Nursery Morphology and Preliminary Comparison of 3-Year Field Performance of 1+0 and 2+0 Bareroot Ponderosa Pine Seedlings

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*The preplanting morphology and subsequent field performance of a relatively new stocktype, 1+0 bareroot ponderosa pine (*Pinus ponderosa *Dougl. ex Laws.), was evaluated on 5 different field sites over a 3-year period. Regression analyses indicate that 1+0 field performance was directly related to initial seedling root volume and total fresh weight. Compared to 2+0 seedlings planted at the same time for comparison purposes, the 1+0 seedlings were initially smaller in absolute total height and, in most cases, remained significantly smaller than 2+0 seedlings after the third season in the field. Although preplanting needle morphology (high percentage of seedlings with only primary needles) and bud phenology (lack of a firm, well-developed bud) of 1+0 seedlings differed from that of the typical 2+0 seedling, the 1+0 seedlings had annual height growth increments (in both absolute and relative terms) after the first year that were equal to, and sometimes better than, 2+0 seedlings.* Tree Planters' Notes 43(4):153-158; 1992.

Traditionally, 2+0 bareroot ponderosa pine *(Pinus ponderosa* Dougl. ex Laws.) have been outplanted throughout eastern and southern Oregon. With this stocktype, 2 years are required to produce a seedling of adequate size for outplanting. Advances in nursery culture in the Pacific Northwest have resulted in larger 1-year-old seedlings than had been thought possible in the past, sparking interest in the 1+0 stocktype as an alternative to the 2+0 stocktype.

Benefits may include greater flexibility and accuracy in planning for seedling needs, reduced cost of production, and increased nursery growing capacity (Hobbs 1984, Owston 1990). The planning horizon and response time can be reduced by 1 year, which is beneficial when nursery bed space is limited, when seedling demand is increased due to natural disasters or changes in harvest levels, or when sites are not ready for planting because of delays in site preparation or harvest. In these situations, seeds can be sown and seedlings ready in 1 year or seedlings can be left in the nursery beds and/or transplanted for outplanting the following year as 2+0 or 1+1 seedlings. In addition, 1+0 seedlings may possess attributes that make them perform as well as or better than larger stock-for example, less outplanting shock.

Over the years, numerous studies have examined the influence of stocktype on field performance (Arnott 1975, Mullin 1980, Hobbs and Wearstler 1983, Burdett et al. 1984, Helgerson et al. 1989, Paterson and Hutchison 1989, Racey et al. 1989, Pendl and D'Anjou 1991), but no clear consensus has been reached on which stocktypes perform best, especially on harsh, dry sites. In the past, 1+0 seedlings have been rarely used in the Pacific Northwest because foresters believed these seedlings were too small to cope with field conditions. A few studies, however, have shown that using 1+0 stock is an acceptable option (Jenkinson and Nelson 1982, Hobbs 1984).

The objectives of this study were to 1) examine the morphological characteristics of 1+0 ponderosa pine, 2) compare field performance of 1+0 bareroot ponderosa pine with 2+0 seedlings that are used operationally, and 3) assess field performance across a wide range of harsh outplanting sites. It was not our intent to determine the best stocktype but to test our belief that 1+0 seedlings are an acceptable alternative to more traditionally planted stocktypes.

Methods

One-year-old (1+0) seedlings from five Oregon seed lots (Left Short, Power, Rox, Sumpter, and Zinc Fink) were grown at the USDA Forest Service's J. Herbert Stone Nursery, Central Point, Oregon, using nursery cultural practices developed for this stocktype-that is, lower density. Seedlings were operationally lifted, graded, and placed in cold storage at 1 to 2 °C. Lift dates ranged from January 29 until February 6, 1988, depending on the seed lot. After the 1+0 seedlings were washed free of dirt and dried of excess water, they were measured on February 23-24, 1988, for total height (centimeters) from root collar to top of terminal bud, stem diameter (millimeters) at the root collar, total fresh weight (grams), root volume (cubic centimeters) according to the displacement method (Burdett 1979), type of terminal (firm versus rosette), and the percent of seedlings with secondary needle development.

The 2+0 seedlings used for a general comparison of outplanting performance were grown according to the standard cultural regimes at the USDA Forest Service's Bend Pine Nursery, Bend, Oregon, (Power, Rox, and Left Short seed lots) and J. Herbert Stone Nursery (Zinc Fink and Sumpter lots). These 2+0 seedlings planted at each site were not measured for pre-planting morphological characteristics and, in all but one instance, were from a seed lot different from that of the 1+0 seedlings (table 1). However, at each planting location the 2+0 seed lots were, in most cases, from the same seed zone and/or breeding block and from the same, or nearby, elevational band as the 1+0 lots. The seed used to grow the 1+0 seedlings planted at Left Short came from a seed zone adjacent to the zone from which the seed for the 2+0, Left Short seedlings originated. Although stocktype comparisons were made, the interpretation of any differences must be limited due to the confounding effects of different nurseries of origin and different seed lots.

