Effect of Root Form on 10-Year Survival and Growth of Planted Douglas-fir Trees

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Douglas fir seedlings (Pseudotsuga menziesii *(Mirb.) Franco.) were planted with three root form treatments including C-roots ("correctly" planted controls), L-roots, and]-roots. After 10 years, there were no significant differences in outplanting performance between the three root form treatments on a good site in western Oregon. The results are in agreement with those of other studies, which suggests that when no other confounding planting errors are present, deformed root systems play a less dramatic role in subsequent field performance than is generally thought. These results in no way imply that poor planting is acceptable.* Tree Planters' Notes 44(2):53-57; 1993.

The majority of forest nursery personnel and tree planters would agree that root deformation during planting is detrimental to the development of the tree. In fact, tree planting contracts often have specifications against root deformation and current reforestation manuals cite J-roots and L-roots as unsatisfactory (Rose 1992). Common problems attributed to root deformities are increased mortality, moisture stress, disease incidence, and decreased wind firmness. However, despite such widespread acceptance of the drawbacks of root deformation during planting, there is uncertainty surrounding this belief.

In an early study, Cheyney (1927) found there was very little difference between seedlings of 3 species with balled roots and with expanded roots. In another early study, Rudolf (1939) found that root deformity in forest plantations had little effect upon mortality. Rather, trees with the majority of their roots in a single plane had greater mortality and poorer growth than those with their roots spread out, regardless of root deformation. Sutton (1969) noted that the relationship between root form and tree performance in conifers was not well understood.

In more recent research, Woods (1980) found no significant differences in survival or height growth after 7 years for loblolly pine *(Pinus taeda* L.) planted with their roots in five configurations. In a study with 4 species, Schantz-Hansen (1945) found no significant differences in survival or root de velopment between planting methods, including a "careless" method in which the roots were placed in an abnormal position. Mexal and Burton (1978) found that deformation of the taproot in loblolly pine was not correlated with seedling growth 4 years after plantation establishment. In a study with several northwestern conifer species, root system deformation was found to be unrelated to tree growth (Long 1978).

Some researchers have contributed data to support the negative effects of root deformation. Brissette and Barnett (1988) concluded that J-rooted loblolly pine seedlings had lower survival and growth. However, from their results, it appeared that mortality and growth were more likely related to planting depth. The J-rooting treatment resulted in seedlings with roots 5 cm shallower than the straight treatment, but when roots were placed at similar depths, survival of J-rooted trees was actually greater than that of straight-rooted trees. This suggests that shallow-planted trees, especially those which are J-rooted, are less likely to perform well. In another study, Lacaze (1968) found that average heights among control, J-rooted, and L-rooted Norway spruce *(Picea abies* L.) seedlings differed significantly with the control having the greatest growth. However, the maximum difference between treatments was only 7 cm. Bergman (1976) cited root deformation as having a negative effect on reforestation. However, he refers to seedlings that have been deformed in containers before being planted to the forest.

Despite some evidence indicating that root deformation is not harmful to seedling development, the evidence is still unclear and many reforestation personnel and researchers are reluctant to forsake their belief in root deformation's detrimental effects In a 24-year study, Hunter and Maki (1980) found no significant differences in survival and growth between straight- and curl-rooted loblolly pine trees, yet the authors stated that they believed curl-rooted trees go through a period of high susceptibility to blowdown between the ages of 3 and 5. Gruschow (1959) found that 67% of excavated young loblolly pine trees had deformed roots but that growth was not related to root form. How ever, this author made it a point to speculate that seedlings with deformed roots are probably more susceptible to disease and that increased attention should be given to "correct" planting of seedlings. Grene (1978) claims that field performance may be misleading and that root deformation leads to reduced root growth and stability, despite concluding that root strangulation is a myth and finding evidence that root deformation decreases over time.

The objectives of this study were to evaluate the effect of root form on the growth and survival of Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) seedlings in a coastal environment. Most research on root form has focused on southern pine species and on spruces. This study will include more data on northwestern species and will contribute to further understanding of the long-term effects of root form at the time of planting.

