Stocktype Influences Western White Pine Seedling Size 6 Years After Outplanting

Donald J. Regan, Kent G. Apostol, and Anthony S. Davis

Assistant Nursery Manager, Center for Forest Nursery and Seedling Research, College of Natural Resources (CNR), University of Idaho (UI), Moscow, ID; Research Scientist, Center for Forest Nursery and Seedling Research, CNR, UI, Moscow, ID; Director and Associate Professor, Center for Forest Nursery and Seedling Research, CNR, UI, Moscow, ID

Abstract

In container seedling nurseries, copper coating that promotes root pruning and varying container volumes are often used to manipulate seedling size in an effort to optimize outplanting success. Western white pine seedlings were grown with or without copper root pruning in two container sizes. Seedling height and root-collar diameter were significantly different at outplanting and after six growing seasons. Seedlings grown in larger containers (130 ml [8 in^3]) outperformed their smaller (80 ml [5 in^3]) counterparts, and copper root pruning resulted in approximately 10 percent more height and root-collar diameter growth. With relatively few studies investigating the longer-term performance of western white pine seedlings of different stocktypes, these results should aid in identifying appropriate seedlings for meeting outplanting objectives.

Introduction

A target seedling is a plant that has been cultured to survive and grow on a specific outplanting site. The specific outplanting objective(s) will have a critical influence on the target seedling characteristics. Stocktype selection is an important tool used to meet certain management objectives (e.g., reforestation, saw logs or pulp production, and restoration or conservation projects) and overcome obstacles to reforestation success such as site conditions, cost constraints, and the silvics of the species of interest. For example, stock grown in large containers require more growing medium, more fertilizer, and more growing space than those grown in smaller containers; therefore, stocktypes with larger, more robust root systems have higher production costs than those grown in smaller containers (Bowden 1993). Stocktype selection is described in detail in Landis (2009), Davis and Brusven (2010), and Pinto et al. (2011a).

The "Target Plant Concept" promotes quantification of the relationship between seedling quality, in terms of morphology and physiology, and outplanting success (Landis 2009). Use of that information to refine propagation protocols and outplanting practices should then yield higher seedling establishment success. In a container seedling nursery, cavity size and cultural practices are commonly managed to manipulate seedling growth to meet objectives and achieve morphological (e.g., height, stem diameter, shoot to root ratio, and root volume) and physiological (e.g., root growth potential, tissue electrolyte leakage, tissue water potential, tissue moisture content, gas exchange, and mineral nutrition) targets (Landis 2009). The stocktype characteristics that are linked to outplanting success will vary depending on the sites where they will be outplanted. For instance, where seedlings experience drought in the field, stocktypes with larger and longer root systems have better survival or growth as they have better access to water and nutrients. Large shoots can create water deficits through large transpirational surface areas, while small shoots may have small surface areas for photosynthetic activity, resulting in low carbohydrate reserves to endure long periods of drought (Pinto et al. 2011b). Larger container size is well correlated with larger seedling size at the end of the nursery production cycle (Pinto et al. 2011a). Typically, larger seedlings cost more initially (Davis and Brusven 2010) but can outperform smaller seedlings in the field (Pinto et al. 2011a).

Given concerns about container seedlings having poor root egress and poor field survival following outplanting (Wenny et al. 1988), techniques to promote post-planting root growth were developed. One such treatment involves copper coating (copper oxychloride) on container walls. Because copper is toxic to roots, roots will self-prune on contact. After outplanting, seedlings treated in this manner tend to grow more lateral roots, particularly in the upper profile of the root plug (Burdett et al. 1983, Dumroese 2000, Campbell et al. 2006). This improved lateral root development can result in altered, and potentially improved, seedling water and nutrient acquisition (Burdett et al. 1983).

Western white pine (*Pinus monticola* Douglas ex D. Don) is an important component of forests in the Inland Northwest; however, white pine blister rust (*Cronartium ribicola* Fisch. VonWaldh.) is diminishing its range and stature, resulting in the colonization of these forests by less economically and ecologically desirable species (Kinloch Jr. 2003). After the extent and cause of western white pine decline were understood, scientists initiated efforts to restore the species using blight-resistance breeding programs were undertaken (Kim et al. 2003). Local and government nurseries across the species' range currently produce and distribute blight-resistant seedlings and encourage plantings for forest health improvement. For this reason, continued interest exists in refining nursery production and early stand silviculture practices to promote western white pine seedling establishment.

