

Morphology Targets: What Do Seedling Morphological Attributes Tell Us?

Jeremiah R Pinto

Jeremiah R Pinto is Research Plant Physiologist, USDA Forest Service, 1221 S Main St, Moscow, ID 83843; Tel: 208.883.2352; E-mail: jpinto@fs.fed.us

Pinto JR. 2011. Morphology targets: what do seedling morphological attributes tell us? In: Riley LE, Haase DL, Pinto JR, technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2010. Proc. RMRS-P-65. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station: 74-79. Available at: http://www.fs.fed.us/rm/pubs/rmrs_p065.html

Abstract: Morphology is classically defined as the form and structure of individual organisms, as distinct from their anatomy or physiology. We use morphological targets in the nursery because they are easy to measure, and because we can often quantitatively link seedling morphological traits with survival and growth performance in the field. In the 20 years since the Target Seedling Concept was developed, morphological targets remain some of the most commonly used attributes to link seedling quality and field performance. Traits such as height and root-collar diameter are still standard attributes, but others have also proven their worth despite being more difficult to measure.

Keywords: Target Plant Concept, seedling performance, performance potential, stocktypes, seedling quality

Morphology Targets

In the context of biology, morphology describes the form and structure of an organism and gives a sense of how that form contributes to function. Morphology, in the context of seedlings, conjures up an image of how a seedling looks after nursery culturing; a stocktype designation also does the same. Measuring morphology in the nursery has been standard practice for quite some time because it is an easy way to track growth and describe a seedling at harvest. Seedling morphology has, therefore, evolved into classification that correlates seedling survival and growth with specific morphological traits.

Over time, morphological traits became targets that drove nursery culture and were also species-specific. For example, a target loblolly pine (*Pinus taeda*) seedling produced in a bareroot nursery 20 years ago was defined as having a height of 20 to 25 cm (7.9 to 9.8 in), a root-collar diameter (RCD; also referred to as stem diameter and caliper) of > 4 mm (0.16 in), mostly secondary needles, a single prominent stem, a well-developed bud with resinous scales, a minimum of six first-order lateral roots, fibrous roots, mycorrhizae, a root volume of ≥ 3.5 ml (0.2 in³), and high root growth potential (Rose and others 1990) (Figure 1). The targets defined grading specifications at harvest; if any seedling did not meet minimum specifications, it was culled. Grading specifications in line with morphological targets ensured planted seedlings would have the best chance for survival and growth.

Just over 20 years ago (1990), the Target Seedling Symposium was held in Roseburg, Oregon. The objectives were to discuss the “latest methods of describing and measuring the ideal seedling for reforestation purposes.” Within this discussion, the Target Seedling Concept was introduced to unify the thought that specific morphological and physiological seedling characteristics could be quantitatively linked to reforestation success. By this time, it was pretty well understood that morphological traits were tied to seedling success in the field; therefore, the emphasis shifted more towards further understanding of seedling physiology. Despite the considerable emphasis on physiological tests for seedling quality and performance, the fact remained that morphological traits were still the easiest and quickest to measure on an operational basis. Furthermore, morphology is a general reflection of physiological quality in that a seedling with poor physiological quality can often have morphological attributes that do not meet targets. With a few basic pieces of equipment, most nurseries could obtain a quick morphological estimate on how well they grew their seedlings, and how well they might perform in the field as a result.

