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Container-Grown Ponderosa Pine Seedlings Outperform Bareroot Seedlings on Harsh Sites in Southern Utah

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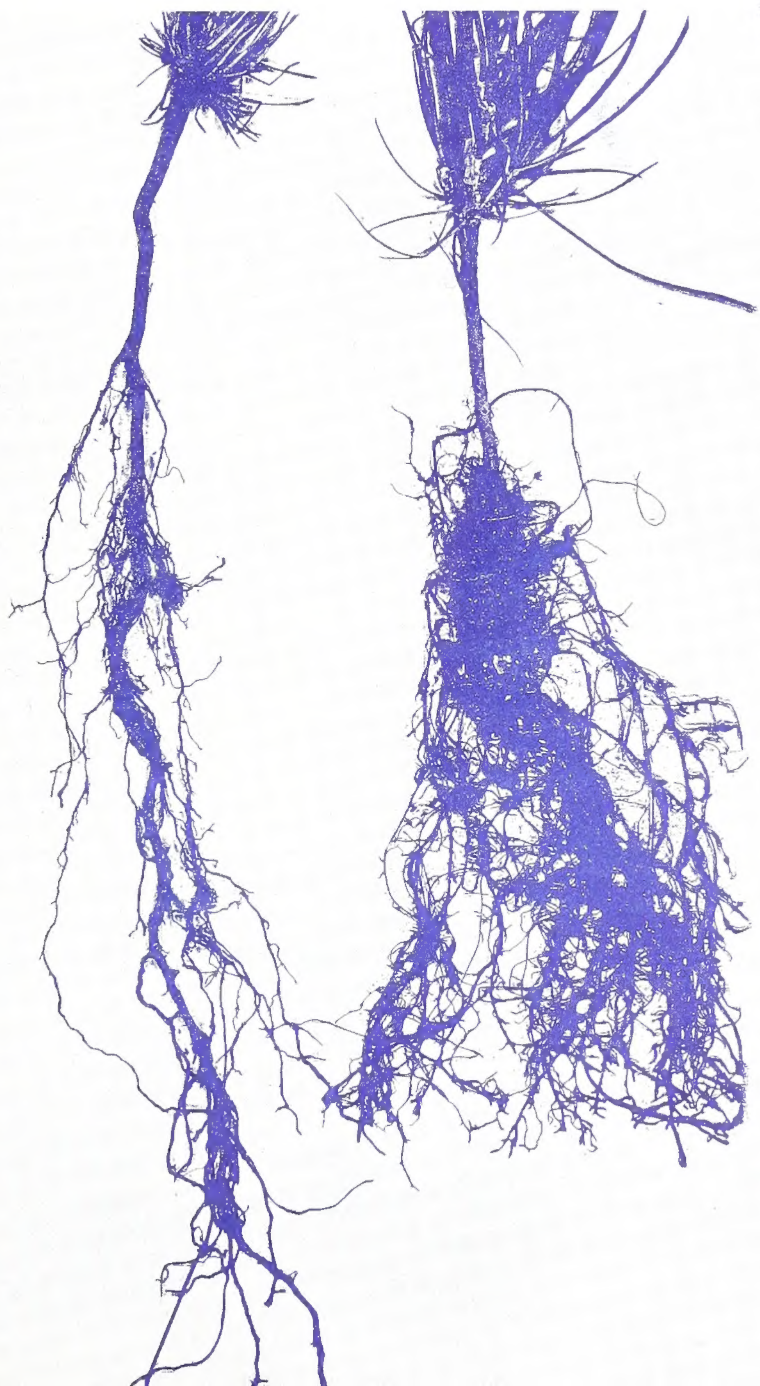

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RESEARCH SUMMARY

Bareroot and container-grown ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) seedlings were planted on five different habitat types in the Dixie National Forest of southern Utah. After five growing seasons, seedling survival, height, and root form were compared.

Container-grown seedlings survived and grew better than bareroot stock on the harshest sites, but there was little difference between the two on sites more conducive to seedling growth. Although the shapes of container-grown and bareroot root systems were different, the root system coverage in the upper 12 inches of soil was similar.

Container-grown seedling survival ranged from 78 to 98 percent. Bareroot stock survival averaged from 64 to 91 percent. After 5 years since planting, seedling mortality continues on the two harshest sites while leveling off on the better sites. Likewise the mean height-growth rates of container grown seedlings continue to increase over the bareroot trees on the poorest sites but stay even on the best sites.

The report includes a summary of other field tests wherein bareroot and container-grown seedlings of North American conifers were compared.

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INTRODUCTION

Reforestation of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) on the lower elevations of the Dixie National Forest in southern Utah has traditionally been challenging. Replanting has often been necessary, costly, and not always successful. Although this problem is not unique, the low levels of available soil moisture during the spring planting season are probably as critical in the Dixie as anywhere in the Intermountain Region. Until this study was initiated, only bareroot seedlings had been planted.

Elsewhere in North America, container-grown seedlings have been planted in attempts to improve survival and growth in plantations. There have been other reasons for planting container-grown stock as well: to produce nursery stock faster and with less lead time, to produce some species that are difficult to grow in bareroot nurseries, to achieve greater production and planting efficiencies, and to extend planting seasons (Ball and Brace 1982; Barnett 1983; Dickerson and McClurkin 1980; Stein 1974, 1977; Stein and Owston 1976, 1977; Tinus 1976). Operational use of container-grown seedlings, and experimental comparisons between bareroot and container stock have produced mixed results (appendix A). Results may have varied because in many comparisons the container stock was much smaller than the bareroot seedlings (Tinus 1979). Generally the container-grown seedlings have performed very well, especially in recent years.

Several investigators have found that the form of root systems of container-grown trees differs from the form of bareroot seedlings and trees seeded in place. Most natural seedlings of ponderosa pine are characterized by a well-developed taproot, with a few evenly distributed laterals starting just below the root collar (Long 1978; Stein 1978). Stein (1978) calculated the average taproot of natural seedlings to be almost six times longer than the shoot after two growing seasons. Bareroot and container culture affected several root system characteristics, including symmetry, balance, constriction, coiling, taproot development, and root system deformations caused by planting. In most cases there is little difference in root balance and symmetry between container-grown and bareroot stock; however, coiling and constriction are more prevalent in the container-grown trees. The bareroot trees showed a much higher incidence of roots bent in the shape of an L, a J, or knotted, and had fewer well-developed taproots. These differences are still visible from 4 to 7 years after planting (Long 1978). Preisig and others (1979) found more variability in the root form of planted Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) bareroot seedlings than container-grown seedlings; but seedling height was not related to differences in root system morphology for trees 5 to 8 years old.