South et al. (2005) and Sword Sayer et al. (2009) observed an increase in seedling size and substantial allocation of root system dry weight to the taproot in longleaf pine (*Pinus palustris* Mill.) when seedlings were grown in copper-coated containers. In addition, Dumroese et al. (2013) reported increased taproot biomass in longleaf pine but no changes to shoot or total root biomass when grown in copper-coated containers. On the other hand, Wenny et al. (1988) reported the use of copper-coated containers resulted in no benefit to western white pine seedling growth 3 years after planting; while Campbell et al. (2006) reported the same for lodgepole pine (*Pinus. contorta* ex Loudon) after two growing seasons.

The objective of this study was to compare the growth and survival of outplanted western white pine seedlings grown in two sizes of containers with and without copper coating. It was hypothesized that seedlings grown with copper treatment would out-perform non-copper seedlings by exhibiting increased growth because of improved water and nutrient uptake, and that seedlings grown in larger containers would maintain their size difference over time.

Materials and Methods

Western white pine seeds (Moscow Seed Orchard seed source) were sown in March 2004. Seedlings were grown under standard operational practices (per Wenny and Dumroese 1987) at the University of Idaho's Franklin H. Pitkin Forest Nursery. Two sizes (120/80 and 91/130) of Styroblock containers (Beaver Plastics, Acheson, Alberta, Canada) either without a copper treatment (Superblock©) or with a copper oxychloride coating (Copperblock©) were included in the study. Containers were identical except for a proprietary application of copper oxychloride made to the surface of each cavity in the Copperblock®, which serves as the root-pruning mechanism. 120/80 containers have a growing density of 120 seedlings per container and a cavity volume of 80 ml (5 in^3), while 91/130 containers have a growing density of 91 seedlings per container and a cavity volume of 130 ml (8 in^3). Following lifting from containers in December 2004, seedlings were placed in cold storage at 2 °C (28 °F) until May 2005, at which time they were thawed and outplanted on a mesic site in Elk River, ID (46°78' N, 116°18' W, elevation 945 m [3,100 ft]), using hoedads (figures 1 and 2).

Figure 1. A general view of the field study site in Elk River, ID. (Photo by D. Regan 2014)

Figure 2. Western white pine seedlings outplanted from (A) Superblock© and (B) Copperblock©. (Photo by D. Regan 2014)

The field study site was generally an ash cap mix in the upper horizons with the habitat type of western redcedar (*Thuja plicata* Donn ex D. Don) and wild ginger (*Asarum caudatum* Lindl.) The soil is in the threebear series, medial over loamy, amorphic over mixed, superactive, frigid oxyaquic udivitrands (Soil Survey Staff 2006). Historic mean maximum and minimum air temperatures were13.6 °C (56.5 °F) and -0.3 °C (31.4 °F), respectively (http://www.wrcc.dri.edu). Mean annual precipitation at the site is 950 mm (37.4 in) with 2,515 mm (99 in) occurring as winter precipitation.

Four replications were established as a randomized complete block design with 20 seedlings per treatment replication. The study was a 2 × 2 factorial (copper coating × container size). Initial height and root-collar diameter (RCD) were measured after outplanting and again at the end of the sixth growing season (September 2010), at which point survival was tallied. Data were analyzed with two-way Analysis of Variance using SAS software version 9.2 (SAS Institute, Cary, NC) and significant differences ($\alpha = 0.05$) were determined using Tukey's HSD.

Results

No significant interactions occurred between copper coating and container size, allowing for analysis of main effects. At outplanting, seedlings grown in the Copperblock® containers had shorter height ($p = 0.0002$) and more RCD ($p < 0.0001$) than those grown in the Styroblock® (no copper) containers and seedlings grown in 91/130 containers were taller ($p < 0.0001$) and had larger RCD ($p < 0.0001$) than those grown in 120/80 containers (table 1).

Six years after outplanting, seedling survival was not influenced by container size ($p = 0.1790$) or copper treatment ($p = 0.5011$) and ranged from 52 to 59 percent across all treatments (data not shown). Height growth ($p = 0.0009$), total height ($p = 0.0002$), RCD growth ($p = 0.0008$), and total RCD ($p = 0.0001$) were significantly more for seedlings grown in larger cavities (91/130 containers) compared with those grown in smaller cavities (120/80 containers) (table 1). Seedlings grown in the Copperblock® containers had more height growth ($p = 0.0048$), RCD

Table 1. Western white pine seedling size (means ± standard errors) at outplanting and after six growing seasons. Different letters indicate significance at $\alpha = 0.05$ between container sizes or between container types. Seedlings were grown in two sizes of Styroblocks either without a copper treatment (Superblock©) or with a copper oxychloride coating (Copperblock©).

