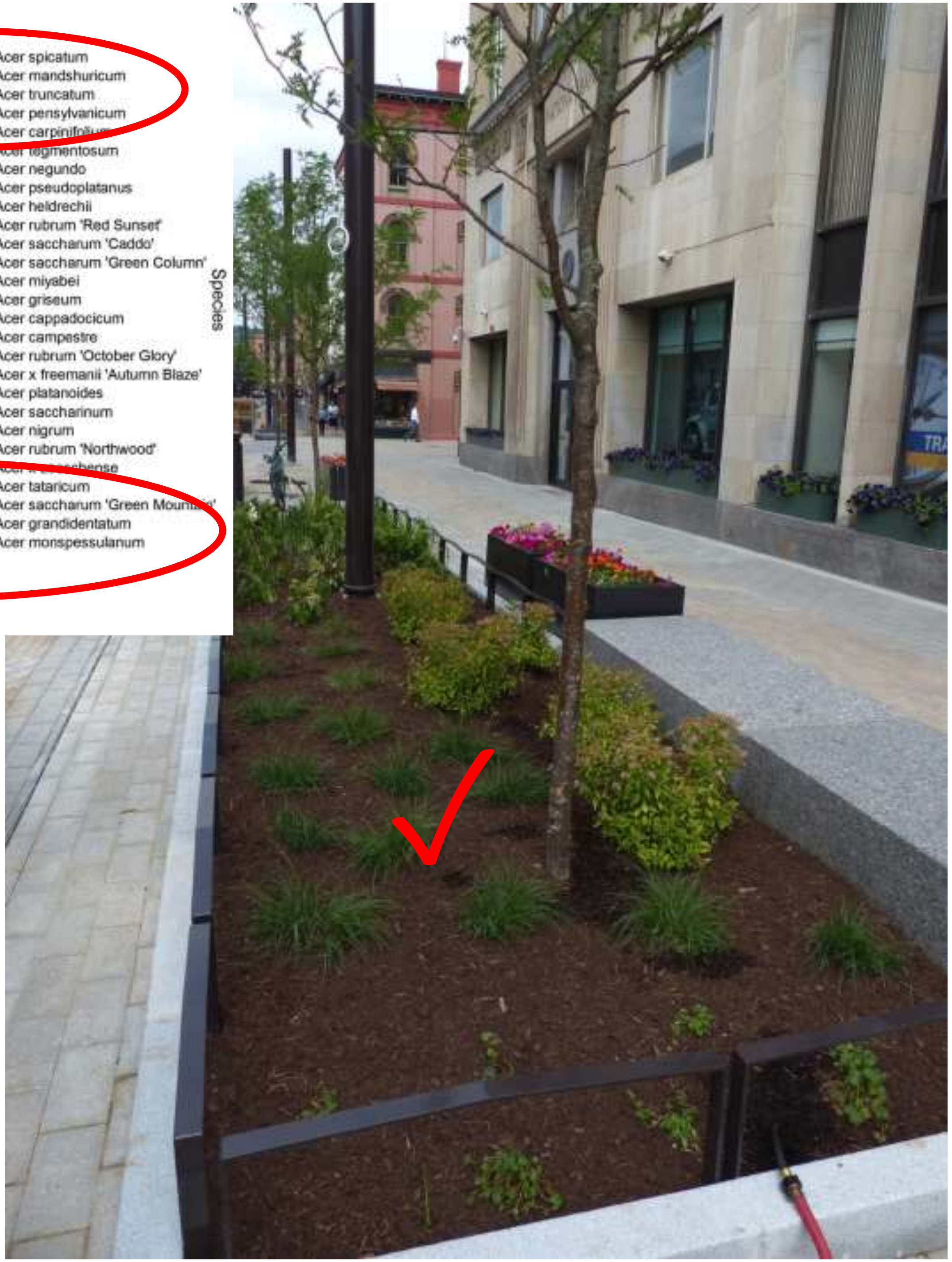
Acer cultivars



Sjöman, Hirons and Bassuk (2015)


MARKET
Urban planting beds in Ithaca


Summer Mean
Spring Mean
P = <0.001
Spring
Summer
Acer spicatum
Acer mandshuricum
Acer truncatum
Acer pensylvanicum
Acer carpinifol
Acer tegmentosum
Acer negundo
Acer pseudoplatanus
Acer heldrechii
Acer rubrum 'Red Sunset'
Acer saccharum 'Caddo'
Acer saccharum 'Green Column'
Acer miyabei
Acer griseum
Acer cappadocicum
Acer campestre
Acer rubrum 'October Glory'
Acer x freemanii 'Autumn Blaze'
Acer platanoides
Acer saccharinum
Acer nigrum
Acer rubrum 'Northwood'
Acer tataricum
Acer saccharum 'Green Moun
Acer grandidentatum
Acer monspessulanum
Species
-5
-4
-3
-2
-1
Ψ_{P0} (MPa)



Conclusions of study

- Wide variation in physiological drought tolerance across closely related species and cultivars.
- May be a useful trait for the screening and selection of urban trees.
- Should provide evidence for nurseries to reduce the risk of taking on new plant material.

Urban Forestry & Urban Greening 14 (2015) 858–865

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/ufug

Urban forest resilience through tree selection—Variation in drought tolerance in *Acer*

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ABSTRACT

It is widely recognized that trees contribute a range of ecosystem services in urban environments. However, the magnitude of their contribution is closely related to their physiological condition and capacity to persist within our towns and cities. Root loss during transplanting, limited soil volume, disruption to soil hydrological processes and impermeable surfaces result in water deficits being major physiological stress limiting the performance of urban trees. The leaf water potential at turgor loss (Ψ_{P0}) provides a robust measure of drought tolerance since a more negative Ψ_{P0} allows the leaf to maintain physiological function over a wider range of leaf water potentials and, by implication, soil matric potentials (Ψ_{soil}). In this study, Ψ_{P0} was calculated for 27 maple (*Acer*) genotypes based on a known linear relationship between the osmotic potential at full turgor ($\Psi_{\pi 100}$) and Ψ_{P0}. In spring, Ψ_{P0} varied between −1.4 MPa in *Acer carpinifolium* and −2.7 in both *Acer rubrum* 'Northwood' and *Acer x freemanii* 'Autumn Blaze'. During summer, *Acer spicatum* had the highest Ψ_{P0} at −1.6 MPa and *Acer monspessulanum* had the lowest Ψ_{P0} at −4.3 MPa. Significant differences in Ψ_{P0} were found between cultivars of *A. rubrum* and *Acer saccharum*. A highly significant relationship was found between seasonal osmotic adjustment and summer Ψ_{P0} suggesting that osmotic adjustment is a driving force for summer Ψ_{P0} in *Acer* leaves. These data confirm the wide range of tolerance to water deficits in *Acer* and give important insight into the potential of species to tolerate periods of low water availability by providing quantitative data not previously available. The technique shows great promise as a screening tool for the drought tolerance of new and traditional plant material. This data will be highly relevant for those selecting trees for urban sites as well as for nurseries seeking to evaluate genotypes for production purposes.

1. Introduction

Trees are major components of the green infrastructure in urban environments and their contribution to a range of ecosystem services is widely recognized. These services include mitigation of flood risk, reduced energy use in buildings, increased thermal comfort, mitigation of the urban heat island effect, recreational values, and the enhancement of cultural and aesthetic qualities, etc. (in e.g. Akbari et al., 2001; Xiao and McPherson, 2002; Grahn and Stigsdotter, 2003; Gill et al., 2007; Tyrväinen et al., 2005; Tzoulas et al., 2007).