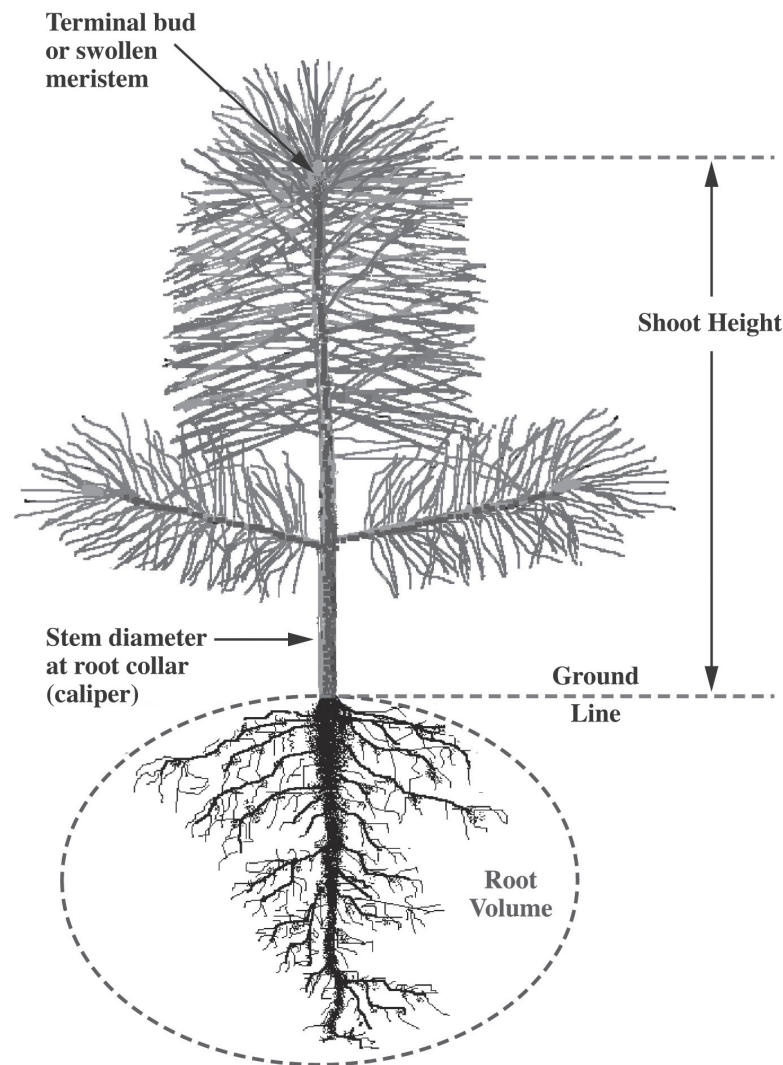


Figure 1. Some of the most common morphological measurements and targets include height, root-collar diameter, root size, and the presence of a well-developed bud (from Landis and others 2010).

The most important morphological traits discussed during the 1990 symposium are still the ones that are discussed today. Height and RCD are two of the most commonly used measurements for specifying seedling targets (and subsequent grading) as well as indicating outplanting performance potential. Thompson (1985) and Mexal and Landis (1990) provide great discussions and reviews on measurement, standards, and quality prediction of height and RCD. In addition to these two common characteristics, other morphological traits have been used as targets, grading criteria, and quality predictors. Thompson (1985) also reviews weights (biomass), root size, bud length, color, secondary needles, mycorrhizae, shoot-to-root ratio (S:R), sturdiness (the quotient of height in cm divided by RCD in mm), and several others.

Morphological Ties to Seedling Field Performance

Many morphological traits and targets have been well-correlated with seedling performance after outplanting. Despite being a physical descriptor of a seedling, morphology has implications toward physiology. Essentially, morphological attributes have become a proxy for physiological processes that occur once a seedling has been outplanted. The key to this assumption is that the actual physiology and vigor of the seedling is of the same high quality as the target morphology. In reality, physiology and vigor can change significantly between harvest and outplanting while morphology tends not to change during that time. However, most correlations stemming from morphology have met the assumption of matched, high quality physiology.

In general, seedlings that are tall at the time of outplanting keep their height advantage in the field over time (Figure 2A). In some cases, initial seedling height may not always indicate a seedling will grow more. For example, Pinto and others (2011b) found that seedlings of different stocktypes (from 60 to 166 ml in container size [4 to 10 in³]) maintained their relative height differences over time because the actual height growth among stocktypes was the same (Figure 2B). Height is closely linked with needle number, and therefore, approximates photosynthetic capacity and potential transpirational surface area. Because other factors, such as S:R and outplanting site conditions, can influence seedling growth, however, it is important to remember that tall seedlings may not always be the desired target. For example, a tall seedling with high transpiration potential is likely not the target seedling for a dry site, nor might it be recommended for a site with lots of wind.