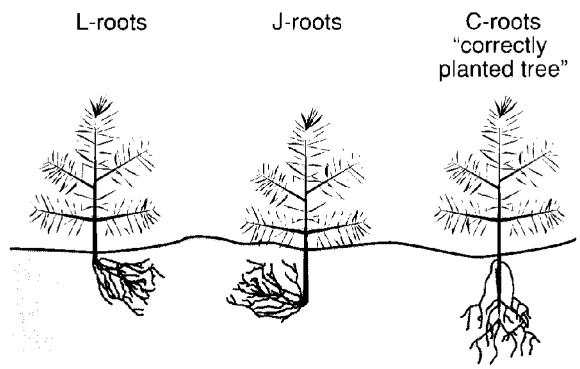

Figure 1—*The three root-form treatments.*

Methods

Two-year-old (2+0) Douglas-fir seedlings were grown at the USDA Forest Service's Humboldt Nursery in northern California. All seedlings were lifted on January 30, 1981, and graded to operational specifications. Seedlings were placed in cold storage before they were outplanted between March 10 and April 14, 1981.

The study area was located in the eastern portion of Coos County, Oregon, on land managed by the U.S. Department of the Interior's Bureau of Land Management. The site is at an elevation of 700 m, with a south aspect and 30 to 50% slope. Soils in the area are generally deep (with an average top soil depth of 60 to 90 cm). The site has a moderate site index and an average annual precipitation of 170 cm. The summer months are fairly dry, with an average of less than 5 cm of precipitation from July through September.

The three root-form treatments included C-roots ("correctly" planted controls), L-roots, and J-roots. All seedlings were planted with a shovel. At each planting spot, a 10- x 18- x 30-cm-deep hole was dug. The seedling was suspended over the hole and the pre-determined root configuration was formed by putting the roots into a J or L shape or leaving the roots suspended naturally for the C-roots (figure 1). Soil was carefully filled in around the root system so the desired root configuration would remain. All seedlings were protected from animal browsing with mesh tubes.

The experimental design consisted of a ran domized complete block design with four blocks of 100 trees each. Each block consisted of four rows of 25 seedlings planted on a 3 x 3 m spacing. The root treatment at each planting spot was determined randomly until there were approximately equal numbers of each treatment in each block (33 seedlings per treatment block). Seedlings were measured for height and survival at the end of the first five growing seasons. In addition, 3 randomly chosen trees, one of each root form, were excavated in June 1984 to observe root configurations. After the tenth season, trees were again measured for survival and height as well as diameter at breast height (DBH).

Data were analyzed using analysis of variance (ANOVA). Tests for normality, linearity, and constant variance of the residuals were performed to ensure the validity of these assumptions. Fisher's protected least significant difference (FPLSD) procedure was used to determine significant differences in data among root-form treatments at the a 0.05 level. Statistical Analysis System (SAS Institute 1982) software was used for analysis of all data.

Results

This study produced no evidence that root form influenced survival or growth of Douglas-fir. After 10 years, there was little difference in outplanting performance among the three root-form treatments (table 1). Differences in survival, growth, height, and diameter were nonsignificant ($\alpha <= 0.05$) among

Table 1-Means of seasonal survival and means and standard errors (SE) for seasonal height and 10-year diameter at breast height (DBH) of control (C), J-rooted, and L-rooted Douglas fir seedlings outplnnted in Oregon

	Control seedlings	J-rooted seedlings	L-rooted seedlings	SE
Survival (%)				
Initial	100	100	100	
1981	100	98	96'	
1982	88	87	87	
1983	88	85	81	
1984	87	85	81	
1985	87	85	81	
1990	87	83	80	
Total height (cm)				
Initial	24.1	22.6	24.1	0.64
1981	36.5	34.3	35.3	0.81
1982	67.5	63.2	65.7	1.73
1983	109.1	105.8	99.5	3.79
1984	148.5	145.9	136.3	5.04
1985	195.9	192.6	180.7	6.71
1990	649.7	634.5	626.6	16.65
DBH (cm)				
1990	9.3	9.2	8.8	0.24

Means within each year followed by an asterisk differ significantly ($\alpha <= 0.05$) from the controls (Fisher's protected LSD procedure),

treatments every year with the exception of firstyear survival (1981), where the L-rooted trees had significantly lower survival than the controls. However, this significance is not particularly meaningful given that the survival of 96% for L-rooted trees is well within acceptable stocking standards. Although not statistically significant, the L-rooted trees consistently exhibited a trend toward reduced survival and growth as compared to the controls and J-rooted trees. This trend, however, may have little impact on the overall yield and quality of the mature stand. Furthermore, this reduced survival and growth may not be entirely attributable to root configuration, because the J-rooted trees, which were the most deformed, tended to perform better than the L-rooted trees.