Stocktype	Initial (May 2005)	Growth (Sept. 2010)	Total (Sept. 2010)
Height (cm)			
80 ml (5 in³)	11.8 ± 0.1 B	105.3 ± 3.6 B	117.1 ± 3.5 B
130 ml (8 in³)	13.7 ± 0.2 A	122.1 ± 3.6 A	136.8 ± 3.6 A
Superblock©	13.2 ± 0.2 A	107.3 ± 3.9 B	120.5 ± 4.0 B
Copperblock©	12.3 ± 0.2	121.2 ± 3.6 A	133.5 ± 3.7 A
Diameter (mm)			
80 ml (5 in³)	3.9 ± 0.1 B	27.4 ± 0.8 B	31.3 ± 0.8 B
130 ml (8 in³)	4.6 ± 0.1 A	31.3 ± 0.9 A	35.9 ± 0.9 A
Superblock©	4.1 ± 0.1 B	28.0 ± 0.9 B	32.1 ± 1.0 B
Copperblock©	4.4 ± 0.1	30.8 ± 0.8 A	35.2 ± 0.9 A

Conversions: 1 mm = 0.061 in; 1 cm = 0.394 in.

growth ($p = 0.0120$), total height ($p = 0.0079$), and total RCD ($p = 0.0061$) than those grown in the Styroblock® (no copper) containers (table 1).

Discussion

Western white pine seedlings grown in larger containers were initially larger and grew more in height and RCD than seedlings in smaller containers after six growing seasons (table 1). These size and growth differences are not surprising given plant use of growing space and resource acquisition (Sword Sayer et al. 2009, Pinto et al. 2011). Although statistically significant, however, it is important for foresters to determine on a case-by-case basis whether the 62.5-percent increase in container cavity volume, yielding a roughly 10 percent gain in size, is operationally or economically significant. In addition, it is possible that nursery cultural practices could have been adjusted to tailor growing regimes for each container size used. Pinto et al. (2011a) identified that stocktype studies are often limited in scope by using operational practices on experimental stocktypes. Under that premise, stocktype differences in the present study may be underestimated.

Although seedlings grown in copper-treated containers were initially shorter, the < 1 cm (0.4 in) difference was overcome by more growth in those seedlings during six growing seasons. RCD was more throughout the study for seedlings grown in Copperblock® containers compared with those grown in Styroblock® (no copper) containers. Given that RCD tends to be positively correlated with root volume, this increased RCD suggests increased root mass as well. Studies have shown greater lateral root egress resulting from copper pruning treatments (Burdett et al. 1983, Wenny et al. 1988, Dumroese 2000, Campbell et al. 2006, Sword Sayer et al. 2009), so it is anticipated that seedling development can be enhanced following outplanting when using such stock. Aldrete et al. (2002) found that seedling root morphology was improved in smooth-bark Mexican pine (*Pinus pseudostrobus* Lindl.) and Montezuma pine (*P. montezumae* Lamb.) following copper root pruning in the nursery, and postulated that seedling establishment could be improved in an economical manner using this treatment. Our results agree with Burdett et al. (1983), who found that longleaf pine height growth 4 years after outplanting was significantly greater in seedlings that had received copper root pruning compared with those that did not. Nonetheless, other studies have shown ambiguous results in the effect of copper treatment on seedling development after outplanting. Wenny et al. (1988) reported no difference in western white pine seedling growth as a result of copper root pruning 3 years following outplanting. Campbell et al. (2006) reported the same for lodgepole pine after two field seasons. Haywood et al. (2012) did not observe a significant increase in survival for longleaf pine 5 years after outplanting, while Sword Sayer et al. (2009) found no improvement in longleaf pine seedling morphology 1 year after outplanting or in survival 5 years after outplanting for seedlings grown in copper-treated containers, but stated that improved root architecture could yield longer term benefits. Given this variability in results across time, species, and sites, future studies must better quantify seedling quality at outplanting, site conditions, and post-planting environmental conditions.

Container size and copper root pruning each resulted in approximately 10 percent gains in height and RCD. The gains yielded by copper coating may provide a greater economic incentive than those achieved through using larger container use. The long-term nature of this study demonstrates that gains in seedling establishment may be interactive with environmental conditions and indicates that stocktype studies should be continued beyond 3 years to provide useful information on the long-term efficacy of such treatments. Furthermore, while most studies have solely investigated morphological attributes of seedlings associated with copper root pruning, effects on seedling physiological status should be carefully examined. For example, Davis et al. (2011) found that longleaf pine seedling cold hardiness was unaffected by copper root pruning and Arnold and Struve (1993) found seedling Ca, Cu, Mg, N, and Zn levels were higher in seedlings grown with copper root pruning compared with seedlings grown in non-copper containers.

Address correspondence to—

Kent G. Apostol, Research Scientist, Center for Forest Nursery and Seedling Research, College of Natural Resources, University of Idaho, PO Box 441133, Moscow, ID 83843; e-mail: kapostol@uidaho.edu; phone: 208–885–3770.

