An assessment of root to shoot balance in tree stock for landscape planting in Australia

Update on the trials for the tree stock standard

Prof Mark Tjoelker
The research team

Prof Mark Tjoelker  
project leader

Dr Remko Duursma  
biometry analyst

Dr Sebastian Pfautsch  
tree growth

Dr Mike Aspinwall  
tree physiology

Courtney Campany  
field researcher

David Thompson  
communications

David Thompson  
communications

Dr Mike Aspinwall  
tree physiology

Dr Sebastian Pfautsch  
tree growth

Western Sydney University
Trees are integral to sustainable landscapes

The EucFACE experiment is determining the response of Cumberland Plain Woodland to rising atmospheric carbon dioxide concentrations.
Urban green infrastructure provides social benefits

Increased tree canopy cover mitigates the “urban heat island” effect while enhancing cityscapes (Vision 202020 project)
Containerized trees are high-value products

Landscape markets depend upon quality tree stock
Trees enhance urban landscapes

Proper root:shoot balance at dispatch is one of several factors that help ensure successful establishment
The importance of root-shoot balance

- **Balancing function** water loss via transpiration area (shoot) and the water absorbing area (root) of a tree

- **Balancing structure** ensures that a properly formed root ball supports a self-standing shoot

- **Managing balance** ensures positive legacy effects following dispatch
Does tree stock balance matter?

• Root:shoot balance must be considered in context of a range other stock quality factors

• Site conditions following dispatch are important

Photo: D Thompson
Australian Standard AS2303:2015
Tree Stock for Landscape Use

Identified outcomes

• Improved tree stock quality
• Recognition for growers of high quality tree stock and a market driver for those growers
• Nationally recognised specifications for growers and consumers of landscape tree stock
• Increased support for green infrastructure investment
“The major area of contention during the formation of the standard centred on the tree stock balance concept and its calculation as it applies to varying production regions and across various species.” (O’ Conner, Nursery Papers, October 2015 vol. 9)
An assessment of root to shoot balance in tree stock for landscape planting in Australia

RESEARCH

Aim 1: acquire information on root to shoot balance of tree planting stock from scientific and trade literature

Aim 2: Quantify root to shoot balance in tree stock for contrasting regions in Australia
Aim 1: Acquire information on root to shoot balance of tree planting stock from scientific and trade literature

Data mining

- Extract and analyze literature data to determine root to shoot balance of containerized stock

Expert synthesis

- Review other standards and industry best practices
Above and belowground quality testing: Comparing global nursery standards

- **USA**: ANSI Z60.1-2014
- **AUS**: AS 2303:2015
- **EUR**: ENA 2010

**What's the Same?**
- Height, calliper, rootball diameter and true to type
- Assessments of crown health, pests and disease
Comparing global nursery standards: Differences from AS 2303:2015

USA

- Many aboveground criteria offered as optional buyer specifications
- Less assessment of root morphology

Europe

- Less attention to stem criteria such as taper, stem structure, included bark, etc.
- Root division and rootball depth not evaluated
Tree Stock Balance:
Comparing major global players

<table>
<thead>
<tr>
<th>Australia</th>
<th>USA</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Size index per container volume</td>
<td>• Plant size &amp; rootball diameter per container volume</td>
<td>• Minimum height per container volume</td>
</tr>
<tr>
<td>• Size Index = Height (m) * Calliper (mm)</td>
<td>• Plant size = height/calliper, height or canopy width depending on tree type</td>
<td>• Container sizes are generally small (&lt;10 litres)</td>
</tr>
<tr>
<td>• Container testing begins at 20 litres</td>
<td></td>
<td>• Species specific relationships</td>
</tr>
</tbody>
</table>
Aim 2: Quantify root to shoot balance in tree stock for contrasting regions in Australia

Photo: D Thompson
Are there important species and regional differences in tree stock root to shoot balance?

• Do species differ in root to shoot balance?

• Do warmer climates accelerate growth resulting in shifts in optimal root to shoot balance?

• Do species differences in root to shoot balance depend upon region?
Temperature directly alters tree morphology

Growing environment has the potential to modify root:shoot balance

Cold (15 – 24 °C) vs. Warm (29 – 38 °C)

*Eucalyptus tereticornis*
Tree growth “self balances” and is constrained by container size

![Graph showing the relationship between pot volume and shoot mass.](image)

*Eucalyptus tereticornis* (Campany et al. unpublished)
Tree stock balance: maximising the potential for transplant success?

