Chapter 24
Planting-Stock Selection: Meeting Biological Needs and Operational Realities

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Abstract

The tremendous variability in Northwest planting sites requires a variety of planting stock. Genetic, physiological, and morphological seedling characteristics must be matched to site and organizational objectives. Vegetation classification schemes help foresters select species, and seed zones help them determine areas where seedlings of any species can safely be moved from their source. Local species and seed sources should always be preferred unless documented research proves otherwise. Large seedlings, if properly conditioned, will grow faster on favorable sites. Seedlings with tall shoots are better suited to brushy areas and where animal damage may be a problem; large-caliper seedlings will perform better where heat, insects, or physical bending are problems. Droughty conditions require seedlings with well-developed roots. Container-grown seedlings can be used to extend the planting season, but spraying soil-active herbicides over them immediately after planting is risky.

24.1 Introduction

Careful selection of planting stock is critical in any reforestation prescription. A good choice of stock may even compensate for inadequate site preparation. But what may be considered high-quality stock for adequately prepared areas might not prove suitable for those that are inadequately prepared.

Foresters and nursery managers are jointly responsible for producing high-quality nursery stock. "Quality" here is defined as the ability of stock to realize management objectives at planting sites [61]. The forester knows what morphological and physiological characteristics of seedlings can maximize performance at planting sites. The nursery manager is charged with producing seedlings that meet those specifications economically. Use of ideal seedlings will result in plantations that have the lowest cost per surviving tree or, better yet, the highest estimated present net value [58]. Using present net value as a criterion bases comparisons on growth as well as survival.

A variety of species and stock types is grown to fit the highly variable topography, soil, and climate of the Northwest. Over 20 species and seven different stock types were produced in 1980 (Table 1) (OSU Nursery Survey; see chapter 1, this volume). Plans for nursery production through 1985 continue to be tailored to meet customer needs. For example, the OSU Survey indicated a trend toward growing larger trees; as a result, more transplants and 2+0 seedlings grown at low densities will be produced.

Over the years, foresters have selected stock on the basis of their experience with its performance and research results. Even though stock performance is at times contradictory, most

Table 1. Estimated 1980 seedling production at major Northwest nurseries by species group and stock type (OSU Nursery Survey).

	Production, in 1.000s of seedlings
Species group	
Douglas-fir	168,047
Western hemlock	1,123
Spruce	37,657
True firs	17,441
Ponderosa pine	26,795
Lodgepole pine	16,323
Other pine	1,899
Western larch	2,832
Miscellaneous species	5,385
Total	277,502
Stock type	
1 +0	1,184
1 + 1	7,356
1 + 2	1,400
2 + 0	219,892
2 + 1	38,479
3+0	1,754
Plug + 1	6,575
Miscellaneous types	862
Total	277,502

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anomalies can be explained and general guidelines for stock selection offered. In this chapter, I review factors influencing stock selection and discuss relationships between seedling characteristics and performance on specific site types.

24.2 Considerations in Selecting Stock

Organizational objectives, planting-stock availability, and environment at the planting site are factors influencing stock selection. Although environment at the planting site is very important biologically for selecting the right stock, there are situations in which organizational objectives and stockavailability may be overriding factors.

24.2.1 Organizational objectives

Organizational objectives influence stock choice by dictating the reforestation system or species. Some organizations, for example, may adopt a container-grown seedling system to mechanize reforestation, extend the planting season, shorten production time, or facilitate production of species difficult to grow as bareroot stock [57]. Planting Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] in lieu of western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] on sites suited for either is an example of managing for a preferred species. Even though hemlock may be suited ecologically, it is generally considered less desirable than Douglas-fir for both lumber and pulpwood. The potential of hemlock, however, gradually is being recognized [51], and the planting of Douglas-fir on hemlock sites is becoming less common. Other resource values also may influence species choice. Wildlife considerations, for example, may justify using a species not normally planted for fiber production [50].

24.2.2 Planting-stock availability

A shortage of the preferred species or stock type often causes foresters to use less desirable planting stock. Shortages can and do occur because of nursery pests, damaging weather conditions, inadequate seed supplies, or poor germination.

24.2.3 Planting-site environment

Classifying the planting-site environment is important, in the long term, for selecting species and seed source and, in the short term, for determining morphological and physiological seedling characteristics. Using the correct species and seed source will ensure that seedlings are adapted to infrequent climatic extremes or diseases which could affect plantation performance in the future but go unnoticed during establishment. Seedlings with the correct morphological and physiological characteristics are better adapted to meet initial threats to survival and optimal growth, such as animals, falling debris, or heavy brush competition.