In container-grown stock, root system deformation is largely affected by the size and design of the container. But with bareroot stock the planter largely determines the root configuration. Budy and Miller (1984) found that after 10 years the container still influenced the root form and number of lateral roots of Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.). Similar comparisons of root form have been documented for lodgepole pine, white spruce (*Picea glauca* [Moench] Voss), Douglas-fir (Van Eerden 1978), lodgepole pine (*Pinus contorta* Dougl.) and white spruce (McMinn 1978), and Douglas-fir and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) (Arnott 1978). Van Eerden (1978) concludes that, although root deformations occur with both container and bareroot seedlings, they do not inevitably lead to plantation failure. Root systems repair themselves and in time acquire a nearly natural habit.

Buchanan (1974) reports mixed results in comparing bareroot ponderosa pine with seedlings grown in Spencer-Lemaire Rootrainers, Styroblocks, Conwed tubes, and peat blocks. Overall, seedling survival with Styroblocks and Rootrainers was close to that of bareroot. Conwed tubes and peat blocks had lower survival.

One and 2 years after planting, survival and growth of container-grown ponderosa pine seedlings was equal to or better than that of seedlings grown in Conwed tubes, Jiffy pots, and Styroblocks planted on the Great Plains (Hite 1974). Although not all field performance showed significant differences, Hite saw an average overall gain in survival of about 20 percent from the use of container-grown seedlings.

This report presents the results of a field comparison between containerized and bareroot ponderosa pine seedlings on the Dixie National Forest after five growing seasons. The administrative study was undertaken by the Dixie National Forest with help from the Intermountain Research Station.

Table 1—Comparison of several characteristics for sites where container stock and bareroot seedlings were tested

Characteristic	Site A	Site B	Site C	Site D	Site E
Ranger District	Cedar City	Cedar City	Powell	Powell	Escalante
Locality	Mammoth Creek Road	Mammoth Cave	Wilson Peak	Dave's Hollow	Allen's Canyon
Parent material	Limestone	Basalt	Limestone	Limestone	Limestone
Soil texture					
0-10 inches	Silt loam	Silt loam	Gravelly loam	Gravelly loam and clay loam	Gravelly silt loam
10-20 inches	Silty clay loam and silt loam	Silty clay loam to silty clay	Very gravelly	Gravelly loam	Gravelly silty clay loam
Percent moisture of soil at 5 bars tension					
4-6 inches	14.06	6.03	19.22	21.52	18.35
10-12 inches	18.22	8.37	23.03	19.99	23.05
Elevation (ft)	8,450	8,100	7,680	7,720	8,260
Slope (pct)	5	4	4	4	10
Aspect	N	N	NE	NE	SE
Habitat type *(Youngblood and* Mauk 1985)	*Abies concolor/ Symphoricarpos oreophilus*	*Pinus ponderosa/ Symphoricarpos oreophilus*	*Pinus ponderosa/ Purshia tridentata* and *Artemisia nova* (transition)	*Pinus ponderosa/ Arctostaphylos patula*	*Abies concolor/ Arctostaphylos patula*
H.t. 50-year ponderosa pine site index classes (ft) (Youngblood and and Mauk 1985)	30 ± 12	45 ± 9	32 ± 3 and 33 ± 8	32 ± 3	34 ± 9

STUDY AREA

In order to ascertain the influence of site conditions on seedling performance, five sites were chosen within the Dixie National Forest, and the test was repeated on each. The study sites were located in the southwestern part of Garfield County, UT, and represent a range of sites on which ponderosa pine is planted on the Dixie.

The ponderosa pine planting season in the Dixie National Forest normally stretches from late March to late May. Soil moisture is usually adequate during that time. Soon afterward, lack of precipitation limits survival and growth. June is the driest month of the growing season, and rainfall during July, August, and September is erratic. Precipitation has averaged 15 inches (381 mm) per year for the last 30 years at Bryce Canyon weather station, elevation 7,911 ft (2,412 m). The average maximum daily temperature peaks around 86° F (30° C) in June and July (Youngblood and Mauk 1985).

Table 1 compares several characteristics for the five study sites. Site B, near Mammoth Cave, is the only one on a basaltic substrate. The other soils were derived from a limestone parent material. Site A, near Mammoth Creek Road, is located at the highest elevation but is only 770 ft (235 m) above the lowest sites, C (Wilson Peak) and D (Dave's Hollow). Site E, with its southeasterly aspect, supports the only study plots which do not face north or northeast. All five sites are different habitat types, but all supported stands dominated by ponderosa pine before they were cut. Although the site index of each habitat type varies, measurements taken by Youngblood and Mauk (1985) indicate that the *Pinus ponderosa/Symphoricarpos oreophilus* habitat type (site B, Mammoth Cave) is the most productive of the five.

METHODS

The comparison test was established in late April of 1981. The same seed source of ponderosa pine was used for both stock types and on all five sites. Container trees were grown at Coeur d'Alene Nursery in Ray Leach Super Cells. The bareroot stock was grown at Lucky Peak Nursery. Container and bareroot seedling heights were similar, but average stem caliper was 20 percent larger for the bareroot trees than the container trees (table 2). The container-grown trees had well-developed root systems limited by the length of the container to 7.5 inches (19 cm). Bareroot trees had 10-inch (25-cm) root

Table 2—Comparison of bareroot and containerized seedling characteristics for ponderosa pine tested in the Dixie National Forest, 1981

Characteristic	Container trees	Bareroot trees
Stock age	1-0	2-0
Root length	19.0 cm	24.7 ± 4.4 cm
Top length	15.0 ± 3.3 cm	15.6 ± 2.8 cm
Stem diameter	3.1 ± 0.6 mm	3.7 ± 0.7 mm
Ovendry weight		
Tops	1.93 g	2.50 g
Roots	0.83 g	0.88 g

Figure 1—The study site near Wilson Peak after thorough site preparation and shortly before planting.

systems, and many of the roots were stripped during lifting from the nursery beds.

Thorough site preparation was done mechanically on each site, and all five areas were fenced to exclude cattle (fig. 1). Trees of both stock types were auger-planted at the same time. Air and soil temperatures and moisture conditions were generally favorable.

The study was installed with a randomized complete block design comprising 10 blocks per site. Each block contained two plots, one with the bareroot treatment, the other with the container treatment. Trees were spaced 6 by 6 ft (1.8 by 1.8 m). Each plot contained two rows of 10 trees. In other words, 20 container-grown and 20 bareroot seedlings were planted in each block.

Tree survival and heights were measured in the fall of 1981, 1982, 1983, and 1985. In addition, two trees were dug from each plot after the fifth growing season to inspect the roots for growth and form. For each tree that was dug, we calculated a rooting index. This was done by laying the tree on a 1-inch grid and counting the numbers of squares that were intersected by one or more roots. We wanted to account for the third dimension of the root system geometry, so after we measured a seedling the first time, we rotated the stem 90 degrees and measured it once more. We averaged the two measurements to calculate the rooting index for the seedling. This was done for three zones within the upper 12 inches of the root systems: 0-4 inches below the ground surface, 4-8 inches, and 8-12 inches (0-10, 10-20, and 20-30 cm).