RCD is often linked with seedling survival in the field. Typically, large RCDs mean higher survival rates (Figure 3). With container seedlings, however, RCDs can become too large, indicating the seedlings have become root bound. South and others (2005) found that container-grown longleaf pine (*P. palustris*) showed decreasing survival with RCDs exceeding 9 mm (Figure 4). This correlation was linked to a root bound index (RBI) value that divides RCD by the container cell diameter. Longleaf pine RBIs with a value greater than 30% indicated seedlings were likely root bound and would consequently exhibit decreased survival. Conversely, bareroot seedlings, suffering no bounds by container walls, tend to survive well with continuously increasing RCD (South and others 2005). The physiological correlate for RCD is that it represents the main plumbing line for piping water from the soil to the leaves and vice versa for piping the products of photosynthate to the roots. Larger RCD values tend to imply well-developed root systems for satisfying transpirational demand.

Root size has been used as an index to predict outplanting success. Many methods for measuring root size exist, and for the purposes of this paper will only be covered briefly. For more detailed information on target root specifications and relationships, see Haase (2011). As mentioned, many methods exist for measuring root size. Root volume, mass, length, area index, and number of first-order laterals are all possible ways to measure and classify root morphology. In bareroot nursery stock, Rose and others (1997) found that larger root volumes led to higher survival in ponderosa pine seedlings after 8 years. For container nursery stock, Pinto (2009) demonstrated that larger container volumes produced taller seedlings after two growing seasons in the field (Figure 5). The importance of a functional and vigorous root system in seedling survival and growth cannot be over emphasized. Physiologically, roots are the first and main connection in the moisture status of the plant and the first point of resistance in the soil-plant-air continuum (Grossnickle 2005).

A few other target morphological traits have been used to predict outplanting success. While the presence of a well-developed bud is desirable, bud length has shown some predictability on shoot height. Kozlowski and others (1973) observed that longer buds meant greater shoot length in red pine (*P. resinosa*). Seedling S:R is a morphological attribute that describes the balance between above and below ground biomass. The ratio quantifies the balance between potential transpiration from the shoots to potential absorption from the roots. In general, values of less than 2.5 are beneficial. Cregg (1994) found that a S:R of 1.7 was ideal among several genotypes of ponderosa pine (*P. ponderosa*). The color and form of a seedling also has some bearing on outplanting performance. Seedlings that are pale green to yellow indicate a mineral nutrient deficiency and are likely to perform poorly on the outplanting site. Similarly, seedlings that appear damaged or malformed are also likely to show decreased field performance.