24.2.3.1 Species

Each species will be best adapted to a given range of environmental conditions. Proper species selection may require more than just surveying native tree species and their relative frequency in the previous stand. Some species may have higher yield potential than others [23] or may be better adapted to the environments created by harvesting or other site disturbances.

Vegetation classifications provide useful aids to selecting species. Habitat types delineate sites with equivalent environments where plant succession leads to the same climax species. If the habitat type is known, identifying the sera] or pioneer species on a given site is possible. A generally accepted rule is that the sera] or pioneer species will survive better and grow faster on clearcuts or burned areas than the climax species [47].

Environments can be classified on the basis of soil characteristics or other site features as well as vegetation. For example, on the Vancouver Forest District, the British Columbia Forest Service considers vegetation types and soil nutrient and moisture characteristics to guide species selection and intensity of prescribed burning [35].

Vegetation descriptions and keys are available for much of the Northwest. Major vegetational units in Oregon and Washington have been described by Franklin and Dyrness [18] and numerous regional plant communities and habitat types by Bailey [4], Daubenmire and Daubenmire [14], Reed [48], Pfister [46], Hall [22], Dyrness et al. [17], Cooper [12], and Wirsing and Alexander [66].

Other site factors also are important in selecting species. Using certain species is risky because of their vulnerability to insects and diseases. Sugar pine (*Pinus lambertiana* Doug].), for example, is particularly well suited to many sites in southwestern Oregon but is susceptible to blister rust. Therefore, it is not recommended for drainages where rust spores remain viable and can travel long distances in the humid night air [26]. Douglas-fir and ponderosa pine (*Pinus ponderosa* Doug]. ex Laws.) are preferred to sugar pine in such situations.

24.2.3.2 Seed source

Merely selecting the correct species will not guarantee that the stock suits the site. Adaptive differences also occur within a species. Coastal Douglas-fir (var. *menziesii*), for example, seems adapted to specific environments even though, as a species, it ranges from British Columbia to northern California. Campbell [5] found differing genetic potentials among different seed sources of Douglas-fir from the same watershed, and Hermann and Lavender [28] noted differences among seed sources from north and south aspects of the same mountain. Using only adapted seedlings will lessen the risk of widespread mortality because of climatic extremes, disease, or insects and will reduce the probability of growth loss.

The best adapted seeds originate from stands close to the area to be reforested—assuming that trees in the immediate vicinity developed naturally and are not plantations from an off-site seed source. How far seed can be moved from its original source depends on how closely the planting-site environment matches that where the seed originated. Limits to seed transfer could be defined as geographic, altitudinal, ecologic, or physiographic intervals across which adaptive differences among populations can be detected [49].

Actual experience is the best way to determine what distance seed can be moved from its source without losing general adaptation. Nevertheless, zones of similar environment have been delineated on maps for the Northwest (available from the Western Forest Tree Seed Council, Portland, Oregon) to guide seed-transfer limits. Such zones are designated by a 3-digit code in which the first digit identifies the physiographic and climatic region within a state, the second identifies the physiographic and climatic subregion within a region, and the third identifies the zone within a subregion. The local seed zone should be selected as a first choice. Seed from adjacent zones will substitute only if the environment there is similar to the local one.

As a general rule, seedlings should also originate from within 150 m (500 ft) in elevation of the planting site. In some areas, however, adhering to such subzones may be less critical than adhering to other gradients. With Douglas-fir, for example, elevational and north-south seed transfers are less dangerous (have lower risk of maladaptation) than east-west transfers [6]. Different species may also have varying elevational intervals. Suggested intervals for some species in the northern Rocky Mountains are 150 m (500 ft) for lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) and Douglas-fir (northern Idaho), 300 m

(1,000 ft) for Douglas-fir (western Montana), 460 m (1,500 ft) for ponderosa pine, 610 m (2,000 ft) for western larch (*Larix occidentalis* Nutt.), and infinite for western white pine (*Pinus monticola* Dougl. ex D. Don) [49]. Seed collected from a particular stand should be transferred (either upward or downward in elevation) about 1/2 the interval indicated.

Use of nonadapted species and seed sources can result in total, immediate mortality—or satisfactory, initial plantation establishment but reduced growth or failure later because of disease, insects, or periodic climatic extremes [8]. Numerous examples demonstrate the need for using adaptive species and seedlings from local sources [13, 25, 33, 37].