RESULTS

After five growing seasons the container-grown ponderosa pine has performed as well as or better than the bareroot stock on all five sites (table 3). Survival ranged from

Table 3—Comparison of mean fifth-year heights and survival of container and bareroot ponderosa pine planted on five sites in the Dixie National Forest. Mean comparisons according to Gabriel (1978)

	Survival	Fifth-year height
	Percent	*cm*
Allen's Canyon		
Bareroot	91*	28.1*
Containerized	98	31.7
Dave's Hollow		
Bareroot	64**	19.6**
Containerized	84	25.7
Mammoth Cave		
Bareroot	91	37.4
Containerized	92	37.8
Mammoth Creek Road		
Bareroot	66*	26.3**
Containerized	78	33.2
Wilson Peak		
Bareroot	84**	31.9
Containerized	96	34.3

*Pairs of means are significantly different (α = 0.05)
**Pairs of means are significantly different (α = 0.01)

64 to 98 percent. The survival differences are statistically significant on four of the five sites. Mammoth Cave is the only site where bareroot stock survived as well as the container-grown seedlings. The biggest difference came at Dave's Hollow, where container-grown trees outsurvived bareroot trees by 20 percent. Dave's Hollow and Mammoth Creek Road sites had the lowest overall survival; Allen's Canyon and Mammoth Cave showed the best survival; Wilson Peak was in between.

Mean height growth on the Mammoth Cave (basalt soil) and Wilson Peak sites was similar for containerized and bareroot trees. But, the height growth of containerized stock was significantly better than that of the bareroot stock on the other three sites. Dave's Hollow showed the biggest difference as well as the poorest overall growth. The best mean growth was measured at Mammoth Cave.

When we excavated a sample of trees 5 years after planting, we found a consistent difference in root form (fig. 2). The root systems of the containerized trees still showed a large mass of roots in the original form of the container plug. From this plug, some lateral roots came out the side but most grew out the bottom. When compared to the containerized stock, the bareroot root systems often did not have as much mass in the upper 12 inches of soil and assumed more of a bell shape.

Table 4 shows the mean rooting index for three root zones. Root zone 1 is 0 to 4 inches (0 to 10 cm) from the ground surface. Root zone 2 is from 4 to 8 inches (10 to 20 cm), and zone 3 is in the 8- to 12-inch (20- to 30-cm) layer. Even though containerized and bareroot root systems are somewhat different in shape, this measurement reveals relatively little difference in total root system in the first 12 inches (30 cm) of soil.

The root index showed trees on the Mammoth Cave site to have more roots in the first 4 inches of soil than on the Dave's Hollow site. The other sites were not different ($\alpha = 0.05$). In the 4- to 8-inch layer, Wilson Peak seedlings had more roots than Mammoth Cave. At 8 to 12 inches from the surface, Wilson Peak was again the best and Mammoth Cave was the worst, but there were also several other differences.

Shoot borer damage to the terminal buds was extensive between the third and fifth growing seasons. The insects did not prefer either container-grown or bareroot seedlings, but there was a difference between sites. The Mammoth Cave and Wilson Peak sites showed the most

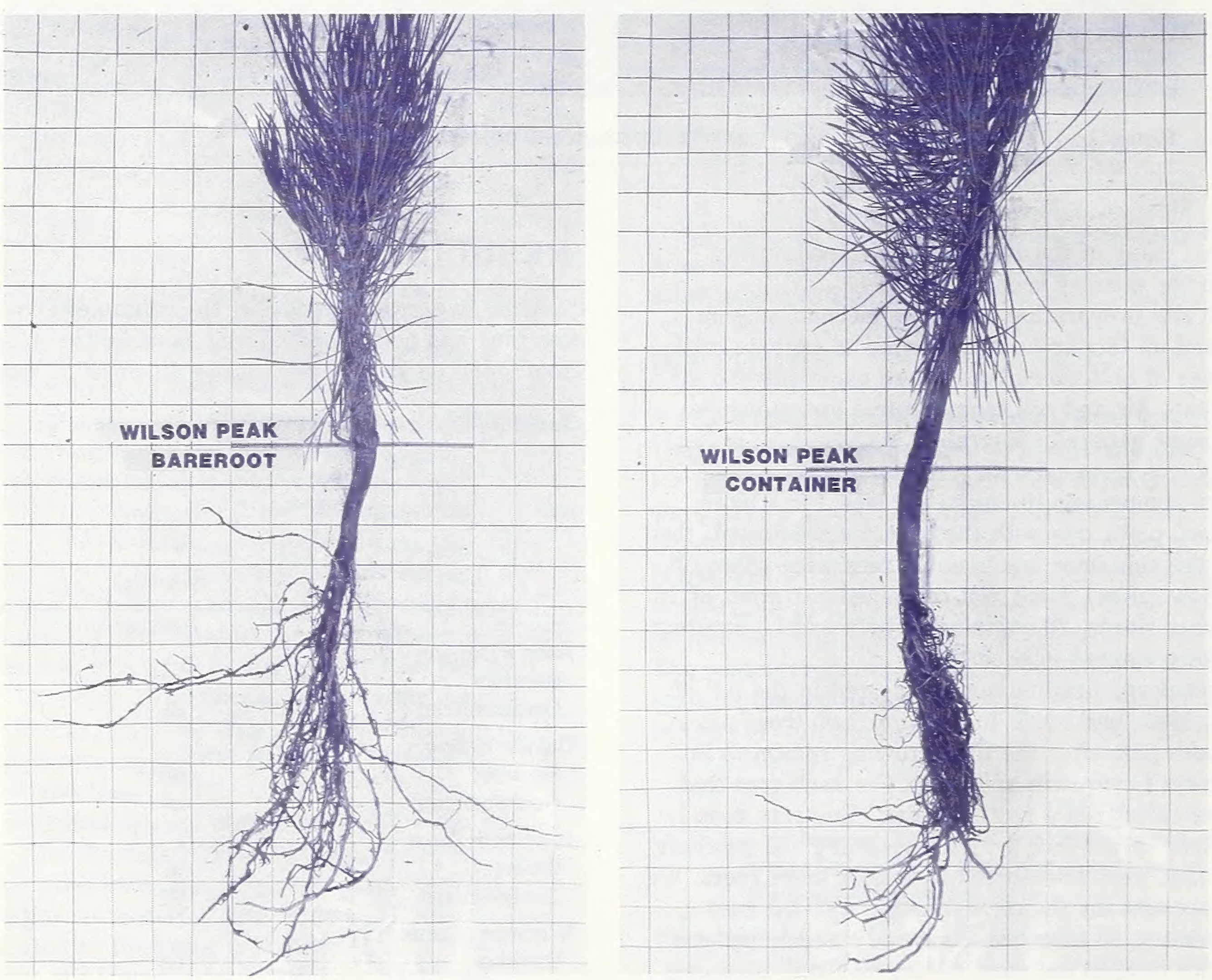

Figure 2—After five growing seasons, the root system forms of container and bareroot ponderosa pine seedlings still show obvious differences. The bareroot tree (left) is shaped like an expanding triangle. The container-grown seedling still has the original plug shape with roots growing out of the bottom. These trees were excavated near Wilson Peak in the Dixie National Forest in September 1985.