Since the provision of these services is reliant on healthy trees, assessments of projected ecosystem services frequently assume large, mature trees with good growth rates (Gómez-Muñoz et al., 2010). This assumption is misguided as many urban sites do not provide a high quality growth environment. Variation in the rooting environment of *Pyrus calleryana* Decne. trees lead to an approximately 80% reduction in evapotranspirational cooling as a result of suppressed stomatal conductance (Rahman et al., 2011). Tree height and girth (DBH at 1.3 m) of *Quercus robur* L. showed marked variation across urban sites with different levels of soil aeration (Weltecke and Gaertig, 2012) suggesting carbon sequestration is reduced where soil gas diffusivity is reduced. These data provide evidence that the magnitude of at least some ecosystem services provided by trees will be closely related to their physiological performance and condition.

Water deficits in trees develop when root uptake of water does not meet the evapotranspirational demand from the crown. In

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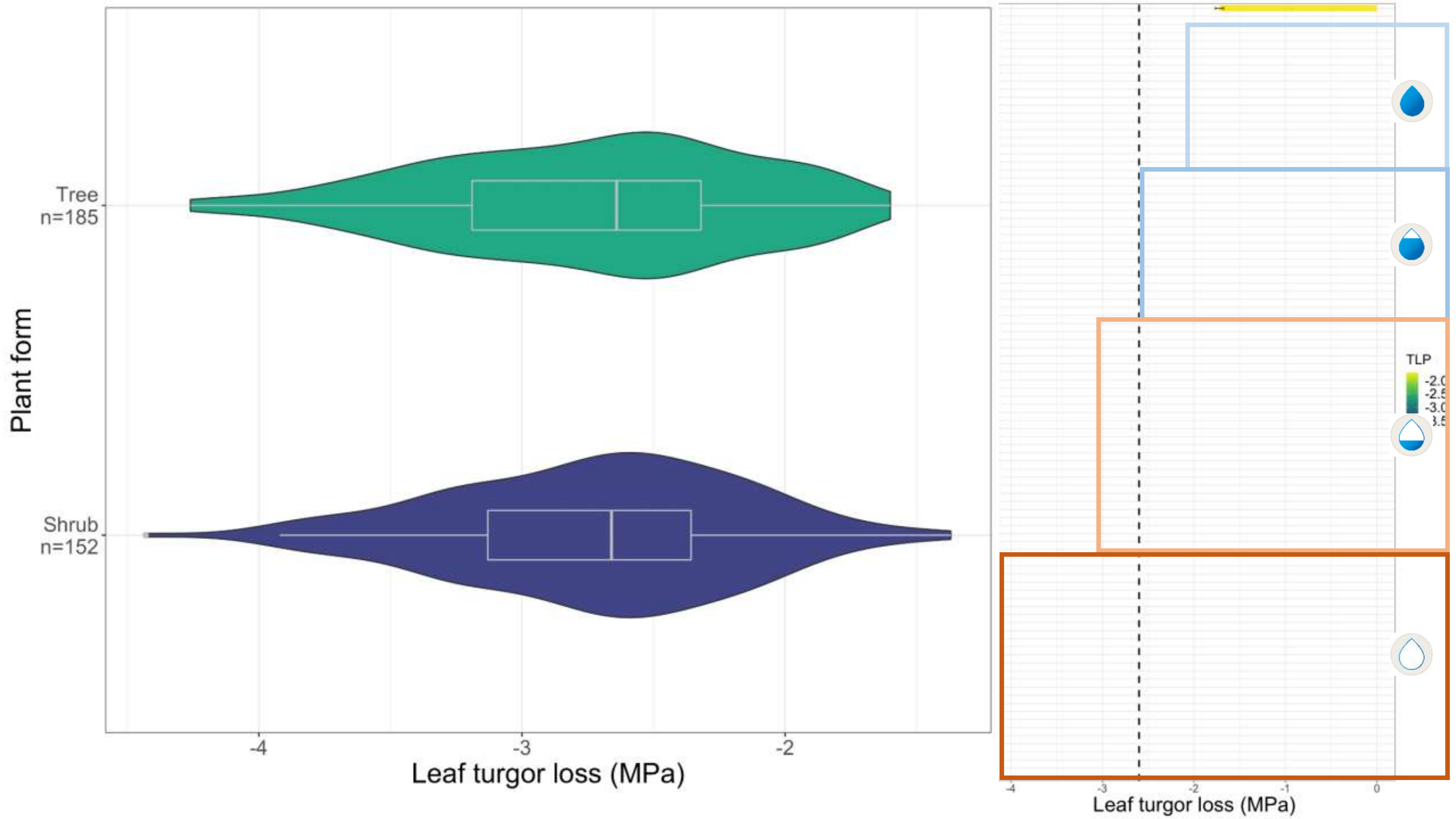
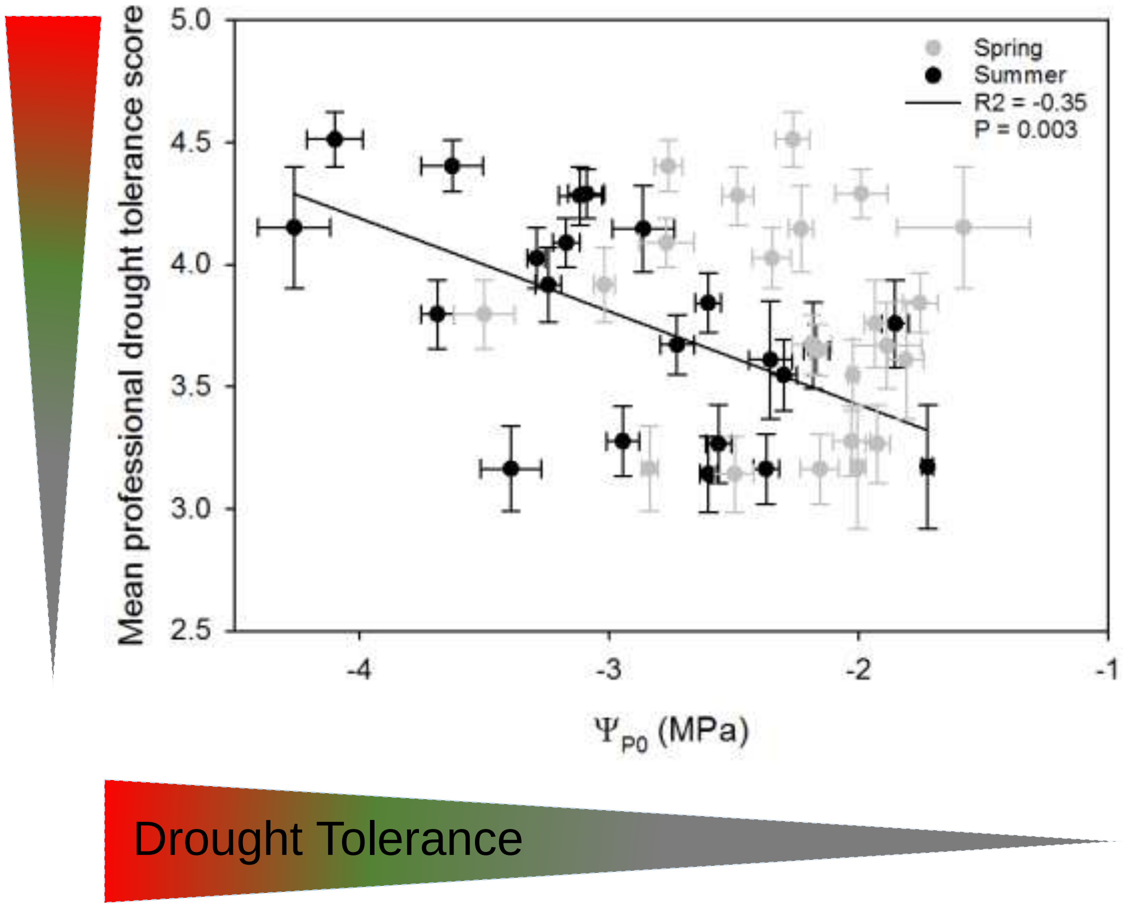
E-mail addresses: henrik.sjoman@slu.se (H. Sjöman), ahirons@myerscough.ac.uk (A.D. Hirons), nlb2@cornell.edu (N.L. Bassuk).