24.2.3.3 Seedling morphology and physiology

Unfortunately, planting stock is often prescribed only by stock type. This practice makes it impossible to correlate seedling characteristics with field performance and does not sufficently describe seedling morphology so that foresters can order what they need. Within a stock type, seedling size can vary between nurseries or within the same nursery in different years. Describing stock only by type in research trials may be one reason that inconsistent performance has been reported for the same and different types (see also chapter 15, this volume).

Some nurseries use a seedling description system [45] that includes stock type, shoot height, root-collar diameter, shoot:root ratio, and sowing date, all based on characteristics for 75% of the seedlings in a lot. This system allows foresters to specify seedling needs in more detail and nursery managers to describe more precisely the characteristics of seedlings. Though the need to grow a variety of seedlings to match planting-site conditions has long been recognized [9, 10, 34], it is now possible to better manipulate seedling morphology and physiology to meet specified needs. Table 2 shows the median values of morphological targets for species and stock types produced at major Northwest nurseries.

Results of past studies do not clearly indicate what seedling characteristics ensure optimum performance. Studies relating performance to seedling size, for example, support one of three conclusions: (1) large seedlings are best; (2) seedling size at time of planting is not of primary significance; and (3) small seedlings are best. Such contradictions are attributable to wide variations in nursery conditions, stock treatment and handling, and site conditions among studies [67]. Yet despite some inconsistent results, past studies show that matching seedling physiological and morphological characteristics to the planting site improves results, perhaps by ensuring fuller utilization of nutrients, water, and light. Though greater flexibility in seedling characteristics is permissible on favorable sites, greater vigor is particularly important on marginal or difficult ones.

Table 2. Median morphological targets for representative species and stock types grown at major Northwest nurseries (OSU Nursery Survey).[1]

Species	Stock type	Shoot height, cm (in.)	Caliper, mm	Shoot:root ratio
Douglas-fir	1+0	11.5 (4.5)	3	1.8
	1+1	38.0 (15)	8	Not specified
	1+2	76.0 (30)	10	1.5
	2+0	30.5 (12)	5	2.0
	2+1	46.0 (18)	7	1.8
	3+0	61.0 (24)	8	Not specified
	Plug+1	46.0 (18)	9	1.9
True firs	2+0	15.0 (6)	4.5	1.5
	2+1	23.0 (9)	6	2.0
Lodgepole pine	2+0	13.0 (5)	4	1.3
Ponderosa pine	2+0	13.0 (5)	4	1.8
Spruce	2+0	18.0 (7)	4	1.5
	1+2	76.0 (30)	10	1.5
	2+1	24.0 (9)	5.5	1.5
Larch	2+0	20.0 (8)	4	Not specified

[1]Targets for some species and stock types may be represented by only one nursery, and some nurseries did not specify targets.

24.3 Matching Stock and Site

24.3.1 Favorable sites

Favorable sites include those that have a long growing season, sparse residual vegetation, low probability of animal or insect damage, gentle slopes, and sufficient moisture so that seedlings are not severely stressed. Though seedlings do not need special characteristics to ensure their survival on favorable sites, fast initial growth rates are desirable.

Under favorable conditions, large seedlings, regardless of size standard used, demonstrate more growth than small seedlings. For example, large white spruce *[Picea glauca* (Moench) Voss] and lodgepole pine seedlings outgrew smaller ones of the same stock types [15]. Similarly, Douglas-fir, western hemlock, and Sitka spruce [*Picea sitchensis* (Bong.) Carr.] grown in 125-cm^3 (8-$in.^3$) styroblocks outperformed seedlings grown in 40-cm^3 (2-$in.^3$) styroblocks after 5 years in the field [2]. Shoot and root dry weights of seedlings produced in the larger container were substantially greater than those of seedlings from the smaller container.

Seedling stem caliper, also related to initial growth and other seedling parameters, is often considered the best morphological index of planting-stock quality [7, 38]. Ponderosa pine seedlings 3.6 mm or more in stem caliper grew more after 2 years on favorable sites in northern California than seedlings 2.5 mm or less in caliper [31]. Similar results were obtained for Douglas-fir and Sitka spruce in Washington [64]. Large-caliper Douglas-fir seedlings (defined as $\geq$ 12 mm in diameter for 2+1 transplants, $\geq$ 5 mm for 2+0 seedlings, and $\geq$ 2 mm for plug seedlings) grew more than smaller caliper ones within the same stock types. Wierman [64] concluded that 2+0 Douglas-fir seedlings less than 3 mm should not be used. Smith [55] found that, on the basis of potential returns, the optimum Douglas-fir seedling is at least 5 mm in diameter at the root collar and 38 cm (15 in.) tall. Because the most cost-effective seedling size is a function of tree performance and production costs, the increased survival and growth of larger seedlings must more than compensate for the additional cost of producing them. Consequently, optimum size will change as either cost or performance changes.

