Species Selection *for* Paved Environments:

Translating Science to Practice

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For those planning the urban forests of the future, selecting appropriate species can be challenging. For park and garden environments that are characterised by high quality soil, ample soil volumes, and plenty of space for crown development, there is a diverse species palette available to choose from. Indeed, in some cases, such locations can be preferable to the tree's natural habitat which may be highly competitive and on rather marginal land.

Conversely, paved environments provide some of the most challenging conditions for tree development in our towns and cities. Whilst a number of approaches exist to improve the plight of trees in paved sites, it is not uncommon to see trees thrust into diminutive planting pits, encapsulated by impervious paving, "gasping" for water and air, barely clinging onto life. In fact, many do not survive at all—instead becoming a buffet for the saprotrophs or fodder for a chipper.

Trees that only just survive, and do not thrive, provide few of the benefits that were ascribed to the planting scheme by those that conceived of it. Unfortunately, those "artistic impressions" from the landscape architect—you know, the ones with joyous couples skipping hand in hand down an avenue as blossom falls like confetti, or with young professionals earnestly discussing the next business venture in the dappled shade of a birch—are more easily achieved on the computer screen than in reality.

Of course, the reasons for this are complex. They involve issues relating to the specification of the rooting environment, economy, education, practitioner expertise, plant quality, and species selection, to name but a few. In this article we do not have the opportunity to look at all these factors, but we would like to explore species selection in a little more detail.

Arguably, the characteristic that is most helpful to a tree in a paved environment is drought tolerance, or more precisely, tolerance to water deficits. Even in cool, humid regions, trees in paved sites are vulnerable to water deficits because the impermeable surfaces effectively decouple soil moisture availability from precipitation: rainfall often gets diverted away from the root-zone or evaporated before it can recharge the soil water within the tree pit.

In situations where soil volumes are small, water deficits in trees can develop rapidly, especially if the tree has a large crown. Therefore, trees often face acute challenges in water acquisition in paved environments. These challenges are also likely to come about with greater frequency and severity than other potential stresses, such as nutrient deficiencies or soil salinity.

In natural environments, trees tend to cope with water deficits either by avoiding them or by tolerating them (Hirons and Thomas 2018). Deep rooting (to access moisture deep in the soil profile), stomatal closure at an early stage of the drying cycle (to increase resistance to water loss from their leaves), and leaf abscission (to reduce the water demand from the crown) are all strategies that help trees avoid water deficits. In contrast, some trees have an ability to tolerate low (more negative) water potentials as water availability declines. They have a lower leaf turgor loss point, tend to keep their stomata open, and can maintain hydraulic conductivity in their stems for longer during the drying cycle.

In paved urban sites with highly constrained rooting environments, species that avoid water deficits tend to be thwarted by the lack of exploitable >>

Figure 1: Avoid the avoiders for paved and highly restricted sites. This birch (Betula utilis subsp. jacquemontii), growing in a highly restricted soil volume, has lost almost all its leaves in an attempt to avoid deleterious water deficits. In this image, other trees with better growing environments still have plenty of leaves. Stress-avoiding species are often poor choices for challenging urban sites.

Figure 2: Species of maple differ widely in their habitat preference. Understorey species, such as mountain maple (Acer spicatum) (upper photo), have been shown to have a high (less negative) leaf turgor loss point whilst maples from relatively dry environments, such as bigtooth maple (Acer grandidentatum) (lower photo), produce much lower (more negative) leaf turgor loss values during summer (-1.6 MPa/-232 psi and -3.8 MPa/-551 psi respectively, in the Sjöman et al. 2015 study).

soil volume, vulnerable to carbon starvation, or lose their leaves very early in the growing season (Figure 1). Even though these strategies may allow trees to survive successive periods of stress, none of these avoidance traits really improve tree performance in the delivery of ecosystem services, such as cooling. It is much better to select species with an inherent tolerance to water deficits as they will maintain physiological function for longer in the drying cycle; they do not metaphorically bury their head in the sand at the first sign of trouble.

The challenge from a tree selection point of view is to distinguish between species that are able to tolerate a low water potential and those that are not. Interestingly, this is not as simple as observing the change in species composition along precipitation gradients, as both avoidance and tolerance mechanisms may be at play in any single forest ecosystem. It is, therefore, necessary to select a trait that will help characterise the extent of a species' tolerance to water deficits.

One of the best candidates for this is the leaf turgor loss point since it can quantify the "drought" tolerance of a species. Although this was once a highly laborious value to determine (typically through the use of pressure-volume curves), a strong linear relationship between the leaf turgor loss point and the leaf osmotic potential at full turgor means that the relatively rapid screening of species is possible (Bartlett *et al.* 2012a, b).

For example, a study of 27 *Acer* species revealed large differences in the leaf turgor loss point of closely related species. In summer, the leaf turgor loss point varied from around – 2MPa (-290 psi) to less than – 4 MPa (-580 psi), with species segregating broadly in line with their preferred habitat niches: *Acer* species specialising in the shady, humid understorey being much less tolerant to a low water potential than those found in drier, warmer habitats (Sjöman *et al.* 2015). This technique has now been used by our group to evaluate a wide range of temperate trees (~200 species to date).

Another trait that is particularly instructive with regards to drought tolerance is the stem water potential at 50% loss of hydraulic conductivity. This is a quantitative measure of the level of water stress that is required for the sapwood to lose 50% of its ability to transport (conduct) water, and is an important trait in many ecological studies evaluating drought-induced tree mortality (Choat *et al.* 2012). These data are highly instructive for those selecting trees for paved urban sites which are characterised by frequent, and often severe, water deficits throughout the growing season.

