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Tall planting stock for enhanced growth and domination of brush in the Douglas-fir region

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Application. Growth of coniferous seedlings is positively related to initial size. Use of tall stock of Douglas-fir or western hemlock leads to best growth over-all and has special significance in brush-threat areas. In fertile, competitive environments, large transplants require 0.6 to 8 years less to attain a height of 6 m than do container or 2-0 bare-root seedlings, and their survival also is better. Tall wildling seedlings have comparable advantages, but survival of wilding hemlock is not reliable.

Abstract. Two long-term experiments followed development of planted stock of various sizes, origins, and species. In one experiment, multiyear comparisons of container, 2-0 bare-root, and 3-year-old Douglas-fir transplants showed strong positive relationship between initial height and long-term (10–14 years) growth under a range of site conditions with high probability of brush development. In the other experiment, Douglas-fir, western hemlock, and Sitka spruce were planted in salmonberry disturbed by logging 0 and 4 years previously. Half the seedlings were released with glyphosate 6 months after planting. Hemlock and Douglas-fir bare-roots all grew well if planted in a fresh burn, despite rapid regrowth of salmonberry, but virtually all seedlings less than 60 cm tall except Sitka spruce were killed by 4-year-old salmonberry if not released. Release improved growth of seedlings in the fresh burn by 6%, gaining an average of about 0.6 year toward reaching a height of 6 m. Release improved growth of survivors in 4-year-old salmonberry by 51% in height, 72% in diameter, and 325% in volume at age 12. Sitka spruce grew well until damaged by insects. Hemlock growth was equal to or greater than that of Douglas-fir of comparable initial height. In all comparisons, the probability of being overtopped by brush decreased with increasing initial stock height, and the effect of suppression on growth was also inversely related to initial height. Field planting operations may require special logistic measures for the largest stock types.

Introduction

Brush-threatened areas of the Pacific Northwest currently are being refor-

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ested on a large scale. Controlling competition from woody plants is a major factor in successful establishment of conifer plantations (Walstad et al. 1987). However, successful control often entails practices that are either costly (multiple hand release) or restricted in use in riparian zones and residential areas (herbicides). All forest burning, herbicide application, and machine scarification are restricted under some circumstances. These problems provide incentive for developing more competitive seedlings as a means of reducing long-term maintenance needs.

In recent years, the use of tall transplant stock of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] in areas of potential brush threat and animal damage has grown in popularity (Iverson and Newton 1980; Howard and Newton 1984; Gourley et al. 1990). Overton and Ching (1978) reported on conceptual advantages of tall stock. This report examines two experiments in which several stock types, sizes, and species were observed for 10 or more years under a range of competitive conditions. We describe the potential of this approach for minimizing need for high-cost, high-visibility brush control and the adaptation of field operations for extraordinarily large seedlings.

Methods

Central Coast Range tests

This analysis includes a portion of a 10,000-seedling test of Douglas-fir stock types on clearcuts in the Central Oregon Coast Range (Iverson 1976). These tests were established over 5 years on 17 sites with 100-year site indices of 43 to 61 m (McArdle et al. 1949). Competitive cover ranged from light herbaceous stands to dense sprout clumps of *Rubus* spp. and bigleaf maple (*Acer macrophyllum* Pursh). All clearcuts had been clean-logged, and most slash had been burned. Six plots were established on each site. Each plot contained 25 seedlings each of several stock types derived from local uncertified seed but different nursery practice. Seedlings were planted 1.8 m apart in rows 1.8 m apart. Each year's planting included a randomized complete block experiment on each of three or more sites in order to test differences among stock types (Iverson 1976). Every plot contained a 25-tree row of container "plug" seedlings and one of 2-0 bare-root stock. In addition, all plots in all years had one or two bare-root transplant types as 1-1's, 1-2's, or 2-1's. The first two years included bullet stock. Plugs (container removed) and bullet stock were grown in rigid 60-cc plastic containers with holes for roots to escape and weak seams expected to allow easy splitting and avoidance of constriction

(Walters 1961). Iverson (1976) observed that bullets did, in fact, grow comparably to plugs. Howard (1979) and Howard and Newton (1984) reported on development of these experiments through years 6 and 7, but they reported only on the first 2 years of installations.

About 10% of the plots were remeasured 7 years later. Ten plots were selected from those that could be relocated; the selected plots previously had had woody competition potentially capable of overtopping and encroaching on upper crowns and showed no evidence of herbicide use. The plots represented all years of planting and were 10 to 14 years old; all live seedlings were found again in each plot (a total of 596 seedlings).