The outplanting sites used in this study were located on the Fremont and Umpqua National Forests in southern and south central Oregon (table 2). The Power site was clearcut in 1986 and machine-piled in 1987. The Rox unit was clearcut in 1983 and slashed and machine-piled in 1987. Left Short was clearcut in 1985 and slashed and machine-piled in 1987. Zinc Fink was partially harvested and machine-piled in 1979 followed by a final harvest in 1987 with hand-piling of slash. The Sumpter unit was clearcut in 1985, the slash hand-piled and burned in 1986, and originally replanted in 1986; this planting showed poor survival. All sites experience hot, dry conditions during the summer and have undergone 7 years of continuous drought conditions.

The 1+0 and 2+0 seedlings were operationally planted at a 1.5 x 1.5 m spacing in alternating rows on February 26, February 26, April 9, April 20, and May 17, on the Sumpter, Zinc Fink, Power, Left Short, and Rox sites, respectively. Each site contained 6 blocks, 2 stocktypes per block, and

Table 1—*Seed lot codes for each location and stocktype*

Location & stocktype	Seed lot code	Seed zone†	Elevation of source (m)
Power			
1+0	122-02051-400-78-SB	Bald Mtn. Breeding Block	1,524–2,134
2+0	122-02051-400-78-SB*	Bald Mtn. Breeding Block	1,524–2,134
Left Short			
1+0	122-702-03-000-65-68-SIB	702	1,981
2+0	122-02032-500-85-SIB*	Gearhart Breeding Block	1,829–2,134
Rox			
1+0	122-712-03-000-70-68-SIB	712	2,134
2+0	122-02032-500-85-SIB*	Gearhart Breeding Block	1,829–2,134
Sumpter			
1+0	122-15-492-02000-25-81	492	762
2+0	122-15-492-02000-15-78	492	457
Zinc Fink			
1+0	122-15-492-02000-35-78	492	1,067
2+0	122-15-492-02000-30-78	492	914

*Seedlings grown at Bend Pine Nursery, Bend, OR; all others grown at J. Herbert Stone Nursery, Centerville, OR.
†State of Oregon Tree Seed Zone Map (Western Forest Tree Seed Council); Bald Mtn. Breeding Block includes seed zone 703, Gearhart Breeding Block includes seed zone 712.

Table 2—*Outplanting sites description*

National Forest	Location	Size (ha)	Elevation (m)	Aspect	Surface soil texture
Fremont	Power	2	1,622	NE	Sandy loam
	Left Short	11	1,823	NE	Loamy sand
	Rox	7	2,063	W	Sandy loam
Umpqua	Zinc Fink	10	1,036	NW	Loam
	Sumpter	7	579	NW	Fine sandy loam

25 seedlings/ stocktype/block. Each row contained 5 seedlings resulting in 5 rows of each stocktype per block. Seedlings were protected from animal browsing with rigid mesh tubes. One month after outplanting, initial field height was measured on both 1+0 and 2+0 seedlings. At the end of the first, second, and third growing seasons all seedlings were measured for height and survival. Annual absolute height growth was determined by subtracting the previous year's absolute total height from the current year's absolute total height-for example, first-year height growth = first-year total height minus initial height at planting. Relative growth, or total height growth as a percentage of initial height, was determined by dividing total height growth after 3 years by initial height at planting.

The experimental design in the field was a 2 (stocktype) x 5 (location) factorial with blocking within location. Data were analyzed using analysis of variance, and, when appropriate (i.e., significant stocktype and/or location effect), Fisher's protected least significance difference test was used to separate means at the 0.05 significance level. Regression analyses were done in order to examine the relationship between pre-planting morphological features and subsequent height growth of 1+0 seedlings after outplanting.

Results

Pre-planting 1+0 nursery morphological characteristics varied by seed lot (table 3). The Sumpter and Zinc Fink seed lots had larger seedling heights, stem diameters, and fresh weights. Power seedlings were generally smaller for most morphological parameters measured. The seedlings planted on the Power site were inadvertently root pruned to 18 cm for nursery transplanting instead of the standard root pruning length of 25 cm for outplanting, which resulted in small root volumes. A high percentage of the 1+0 seedlings at all locations had terminal buds that typically were small

Table 3—*Pre-planting morphological characteristics of five Oregon seed lots of 1+0 bareroot ponderosa pine grown in two different nurseries (see table 1)*