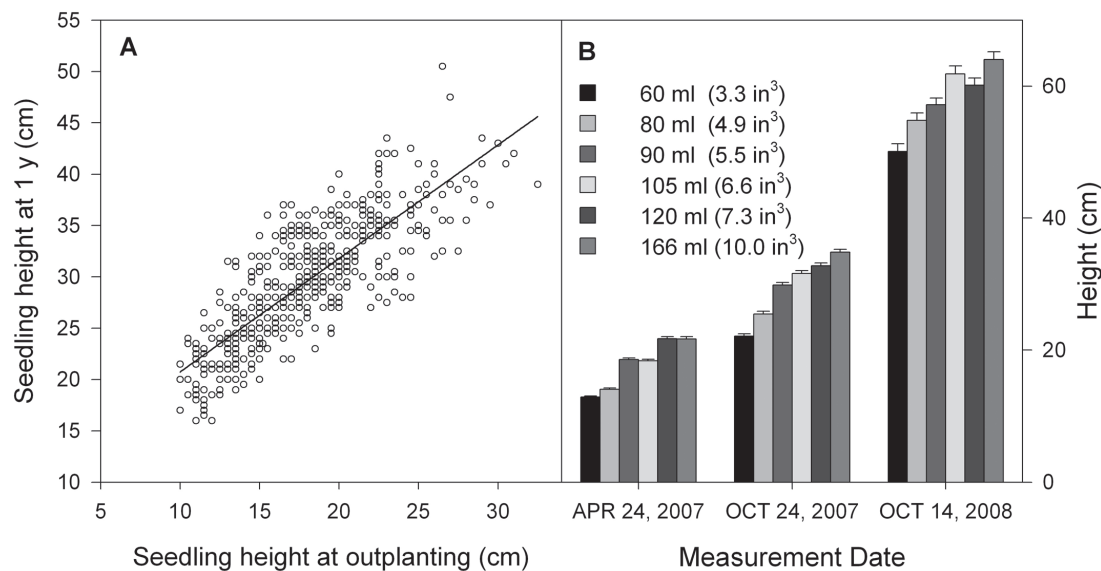


Figure 2. Initial seedling height corresponds well to absolute seedling height (1 cm = 0.4 in) after outplanting (A) (from Pinto 2009). When differently sized stocktypes are planted, and similar growth occurs among stocktypes, absolute heights can remain stratified over time (B) (adapted from Pinto and others 2011b).

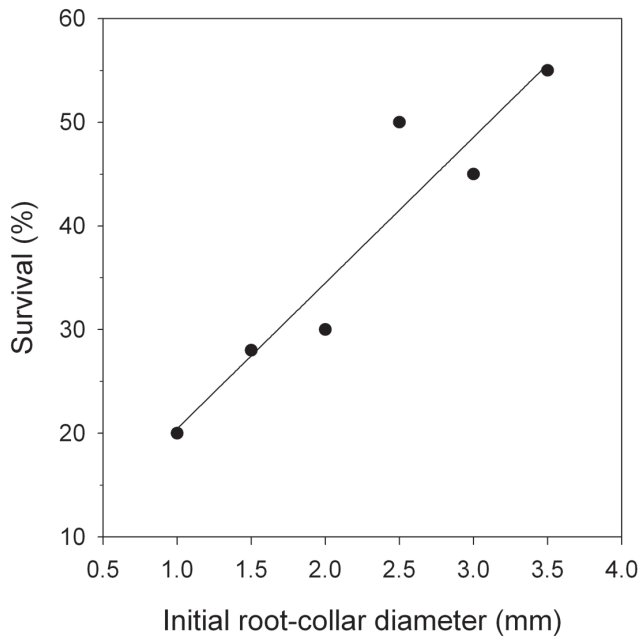


Figure 3. For outplanted Engelmann spruce, seedlings with larger root-collar diameters (1 mm = 0.04 in) exhibited better survival after 2 years (modified from Hines and Long 1986).

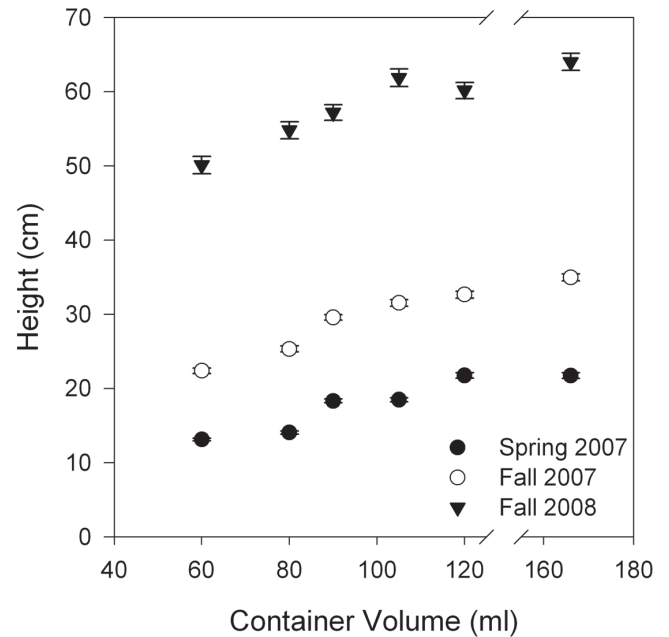


Figure 5. Heights of ponderosa pine seedlings (1 cm = 0.4 in) grown in six different container volumes ranging in size from 60 ml (3.3 in³) to 166 ml (10.0 in³). Seedlings were measured after planting (spring 2007), after one growing season (fall 2007), and after two growing seasons (fall 2008) (modified from Pinto 2009).

