Vanhinsberg, N. B.; Colombo, S. J. 1990. Effect of temperature on needle anatomy and transportation of *Picea mariana* after bud initiation. Canadian Journal of Forest Research 20:598-601.

Vidaver, N.; Binder, W; Brooke, R. C.; Lister, G. R.; Toivonen, P M. A. 1989. Assessment of photosynthetic activity of nursery-grown *Picea glauca* seedlings using an integrating fluorometer to monitor variable chlorophyll fluorescence. Canadian Journal of Forest Research 19:1478-1482.

Vidaver, N.; Lister, G. R.; Brooke, R. C.; Binder, W 1991. A manual for the use of variable chlorophyll fluorescence in the assessment of the ecophysiology of conifer seedlings. FRDA Rep. 163. Victoria, BC: British Columbia Ministry of Forests and Forestry Canada. 166 p.

Weatherspoon, P; Laacke, J. 1985. Infrared thermography for assessing seedling condition: Rational and preliminary observations. In: Duryea, M. L., ed. Evaluating seedling quality: Principles, procedures, and predictive ability of major tests. Corvallis, OR: Oregon State University, Forestry Research Laboratory: 127 136.

# Sowing at 1.5-cm (0.6-inch) Depth Produces Heaviest Douglas-Fir Roots in Small Containers

Don Minore, Howard G. Weatherly, and Patrick G. Cunningham

*Plant ecologist, forestry technician, and statistician, USDA Forest Service Pacific Northwest Research Station Forestry Science Laboratory, Corvallis, Oregon*

*Sowing seeds of Douglas-fir* (Pseudotsuga menziesii *(Mirb.) Franco) at five depths in Leach Super Cells® indicated that the only benefit of deep sowing in small containers occurred at a depth of 1.5 cm (0.6 inch). Planting at this depth produced heavier roots without a significance reduction in seedling emergence.* Tree Planters' Notes 44(3): 122-124; 1993.

The sowing depth recommended for Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) in cultivated nursery soil is 0.3 to 1.0 cm (0.1 to 0.4 inch) (Owston and Stein 1974). Although sowing depths may vary, Steven (1928) found that Douglas-fir germination was not seriously reduced in a sandy loam until sowing depths exceeded 1.9 cm (0.7 inch). Show (1930) noted that germination rates, germination percentage, and the total number of Douglas-fir seedlings produced decreased, but that the percentage of large, high-quality seedlings tended to increase with sowing depth.

Minore (1985) also found that fewer but larger Douglas-fir seedlings were produced at greater sowing depths. A sowing depth of 1 cm (0.4 inch) produced the best height growth in a greenhouse soil without reducing emergence, but total seedling weigths increased with sowing depths of 0.5 to 4.5 cm (0.2 to 1.8 inch) when Minore sowed seeds in large pots (15 cm [6 inches] diameter and 15 cm [6 inches] deep) filled with a peat-vermiculite mixture. He concluded that a sowing depth of 2.5 cm (1.0 inch) in the peat-vermiculite mix used in the production of container stock would require 40% more seed and 2 weeks more emergence time than the normal sowing of 0.3 to 1.0 cm (0.1 to 0.4 inch) but should produce 50% heavier seedlings after 6 months of growth.

These conclusions on sowing depth in large pots may not apply to the smaller containers usually used in producing container planting stock. Acceptable seedlings can be produced in many types of containers, however, and no single container type is best for all nurseries and outplanting sites (Landis et al. 1990). We sowed Douglas-fir seeds at several depths in Leach Super Cells, which are the most popular container type for tree improvement and other uses where consolidation is critical. Our objective was to determine the effects of sowing depth on seedling emergence and growth in these smaller containers.

## Methods

Douglas-fir seeds collected in Oregon near the mouth of the Columbia River at an elevation of less than 152 m (500 feet) were sown at five depths in Ray Leach Super Cell® containers:

0.5 cm (0.2 inch)
1.5 cm (0.6 inch)
2.5 cm (1.0 inch)
3.5 cm (1.4 inches)
4.5 cm (1.8 inches)

Leach cells are one of a variety of container types. They produce plug seedlings that are typical of those used in the Pacific Northwest.

The containers were 21 cm (8.3 inches) tall, with an inside top diameter of 4 cm (1.6 inches). They were partially filled to five levels with a 1:1 mixture of peat and vermiculite. Seeds then were placed on the surface, and additional medium was added to achieve the five sowing depths. No surface grit was used. Every sowing depth was replicated in 19 containers with 6 seeds sown at a single depth in each to provide a replicated measure of seedling emergence. The depths were randomized in a rack that held 7 rows with up to 14 containers in each row. Ninety-five of those containers were used (5 treatments replicated 19 times), thus filling all but three spaces in the rack. That rack was placed in a greenhouse, watered daily, and given supplemental lighting as needed to provide 16-hour photoperiods. Thus, 95 experimental units (the containers) were used in a completely random design.

Seedling emergence was tallied at weekly intervals. The seedlings were thinned to the single tallest in each container when two or more developed epicotyls. All were fertilized at weekly intervals with equal amounts of a dilute nutrient solution (1.7 ml "Schultz Instant" Liquid Plant Food per liter $H_20$). Nine months after the seeds were sown, shoot heights were measured, and the seedlings were harvested. Shoot, root, and total seedling weights were determined after ovendrying for 48 hours at 65 /C (149 /F).