Location	Height (cm)	Stem diameter (mm)	Fresh weight (g)	Root volume (cm³)	Secondary needles* (%)	Type of bud (%)†
Power	15.6 a	4.5 a	12.3 a	4.3 a	41 a	19 a
Left Short	16.1 a	4.6 a	14.3 bc	5.9 bc	47 ab	7 b
Rox	16.0 a	4.3 b	13.0 ab	5.4 b	46 ab	14 ab
Sumpter	17.4 b	4.8 c	14.7 c	4.5 a	57 bc	7 b
Zinc Fink	18.4 c	5.2 d	18.5 d	6.2 c	67 c	7 b

Means followed by a different letter are significantly different at the 0.05 level.
*Percent of seedlings from each location with any secondary needle development.
†Percent of seedlings from each location with a firm, well-developed terminal bud.

and rosette-like instead of the firm, well-developed terminals normally found on 2+0 seedlings. Only 41 to 67% of the 1+0 seedlings had begun to produce any secondary needles, depending upon the seed lot.

Seedling survival remained high through the first 3 years (table 4). There were no stocktype by location interactions so main effect means were examined. The 1+0 seedlings survived significantly better than 2+0 seedlings after the first two seasons. By the end of the third year, 1+0 and 2+0 survival was identical. Survival among locations was similar except for the Rox unit, which had lower survival all 3 years.

Table 4—*First-, second-, and third-year seedling survival by stocktype and location*

	Survival (%)		
	1st yr.	2nd yr.	3rd yr.
Stocktype			
1+0	98 a	90 a	87 a
2+0	95 b	87 b	87 a
Location			
Power	99 a	97 a	95 a
Left Short	99 a	95 a	95 a
Rox	91 b	69 b	60 b
Sumpter	96 a	85 a	83 a
Zinc Fink	99 a	97 a	97 a

Means within a stocktype or location followed by a different letter are significantly different at the 5% level.

The stocktype x location interaction was significant for all height parameters measured so the analysis was done by location (table 5). The 2+0 seedlings maintained their greater total height after the first 3 years compared with 1+0 seedlings at the Power, Sumpter, and Zinc Fink sites. The Left

Table 5—*First-, second-, and third-year mean total height and height growth of 1+0 and 2+0 bareroot ponderosa pine seedlings outplanted on five sites in southern and southwestern Oregon*

	Total seedling height (cm)								Height growth increment									
	Initial height at planting		1st-yr. total height		2nd-yr. total height		3rd-yr. total height		1st-yr. height growth (cm)		2nd-yr. height growth (cm)		3rd-yr. height growth (cm)		Total height growth (cm)		Total height growth (% initial height)	
Location	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0
Power	13.9*	19.5	17.5*	24.8	25.2*	31.4	38.2*	45.2	3.6*	5.3	7.7*	6.7	12.9	13.8	24.2	25.6	174*	131
Left Short	13.1*	9.4	14.8*	11.1	25.3*	18.4	38.6*	28.2	1.7	1.8	10.8*	7.3	13.3*	10.0	25.6*	18.7	204	213
Rox	10.5*	7.0	12.5*	8.7	13.9	11.2	—	—	2.0	1.8	2.2	2.0	—	—	—	—	—	—
Sumpter	19.9*	33.0	25.0*	41.7	33.2*	50.5	44.8*	55.1	5.1*	8.7	8.2	8.6	13.5	11.0	24.8	24.9	118*	73
Zinc Fink	19.5*	32.1	26.6*	41.7	37.0*	49.8	57.3*	70.2	7.1*	9.6	10.4*	7.8	20.6	20.4	37.8	37.8	198*	118

Height growth increments were calculated as follows (note that all means shown in the table have been adjusted for missing values):
1st-year height growth = 1st-year total height − initial height at planting.
2nd-year height growth = 2nd-year total height − 1st-year total height.
3rd-year height growth = 3rd-year total height − 2nd-year total height.
Total height growth = 3rd-year total height − initial height at planting.
Total height growth (as percentage of initial height) = (total height growth/initial height at planting) × 100.
*Mean for these 1+0 seedlings differ significantly from mean for their matched 2+0 seedlings at the 5% level.

Short and Rox 2+0 seedlings, however, were significantly shorter than the 1+0 seedlings after planting because on the Forest Service district on which those two sites are located, seedlings are operationally planted deeply, that is, up to the first green needles. The 1+0 seedlings, in contrast to 2+0 seedlings, retained their juvenile needles along the lower portion of the stem and, thus, were not planted as deeply as the 2+0 seedlings. During the first growing season, 2+0 seedlings had significantly greater absolute annual height growth increment than 1+0 seedlings at all locations except at the Left Short and Rox sites where absolute height growth increment of both stocktypes was poor and not significantly different from one another. Rox is a harsh site and was planted late (in the later part of May). The Rox site was dropped from the experiment after 2 years because of severe frost, livestock, and browsing damage on a majority of seedlings in the study.