http://dx.doi.org/10.1016/j.ufug.2015.08.004


Plant form
Tree
n=185
Shrub
n=152
-4
-3
-2
Leaf turgor loss (MPa)
TLP
-4
-3
-2
-1
0
Leaf turgor loss (MPa)

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



Urban Ecosystems
https://doi.org/10.1007/s11252-018-0791-5

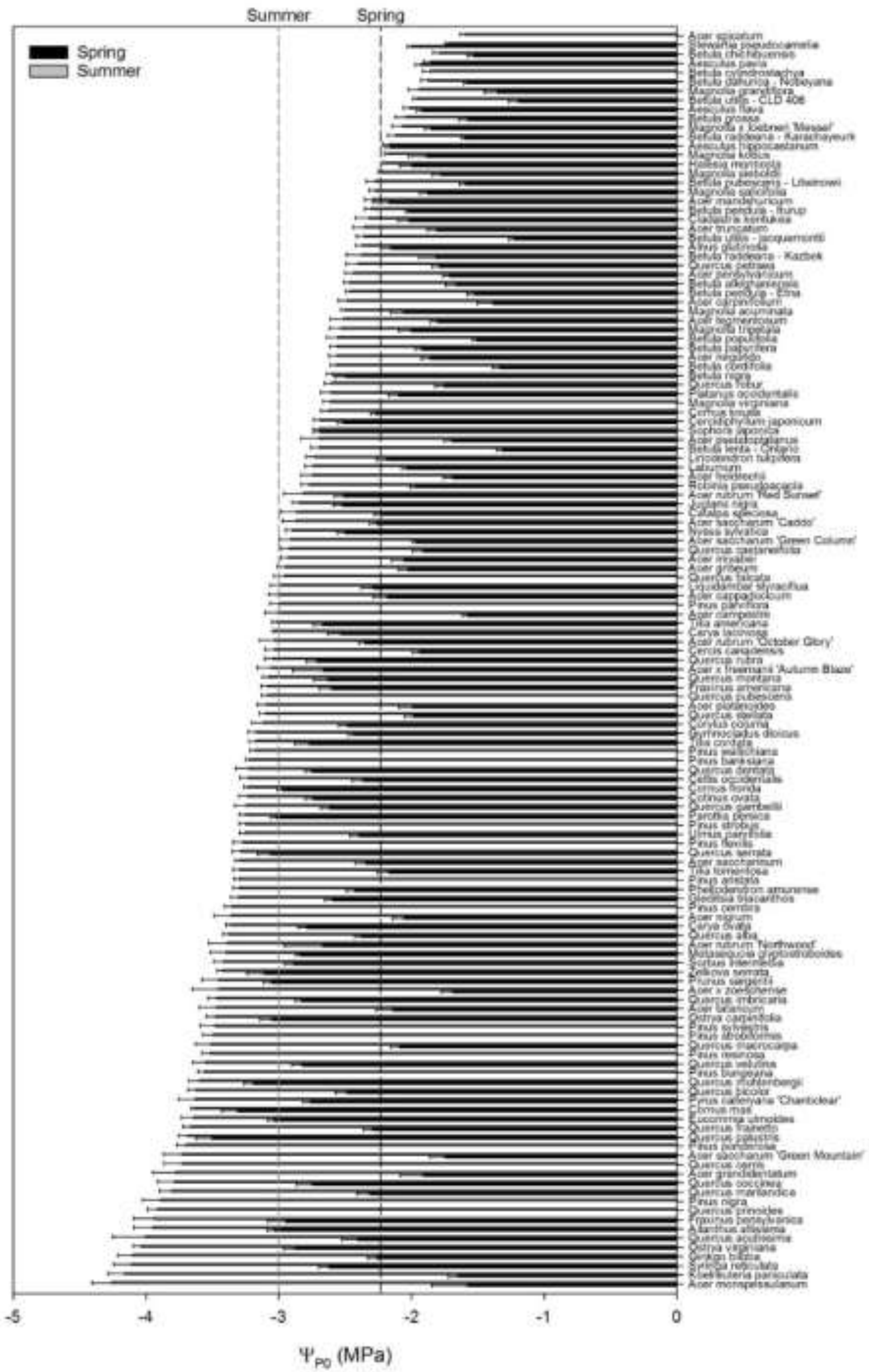
CrossMark

Improving confidence in tree species selection for challenging urban sites: a role for leaf turgor loss

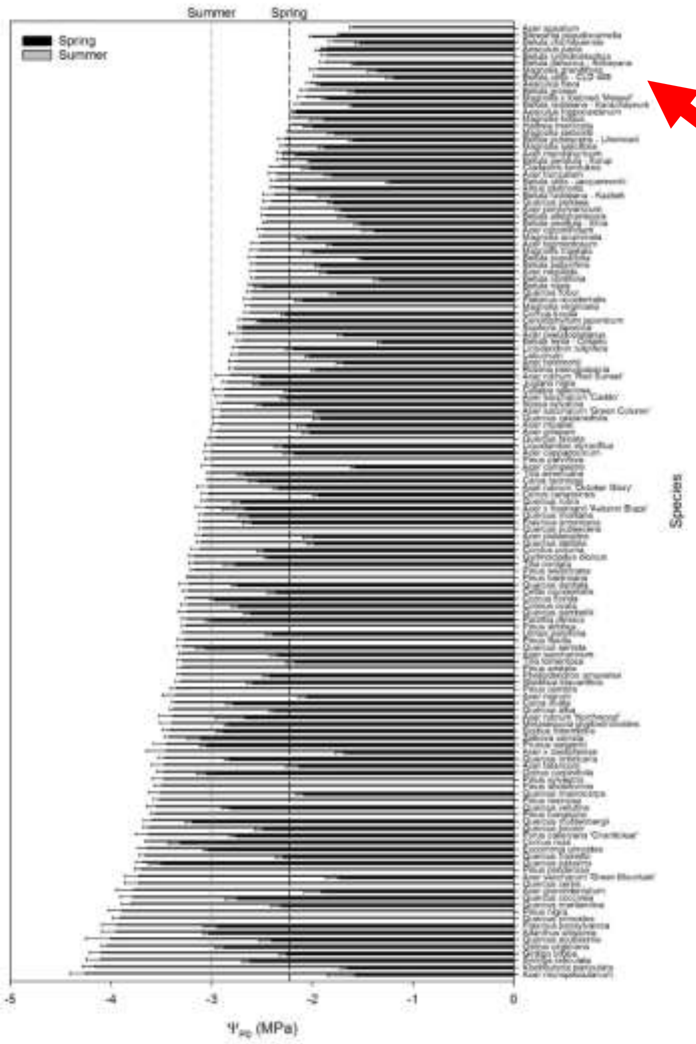
H. Sjöman[1,2,3] · A. D. Hirons[4] · N. L. Bassuk[5]