Though not quantified, there was observed to be little or no difference in the number, length, or distribution of major lateral roots among the three root-form treatments for seedlings excavated in June 1984 (figure 2). The original taproot on the J-rooted seedling appeared to have quit functioning. The trees in each treatment seemed to be anchored stably in the ground.

Discussion

The results of this study are in agreement with those of other studies, which have found root deformation at the time of planting to have no adverse effects. Owston and Stein (1978) found that initial deformities did not seem to hamper the development of a strong root system for bareroot Douglas-fir and noble fir (Abies procera Rehd.) seedlings. Seiler et al. (1990) found that J-rooting did not significantly lower the water potential of loblolly or eastern white pine (Pinus monticola Dougl.) seedlings. They state that tree planters should be primarily concerned with planting seedlings quickly and at the correct depth. They warn that instructing planters to avoid J-roots by pulling back up on the seedlings when they are placed in the planting hole may do more damage than good because the end result could be shallower root placement. In a study by Schultz (1973), there was no indication that early growth of slash pine *(Pinus* elliottii Engelm.) was inhibited by deformed roots, and, after 12 years, root deformation was no longer visible.

Some researchers have even found favorable effects of root deformation on seedling development. Hay and Woods (1974a) found that dry weights of loblolly pine seedlings with deformed roots increased at a faster rate than those with straight roots. They attribute this to the proliferation of lateral roots in the upper soil zones, which may have enhanced the nutrient and water absorption capacity of the seedling and stimulated stem and foliage growth. In other studies, Hay and Woods (1968, 1975, 1978) reported that the development of extensive lateral root systems in seedlings with deformed roots seems to be promoted by carbohydrates accumulated above taproot curvatures. In addition, Hay and Woods (1974b) found that root systems of large saplings (on a weight basis) in 4- to 6-year-old plantations showed more deformation characteristics than did the roots of small saplings. They note that although large, hard-to-plant seedlings could have an initial growth advantage, large saplings probably developed extensive shallow root systems, which could utilize nutrients in the fertile upper soil layers more effectively than the deeper taproots of "correctly" planted saplings. In a study by Huuri (1978), seedlings planted with balled roots actually had better stability than the control trees. The author concludes that there appears to be no risk of Scotch pine *(Pinus* sylvestris L.) plantations being jeopardized by root deformation.

The results of this study cannot lead to any firm conclusions concerning root form. Given the variability of the data, this study had a low statistical power to detect the measured differences between treatments. However, although the trend was very weak, the biological order of results in terms of height and survival (C > J > L) concurs with the practical forester's expectation.

This study, like other applied research of its kind, was set up as a simulated operational test to examine long-term effects of root form. However, this study could not simulate deformed planting with the occasional air pocket, exposed roots, non-perpendicular shoot orientation, extremely deep or shallow planting holes, and other common planting errors that accompany operational J- and L-rooting of seedlings. In other words, if other confounding errors of poor planting are eliminated, and all other factors are kept equal except root form, there *is* a possibility that J- and L-rooted seedlings will become established and grow as well as correctly planted seedlings.

Conclusion

These results indicate that seedlings in this study were not adversely affected by variations in root form at the time of planting. This conclusion is based on the results of seedling performance on one specific site with relatively favorable growing conditions. On a harsher site, the differences be tween root forms may be more dramatic. Therefore, no widespread conclusions can be drawn from the data. This study in no way implies that "sloppy" planting is acceptable nor does it suggest that root form should be ignored. However, this study does add to the literature that suggests that when all other factors are equal, root form of planted bare root seedlings plays a less dramatic role in subsequent field performance than some foresters may have thought.

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