During the second and third growing seasons, the 1+0 seedlings had absolute annual height growth increments that were greater than, or not significantly different from 2+0 seedlings. The 1+0 seedlings on one site, Left Short, had significantly more absolute total height growth after 3 years than 2+0 trees. The 1+0 seedlings' total height growth increment after 3 years was not significantly different from the 2+0 seedlings at the other locations. When total height growth increment after 3 years is expressed as a percent of initial height (total relative growth), 1+0 seedlings exceeded the 2+0 seedlings on 3 of 4 sites.

The coefficients of determination (r^2) for the regression analyses for the morphological variables and height growth are low, 0.32 or less, but, in most cases, significant (tables 6 and 7) indicating these variables explain a statistically significant amount of the variation in height growth.

The coefficients of determination for fresh weight are larger than those for root volume which means that fresh weight explains more of the variation in height growth than does root volume (tables 6 and 7). Coefficients of determination for root volume and fresh weight decreased for second- and third-year height growth but remained statistically significant in most cases (table 6). The positive correlations indicate 1+0 seedlings with larger root volumes and fresh weights at time of planting tend to grow more in height during the first growing season after outplanting.

Coefficients of determination for initial stem diameter and height growth are similar although slightly smaller than those for root volume while those for initial height and height growth are mostly nonsignificant and small ($r^2 \leq .10$, tables 6 and 7).

Discussion

Based on the regression analyses (table 5), the growth of the 1+0 seedlings appears directly related to their initial fresh weights and root volumes, whereas initial height was very poorly correlated with subsequent absolute height growth increment in the field. This indicates that although overall seedling size is important in the success of the 1+0, it is a poor predictor of third-year growth.

Two-year-old ponderosa pine generally have a firm, well-developed terminal bud with foliage

Table 6—*Coefficients of determination for pre-planting 1+0 morphological characteristics and subsequent absolute annual height growth increments*

	Root volume			Total fresh weight			Stem diameter			Initial height		
Location	1st-yr.	2nd-yr.	3rd-yr.	1st-yr.	2nd-yr.	3rd-yr.	1st-yr.	2nd-yr.	3rd-yr.	1st-yr.	2nd-yr.	3rd-yr.
Power	.03*	.06**	.02	.12**	.12**	.05**	.04*	.07**	.04*	.03*	<.01	.03*
Left Short	.20**	.18**	.10**	.21**	.26**	.11**	.19**	.13**	.09**	<.01	<.01	.02
Rox	.06**	<.01	—	.08**	.01	—	.09**	<.01	—	<.01	.01	—
Sumpter	.12**	.06**	.08**	.18**	.12**	.08**	.04*	.06**	.04*	<.01	<.01	.10**
Zinc Fink	.26**	.03*	.01	.32**	.04*	.03*	.18**	.01	.02	.08**	<.01	.02

*Significant at the 5% level.
**Significant at the 1% level.

Table 7—*Coefficients of determination for pre-planting 1+0 morphological characteristics and total absolute height growth increment (final 3rd-year height minus initial height at planting) after three growing seasons*

Location	Root volume	Fresh weight	Stem diameter	Initial height
Power	.05**	.11**	.07**	.03
Left Short	.22**	.28**	.17**	<.01
Sumpter	.15**	.19**	.07**	.07**
Zinc Fink	.07**	.11**	.05**	.02

*Significant at the 5% level.
**Significant at the 1% level.

comprised mainly of fascicles of secondary needles. At the time of nursery lifting, most of the 1+0 seedlings in this study possessed an underdeveloped, rosette-like terminal bud, and many seedlings had not yet produced any secondary needles by the time of outplanting. These needle morphology and bud phenology characteristics, however, did not appear to have any negative effect upon the subsequent field performance of the 1+0 stock.

The preliminary results of this study indicate that 1+0 seedlings are an excellent alternative to the more traditionally planted 2+0 stocktype. This study will continue to be measured in order to determine if the stocktypes maintain their total height differences or if one outgrows the other in the future. Although caution is necessary in comparing the performance of the two stocktypes due to several confounding factors mentioned earlier, the 1+0 trees, although initially smaller in absolute total height, survived and had annual height growth increments as large as 2+0 seedlings, a finding that agrees with those of other studies (Jenkinson and Nelson 1982, Hobbs 1984).

However, other studies also suggest that the smaller 1+0 stocktype, compared to larger stocktypes, may be at a disadvantage on sites with severe animal or vegetative competition (Racey et al. 1989, Tanaka et al. 1988). The 1+0 seedling appears to be a stocktype that provides increased management flexibility in a more cost-efficient manner while maintaining necessary field performance characteristics.

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