Large seedlings can grow more than smaller ones because of their greater photosynthetic area. However, faster growth will occur only if seedling development is properly synchronized. Nursery practices that induce dormancy at the correct time and fulfill chilling requirements will provide for early, rapid shoot growth and high root-growth capacities [39]. That is, a seedling must be physiologically prepared for planting (see chapters 14 and 15, this volume).

24.3.2 Difficult sites

Difficult sites are defined as those requiring careful effort to reforest successfully by planting. High-elevation sites, for example, have a short growing season and a short period of favorable planting conditions in the spring. Similarly, sites with heavy cover of residual woody and herbaceous weeds, areas populated with animals or insects that feed on seedlings, droughty sites, steep slopes prone to soil and debris movement, and frost pockets all require specialized planting stock.

24.3.2.1 High-elevation sites

on high-elevation sites, cold soils or spring snow may make it necessary to extend normal planting periods. Soil temperatures at 900 m (2,953 ft) in the Northwest can remain below 10°C (50°F) at 22 cm (8.7 in.) depth until June, whereas soil temperatures reach 10°C in April at 200 m (656 ft) [16]. At some high elevations, favorable conditions for both soil moisture and temperature are short lived because once soils warm, moisture is rapidly depleted.

Container-grown seedlings are often used when the planting season must be extended. They may adjust better in less favorable planting conditions because their roots are not stressed by pruning or handling, and they have immediate access to some moisture and fertilizer in the enclosing medium [57]. Bareroot seedlings, on the other hand, must reestablish all root-soil contacts after planting. Containerized stock has been used successfully in eastern Oregon by Weyerhaeuser Company to extend the planting season [65]: container-grown seedlings reportedly achieved 85% survival, and growth rates equaled those of bareroot stock. It is not certain, however, whether the present net value of the container-grown stock exceeded that of the bareroot stock because initial costs were higher.

24.3.2.2 Sites with competing woody vegetation

Where woody vegetation threatens to overtop seedlings, large seedlings and those with long shoots are particularly desirable. In heavy brush, initial seedling height may be more important than initial growth rate [56]; if seedlings are quickly overtopped, there is little chance they will outgrow competing vegetation in a reasonable time without release [30, 53]. Initial height of Douglas-fir seedlings was shown to be especially important to seedling establishment on Oregon coastal sites with overtopping woody vegetation [32]. Arnott [1] also found that large bareroot Douglas-fir seedlings grew more than smaller containerized stock in areas where vegetative competition was severe. In both studies, the large seedlings were 1+2 transplants averaging 43 cm (17 in.) tall.

The tallest seedlings, however, may not always grow more. In a test that compared 2+1, 3+0, plug+1, and several sizes of containerized seedlings, Hahn and Smith [21] found that 3+0 seedlings grew slower after 3 years in the field than bareroot transplants even though the 3+0 seedlings were taller initially. However, the 2+1 and plug+1 seedlings, which were initially taller than the containerized seedlings, did grow faster after 3 years than the containerized stock on a north slope with vegetative competition. The poor performance of the 3+0 seedlings may be attributable to differences in physiology or shoot:root ratio of the 3+0 and other stock types. I recommend using Douglas-fir seedlings that are at least 43 cm (17 its.) tall and have at least a 7-mm root-collar diameter in areas where woody vegetation is a problem and water is not limiting.

In brushy environments, initial shoot height is important for other species as well as Douglas-fir. Newton [42] studied the performance of western hemlock wildlings and concluded that success decreased rapidly below a height of 61 cm (24 in.). Similarly, large white spruce and lodgepole pine seedlings planted on nonscarified plots outperformed small seedlings on scarified plots [15]; shoots of large pines averaged 15.2 cm (6.0 in.) long for 2+0 stock and 21.1 cm (8.3 in.) for 2+1 stock and those of large spruce 20.4 cm (8.0 in.) for 2 +0 stock and 19.8 cm (7.8 in.) for 2 +1 stock.

Studies of containerized stock have shown that large seedlings are needed where vegetative competition is a problem. White spruce seedlings grown in styroplug 8 (8-in.^{3}) containers were compared with seedlings grown in styroplug 2 (2-in.^{3}) and styroplug 4 (4-in.^{3}) containers on prepared areas and those with dense competing vegetation [41]. The small seedlin gs (initially 16 cm, or 6.3 in., tall) grew less than the larger ones (initially 22 cm, or 8.7 in., tall) on sites where competition was stiff. Large stock growing on untreated sites or small stock growing where soil had been tilled instead of just scarified gained 50 to 100% in total seedling. mass by the end of five growing seasons, compared to small stock planted on untreated sites. In this example, the better performance of large stock on unprepared sites could more than compensate for its higher initial cost.