Measurements of each tree included basal diameter (15 cm above ground), dbh, total height, and height to nodes formed 1 and 2 years previously. Competition was measured in terms of overtopping cover, total cover, basal area of hardwoods, basal area of conifers, and basal area of Douglas-fir alone. All measures of competition that had been made 7 years earlier were used in this analysis, including herb and encroaching shrub cover in the history of each tree. Each measure of competition was specific for individual trees and included tree-centered prism counts of nearby hardwoods and conifers. Overtopping cover was measured by the cone-occlusion method (Howard and Newton 1984) and projected from the second whorl from the top of each tree.

Salmonberry tests

Eleven classes of planting stock (species, sizes, types) were evaluated for use in brushfields where salmonberry (*Rubus spectabilis* Pursh) was or had been dominant. The tests were established 20 km southeast of Newport, Oregon, on sites where salmonberry either was well established in a 4-year-old clearcut, or was present as root stocks after a slash burn. In the first winter after the burn, 880 trees were planted in the burn, and 880 were simultaneously planted in the 4-year-old stand, which was on a site and exposure nearly identical to the first and fully reoccupied by salmonberry. Eighty of each stock class were planted in each unit.

The eleven stock classes planted in each salmonberry age class included six wildling and five nursery stocks. The wildlings included Douglas-fir and western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] in three height classes (30, 60, and 90 cm). All were within ± 5 cm of their nominal heights. Nursery stock included three Douglas-fir types (plug, 2-0 and 2-1 bare-root) and container stock of western hemlock and Sitka spruce [*Picea sitchensis* (Bong.) Carr.] similar to the Douglas-fir plugs.

All seedlings were planted by hoedad in early March. Seedlings were planted in circular clusters within blocks (20 clusters/block), with one seedling of each type per cluster and 60 cm between seedlings on the perimeter. Four blocks were planted in a freshly burned clearcut where salmonberry had been, and another four were planted in a 4-year-old salmonberry-dominated clearcut. Half of the blocks, at random, were released in September, 5 1/2 months after planting; by broadcast application of glyphosate at 1.1 kg/ha. Clustering allowed a complete comparison of all types on each microsite. Randomly mixing the stock types in a circle at each cluster gave a random chance of any stock type being next to any two other types, so complete comparisons were free of confounding by site variability or neighbors. The experiment was designed and analyzed as a randomized block factorial split plot, with the split according to release.

After measurements in year 7, each cluster was thinned to three or four trees in the freshly burned site. Small tree size and mortality rendered this impracticable in 4-year-old salmonberry. Seven of each stock type were left after thinning in each block, and each stock type had a random but equal chance of competing with any other. Basal diameter (15 cm above ground) and total height were measured in year 12. Nearly all surviving conifers at this time were as tall as or taller than salmonberry; hence, sizes reported in this study reflect the status of dominant or codominant trees with different early histories of competition and initial height.

Data recorded here are from all 224 survivors of the 880 seedlings planted in 4-year-old salmonberry, and from 310 trees remaining after thinning.

Results

Central Coast Range tests

Major differences in growth were observed among Douglas-fir stock types in each year of establishment (Table 1). Planting stock used in the years of establishment varied in height. In the third and fourth years of planting, differences between initial stock heights among the types were small (i.e., 22 to 15 cm), whereas initial heights in the first year differed by as much as 40 cm. The effects of initial height in these observations extend those made by Iverson and Newton (1980) and by Howard and Newton (1984), but are carried to the point of "free to grow" stature. The last 7 years of growth substantially increased the spread between stock types. At the time of this study, growth rates were clearly enough defined to offer a comparative basis for projecting growth. Height increments were close enough to the linear stage of growth, and enough trees were taller than 6 m that the difference in age at 6 m could be estimated from data. Growth of the stock types was not parallel at that point, however, and differences generally increase with time.

Where differences in initial size ranking existed, they were generally associated with substantial differences in final measurements (Table 1). In all years except the last, each height difference between the tallest stock type and shorter types was equated with differences in size at 11 to 14 years. In those years, growth advantage of tall transplants was at least 1.2 year over the bare-root 2-0; the short container stock types were considerably more inferior (Table 2). In the last year's plantings, the initial difference between transplants and 2-0's was small, and the growth advantage of bare-root over container stock was less than a year. In every comparison showing significant height differences at the time of planting, there were similarly arrayed significant differences in the final measurements of tree volume. Height generally followed the same pattern, but differences were not always significant.