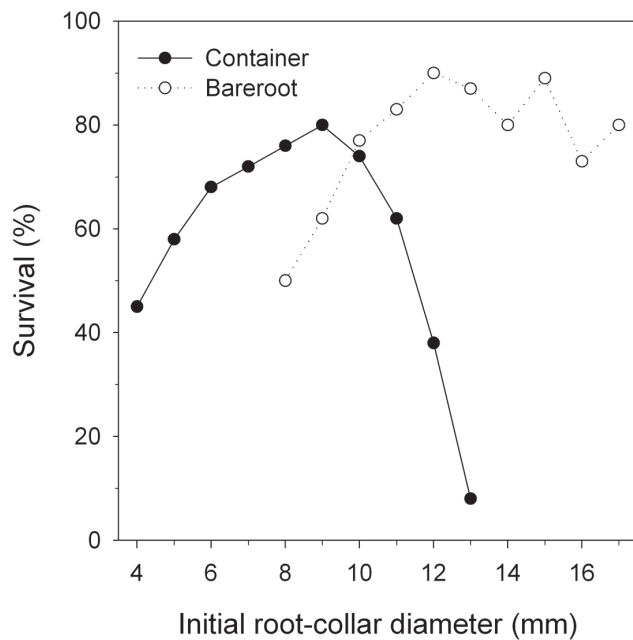


Figure 4. Longleaf pine seedlings can become too large for their containers, thus becoming root bound; consequently, root bound seedlings with large root-collar diameters (RCD; 10 mm = 0.4 in) can show reductions in survival after outplanting. Because bareroot seedlings are not limited by container environments, increasing RCD values continue to show increases in outplanting survival (modified from South and others 2005).

Most morphological targets are determined because they can be quantitatively linked with outplanting success. Although these morphological attributes describe physical characteristics, they are often tied to physiological processes that aid a seedling's establishment on the outplanting site. The model of seedling establishment proposed by Burdett (1990) outlines this link and forms it into a positive feedback loop. Any interruption in the loop will decrease survival or growth (Figure 6).

Seedling Morphology and Stocktypes

In early seedling production, nursery managers learned how to manipulate seedling characteristics to maximize survival and growth for the benefit of the practicing forester. The dialogue between the two helped develop specific targets for species and outplanting sites. Eventually, nursery managers began expanding their products, offering various types of bareroot, bareroot transplant, and container seedlings. Since then, the number of seedling stocktypes has increased dramatically, thereby expanding the range of target seedlings—and morphological attributes—for practicing foresters. The range of stocktypes has not only benefited foresters, but has also aided restorationists. In fact, restoration projects have greatly increased the diversity of stocktypes because of the broad range of species and unique outplanting sites being managed.