Table 4—Mean root index of trees on each site for both treatments and each of three root zones. Larger numbers represent more extensive root system coverage. See text for explanation. Values followed by the same letter are not significantly different (α = 0.01). Mean comparison methods according to Gabriel (1978)

Site and treatment	Zone 1 (0-4 inches)	Zone 2 (4-8 inches)	Zone 3 (8-12 inches)	Zones 1+2+3 (0-12 inches)
Allen's Canyon	9.8 ab	15.8 b	9.5 ab	35.1
Dave's Hollow	8.2 a	12.1 ab	13.5 bc	33.7
Mammoth Cave	10.8 b	10.2 a	4.5 a	25.5
Mammoth Creek Road	8.6 a	12.6 ab	9.7 ab	30.8
Wilson Peak	9.2 ab	16.2 b	17.5 c	42.4
Bareroot	8.8	12.8	10.5	24.4
Containerized	9.7	13.9	11.3	28.5

Figure 3—After five growing seasons on the Allen's Canyon site, few signs of site preparation are evident. The trees are still too small to be conspicuous from a distance. The photo was taken in September 1985.

terminal bud damage from shoot borers. Of all trees surviving after the fifth growing season, 57 and 58 percent showed signs of insect damage, respectively. Mammoth Creek Road and Allen's Canyon sites had about half the leader damage of Mammoth Cave and Wilson Peak (26 percent); Dave's Hollow was intermediate, with 40 percent of live trees infected.

Figure 3 shows how the study site near Allen's Canyon looked in September of 1985, five growing seasons after planting. Most of the vegetation had recovered to prestudy condition.

DISCUSSION

Survival and growth of the ponderosa pine stock differed considerably between sites. Figure 4 compares the yearly survival and height growth of bareroot and containerized stock for all five sites. The order is from best overall performance (top graphs—Mammoth Cave site) to the poorest (bottom graphs—Dave's Hollow site).

After 5 years on the Mammoth Cave site where the trees are the tallest (α = 0.01), there is no difference between the survival and height growth of bareroot compared to containerized stock. But on harsher sites, seedling performance is poorer and container-grown seedlings survive and grow better than bareroot seedlings. Dave's Hollow is the poorest site and the trees are shorter (α = 0.01). Even though the containerized stock at Dave's Hollow did not grow as tall and suffered higher mortality than on other sites, it still performed significantly better than the bareroot stock.

On the other sites seedling survival and growth fell between Mammoth Cave and Dave's Hollow. Again, as survival and height growth improve from site to site, the difference between containerized and bareroot stock diminishes.

Seedling mortality on the best three sites (Mammoth Cave, Allen's Canyon, Wilson Peak) leveled off between the second and third years but has continued on the two harshest sites (Mammoth Creek Road, Dave's Hollow) through the fifth growing season. Survival should not still be declining in the fifth year. Often this indicates an inadequate degree of site preparation. On dry sites in central Idaho, extensive site preparation is needed to ensure ponderosa pine plantation success (Sloan and Ryker 1986).

Heights of container-grown seedlings have continued to increase over the bareroot on the two harshest sites. On the better sites, the margin between bareroot and containerized stock heights has stayed fairly constant. The exception is at Mammoth Cave, where the bareroot trees have caught up since falling behind in the second year (fig. 4).