Overtopping hardwoods and total stocking of trees exerted significant negative effects on dbh and volume for each year of planting. Small initial size increased the probability of being overtopped. In each year, adjustment of means by analysis of covariance was positive among the shorter stock types and negative among the taller. Thus, competition affected short trees more than tall. Even after adjustment for competition by analysis of covariance, stock classes remained a significant factor in all parameters except final height of trees planted in the last year (Table 3), and height was more important than nursery regime in segregating effects of stock type.

The inferior competitive position of short stock types is also attested by their position relative to other competing conifers. Containerized seedlings had 4 to 27% more conifer cover in their upper crown space than did transplants. The height:diameter ratios of the transplants also tended to be lower at the time of measurement (Table 3).

Salmonberry test

Stock height (apart from check injury in large wildlings) and release were important in the ability of conifer seedlings to dominate salmonberry (Table 4). Differences in effect of stock height were modified to some extent by the presence or absence of salmonberry at the time of planting and by release treatment. Volume growth in surviving large Douglas-fir or hemlock (60 cm or more tall) planted in 4-year-old salmonberry was depressed 3- to 6-fold relative to those planted in a fresh burn, whereas

Table 1. Initial height (H_0, cm), height *n* years after planting (H_n, cm) and stem volume (V_n, dm^3) of six Douglas-fir stock types in variable competition, 10 to 14 years after planting in the central Coast Range of Oregon (planted 1970, 1971, 1973 and 1974, observed 1984). Basis: 596 trees

Age at last measurement	Dimension	Stock type: Bullet	Plug	2—0	1—1	2—1	1—2
14	H_0	8.5 c	7.4 c	18.5 b			47.2 a
	H_{14}	418.2 b	374.0 b	736.6 a			837.1 a
	V_{14}	6.4 c	4.8 c	26.4 b			44.7 a
13	H_0	12.7 c	14.8 c	22.4 b	23.3 b	26.2 a	
	H_{13}	460.4 d	496.5 cd	655.1 b	610.1 bc	894.8 a	
	V_{13}	11.7 d	15.5 cd	32.9 b	23.3 bc	78.6 a	
11	H_0		16.5 c	20.2 b		38.8 a	
	H_{11}		316.1 c	398.3 b		522.8 a	
	V_{11}		4.0 c	6.8 b		15.6 a	
10	H_0		20.5 a	29.1 a		35.6 a	
	H_{10}		391.6 a	429.5 a		437.2 a	
	V_{10}		6.1 b	10.9 a		11.6 a	

Within rows, comparisons followed by different letters differ significantly ($P \leqslant 0.05$) according to Tukey's honest significant difference (HSD) test. Means are adjusted by covariance for variability in stand stocking level and overtopping.

volume growth of surviving shorter Douglas-fir and hemlock stock was diminished 15-fold or more. Five stocks survived so poorly in 4-year-old cover that measurements could not be analyzed.

In general, hemlock of a given initial height ranked marginally higher than the analogous Douglas-fir. Differences in volumes, diameters, and heights were nonsignificant. Sitka spruce, although planted only as container stock, sporadically reached the greatest heights by year 4. Because loss of apical dominance resulting from attack by the terminal weevil (*Pissodes strobi*) and from antler rubbing eventually reduced both form and height, we therefore cannot generalize the relation of initial size to competitive ability in this species. However, we did observe that it grew and persisted in dense shrub cover better than other species of comparable size.

Tall wildings tended to be visibly checked in the first year after planting. Initial mortality was heavy in the tall hemlock, although mortality was later equalized by thinning. Mortality was also heavy in the short containerized stock, especially when stock was planted in established salmonberry.

Table 2. Initial height (IH) difference (cm) and effective age difference (years) of Douglas-fir stock types in the central Oregon Coast Range when growth trends were extended to 6 m, adjusted for stocking and overtopping. Age difference is expressed as years behind the tallest type planted

Age at final measurement	Reference stock	Bullet IH	Bullet Age	Plug IH	Plug Age	2—0 IH	2—0 Age	1—1 IH	1—1 Age
14	1—2	−38.7	−7	−39.8	−8	−28.7	−1.2		
13	2—1	−13.5	−5	−11.4	−4.5	−3.8	−2.5	−2.9	−3.0
11	2—1			−22.3	−3.9	−18.6	−2.1		
10	2—1			−15.1	0.6	−6.5	0		