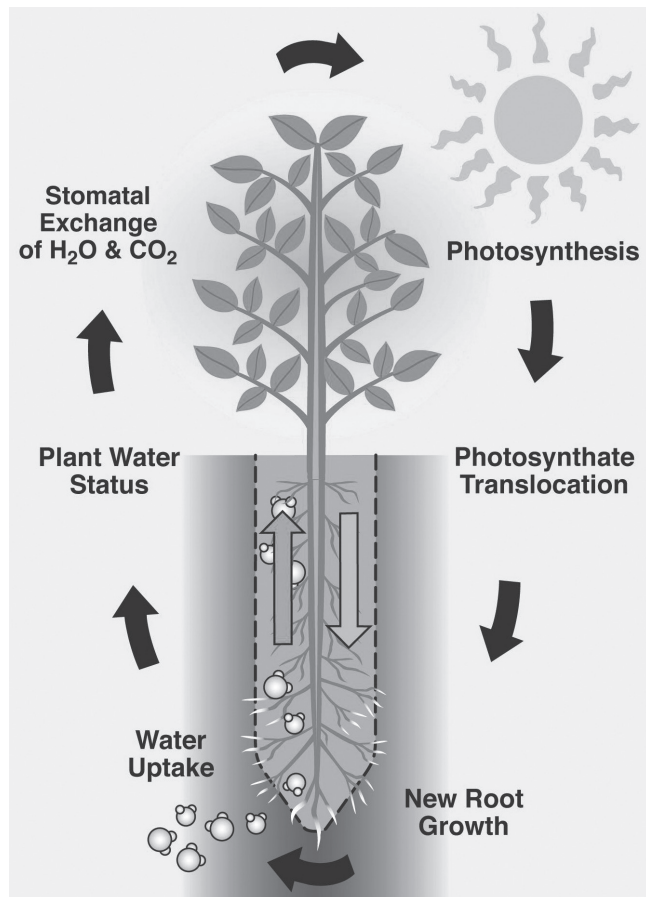


Figure 6. The model of seedling establishment proposed by Burdett (1990). Morphological attributes that contribute to photosynthesis (that is, seedling height) and potential new root growth (that is, root size) are part of the feedback relationship and contribute to seedling establishment, survival, and growth (Pinto and others 2011a).

The Target Plant Concept

“The Target Seedling Concept means to target specific physiological and morphological seedling characteristics that can be quantitatively linked with reforestation success” (Rose and others 1990). Over the years, this concept has evolved to include other types of plant materials and is now termed the Target Plant Concept (TPC) (Landis 2009). The concept unifies the three ideas that: 1) you start at the outplanting site; 2) the nursery and client are partners; and 3) the emphasis is on seedling quality. From these ideas, the target plant materials are defined in six-interrelated steps: 1) what are the project objectives?; 2) what are the type(s) of plant material needed?; 3) are there genetic or sexual considerations?; 4) what are the limiting factors on the outplanting site?; 5) what is the outplanting window?; and 6) what are the best outplanting tools and techniques for the outplanting site? For greater, in-depth coverage of the TPC, see Landis (2009, 2011) and Landis and others (2010).

To define the target morphology of a seedling, the outplanting objective must be known. Second, a major consideration is the limiting factors on the outplanting site. Once these two variables of the TPC are characterized, the nursery manager and client can better define the type of plant material needed. The subsequent steps including genetics, outplanting timing, and tools will also be better sorted out once the plant material is known. In essence, the target morphology for the target plant becomes the target stocktype. Because of the increasingly unique circumstances of reforestation and restoration—drastically disturbed sites, mining, road construction, invasive species, and changing conditions due to climate change—stocktypes are constantly evolving. With this new development, testing needs to validate not only stocktype use, but also target morphology with the stocktype. Properly executed trials will identify key performance advantages that help overcome site limiting factors (see Pinto and others 2011a).

Summary

The morphological attributes of height and RCD are the most commonly used to define seedling targets and infer seedling quality. These attributes are the easiest to measure lending to their popular use in operational settings. Morphological attributes are physical in nature and tend not to change appreciably between harvest and outplanting. Therefore, despite not being direct measures of seedling physiology, inferences to seedling quality assume optimum physiology and vigor. When this assumption is met, morphological attributes have been shown to predict performance potential in most circumstances. Morphological targets and stocktypes are intimately related. The Target Plant Concept provides a framework for defining the target plant material.

Acknowledgments

I would like to thank Thomas D Landis and Anthony S Davis for their help on the preparation of the presentation for the Symposium. I also want to thank R Kasten Dumroese, Diane Haase, and Lee Riley for their editorial assistance on this paper. Special thanks to Lee and Diane for their patience in working with me on these proceedings—well done!