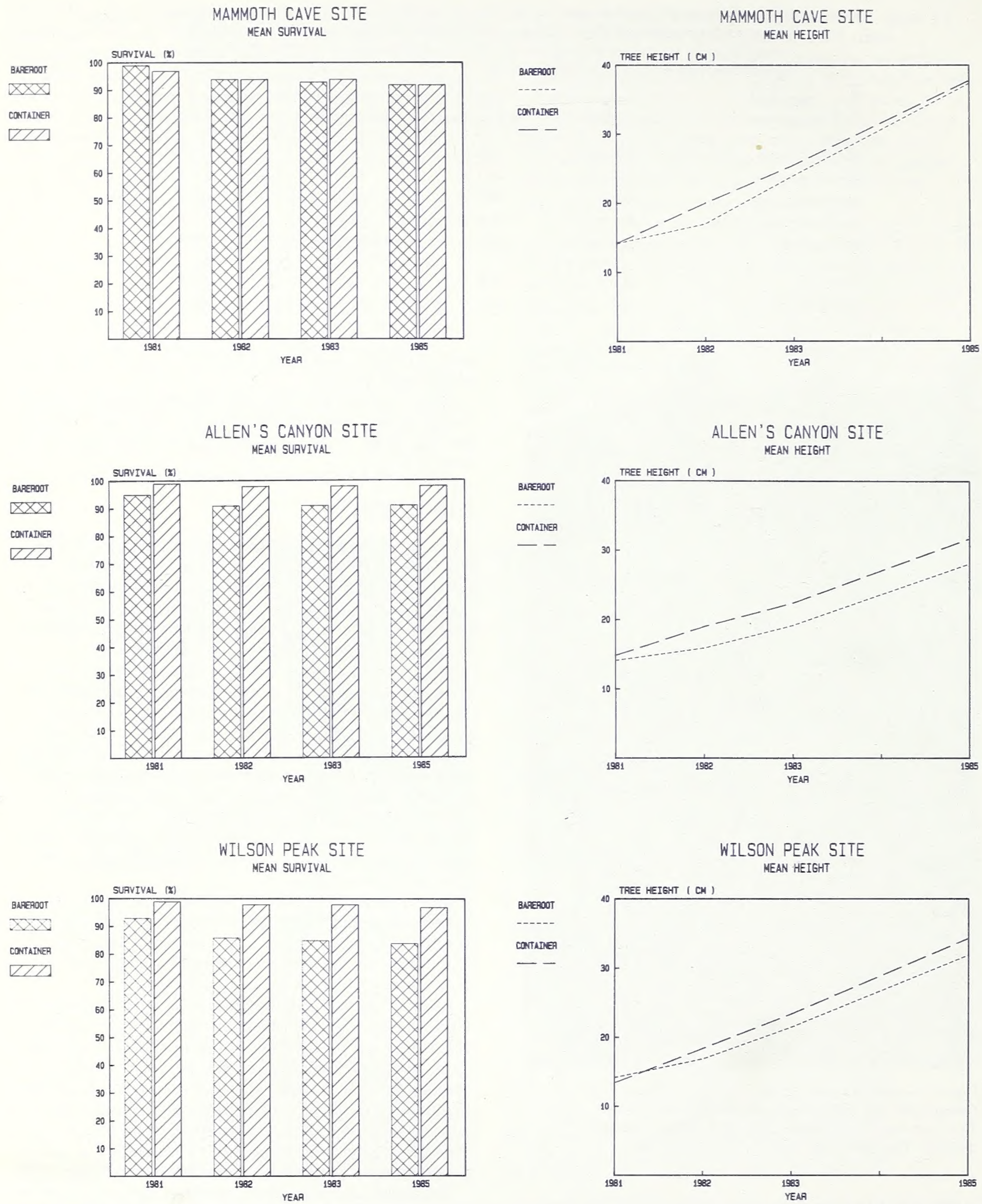

Figure 4—Mean seedling survival and heights of container and bareroot seedlings over five growing seasons on five sites in the Dixie National Forest.

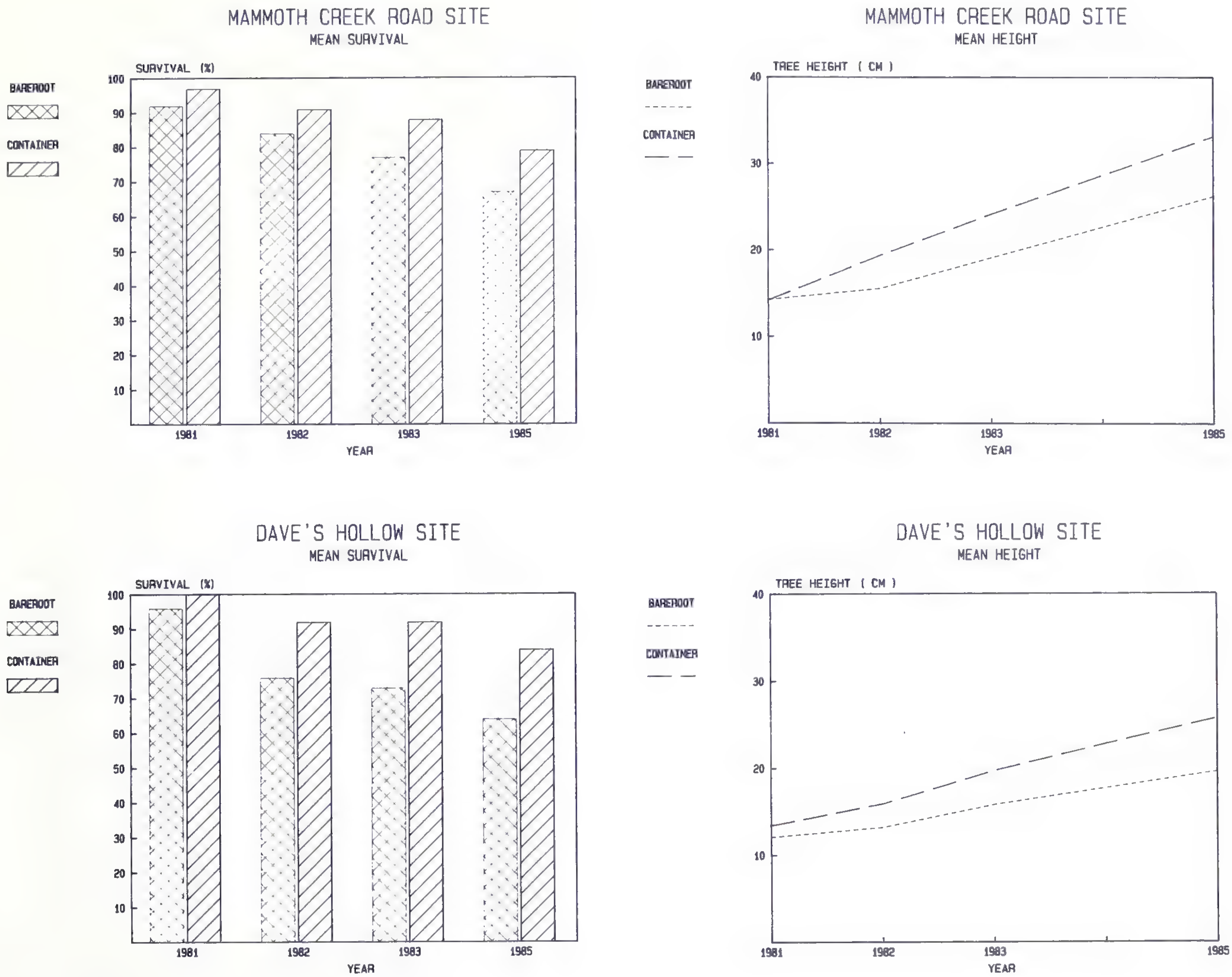

Figure 4 (Con.)

The shoot borer decreased the overall mean heights of the trees but did not affect the results because damage was spread evenly between the bareroot and containerized stock. If anything, the insect damage minimized the difference in height growth between sites because the damage was heaviest on the best sites. There is no evidence that shoot borer damage has affected survival.

Although many of the differences are not statistically significant, the root index in the upper 4 inches of soil followed the fifth year field performance very closely (fig. 4 and table 3). This was not the case in the root zones between 4 and 12 inches, however, perhaps because many roots were stripped when they were excavated from the rocky soil, especially at Mammoth Cave. We found few signs of root deformation in either bareroot or containerized seedlings.

Other studies comparing bareroot and containerized ponderosa pine were mostly in agreement with our results. On a dry site near Rogue River, OR, bareroot ponderosa pine survived and grew better than containerized seedlings (Helgerson 1985). Both performed very well, however, and the differences were small. In tests on the Lincoln National Forest of New Mexico where site and weather conditions are similar to the Dixie, results were mixed (Buchanan 1974). Overall there was no clear winner. Hite (1974) reported superior performance of container-grown seedlings in Rocky Mountain trials.

CONCLUSIONS

Container-grown stock has been used operationally and in field tests throughout North America and has performed very well within the last few years. In the Dixie National Forest in southern Utah, where soil moisture is low following the planting season, container-grown seedlings have shown better overall height growth and survival than similar bareroot stock after five growing seasons. Results on five sites vary from little difference in performance on the best sites to significant differences on the harshest sites. As we move from the best to the poorer quality (fig. 4), seedling survival and fifth year mean heights decrease. Also, on the harshest sites the containerized stock performance becomes superior to that of bareroot stock. Nevertheless, even on the best sites in this study, seedling growth was slower than what we had hoped for with both treatments.