- **Oversized shoot** evaporative surface may exceed water uptake capacity

- **Undersized shoot** lack of photosynthetic capacity to produce needed carbohydrates

- Should **balance** be managed alongside possible effects of climate/species differences?

Photo: D Thompson
Aim 2: Quantify root to shoot balance in tree stock for contrasting regions in Australia

• Collect quantitative data from production nurseries throughout Australia

• Aggregate species into “stock types”

• Resolve regional/climatic differences

• Produce easy to use tables

Photo: D Thompson
Are there important regional differences in tree stock root to shoot balance?

- Cover major regions and landscape tree markets in five states
- Site visits to be completed in 2016
Working list of 28 tree species/cultivars for assessment

<table>
<thead>
<tr>
<th>Species</th>
<th>Type</th>
<th>Origin</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agathis robusta</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Agonis flexuosa</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Angophora costata</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Callistemon ‘Kings Park’</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Corymbia citriodora</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Corymbia ficifolia</td>
<td>Evergreen</td>
<td>Native</td>
<td>Moderate</td>
</tr>
<tr>
<td>Corymbia maculata</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Eleaocarpus reticulatus</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Eucalyptus caesia ‘Silver Princess’</td>
<td>Evergreen</td>
<td>Native</td>
<td>Slow</td>
</tr>
<tr>
<td>Eucalyptus leucoxyylon ‘Rosea’</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Eucalyptus sideroxylon</td>
<td>Evergreen</td>
<td>Native</td>
<td>Moderate</td>
</tr>
<tr>
<td>Eucalyptus torquata</td>
<td>Evergreen</td>
<td>Native</td>
<td>Moderate</td>
</tr>
<tr>
<td>Ficus hili ‘Flash’</td>
<td>Evergreen</td>
<td>Native</td>
<td>Moderate</td>
</tr>
<tr>
<td>Lophostemon confertus</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Tristaniopsis ‘Luscious’</td>
<td>Evergreen</td>
<td>Native</td>
<td>Slow</td>
</tr>
<tr>
<td>Waterhousia floribunda</td>
<td>Evergreen</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Brachychiton acerifolia</td>
<td>Deciduous</td>
<td>Native</td>
<td>Slow</td>
</tr>
<tr>
<td>Melia azedarach</td>
<td>Deciduous</td>
<td>Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Magnolia grandiflora ‘Little Gem’</td>
<td>Evergreen</td>
<td>Non Native</td>
<td>Slow</td>
</tr>
<tr>
<td>Olea europa</td>
<td>Evergreen</td>
<td>Non Native</td>
<td>Slow</td>
</tr>
<tr>
<td>Acer ‘Autumn Blaze’</td>
<td>Deciduous</td>
<td>Non Native</td>
<td>Moderate</td>
</tr>
<tr>
<td>Jacaranda mimosifolia</td>
<td>Deciduous</td>
<td>Non Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Lagerstroemia ‘Natchez’</td>
<td>Deciduous</td>
<td>Non Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Lagerstroemia ‘Sioux’</td>
<td>Deciduous</td>
<td>Non Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Pyrus ‘Chanticleer’ or ‘Cleveland Select’</td>
<td>Deciduous</td>
<td>Non Native</td>
<td>Moderate</td>
</tr>
<tr>
<td>Auracaria heterophylla</td>
<td>Evergreen</td>
<td>Non-Native</td>
<td>Fast</td>
</tr>
<tr>
<td>Platanus x acerifolia</td>
<td>Deciduous</td>
<td>Non-Native</td>
<td>Moderate</td>
</tr>
<tr>
<td>Ulmus parvifolia</td>
<td>Deciduous</td>
<td>Non-Native</td>
<td>Fast</td>
</tr>
</tbody>
</table>
Aggregation of species into stock types

• Stock type A: tall, slender species, typically faster growing

• Stock type B: average form and growth rate

• Stock type C: stockier/thick stemmed species, typically slower growing
Does root:shoot balance differ among regions and species?