References

- Burdett AN. 1990. Physiological processes in plantation establishment and the development of specifications for forest planting stock. *Canadian Journal of Forest Research* 20:415-427.
- Cregg BM. 1994. Carbon allocation, gas exchange, and needle morphology of *Pinus ponderosa* genotypes known to differ in growth and survival under imposed drought. *Tree Physiology* 14:883-898.
- Grossnickle SC. 2005. Importance of root growth in overcoming planting stress. *New Forests* 30:273-294.
- Haase DL. 2011. Seedling root targets. In: Riley LE, Haase DL, Pinto JR, technical coordinators. *National Proceedings: Forest and Conservation Nursery Associations—2010*. Fort Collins (CO): USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-65. 80-82.
- Hines FD, Long JN. 1986. First and second-year survival of containerized Engelmann spruce in relation to initial seedling size. *Canadian Journal of Forest Research* 16:668-670.

- Kozlowski TT, Torrie JH, Marshall PE. 1973. Predictability of shoot length from bud size in *Pinus resinosa* Ait. *Canadian Journal of Forest Research* 3:34-38.
- Landis TD. 2009. The target plant concept. In: Dumroese RK, Luna T, Landis TD, editors. *Nursery manual for native plants: A guide for tribal nurseries, Vol 1, Nursery management*. Washington (DC): USDA Forest Service, Agricultural Handbook 730. p 14-31.
- Landis TD. 2011. The target plant concept—a history and brief overview. In: Riley LE, Haase DL, Pinto JR, technical coordinators. *National Proceedings: Forest and Conservation Nursery Associations—2010*. Fort Collins (CO): USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-65. 61-66.
- Landis TD, Dumroese RK, Haase DL. 2010. Seedling processing, storage, and outplanting. Vol 7. *The container tree nursery manual*. Washington (DC): USDA Forest Service, Agricultural Handbook 674. 200 p.
- Mexal JG, Landis TD. 1990. Target seedling concepts: height and diameter. In: Rose R, Carlson WC, Landis TD editors. *Target seedling symposium: proceedings—combined meeting of the western forest nursery associations; 13-17 Aug 1990*; Roseburg, OR. Fort Collins (CO): USDA Forest Service, Rocky Mountain Research Station. General Technical Report RM-200. p 17-35.
- Pinto JR. 2009. Growth and gas exchange of different ponderosa pine stock types on dry sites. [PhD dissertation]. Moscow (ID): University of Idaho. 78 p.
- Pinto JR, Dumroese RK, Davis AS, Landis TD. 2011a. Conducting seedling stock type trials: a new approach to an old question. *Journal of Forestry* 109:293-299.
- Pinto JR, Marshall JD, Dumroese RK, Davis AS, Cobos DR. 2011b. Establishment and growth of container seedlings for reforestation: a function of stocktype and edaphic conditions. *Forest Ecology and Management* 261:1876-1884.
- Rose R, Carlson WC, Morgan P. 1990. The target seedling concept. In: Rose R, Carlson WC, Landis TD editors. *Target seedling symposium: proceedings—combined meeting of the western forest nursery associations; 13-17 Aug 1990*; Roseburg, OR. Fort Collins (CO): USDA Forest Service Rocky Mountain Research Station. General Technical Report RM-200. p 1-16.
- Rose R, Haase DL, Kroiher F, Sabin T. 1997. Root volume and growth of ponderosa pine and Douglas-fir seedlings: a summary of eight growing seasons. *Western Journal of Applied Forestry* 12:69-73.
- South DB, Harris SW, Barnett JP, Hains MJ, Gjerstad DH. 2005. Effect of container type and seedling size on survival and early height growth of *Pinus palustris* seedlings in Alabama, U.S.A. *Forest Ecology and Management* 204:385-398.
- Thompson BE. 1985. Seedling morphological evaluation - what you can tell by looking. In: Duryea ML, editor. *Evaluating seedling quality: principles, procedures, and predictive abilities of major tests*. Corvallis (OR): Forest Research Laboratory, Oregon State University. p 59-71.