	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	○	○	○	○	○	○

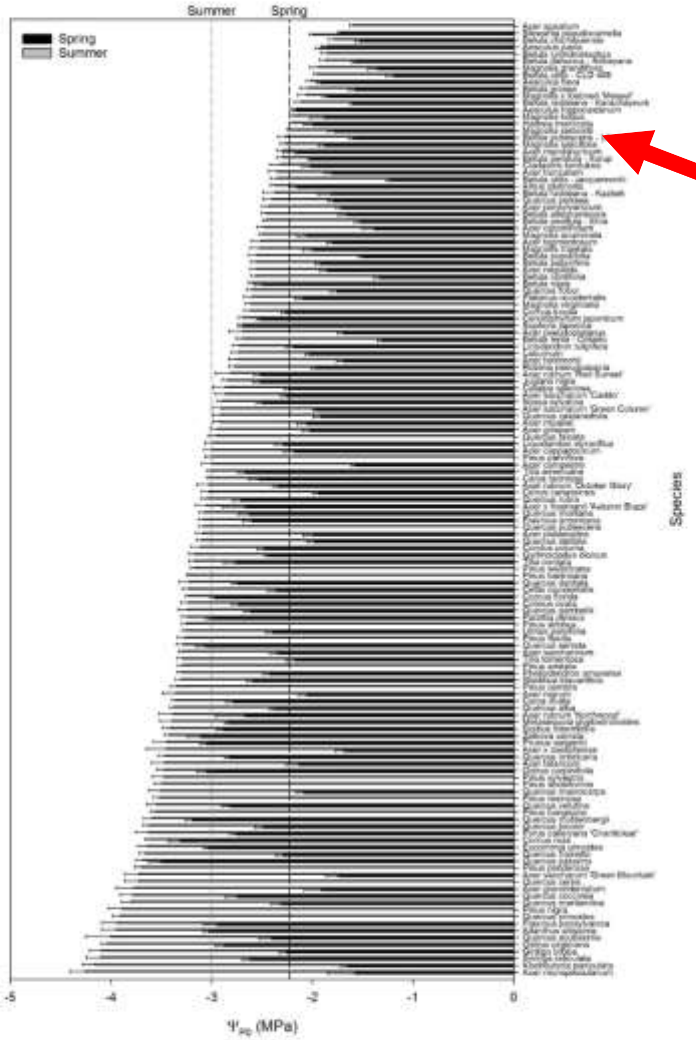
- Highly significant relationship between practitioners experience of a tree’s drought tolerance and summer turgor loss.


Summer
Spring
Spring
Summer
Species
-5
-4
-3
-2
-1
0
Ψ_P0 (MPa)


Urban Forestry & Urban Greening
Urban forest resilience through tree selection—Variation in drought tolerance in Acer
Improving confidence in tree species selection for challenging urban sites: a role for leaf turgor loss
Plants People Planet PPP
RESEARCH ARTICLE
Using botanic gardens and arboreta to help identify urban trees for the future
Selection of Shrubs for Urban Environments—An Evaluation of Drought Tolerance of 120 Species and Cultivars
OPINION
Resilient trees for urban environments: The importance of intraspecific variation
Species-specific evaluation of growth and environmental tolerance for ecosystem services – evaluation from a botanic tree collection



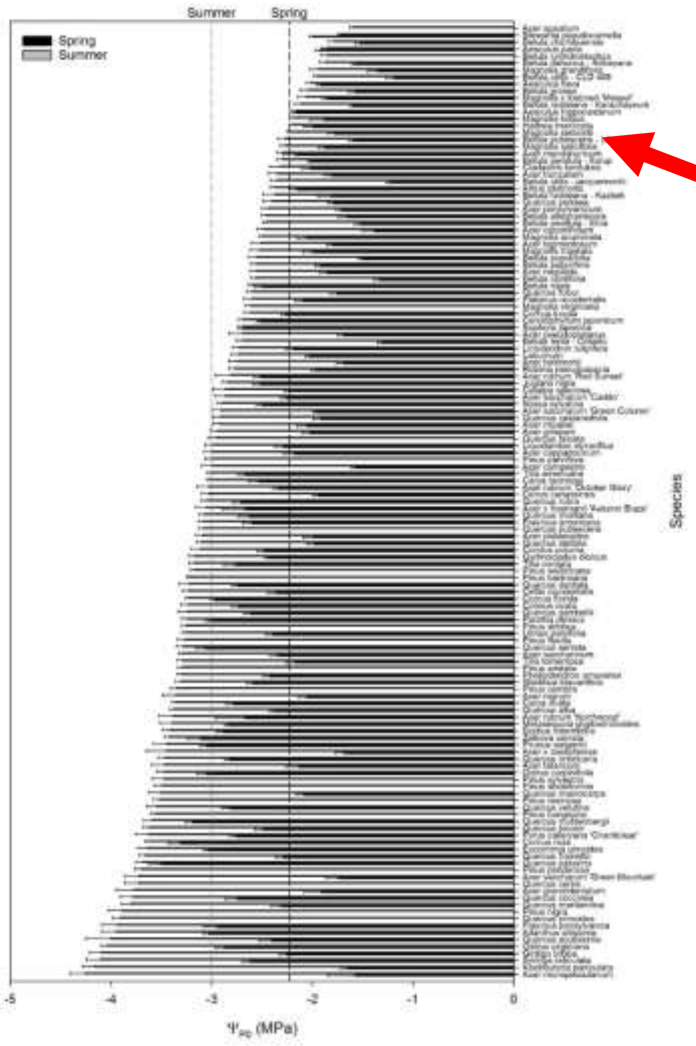
Aesculus flava



Magnolia kobus

Magnolia x soulangeana

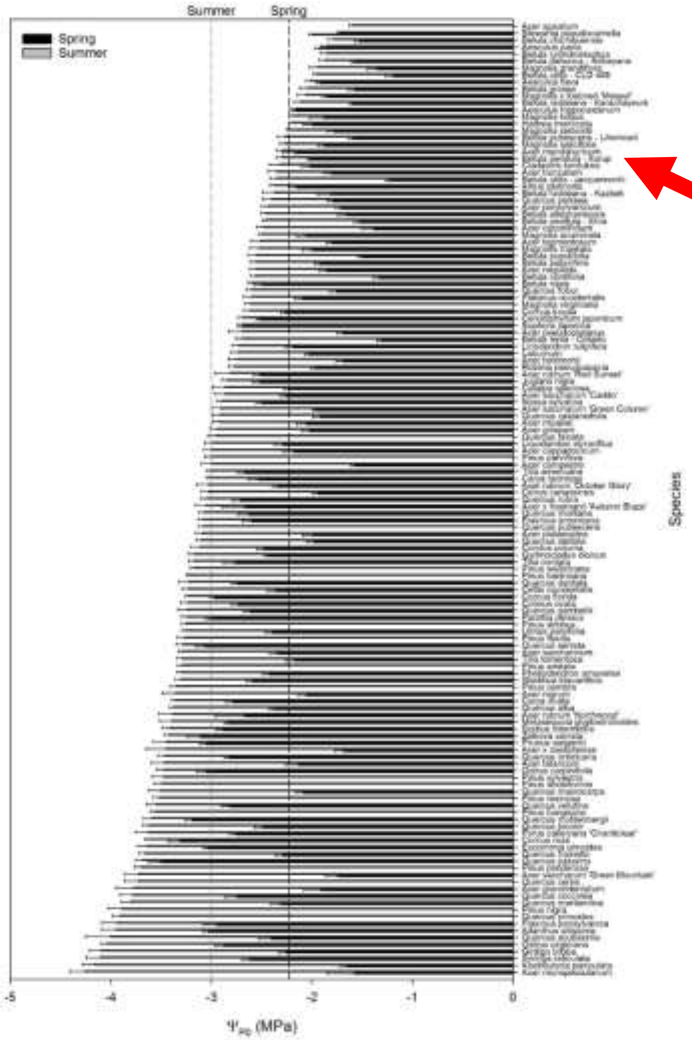
Magnolia x loebneri 'Messel'