Seedling emergence percentages, shoot heights, shoot weights, root weights, and shoot to root ratios were compared among sowing-depth treatments by analyses of variance. An orthogonal polynomials analysis procedure was then used to determine the presence or absence of trends in relating these response variables to sowing depth. The 4.5-cm treatment was not included in these analyses because of the small caught up, and total emergence at the 0.5- and 1.5-cm (0.2- and 0.6 inch) depths was similar (table 1). At depths below 1.5 cm (0.6 inch), emergence rate and total number of emerging seedlings decreased with sowing depth. Those decreases were significant ($P < 0.01$) and nonlinear.

Sowing depth did not significantly affect seedling shoot heights ($P = 0.28$), but the uppermost roots of seedlings grown from deeply sown seeds were at greater depths than those sown at 0.5 cm (0.2 inch)

## Results and Discussion

After lagging slightly behind the 1.5-cm (0.6-inch) depth during the second week, seedling emergence at 0.5 cm (0.2 inch) was faster than at other depths (figure 1). Emergence at 1.5 cm (0.6 inch) eventually

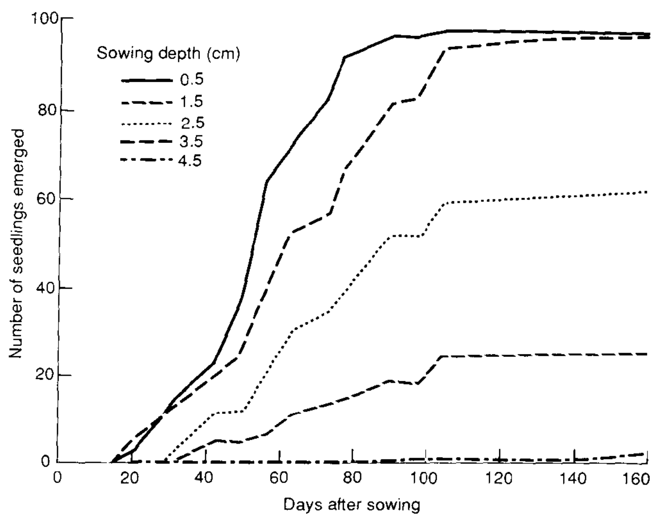


Figure *1-Douglas-fir seedling emergence after 114 seeds per depth (6 per container) were sown at each of five depths.*

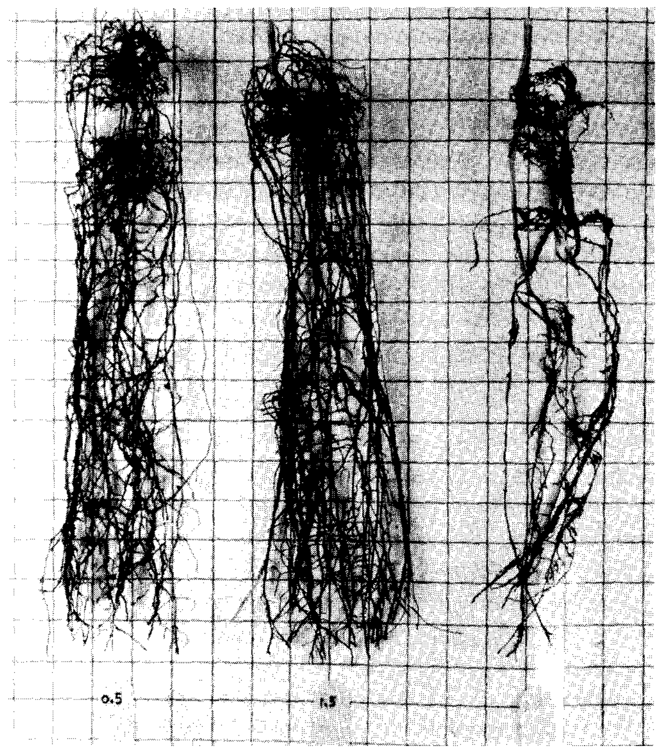


Figure *2-Roots of the largest Douglas-fir seedlings sown at depths of 0.5* (left), *1.5, and 2.5* (right) *cm (0.2, 0.6, and 1.0 inch). Stems were cut at the surface of the planting medium and lined-up along the 0.5-inch (1.3-cm) grid to compare root distribution at each depth. Note that the origin of topmost roots became deeper as sowing depth increased.*

Table 1-*Average emergence, heights, weights, and shoot to root ratios of Douglas fir seedlings sown at five depths in Ray_Leach Super Cells®*

| Sowing depth | Number of cells with seedlings | Seedling emergence* (%) | Shoot height† (cm) | Shoot weight‡ (g) | Root weight‡ (g) | Shoot/root ratio |
|---|---|---|---|---|---|---|
| 0.5 cm (0.2 in) | 19 | 86.0 a (3.2) | 8.38 a (0.38) | 0.217 a (0.017) | 0.368 b (0.022) | 0.594 a (0.033) |
| 1.5 cm (0.6 in) | 19 | 85.1 a (3.8) | 9.21 a (0.38) | 0.266 a (0.016) | 0.470 a (0.028) | 0.582 a (0.025) |
| 2.5 cm (1.0 in) | 18 | 54.4 b (7.4) | 8.14 a (0.70) | 0.227 a (0.027) | 0.333 b (0.017) | 0.674 a (0.070) |
| 3.5 cm (1.4 in) | 16 | 22.0 c (3.6) | 7.52 a (0.90) | 0.202 a (0.032) | 0.267 b (0.042) | 0.884 a (0.165) |
| 4.5 cm (1.8 in) | 2 | 1.8 | 4.15 | 0.100 | 0.095 | 1.972 |

Averages in the same column followed by a different letter are significantly different ($P < 0.05$). Standard error of the mean in parentheses.

*Based on 114 seeds at each depth (6 seeds in each of 19 cells)

†Divide by 2.54 to obtain inches.

‡Multiply by 0.03527 to obtain ounces.