Although the shape of root systems differed, the amount of roots in the upper 12 inches of soil was similar for both kinds of stock. An infestation of shoot borers reduced the mean heights slightly but was not related to treatment and did not affect our conclusions.

After five growing seasons, survival averaged 90 percent for all containerized grown seedlings and 79 percent for bareroot stock. On the good sites not much is gained by planting containerized trees, but on the poor sites containerized trees will definitely outperform bareroot stock.

REFERENCES

Alm, A. A. 1983. Black and white spruce plantings in Minnesota: container vs bareroot stock and fall vs spring planting. Forestry Chronicle. 59(4): 189-190.

Anderson, Robert L.; Knighten, John L.; Powers, Harry R., Jr. 1984. Field survival of loblolly and slash pine seedlings grown in trays and Ray Leach containers. Tree Planters' Notes. 35(2): 3-4.

Arnott, J. T. 1974. Performance in British Columbia. In: Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. Proceedings, North American containerized forest seedling symposium; 1974 August 26-29; Denver, CO. Publ. 68. Lincoln, NE: Great Plains Agricultural Council: 283-290.

Arnott, J. T. 1978. Root development of container grown and bareroot stock: coastal British Columbia. In: Proceedings, root form of planted trees symposium; 1978 May 16-19; Victoria, BC. Victoria, BC: Ministry of Forests and Canadian Forestry Service: 257-267.

Arnott, J. T. 1981. Survival and growth of bullet, styroplug and bareroot seedlings on mid-elevation sites in coastal British Columbia. Forestry Chronicle. 57(2): 65-70.

Ball, W. J.; Brace, L. G. 1982. Production, use, and field performance of container seedlings in the prairie provinces. In: Scarratt, J. B.; Glerum, C.; Plexman, C. A., eds. Proceedings, containerized tree seedling symposium; 1981 September 14-16; Toronto, ON. COJFRC Symposium Proceedings O-P-10. Sault Ste. Marie, ON: Canadian Forestry Service, Great Lakes Forest Research Centre: 313-320.

Barnett, James P. 1983. Containerized seedlings for revegetating difficult sites. Journal of Soil and Water Conservation. 38(6): 462-464.

Boyer, William D. 1985. First-year survival of planted longleaf pine bare-root and container stock as affected by site preparation and release. In: Proceedings of the third biennial southern silvicultural research conference; 1984 November 7-8; Atlanta, GA. Gen. Tech. Rep. SO-54. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 74-78.

Buchanan, Bruce A. 1974. Containerized seedlings on the Lincoln National Forest. In: Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. Proceedings, North American containerized forest seedling symposium; 1974 August 26-29; Denver, CO. Publ. 68. Lincoln, NE: Great Plains Agricultural Council: 350-365.

Budy, J. D.; Miller, E. L. 1984. Survival, growth, and root form of containerized Jeffrey pines ten years after planting. In: Murphy, Patrick M., ed. The challenge of producing native plants for the Intermountain area: Intermountain Nurseryman's Association conference; 1983 August 8-11; Las Vegas, NV. Gen. Tech. Rep. INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 82-88.

Dickerson, B. P.; McClurkin, D. C. 1980. A field trial of year-round planting of bullet seedlings. Tree Planters' Notes. 31(2): 21-22.

Gabriel, K. Ruben. 1978. A simple method of multiple comparisons of means. Journal of the American Statistical Association. 73(364): 724-729.

Gardner, A. C. 1982. Field performance of containerized seedlings in interior British Columbia. In: Scarratt, J. B.; Glerum, C.; Plexman, C. A., eds. Proceedings, containerized tree seedling symposium; 1981 September 14-16; Toronto, ON. COJFRC Symposium Proceedings O-P-10. Sault Ste. Marie, ON: Canadian Forestry Service, Great Lakes Forest Research Centre: 299-305.

Gutzwiler, Jerry R.; Winjum, Jack K. 1974. Performance of containerized coniferous seedlings in recent forest regeneration trials in Oregon and Washington. In: Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. Proceedings, North American containerized forest seedling symposium; 1974 August 26-29; Denver, CO. Publ. 68. Lincoln, NE: Great Plains Agricultural Council: 306-309.

Hahn, Phillip F.; Smith, Allen J. 1983. Douglas-fir planting stock performance comparison after the third growing season. Tree Planters' Notes. 34(1): 33-39.

Helgerson, Ole T. 1985. Survival and growth of planted Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) on a hot, dry site in southwest Oregon. Tree Planters' Notes. 36(4): 3-6.

Hite, Wayne A. 1974. Container field performance in the Rockies and plains. In: Proceedings, North American containerized forest tree seedling symposium; 1974 August 26-29; Denver, CO. Publ. 68. Lincoln, NE: Great Plains Agricultural Council: 306-309.

Hobbs, Stephen D.; Wearstler, Kenneth A., Jr. 1983. Performance of three stocktypes on a skeletal soil. Tree Planters' Notes. 34(3) : 11-14.

Long, James N. 1978. Root system form and its relationship to growth in young planted conifers. In: Proceedings, root form of planted trees symposium; 1978 May 16-19; Victoria, BC. Victoria, BC: Ministry of Forests and Canadian Forestry Service: 222-234.

Marion, Susan P.; Alm, Alvin A. 1986. Performance of fall- and spring-planted bareroot and container-grown red pine (*Pinus resinosa* Ait.). Tree Planters' Notes. 37(2): 24-26.

Mattice, C. R. 1982. Comparative field performance of paperpot and bare-root planting stock in northeastern Ontario. In: Scarratt, J. B.; Glerum, C.; Plexman, C. A., eds. Proceedings, containerized tree seedling symposium; 1981 September 14-16; Toronto, ON. COJFRC Symposium Proceedings O-P-10. Sault Ste. Marie, ON: Canadian Forestry Service, Great Lakes Forest Research Centre: 321-330.

McMinn, R. G. 1978. Root development of white spruce and lodgepole pine seedlings following outplanting. In: Proceedings, root form of planted trees symposium; 1978 May 16-19; Victoria, BC. Victoria, BC: Ministry of Forests and Canadian Forestry Service: 186-190.

Owston, Peyton W. 1972. Field performance of containerized seedlings in the western United States. In: Committee proceedings. Portland, OR: Western Forestry Conservation Association: 109-111.

Owston, Peyton W.; Stein, William I. 1978. Survival, growth and root form of containerized and bare-root Douglas-fir and noble firs seven years after planting. In: Proceedings, root form of planted trees symposium; 1978 May 16-19; Victoria, BC. Victoria, BC: Ministry of Forests and Canadian Forestry Service: 216-220.