Table 3. Diameter (dbh) and total height, adjusted for total stocking and hardwood cover, and ratios of height:basal diameter (15 cm above ground) of Douglas-fir stock types 10—14 years after planting. Basis: 596 trees

Parameter/ stock type	Years since planting: 14	13	11	10
Diameter (cm)[1]				
Bullet	3.7 c[1]	4.9 c		
Plug	3.6 c	5.8 c	3.3 c	3.9 b
2—0	7.2 b	8.2 b	4.0 b	4.7 a
1—1		6.8 b		
2—1		11.8 a	5.7 a	4.8 a
1—2	8.8 a			
Height (cm)[1]				
Bullet	400 c[1]	460 d		
Plug	444 c	496 cd	350 c	395 a
2—0	729 b	655 b	402 b	428 a
1—1		610 bc		
2—1		895 a	506 a	435 a
1—2	816 a			
Height:diameter				
Bullet	71	62		
Plug	64	58	61	61
2—0	68	55	60	57
1—1		56		
2—1		52	57	56
1—2	64			

[1] Within years, comparisons of stock types followed by different letters differ significantly ($P \leqslant 0.05$) by Tukey's honest significant difference (HSD) test.

Table 4. Height (H), diameter at 15 cm (D), and volume (V) of 11 stock types planted in freshly burned and 4-year-old salmonberry, evaluated 12 years after planting.[1] Basis: 224 trees in 4-year-old salmonberry, no thinning; 310 trees in 0-year-old salmonberry, after thinning. Each mean of stock type × age of salmonberry represents 8—45 trees in 4-year-old salmonberry, 19—32 trees in 0-year-old salmonberry

		Salmonberry age class (yr)					
		0			4		
Stock type/ size	Initial height (cm)	H (cm)	D (cm)	V (dm^3)	H (cm)	D (cm)	V (dm^3)
Hemlock							
wild							
small	30	1077 ab	19.6 a	113 ab			—[2]
medium	60	1115 a[1]	20.9 a	129 a[1]	622 a	12.2 ab	39 a
large	90	1084 a	21.0 a	127 a			—[2]
plug	13	898 bcd	12.7 b	41 c	400 bc	3.7 d	2 b
Douglas-fir							
wild							
small	30	1025 abc	16.9 ab	77 abc			—[2]
medium	60	975 abc	15.7 ab	65 bc	519 abc	8.1 bcd	11 b
large	90	1075 ab	19.5 a	111 ab	608 a	10.0 ab	18 ab
bareroot							
2—1	35	1035 abc	17.0 ab	79 abc	379 b	5.4 cd	5 b
2—0	25	1027 abc	18.1 ab	88 abc			—[2]
plug	14	865 cd	13.1 b	40 c			—[2]
Sitka spruce							
plug	15	735 d	19.8 a	78 abc	470 ab	13.6 a	27 ab
Released		1025 a	185 a	96 a	601 a	11.2 a	26 a
Not released		960 b	169 a	76 b	397 b	6.5 b	8 b

[1] Within columns, comparisons followed by different letters differ significantly by Tukey's honest significant difference (HSD) test ($P \leqslant 0.05$).
[2] Too few survivors for comparison (< 5 trees).

Release significantly affected growth of trees in both age classes of salmonberry, but the effect was proportionally much greater in the established shrub cover, despite a smaller absolute response (Table 4). Release increased growth in the fresh burn by preventing salmonberry development, providing 6 and 9% increases in height and diameter, respectively, and contributing a significant 20% in volume growth. Release after 6 months in established salmonberry was too late to prevent heavy mortality in all stock types other than spruce and triggered several years' loss of volume increment in survivors.

Discussion

The two experiments described in this paper were established with many different stock descriptions under substantially different conditions. In both experiments, stock included a range of sizes, and histories of shrub development were known. In every comparison, shrub cover depressed conifer growth, but using tall stock minimized losses. Tall stock also were able to develop a stand if overtopping did not place planted seedlings beneath the discrete canopy, although they grew substantially faster when free of shrub competition.

The tendency for tall seedlings to outperform short stock was consistent, but effects of stock classes varied from year to year in magnitude. When this research was installed, quality of nursery practice was improving, and size was increasing more rapidly in containerized stock than in bare roots. In the multiyear Central Coast Range study, for example, plugs planted in the first and last years, 4 years apart, were very different in height when planted, but about the same height when measured 11—14 years later. However, quality improvement in bareroot stock may have received less attention. Initial heights of the largest transplant stock types were greatest in the year in which the container stock was shortest. Only in the last year of planting did transplants not grow significantly faster than any other stock type. In that year (1974), the 2-0 and 2-1 stocks differed in initial height by only 6 cm; apparently, the transplants had a very poor year in the transplant bed, and growth was less than expected.