Magnolia obovata

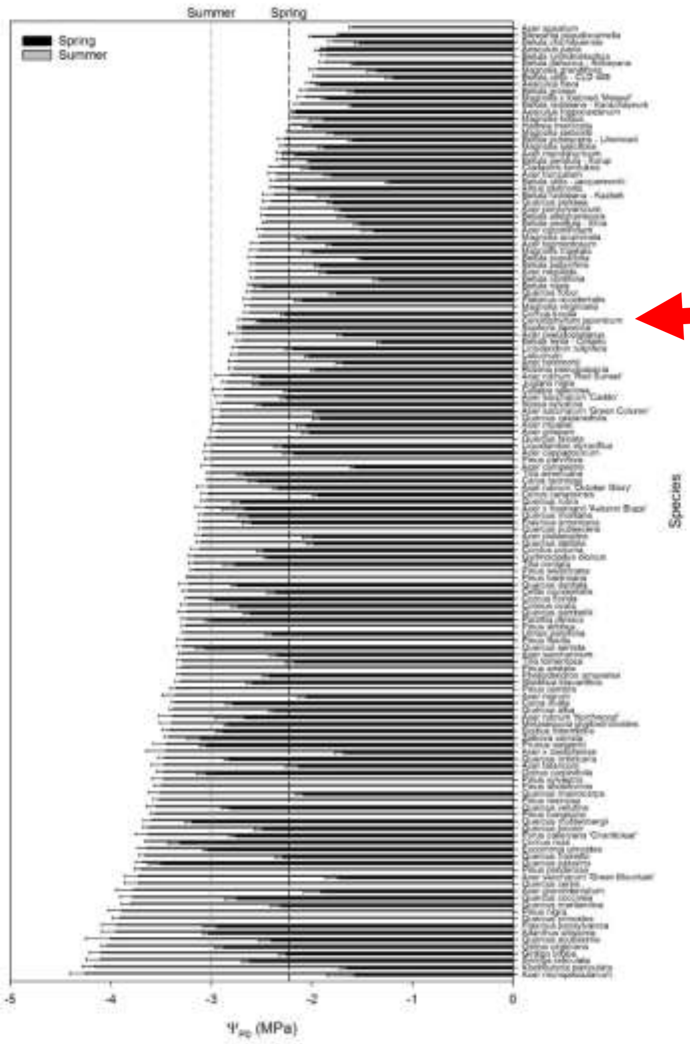
Cladastris kentukea

Betula utilis



Betula albosinensis

Liriodendron tulipifera

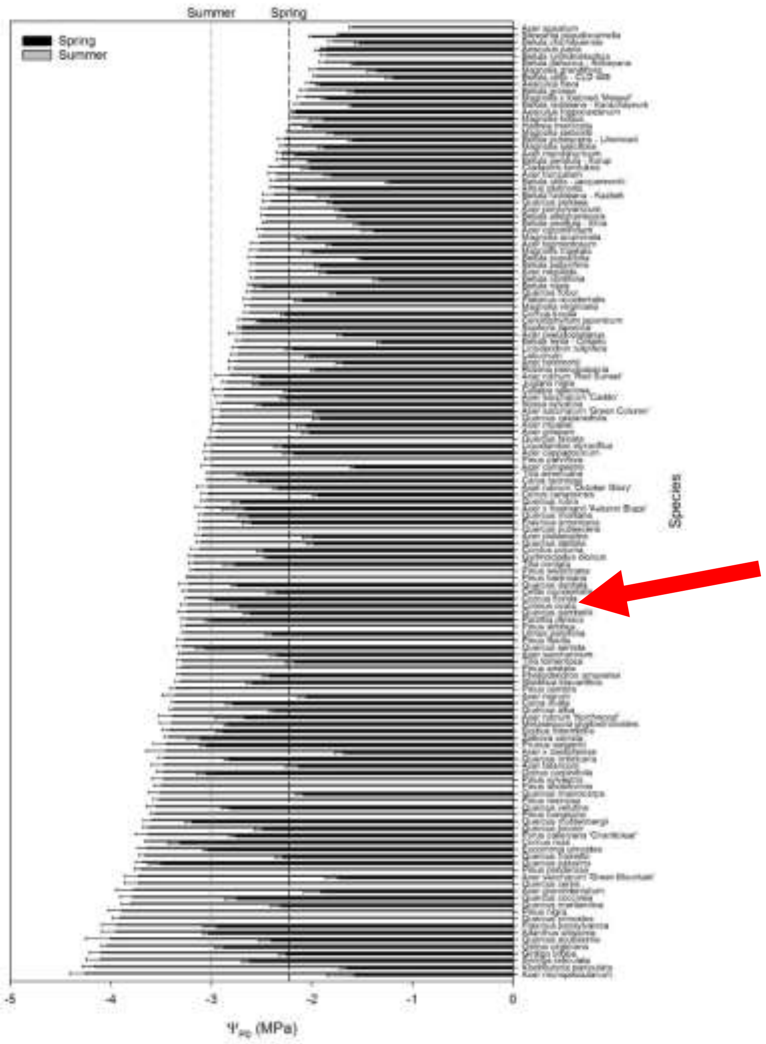


Cercidiphyllum japonicum

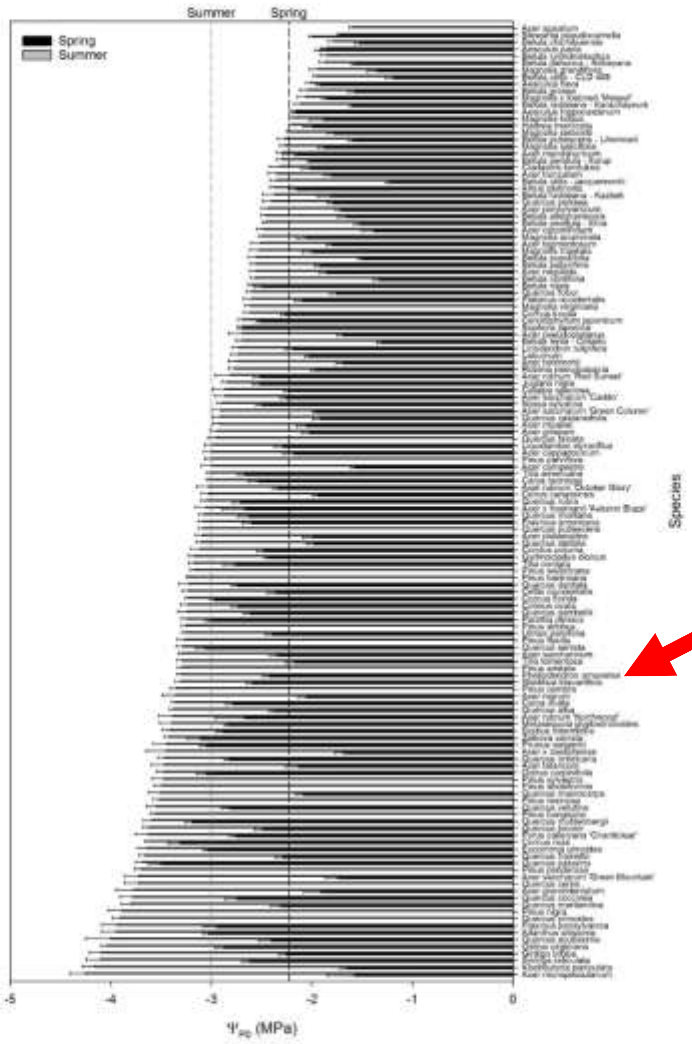
Corylus colurna

Parottia persica 'Venessa'