Preisig, C. L.; Carlson, W. C.; Promnitz, L. C. 1979. Comparative root system morphologies of seeded-in-place, bareroot, and containerized Douglas-fir seedlings after outplanting. Canadian Journal of Forest Research. 9(3): 399-405.

Ruehle, John L.; Marx, Donald H.; Barnett, James P.; Pawuk, William H. 1981. Survival and growth of container grown and bare-root shortleaf pine with *Pisolithus* and *Thelephora* ectomycorrhizae. Southern Journal of Applied Forestry. 5: 20-24.

Sloan, John P.; Ryker, Russell A. 1986. Large scalps improve survival and growth of planted conifers in central Idaho. Res. Pap. INT-366. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 9 p.

Stein, William I. 1974. Improving containerized reforestation systems. In: Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. Proceedings, North American containerized forest seedling symposium; 1974 August 26-29; Denver, CO. Publ. 68. Lincoln, NE: Great Plains Agricultural Council: 434-447.

Stein, William I. 1977. Prospects for container grown nursery stock. In: Conference proceedings, tree planting in the northwest; 1976 February 17-19; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service: 89-103.

Stein, William I. 1978. Naturally developed seedling roots of five western conifers. In: Proceedings, root form of planted trees symposium; 1978 May 16-19; Victoria, BC. Victoria, BC: Ministry of Forests and Canadian Forestry Service: 28-35.

Stein, William I.; Owston, Peyton W. 1976. Why use container grown seedlings? In: Western Forestry and Conservation Association, Permanent Association Committee Proceedings. Portland, OR: Western Forestry and Conservation Association: 119-122.

Stein, William I.; Owston, Peyton W. 1977. Containerized seedlings in western reforestation. Journal of Forestry. 75: 575-578.

Tinus, R. W. 1976. Greenhouse container nurseries for better trees. In: Shelterbelts on the Great Plains: Proceedings of the symposium; 1976 April 20-22; Denver, CO. Publ. 78. Lincoln, NE: Great Plains Agricultural Council: 137-140.

Tinus, R. W. 1979. Use of container-grown hardwoods for reforestation. In: Regenerating oaks in upland hardwood forests: Proceedings of the 1979 John S. Wright Forestry Conference; West Lafayette, IN. West Lafayette, IN: Purdue University, Department of Forestry and Natural Resources: 120-125.

Van Eerden, E. 1978. Roots of planted trees in central British Columbia. In: Proceedings, root form of planted trees symposium; 1978 May 16-19; Victoria, BC. Victoria, BC: Ministry of Forests and Canadian Forestry Service: 201-208.

Walker, N. R. 1980. Containerized conifer seedling field performance in Alberta and the Northwest Territories. Inf. Rep. NOR-X-218. Edmonton, AB: Environment Canada, Northwest Forest Research Centre. 32 p.

Youngblood, Andrew P.; Mauk, R. L. 1985. Coniferous forest habitat types of central and southern Utah. Gen. Tech. Rep. INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 89 p.

APPENDIX: STUDIES THAT HAVE COMPARED FIELD PERFORMANCE OF BAREROOT AND CONTAINERIZED SEEDLINGS IN THE UNITED STATES AND CANADA

Study	Species	Type of container	Time since field planting	Results	Survival	
					Bareroot	Container
			Years		*Percent*	
Alm (1983)	Black spruce (*Picea mariana* [Mill.] B.S.P.)	Styroblocks	4	Containerized stock survived and grew better than 3-0 bareroot stock.	82,83	94,98
		Paperpots	4	Containerized stock survived and grew better than 3-0 bareroot stock.	82,83	94,99
	White spruce (*Picea glauca* [Moench] Voss)	Styroblocks	4	Containerized stock survived and grew better than 3-0 bareroot stock.	72,86	97,100
		Paperpots	4	Containerized stock survived and grew better than 3-0 bareroot stock.	72,86	94
Anderson and others (1984)	Loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.)	Ray Leach seedling containers	1½	Containerized plugs performed better than bareroot stock grown in trays and planted in the summertime.	64 64	85 86
Arnott (1974)	Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco)	Bullets	3-5	Little difference between bareroot and containerized stock growth rates.	82	58
		Bullet plugs	3-5	Little difference between bareroot and containerized stock growth rates.	82	68
		Styroblocks	1-2	Containerized outperformed bareroot in fall and summer plantings but bareroot performed as well or better than container in other spring and fall plantings.	4-100	28-95
	Western hemlock (*Tsuga heterophylla* [Raf.] Sarg.)	Bullets	3	Containerized stock showed superior survival while growth rates were comparable.	35	49
		Bullet plugs		Containerized stock showed superior survival while growth rates were comparable.	35	59
	Lodgepole pine (*Pinus contorta* Dougl.)	Bullets	5	Little difference in performance of summertime planting.	81-83	81-88
		Bullet plugs	5	Containerized stock performed best.	83	95
		Styroblocks	2	Containerized stock performed best.	44,71	75,77
	White spruce	Bullets	5	Little difference in performance.	62	65
		Bullet plugs	5	Containerized stock performed best.	62	87
		Styroblocks	2	Containerized stock showed superior survival and height growth.	53	92
	Engelmann spruce (*Picea engelmannii* Parry)	Styroblocks	2	Containerized stock showed superior survival.	86,92	69,64

(con.)

Study	Species	Type of container	Time since field planting	Results	Survival: Bareroot	Survival: Container
			Years		- - - - - *Percent*	- - - - -
Arnott (1978)	Douglas-fir	Bullets	5	Bareroot stock survived and grew best on the site with heavy vegetative competition.	71-88	61-69
		Bullet plugs and tubes		Bullet plug performed best on drier sites.	88,71 88,71	78,83 73,66
	Western hemlock	Bullets	5	Containerized stock showed superior survival.	24-36	47-58
		Bullet plugs and tubes			24-36 24,36	61,69 43,45
Arnott (1981)	Douglas-fir	Walter's Bullets	5	Differences were not significant	81	77
		Styroblocks	5	Differences were not significant.	81	84
	Western hemlock	Walter's Bullets	5	Variable results.	63	69
		Styroblocks	5	Containerized stock was superior in survival and height growth.	63	87
Boyer (1985)	Longleaf pine (*Pinus palustris* Mill.)	RL Single cells	1	Containerized stock performance was superior to bareroot and differences were greater on dry sites.	59	80
Buchanan (1974)	Ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.)	Conwed tubes and peat blocks	1	Bareroot stock performed better than containerized stock.	30-40	3-10
		Book planters and styroblocks	1	Results were variable but overall containers performed as well as bareroot.	10-65	20-44
Dickerson and McClurkin (1980)	Loblolly pine	Bullets	3	In plantings made after March, containerized seedlings had greater survival. For trees planted in February and March (shorter storage period) bareroot was best.	0-85	36-69
Gardner (1981)	Douglas-fir	Styroblocks	10	Higher survival rate of containerized stock was not significantly better than bareroot. Bareroot height growth was best but again, not significantly better.	66	75
		Bullets	10	Bareroot survival and growth was significantly higher than containers.	66	53
		Bullet plugs	10	Bareroot stock showed higher survival and height growth. Survival differences were significant.	66	52
	White spruce	Styroplugs	10	There were no differences in survival but bareroot height growth was significantly greater.	87	88

(con.)