Acknowledgments

Potlatch Corporation and the University of Idaho Center for Forest Nursery and Seedling Research funded this study. Dave Wenny, Kasten Dumroese, Daniel L. Miller, Abbie Acuff, John Mandzak, and Raini Rippy provided field and technical support. Kea Woodruff and Diane Haase provided helpful comments on the manuscript.

REFERENCES

Aldrete, A.; Mexal, J.G.; Phillips, R.; Vallotton, A.D. 2002. Copper coated polybags improve seedling morphology for two nursery-grown Mexican pine species. Forest Ecology and Management. 163: 197–204.

Burdett, A.N.; Simpson, D.G.; Thompson, C.F. 1983. Root development and plantation establishment success. Plant and Soil. 71: 103–110.

Campbell, D.B.; Kiiskila, S.; Philip, L.J.; Zwiazek, J.J.; Jones, M.D. 2006. Effects of forest floor planting and stock type on growth and root emergence of *Pinus contorta* seedlings in a cold northern cutblock. New Forests. 32: 145–162.

Davis, A.S.; Brusven, A.D.L. 2010. A guide to seedling selection. Misc. Pub. No. 18. Moscow, ID: University of Idaho. 36 p.

Davis, A.S.; Ross-Davis, A.L.; Dumroese, R.K. 2011. Nursery culture impacts cold hardiness in longleaf pine (*Pinus palustris*) seedlings. Restoration Ecology. 19: 717–719.

Dumroese, R.K.; Sung, S.S.; Pinto, J.R.; Ross-Davis, A.; Scott, D.A. 2013. Morphology, gas exchange, and chlorophyll content of longleaf pine seedlings in response to rooting volume, copper root pruning, and nitrogen supply in a container nursery. New Forests. 44: 881–897.

Haywood, J.D.; Sung, S.S.; Sword, S.M.A. 2012. Copper root pruning and container cavity size influence longleaf pine growth through five growing seasons. Southern Journal of Applied Forestry. 36: 146–151.

Kim, M.S.; Brunsfeld, S.J.; McDonald, G.I.; Klopfenstein, N.B. 2003. Effect of white pine blister rust (*Cronartium ribicola*) and rust-resistance breeding on genetic variation in western white pine (*Pinus monticola*). Theoretical and Applied Genetics. 106: 1004–1010.

Kinloch, B.B., Jr. 2003. White pine blister rust in North America: past and prognosis. Phytopathology. 93: 1044–1047.

Landis, T.D. 2009. The target plant concept. In Dumroese, R.K.; Luna, T.; Lands, T.D., eds. Nursery manual for native plants: a guide for tribal nurseries, Vol. 1, Nursery management, Agriculture Handbook 730. Washington, DC: U.S. Department of Agriculture, Forest Service: 14–31.

Pinto, J.R.; Dumroese, R.K.; Davis, A.S.; Landis, T.D. 2011a. A new approach to conducting stock type studies. Journal of Forestry. 109: 293–299.

Pinto, J.R.; Marshall, J.D.; Dumroese, R.K.; Davis, A.S.; Cobos, D.R. 2011b. Establishment and growth of container seedlings for reforestation: a function of stocktype and edaphic conditions. Forest Ecology and Management. 261: 1876–1884.

Soil Survey Staff. 2006. Keys to soil taxonomy. 10th ed. Washington, DC: U.S. Department of Agriculture, Natural Resource Conservation Service; U.S. Government Printing Office. 332 p.

South, D.B.; Harris, S.W.; Barnett, J.P.; Hainds, M.J.; Gjerstad, D.H. 2005. Effect of container type and seedling size on survival and early height growth of *Pinus palustris* seedlings in Alabama, USA. Forest Ecology and Management. 204: 385–398.

Sword Sayer, M.A.; Haywood, J.D.; Sung, S.J.S. 2009. Cavity size and copper root pruning affect production and establishment of container-grown longleaf pine seedlings. Forest Science. 55: 377–389.

Wenny, D.L.; Dumroese, R.K. 1987. A growing regime for containerized western white pine seedlings. Bull. 44. Moscow, ID: University of Idaho, Idaho Forest, Wildlife and Range Experiment Station. 12 p.

Wenny, D.L.; Liu, Y.; Dumroese, R.K.; Osborne, H.L. 1988. First year field growth of chemically pruned containerized seedlings. New Forests. 2: 111–118.

Wenny, D.L.; Woollen, R.L. 1989. Chemical root pruning technique improves the root system morphology of containerized seedlings. Western Journal of Applied Forestry. 4: 15–17.