Current standard

Test for regional differences
Root:shoot balance metric is influenced by time since transplanting

![Graph showing the relationship between container volume (L) and size index range (calliper x height), with data points for different container volumes (5L, 10L, 15L, 20L, 25L, 35L) and a time axis indicating the influence of time since transplanting.](image)

*Eucalyptus tereticornis* (Campany et al. unpublished)
An Assessment of Root to Shoot Balance in Tree Stock for Landscape Planting in Australia

Hawkesbury Institute for the Environment
University of Western Sydney

Testing balance parameter relationships for species stock types and regions. We will examine allometric relationships (mathematical models) using regression analysis of above- and below-ground size metrics (Table 1). For example, log-transformed size metrics exhibit linear relationships that can be formally compared using statistical analyses and be used to generate interpolated, predictive relationships. Of primary interest is testing whether or not the size index vs. container volume (or rootball diameter) relationship differs among stock types (A, B and C) and climate (region) in Australia. Using inferential statistics, we will test for: 1) regional differences, 2) stock type differences and 3) the presence of stock type x region interactions. Theses analyses will test the three stated hypotheses, and in doing so provide research-based information regarding both potential regional and species stock type differences in root to shoot balance.

The study design will enable quantification and robust tests of the role of stock type and climate zone in root to shoot balance, and the development of parsimonious predictive models and generation of simplified lookup tables (i.e. Tables E1, E2 in AS2303:2015), including a new lookup table for small trees. For small trees grown in containers (tube or plant cell stock), we expect a ratio of tree height to height of the tube or cell may suffice. For trees in larger volume pots (but < 20 L) or bareroot, a height range may be specified for a given container size or rootball volume, whereas larger trees (≥ 20 L) may be assessed using size index and container or rootball volume.

When completed, the field trials will provide important information and new tools, particularly research-based lookup tables (and a web-based tool or application) that tree growers can use to recommend appropriately balanced planting stock for landscape plantings throughout Australia. This information is crucial for ensuring a high quality product and maximizing the benefits that landscape plantings provide to urban ecosystems and communities.

Table 1
Field sampling design for determination of root to shoot balance in tree stock at individual grower nurseries in each of five states, encompassing the range of climate zones throughout Australia

<table>
<thead>
<tr>
<th>Stock Type</th>
<th>Product types</th>
<th>Samples</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, C minimum of 5 species per stock type</td>
<td>- Tube/cell stock (&lt; 20 L), bareroot</td>
<td>- 200 trees per stock type (non-destructive)</td>
<td>Aboveground Height</td>
</tr>
<tr>
<td></td>
<td>- Container (20 to 2500 L)</td>
<td>- 20 trees per stock type (destructive)</td>
<td>Size index = height (m) x caliper (mm)</td>
</tr>
<tr>
<td></td>
<td>- Ex-ground stock (ca. 57 to 3075 size index)</td>
<td></td>
<td>Stem taper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aboveground drymass (research only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Belowground Rootball diameter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rootball depth, height of root crown</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rootball occupancy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Root direction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Root division</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Root dry mass (research only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Allometric relationships¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Height vs. calliper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Size index vs. rootball diameter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rootball diameter vs. container volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Size index vs. container volume</td>
</tr>
</tbody>
</table>

¹Using log-transformed data to interpolate predictive linear relationships (e.g. log [size index] = a + b log [container volume]). These relationships will be used to create lookup tables for discrete ranges of values.
Tree stock balance: Summary and take-home message

- Root:shoot balance reflects a range of **functional** and **structural** traits important for healthy, successful trees.

- Our study aims to determine **whether or not** regional/species differences are important.

- Our findings will inform tree stock balance in “Australian Standard AS2303:2015 Tree Stock for Landscape Use”.

Photo: D Thompson
Would like more information?

Prof Mark Tjoelker  
project leader  
m.tjoelker@westernsydney.edu.au

Courtney Campany  
field researcher  
c.campany@westernsydney.edu.au
Advisory board members

Dr Anthony Kachenko (Horticulture Innovation Australia)
Ms Leanne Gillies (Fleming’s Nurseries – VIC)
Mr Ken Bevan (Alpine Nurseries – NSW)
Mr Chris O’Connor (Nursery and Garden Industry NSW)
Ms Carole Fudge (Benara Nurseries – WA)
Mr Hamish Mitchell (Specialty Trees- VIC)
Mr Tim Carroll (Andreasens Green – NSW)