# Trends in Australian tree nurseries: past and present

In 1997 the Australian federal government set a target to triple the nation’s plantation estate by 2020 with the ‘2020 Vision’ initiative (www.plantations2020.com.au). This initiative led a massive decade long expansion of the plantation estate (>50 %) in Australia to over 2 million ha, with the majority of the increase composing of Eucalyptus hardwood species (Gavran & Parsons, 2010). This 2020 vision created a shift from bare root to containerized production of tree seedlings in nurseries to meet high volume demands of forestry companies (Close, 2012). During this period, it was necessary to increase emphasis on quality seedling testing to ensure containerized seedlings had characteristics that were favorable to out-planting in a wide range of planting sites (Close *et al.*, 2003). Recently, Horticulture Innovation Australia has introduced the new "202020 Vision" that aims increase urban green space by 20% by the year 2020 (<http://202020vision.com.au>). This new initiative represents a significant market shift towards landscape use and introduces a new set of challenges to the Australian tree nursery industry for the foreseeable future.

These new challenges are highlighted by the difficulty in establishment and survival of newly planted urban trees (Nowak *et al.*, 2004; Miller *et al.*, 2015), and the pressure this places on individual tree nurseries to provide tree stock that can endure increasingly harsh environments. Hot and dry conditions in Australian cities, inconsistent irrigation, infertile soils, pests, diseases and high pressure from urban heat islands threaten the survivability of urban trees, and success of green infrastructure (HIA, 2016). Additionally, valuing trees to be selected for urban planting sometimes neglects considerations of stress endurance in favor of trees with higher aesthetic appeal (Ware, 1994; Pandit *et al.*, 2013). Consequently, Australian tree nurseries are now expected to provide a large array of native and non-native trees species that are all capable of enduring less than ideal out-planting site conditions.

As planting, establishment and monitoring of trees in urban environments requires considerable investment by local Councils (Lawry & Gardner, 2001), concerns over tree stock quality and out-planting success are inevitable. Selecting the appropriate cultivar, properly preparing the out-planting site and management of out-planted trees will be wasted if the quality of the planted seedling is initially poor (Moore, 2001). Confounding with the demands for diverse high quality trees is that variability within tree stock is a near certainty during nursery production. This variability presents a unique challenge for nurseries attempting to produce planting stocks with uniform morphological characteristics (Puttonen, 1997). In 2015, the Australian nursery industry adopted a new standard to assess the qualtiy of tree stock for landscape use (AS2303:2015). This new standard was designed to assess above- and belowground characteristics of production tree stock for all stages of growth. Although the AS2303 standard is not currently mandatory, it is likely to be increasingly called on in attempts to minimize risks of out-planting failure with new landscape and green infrastructure projects.

## Assessing Seedling Quality

Evaluating nursery seedling quality is necessary to understanding seedling development and the capacity for growth after out-planting (Wakeley, 1954), however the quality of tree stock is often assessed inconsistently (Haase, 2008). Overall, nursery seedlings should embody the structural and physiological traits that can be quantitatively linked to success in the field (Rose *et al.*, 1990). Seedling quality is a dynamic process that is the culmination of all the practices that have preceded that point for measurement (Mexal & Landis, 1990). The term "stock type" is used to describe a seedlings age and method production, while also serving as a visual reference of what the seedling should look like before out-planting (Pinto *et al.*, 2011a). A primary goal of seedling quality assessments is to quantify levels of morphological and physiological attributes which accurately assess the condition and potential for growth and development of different stock types (Wilson & Jacobs, 2006). As there is no one single test which encompasses seedling quality, assessing a seedling is analogous to a physician conducting a multitude of measurements to characterize a patients general health (Ritchie, 1984).

Seedling quality is the basis for tree planting success and high quality trees will have a higher survival rate and faster growth in the field than poor quality trees (Wightman, 1999). Importantly, planting seedlings with desirable plant attributes will not guarantee survival, but should increase survivability (Grossnickle, 2012). As seedlings are more acclimatized to nursery conditions than to planting site conditions, quality assessments inherently include some systematic error (Puttonen, 1997). Assessments during nursery production can also be problematic as seedling characteristics often change during the high grow phase (Mattsson, 1997). Regardless, the ultimate goal of a generating a high quality tree stock is to ensure a very high percentage of out-planting establishment. Thus, specifications for tree stock are designed to ensure that seedlings can endure stresses from variable site conditions and growing climates, but are also applicable to a wide range to species and tree types.

## Review of the 'target seedling concept'

Nursery stock can be graded by both morphological and physiological characteristics, but these characteristics must be related to out-planting performance (Landis, 2011). Physiology and vigor can change significantly between harvest and out-planting while morphology tends not to change during that time, however, seedling morphology can serve as a proxy for physiology (Pinto, 2011). As cheap and quick physiological tests are lacking, morphological and physiological assessments are rarely conducted together (Hobbs, 1984; Pinto *et al.*, 2011a). As a result, non-destructive measurements of seedling form and structure are commonly used as indices of quality and as surrogates for physiology.

Measuring morphology in the nursery is now standard practice and has evolved into a classification system which correlates growth and survival with specific morphological traits (Ritchie, 1984; Pinto, 2011). The measured morphological attributes represent the cumulative series of physiological responese to resources and stresses during nursery production (Mexal & Landis, 1990). Although the physiological condition of seedlings can override morphology, the size and shape of the plant still provides a beneficial tool for nurseries to grade tree stock and evaluate potential field survival and growth (Thompson, 1985). Thus, morphological attributes are considered a reliable measure of seedling quality as they retain their mark on the seedling identity for extended time frames after seedlings are field planted and start to grow (Puttonen, 1997; Grossnickle, 2012).

The main morphological attributes used to address stock quality are: height, diameter and root system size (Thompson, 1985; Mexal & Landis, 1990; Rose *et al.*, 1990; Haase, 2011; Pinto, 2011). Consequently, seedling quality represents how each of these attributes act together and influence one another (Wightman, 1999). Importantly, no single morphological factor has been shown to provide a perfect prediction of out-planting success, but many are linked with aspects of seedling performance potential (Mattsson, 1997; Haase & Others, 2007). Thus, seedling morphological characteristics are best described with a combination of height, diameter and root:shoot ratio (Cleary *et al.*, 1978). Of these, height and diameter are easily the two most common parameters examined in tree stock, and minimum and maximum targets are usually established in grower specifications (Thompson, 1985; Haase, 2008).

The realization that no single factor predicts seedling success led to the 'target seedling concept' by Rose *et al.* (1990), which proposes that numerous physiological and morphological seedling traits should be tracked and developed to quantitatively assess seedling performance (Rose & Hasse, 1995). An overarching aim of the target seedling approach is that seedling quality is of the utmost importance. Global adaptation of this concept has led to a suite of quality assessment criteria, that are now essential elements in seedling testing standards. It is now commonly accepted that height and diameter measurements alone do not always correlate with seedling performance following out-planting. For example, including height, stem diameter and shoot-root ratio each influence seedling tolerance to environmental stress and thus should be considered in relation to each other (Cleary *et al.*, 1978). Indices combining various morphological traits (i.e. root:shoot, height:diameter) have therefore been adopted to better assess overall seedling quality.

# Mini-Review of common morphological indices

## Aboveground (Height, Diameter/Calliper)

## Belowground (Rootball diameter and volume)

## Pitfalls with morphological assessments and single parameter relationships

## Tree Root:Shoot balance

## General plant ecology

## Building quantitative links between morphological parameters

## Tree stock balance in production nurseries

## Effect of container size

* + Effect of nursery practices