The relation between stock height and performance that we observed in northwest coastal conifers has also been observed in pines (Barnett 1984; Autry 1972). Southern pine growth was positively correlated to seedling weight, diameter and height, with height or diameter variously being the best indicator. Autry (1972) showed that this advantage extends to the age of 14 years. These reports on pines are all pertinent only to container seedlings <10 g.

At the time these studies were installed, seedling diameter was not recorded. However, subsequent study has borne out early evidence of its importance. Walters and Kozak (1965) indicated that accounting for planting check in Douglas-fir greatly improves predictability of seedling performance but that height alone does not. Their ambivalence over the relation between height and subsequent growth may have originated in their basis for grading. Smith and Allen (1962) described height-based grades from poorest to best as inversely related to ratio of height to diameter. Van Goor (1977) showed that Douglas-fir seedlings with a H:D range of 45—77 grew most rapidly when H:D at time of planting was about 50, decreasing markedly above that. Cole and Newton (1987) have described H:D of 50—60 as preceding maximum future growth in Douglas-fir saplings, 65—70 as associated with maximum current growth, and > 70 as preceding to growth decline. This suggests that the Walters and Kozak (1965) grades may not have been independent of H:D, and that tall seedlings were at a relative disadvantage, perhaps because of crowding in the nursery beds.

The trend in the height:diameter ratio observed in Douglas-fir is within the range associated with maximum current or future height growth by Cole and Newton (1987). Trees in the upper end of this range reflect a competitive status pointing toward a future decline in growth rate, whereas those in the lower part are likely to continue maximum growth. Differences in size classes can therefore be expected to continue to increase, especially where crown competition is exerting some effect on those that were initially inferior in competitive position.

Our observations in these experiments confirmed earlier work (Smith and Walters 1965; Arnott and Burdett 1988) showing that seedlings with the lowest survival emerged from check last. Our tallest wild seedlings of both Douglas-fir and hemlock required more time to accelerate, as has been reported previously for hemlock (Newton 1978). The tallest hemlocks also sustained relatively high early mortality, although that effect later was obscured by thinning to a standard number of trees.

Environmental parameters at and after the time of planting determine suitability of seedlings for a site. Light, litterfall, and animals close to the ground are lethal to seedlings in many forest regeneration environments, but hazards are decreased for trees of good stem diameter and 50—100 cm tall. Use of very tall seedlings may prevent mortality and growth losses attributable to these factors. Very tall seedlings (> 60 cm high) tolerate browsing by hares, rabbits and deer better than shorter seedlings (Newton and Black 1965; Hartwell 1973). Van Goor (1977) identified the need for large stock to counteract lack of herbicides, but did not specify stock characteristics.

Survival in a brushy fertile environment has been strongly related to seedling size within species (Iverson and Newton 1980; Newton and White 1985). Newton (1978) also demonstrated strong interactions between height of wild hemlock seedlings and density of brush: very tall (> 90 cm) seedlings performed better in moderate brush than in the open, whereas the opposite was the case with stock < 60 cm tall. Despite increased check in the tallest hemlock wildlings, the seedlings that were tallest when planted were still tallest 4 years later. Hahn and Smith (1983) reported that short containerized stock performed relatively better than the taller bareroot types on south slopes versus north slopes. Walters and Kozak (1965) found that taller stock had comparable or greater absolute growth, but lesser relative growth, than their smaller analogs. Hahn and Smith (1983) observed a similar pattern on favorable sites, but Hobbs et al. (1989) and Helgerson et al. (1989) have reported variable results on extremely hot dry sites. Zaerr and Lavender (1976) reported that seedling weight was positively correlated with survival of and growth of 2-0 Douglas-fir, and also that this was consistent on bare and weedy sites.

The age equivalency of a brushfield at the time of planting is a crucial factor in biological potential for achieving dominance (Newton et al. 1968). Overton and Ching (1978) expressed differences in initial seedling height in terms of gain in effective age. Shrub and hardwood species differ in their abilities to exceed juvenile growth rates of crop conifers. Height development of shrubs is limited by definition, but sprout growth reaches a maximum relatively rapidly (Zavitkovski and Newton 1968; Allen 1969). Zavitkovski et al. (1969) found that at no time in the life of a mixed stand of seedling Douglas-fir and snowbrush (*Ceanothus velutinus*) were the shrubs more than about 3 years ahead of the conifers. Petersen et al. (1988) showed that Douglas-fir is only marginally able to tolerate presence of equal-aged snowbrush. However, if 1 to 3 years could be gained by planting large transplants in this competitive regime, long-term dominance of the conifer would more likely be assured without release.