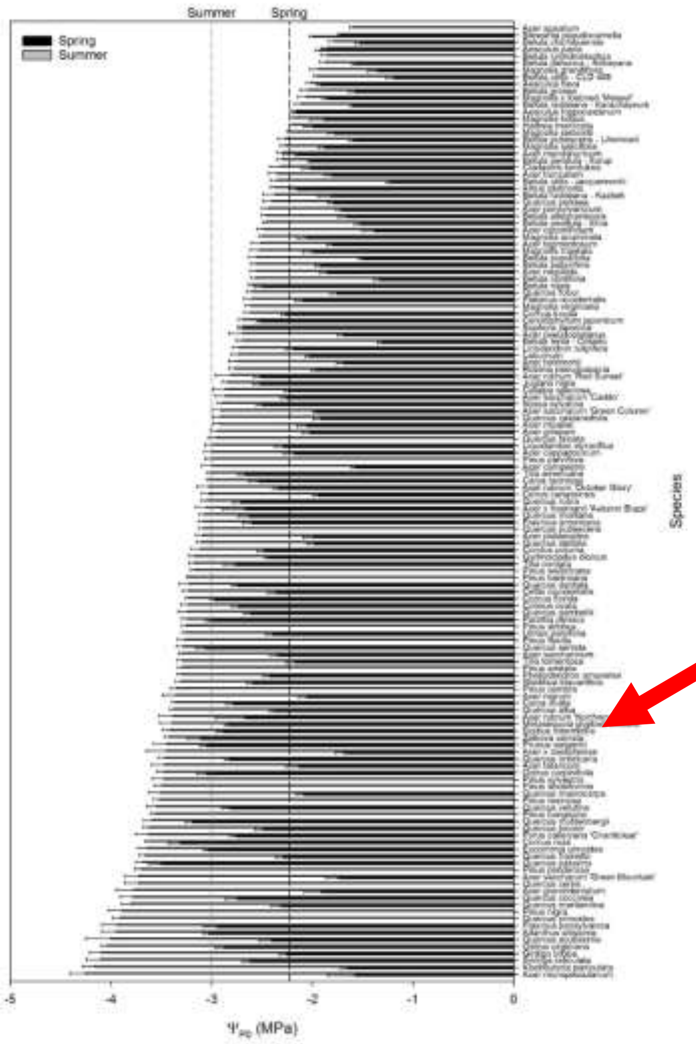
Tilia tomentosa



Cotinus obovatus

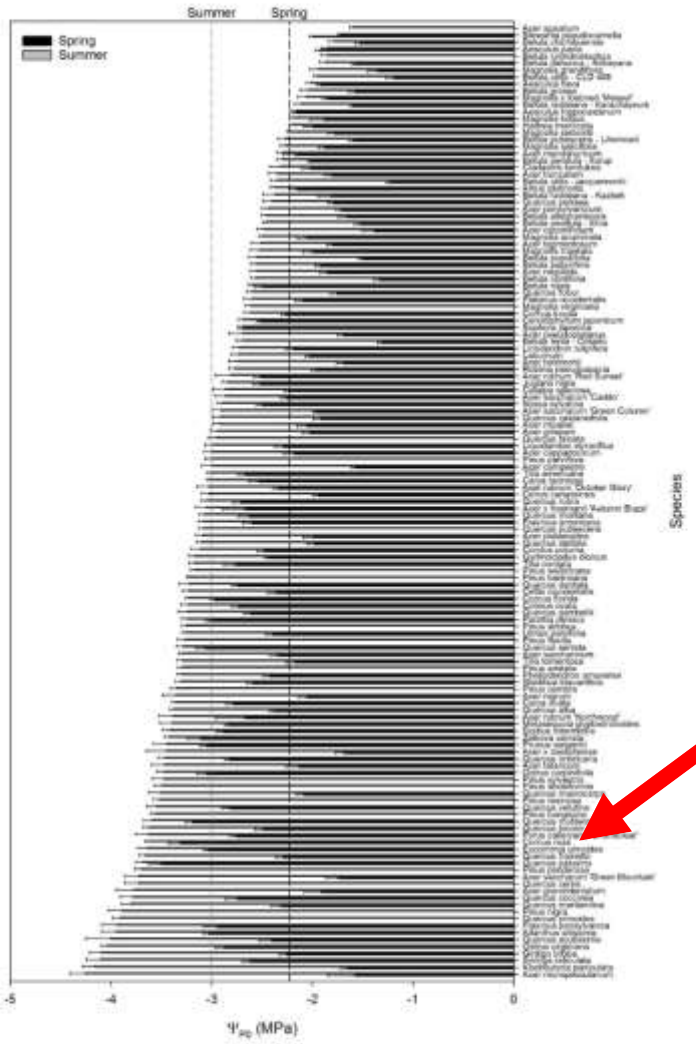


Phellodendron amurense

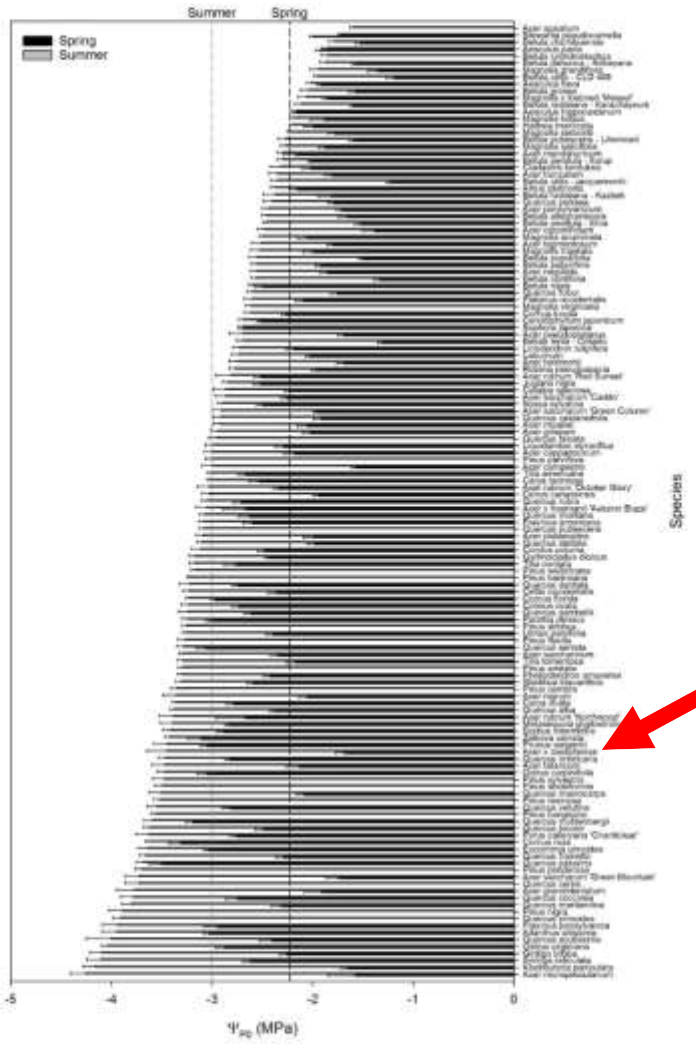


Zelkova serrata

Prunus sargentii

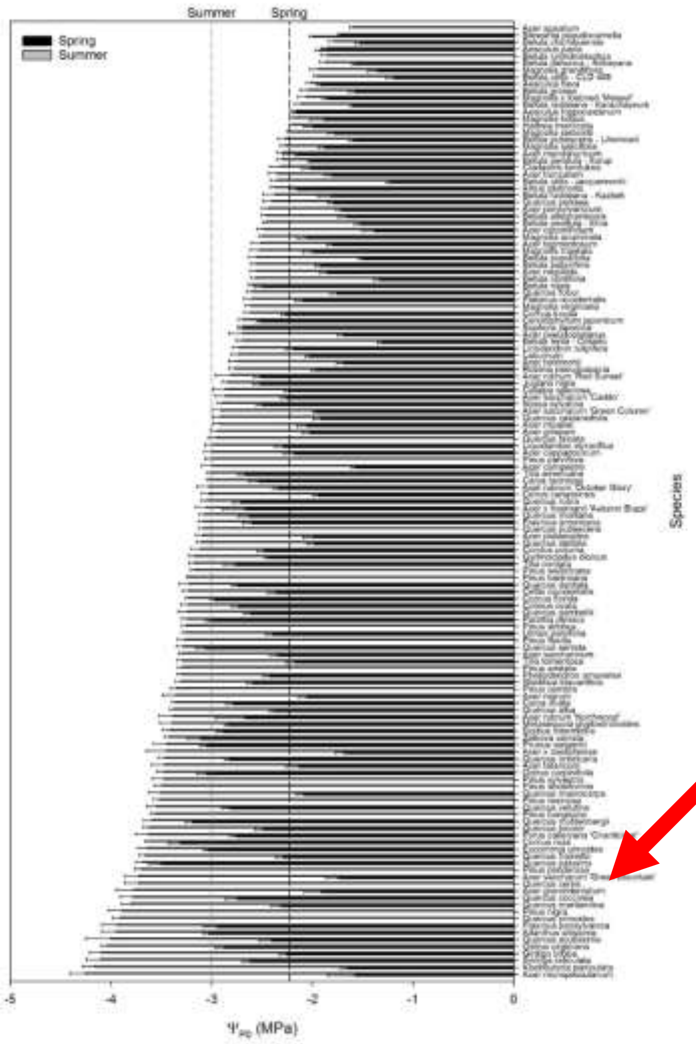


Cornus mas

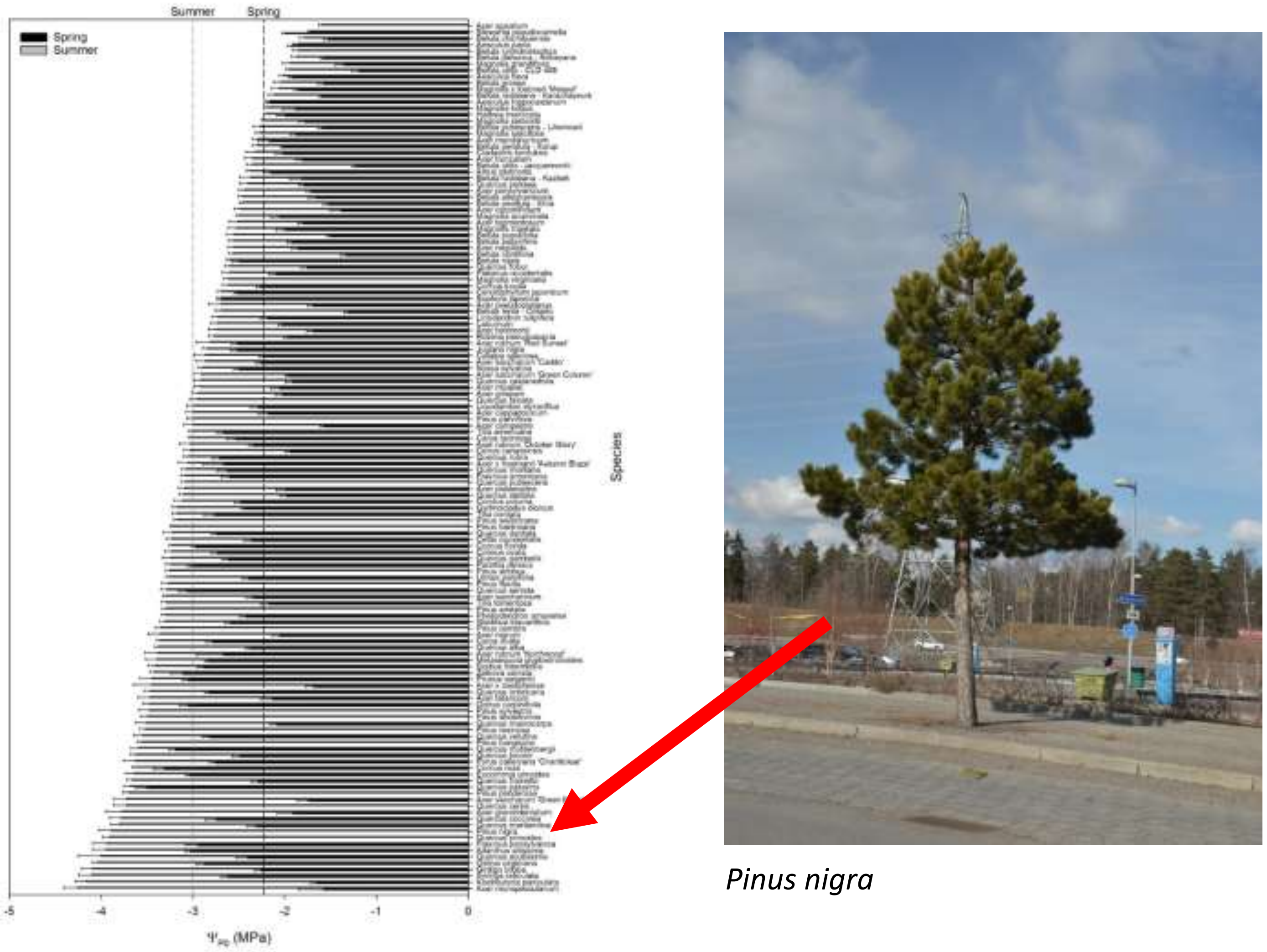


Acer x zoeschense

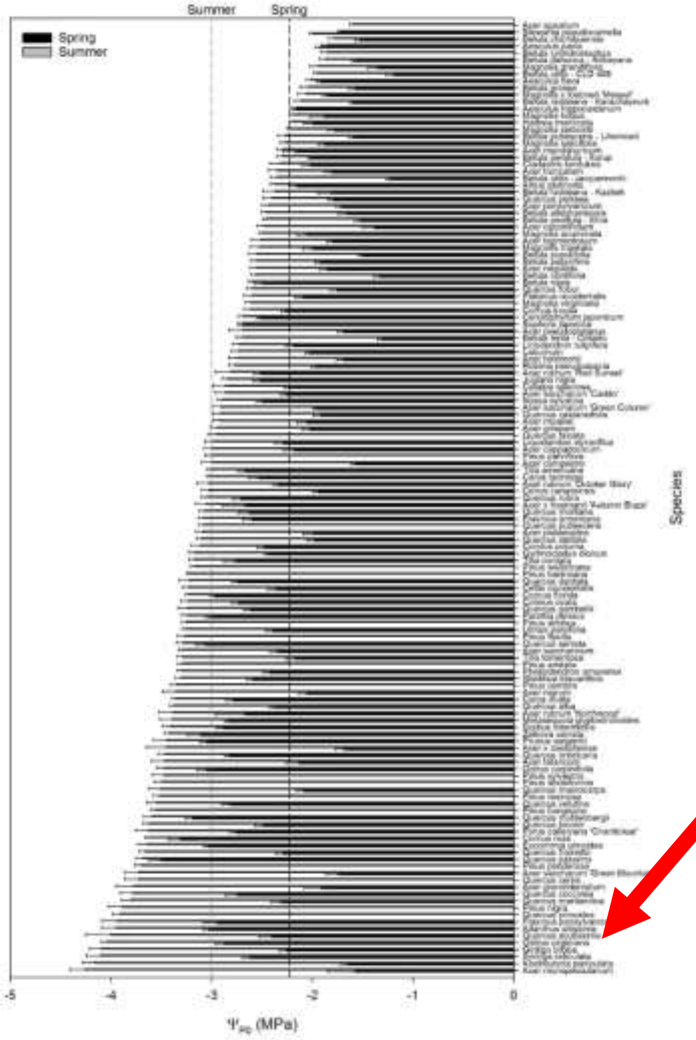
Eucommia ulmoides



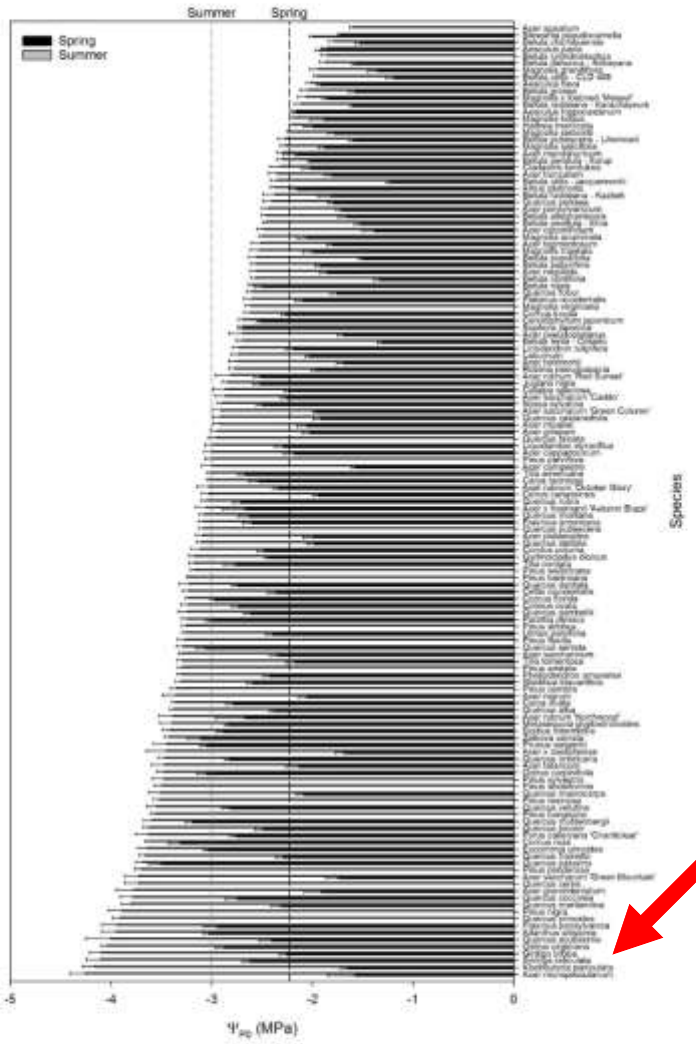
Quercus cerris



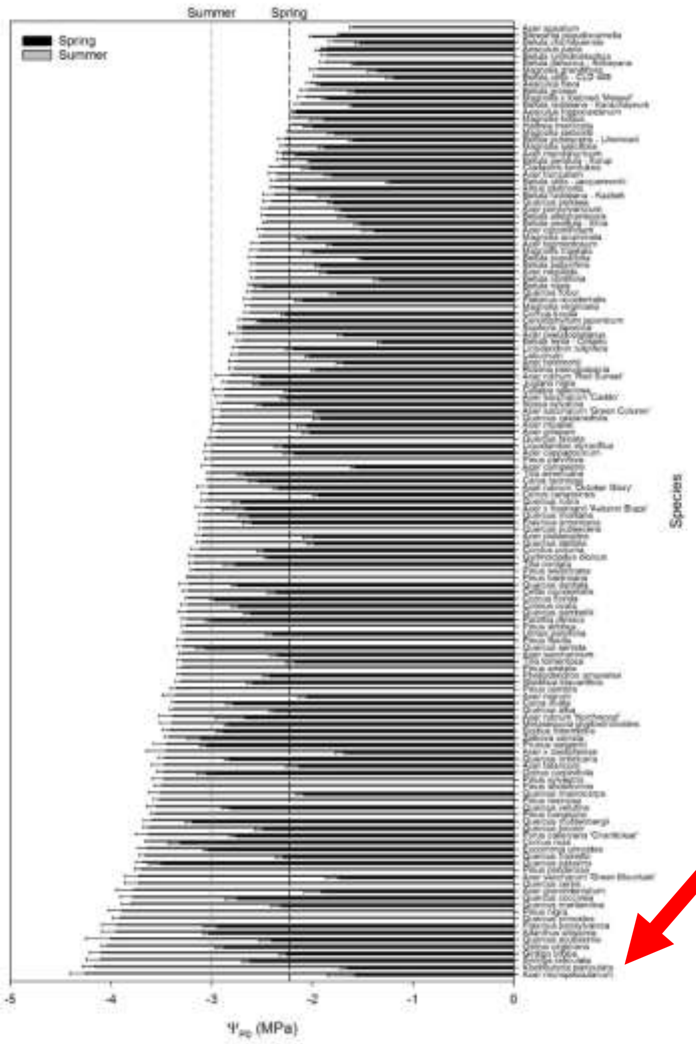
Pinus nigra



Ginkgo biloba



Syringa reticulata



Koelreuteria paniculata

Trees & Design Action Group

Working in collaboration for better places

The Trees and Design Action Group (TDAG), brings together individuals, professionals, academics and organisations from wide ranging disciplines in both the public and private sectors to improve knowledge and good practice to support the role of urban trees through better collaboration in the planning, design, construction and management and maintenance of our urban places.

What we do How we are funded Our governance

Support our work

Make a donation via GoodHub

News

***Tree Species Selection for Green Infrastructure* now available as French and Dutch versions**

The success of *Tree Species Selection for Green Infrastructure* within the UK has led to a collaboration between TDAG and Environnement.brussels, to bring the evidence-based guidance to new audiences in Belgium and beyond. We are proud to announce that this guide is now available in French and Dutch from the 'Our Guides' page above. These direct translations of the original English version will expand the value of the original work and support those specifying trees across a larger region in north-west Europe. Bruxelles Environnement has also published

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The profiles (280+)