Study	Species	Type of container	Time since field planting	Results	Survival	
					Bareroot	Container
			Years		*- - - - - Percent - - - - -*	
		Bullets	10	There was little difference in survival but the bareroot were significantly taller.	87	81
		Bullet plugs	10	There was little difference in survival but the bareroot was significantly taller.	87	81
	Lodgepole pine	Styroblocks	10	There was no significant difference in survival and height growth between containerized and bareroot stock.	82	90
		Bullets	10	There was little difference in survival but bareroot seedlings were significantly taller.	82	81
		Bullet plugs	10	There was little difference in survival but bareroot seedlings were significantly taller.		
Gutzwiler and Winjum (1974)	Douglas-fir	Styroblocks, Bullets, Bullet plugs, and Tree trainers	1-2	Results were mixed. Neither bareroot or containerized seedlings were consistently better than the other in growth. Overall, bareroot seemed to have greater survival.	37-90	05-87
	Western hemlock	Styroblocks	1	Little difference in survival.	84-97	85-99
Hahn and Smith (1983)	Douglas-fir	Styroblocks	3	Containerized stock seemed to perform better than bareroot on north slopes. Containers were clearly superior on south slopes.	84,74	91,96
Helgerson (1985)	Douglas-fir	Ray Leach tubes	2	Bareroot survived and grew better on a very dry site.	99	88
	Ponderosa pine	Ray Leach tubes	2	Bareroot survived and grew better on a very dry site.	98	91
Hite (1974)	Ponderosa pine	Conwed mesh and Jiffy pots	5	Bareroot stock did not survive August planting.	0 0	28-60 50
		Conwed mesh	4	Bareroot stock showed very poor survival in November planting.	8	38-74
		Conwed mesh and Styroblocks		Containerized stock was superior to bareroot in June plantings.	56 56	76,91 73
		Book planters	2	Containerized stock was superior to bareroot.	49	78
	Lodgepole pine	Hillson's	1	Containerized stock outperformed bareroot.	60	89
		Styroblocks	1	Containerized stock outperformed bareroot.	60	98
		Univ. of Idaho	1	Containerized stock outperformed bareroot.		

(con.)

Study	Species	Type of container	Time since field planting	Results	Survival	
					Bareroot	Container
			Years		*- - - - - Percent - - - - -*	
Hobbs and Wearstler (1983)	Douglas-fir	Leach cells	2	Containerized stock survived better than bareroot, but growth was about even.	56	91
Marion and Alm (1986)	Red pine (*Pinus resinosa* Ait.)	Styroblock	3-4	Bareroot 2-2 stock was best. Other bareroot stock performed similar to containerized trees except in fall plantings (3-0) bareroot did not survive as well as containers and in spring plantings bareroot (2-0) grew better than containerized stock.	51-97	78-83
Mattice (1981)	Black spruce	Paperpots	5	Results are mixed.	62-85	48-99
	White spruce	Paperpots	2	Mostly little difference in survival and height growth.	89-96	91-96
			5	Little difference except bareroot had higher survival in summer planting.	69,70	45,65
	Jack pine (*Pinus banksiana* Lamb.)	Paperpots	3	Little difference in spring planting but containers showed superior survival and growth in summer planting.	89,11	91,98
Owston (1972)	Douglas-fir	Styroblocks	1	Little difference in survival.	67	73
		Styroblocks	1	Trees on north slopes outperformed those on south slopes, but there was little difference between bareroot and containers.	55,84	49,86
Owston and Stein (1978)	Douglas-fir	1½-yr-old seedlings were transplanted into:	[1]7	Containers showed superior survival and height growth over bareroot seedlings.		
		Quart milk cartons			54	65
		Cardboard tubes			54	71
		Peatpots			54	82
		Plastic mesh tubes			54	71
	Noble fir (*Abies procera* Rehd.)	1½-yr-old seedlings were transplanted into:	[1]7	Containers showed superior survival and height growth over bareroot seedlings.		
		Quart milk cartons			60	66
		Cardboard tubes			60	80
		Peatpots			60	88
		Plastic mesh tubes			60	76
Ruehle and others (1981)	Slash pine	Styroblock	2	Containerized seedling survival and height growth was superior on the moister site while bareroot seedlings survived and grew best on the drier site.	65,57	85,50

(con.)

APPENDIX (Con.)

Study	Species	Type of container	Time since field planting	Results	Survival	
					Bareroot	Container
			Years		- - - - - *Percent* - - - - -	
Walker (1980)	Lodgepole pine	Styroblock	5	Containerized seedling survival rates were consistently higher than bareroot. Growth rates were variable.	20-92	70-98
		ARC Sausage	5	Containerized seedling survival rates were consistently higher than bareroot. Growth rates were variable.	20-92	59-98
	White spruce	Styroblock	5	Containerized seedling survival rates were consistently higher than bareroot. Bareroot seedling heights were as great or greater than container.	22-77	58-92
		ARC Sausage	5	Containerized seedling survival rates were consistently higher than bareroot. Bareroot seedling heights were as great or greater than container.	22-77	88-92
	Engelmann spruce	Styroblock	5	Containerized seedling survival rates were consistently higher than bareroot. Bareroot seedling heights were as great or greater than container.	10-40	65-72
		ARC Sausage	5	Survival rates were variable and poor. Bareroot seedling heights were as great or greater than container.	10-40	23-32

[1]See Owston (1972) for third-year results.

Sloan, John P.; Jump, Lewis H.; Ryker, Russell A. 1987. Container-grown ponderosa pine seedlings outperform bareroot seedlings on harsh sites in southern Utah. Res. Pap. INT-384. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 14 p.

Survival and height growth of container-grown and bareroot ponderosa pine seedlings planted on five different habitat types in southern Utah were compared after five growing seasons. Survival of container-grown stock ranged from 78 to 98 percent; bareroot stock, 64 to 91 percent. On good sites there was no difference in growth rates and survival, but on harsh sites container-grown stock proved superior to bareroot stock in both respects.

KEYWORDS: reforestation, *Pinus ponderosa*, tree planting, tree nursery, seedlings, survival, height growth, root system

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