Despite trait data being of inherent value to those specifying trees for urban environments, it can be somewhat complex to interpret for those without a background in plant sciences. Therefore, in our new digital guidance on species selection, *Tree Selection for Green Infrastructure: A Guide for >>*

Figure 3: New, free digital guidance on tree selection is available from the Trees & Design Action Group website.

Specifiers (Hirons and Sjöman 2018), we have determined a four-level qualitative scale (Tolerant, Moderately Tolerant, Moderately Sensitive, and Sensitive) that is underpinned by trait data wherever possible. This is then used to help inform recommendations for the "use potential" of a species. For example, a key criteria for species recommended for paved environments is that they must be tolerant or moderately tolerant to drought.

As well as providing information on the drought tolerance of species, we provide information on shade and waterlogging tolerance, ornamental qualities, tree and crown characteristics, and known species-specific issues. Please go to the *Trees & Design Action Group* website (www.tdag.org.uk) if you are interested in this free guidance (Figure 3).

It is critical to note that the selection of appropriate species is only one element of successful tree establishment. Designing high-quality rooting environments, procuring excellent plant material, and sound arboricultural practices are also required if trees are to establish and thrive in our urban landscapes (Hirons and Percival 2012).

If any readers are interested in discussing this work further, please feel free to contact Dr. Andrew Hirons: ahirons@myerscough.ac.uk.

Citations:

Bartlett, M.K., Scoffoni, C., Sack, L. (2012a) The Determinants of Leaf Turgor Loss Point and Prediction of Drought Tolerance of Species and Biomes: A Global Meta-analysis. *Ecology Letters*, 15, 393-405.

Bartlett, M. K., Scoffoni, C., Ardy, R., Zhang, Y., Sun, S., Cao, K., Sack, L. (2012b) Rapid Determination of Comparative Drought Tolerance Traits: Using an Osmometer to Predict Turgor Loss Point. *Methods in Ecology and Evolution*, 3, 880-888.

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Hirons, A.D. and Thomas, P.A. (2018) *Applied Tree Biology.* Wiley-Blackwell. Oxford, UK.

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Acknowledgements

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Recommended Viewing

Selecting Species for a Better Urban Landscape

With Drs Andy Hirons and Henrik Sjöman

Nina Bassuk Reviews *Applied Tree Biology*

by Andrew Hirons and Peter Thomas

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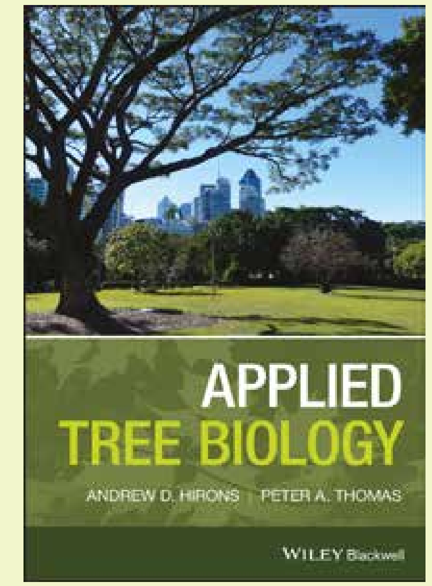

The first thing to notice in this very excellent text is the title, *Applied Tree Biology.* This is not exactly an arboriculture manual or a tree biology textbook. It very deftly explores tree biology and then links it to the art and practice of arboriculture. Although the "applied" part of the text is not limited to managing trees in difficult environments, there is a definite subtext focusing on the trials of trees growing in managed or urban environments.

Ten comprehensive chapters address tree structure (wood, leaves, and roots), seed growth, water relations, carbon acquisition, nutrition, interactions with other organisms, and finally, environmental challenges. Each chapter is lavishly illustrated with graphics and pictures; it is difficult to find a page that does not have some illustrative feature. Given that this book is up-to-date and rather dense in content, the illustrations are very welcome.

Also notable is the inserted content written by other authors with specific subject-matter expertise. It is useful and interesting to have a different voice explain an issue in greater detail than what was previously provided by the authors. Engaging material expressed in multiple ways serves to solidify the content for the reader.

The most impressive feature of *Applied Tree Biology* is its seamless linking of what we might call basic functions with applied use in the landscape. For example, the chapter "The Next Generation of Trees: From Seeds to Planting" begins with a thorough discussion of pollination, flowering, fruit and seed formation, asexual reproduction, and then growing trees, including a discussion on provenance. Considerable time is given to seed dormancy, germination, and initial seedling growth. This fundamental discussion leads to a comprehensive section on transplanting that includes plant selection, nursery production, root growth in containers, and planting specifications. Arboricultural practices at planting, including initial care, are presented to finish the chapter.

The chapter "Environmental Challenges for Trees" is particularly current given the changes in climate and urban microclimates that we expect trees to grow in. The authors' exploration of plant response to stress is particularly elucidating. Trees have developed mechanisms to avoid and/or tolerate stress that directly inform our decisions about species selection and landscape management. The authors deftly break down how each category of environmental stress affects trees. Conditions of low and high temperatures, water deficits, flooding, and salt stress are discussed in some detail.

Who should use this book? Undoubtedly, university courses in arboriculture, woody plant physiology, and landscape management and technology would make good use of *Applied Tree Biology.* Because the practical is intertwined with the fundamental, it meets many needs and provides a scientific basis for best practices in the managed landscape.

This book will also be of use to researchers in our field. I wholeheartedly recommend this new text for everyone who is involved with the management of trees in the urban and managed landscape. I am particularly thankful for the copious and up-to-date references at the end of each chapter.

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Hirons, A.D., and P.A. Thomas. 2018. Applied Tree Biology. John Wiley & Sons, Ltd., Chichester, UK. 432 pp. ISBN 978-1-118-29640-0.