Survival and biomass growth of Sitka spruce container seedlings were noteworthy. This species was remarkably tolerant of deep shade. Growth was poor when domination by salmonberry was complete, but Sitka spruce survived shading that was lethal to western hemlock or Douglas-fir. The cluster design of the experiment minimizes the possibility that this finding resulted from confounding stock type with microenvironment. Despite the excellent adaptation of container-grown Sitka spruce to a shrub-dominated environment, its emergence as a dominant in the first 12 years did not lead to good growth or form because of terminal damage. Nearby experiments with 80-cm 2-2 transplants did not change this conclusion (Newton and White 1985). This species is capable of superior growth if free from terminal damage, as is possible, for example, from the Queen Charlotte Islands north (> 53 °N). In this experiment, the probability that a spruce would remain dominant and without weevil damage was less than 0.1. Thus, the very high potential of this species is unlikely to be realized without freedom from weevil injury.

Smith and Walters (1965) and Iverson and Newton (1980) have addressed the economics of using tall stock. Smith and Walters concluded that the optimum height for Douglas-fir from 3-0 stock was less than the maximum height, but was still considerably above average. Their tallest stock required the least time to reach breast height, but sustained above-average mortality. Iverson and Newton (1980) used different nursery regimes, rather than sorting, to produce their arrays of stock types. Both survival and growth were enhanced by the tallest classes. They concluded that very tall transplant stock provided the most favorable cost/benefit ratio, especially where brush was present. The data presented here demonstrate the validity of the biological assumptions in this argument and the major opportunities for developing low-cost approaches that make use of the tallest stock more viable.

Tall planting stock has several limitations. First, such seedlings are bulky and place heavy demands on storage and transportation facilities. Field transplant nurseries close to the sites of use would have several advantages. Second, tall seedlings are cumbersome for the planter to carry. Pallet loads of seedlings could be placed every few acres by helicopter or all-terrain vehicle, so planters need not handle large loads or carry them far. Third, very tall trees are impractical where very large root systems are needed (i.e., large ratio of roots to shoots coupled with tall tops). These trees may require root-pruning; hence, their use may be limited to protected, shady or moderately moist sites, such as zones with considerable cloud cover, riparian zones, north slopes, or among residual trees. On such sites, both the first author and the U.S. Forest Service (Siuslaw National Forest) have planted Douglas-fir over 150 cm tall in salmonberry with good success (E. Lohmeier, U.S. Forest Service, Waldport, Oregon, unpublished data). The relatively small roots will also make them vulnerable to "wind-twizzling" on exposed ridges. (Twizzling, the circular motion of seedling crowns by wind, causes girdling when seedlings are planted deeply enough so that the stem is abraded by the soil. This can be avoided, strangely, by planting shallow enough so that there is little buried stem.) Their use in very rocky or shallow soils is not appropriate; even on good sites, planters may have a tendency to "stuff" the large roots into too-small holes, with undesirable results.

Specification of the environment into which a specialized seedling is to be planted helps identify the needed characteristics of planting stock. Rose et al. (1990) has elaborated on the "Target Seedling" concept for nursery production. It is proposed that each target seedling be destined toward a "target environment". Thus, a silviculturist can choose options of site preparation and animal damage control within the local constraints and then order a seedling adapted to the best environmental preparation possible or practical. For example, Edgren (1977) did not recommend tall or transplant stock for clearcuts at 1000 m elevations in the Cascade Mountains. Helgerson (1990) did not recommend 2-0 bare-root stock over container stock for planting under treated or untreated stands of tanoak (*Lithocarpus densiflorus (Hook. &Arn.) Rehd.*), despite the height difference at time of planting, because either was much shorter than the dominant cover.

If nurseries can respond to the need for very tall "target trees", an advantage of several years over competitors and herbivores avoids many hazards of planting, especially on good sites. Gaining several years on succession reduces costs of vegetation management and animal protection, and increases yields. Tall trees also survive better under these conditions, so planting densities as low as 250 trees/ha may be feasible. The low planting density would reduce over-all costs of planting and pre-commercial thinning. Finally, this approach makes lands on which conventional methods may be constrained suitable for management.

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