24.3.2.3 Sites with downslope movement and falling debris

Large-caliper seedlings are more suitable than small-caliper ones in areas prone to downslope soil movement or falling debris. Soil deposition or debris lodged on seedlings can create stat ic bending stress that will reduce height growth [52] or even bury seedlings [19]. Large-caliper 2+0 Douglas-fir seedlings grew 82% more after 3 years than smaller caliper ones on unstable granitic soils where 153 of 200 trees had varying degrees of soil deposited around them [60]. Stems of larger seedlings averaged 8 mm, those of smaller ones 6 mm.

Large stem caliper provides other advantages in addition to bending resistance. The thicker bark on larger stems may allow heat to dissipate along and away from the stem, making large-stemmed seedlings more heat tolerant on sites where high temperature is a problem. The succulent thin stems of newly germinated Douglas-fir and hemlock seedlings generally die at temperatures between 51°C (123°F) and 60°C (140°F) [54].

24.3.2.4 Sites with insects and animals

Insects are not a common threat to plantation establishment. Nevertheless, *Stremnius carinatus* (Boheman), a weevil native to Pacific Coast forests, caused 2 to 11% mortality in plug plantations sampled in a 1975 survey [20]. Thick bark is believed to discourage attack by weevils. Therefore, large stock is recommended where sizable weevil populations are suspected. A total catch of 30 weevils from 10 traps collected over a 2-week period indicates a potential hazard.

Large planting stock also is needed in areas where animals may damage trees. Large shoots lessen the frequency and consequences of clipping by hares [24, 44]. After exposure to a large number of hares for 4 months in a l-acre enclosure [24], Douglas-fir seedlings 74 cm (29 in.) tall were not reduced in size, but shorter seedlings were. In another test in the same study, seedlings 48 cm (19 in.) or more in height withstood hare damage when an effective repellent (e.g., TMTD) was applied before planting; the initial protection enabled the terminal shoot to rapidly grow above the reach of hares. Large seedlings also are more likely to recover from clipping because of their greater photosynthetic surface. Further, numerous branches on seedlings may be helpful because they provide a choice of browse; if the terminal is browsed, a lateral branch is available to replace it.

24.3.2.5 Droughty sites

Seedlings with well-developed root systems are needed on moisture-limited sites so that the absorptive capacity of roots can counteract transpirational losses from shoots [3, 27, 29]. Douglas-fir seedlings with large roots (shoot:root ratio 1.25, oven-dry basis) had 22 to 26% higher survival than those with small roots (shoot:root ratio 0.71) on dry sites in north-central Washington [40]. Similarly, wrenched Douglas-fir seedlings developed higher shoot:root ratios and survived well on a dry south slope in the Cascade Mountains near Springfield, Oregon [62] and on a dry Coast Range site in northern California [36], as compared to seedlings not wrenched. Even though shoot:root ratio may not always indicate root size or absorptive capacity, it is a convenient index of seedling balance.

Root characteristics such as surface area and root form also could be important on droughty sites. Comparing nursery and natural stock, Stein [58] noted that lateral roots of nursery stock are usually trimmed to the same length as tap roots or are shaped in containers to parallel the tap root, whereas lateral roots of natural seedlings develop a short distance from the soil surface and branch extensively to tap both surface and lower soil layers. Differences in the form and balance of nursery stock and seedlings that develop on site should be evaluated further to determine which of these differences may be critical to a tree's normal top and root development.

Foresters have long recognized that controlling competing grasses and other herbaceous vegetation with herbicides will reduce moisture stress in seedlings. The use of container-grown seedlings on sites treated with soil-active herbicides could be risky, however. Potting medium apparently does not adsorb the chemical, which deposits near fine seedling roots, causing severe damage [43]. Bareroot seedlings or plug transplants would less likely be damaged on sites where soil-active herbicides are applied the year of planting.

24.3.2.6 Sites with frost pockets

The physiological condition of seedlings is crucial on sites where frost is likely. Nursery cultural operations should be synchronized with seedling dormancy to ensure dormancy requirements are fulfilled (see chapters 14 and 15, this volume). Failure of seedlings to complete the requirements of each dormancy phase will result in decreased seedling vigor and increased vulnerability to environmental stress, including frost. Frost hardiness of seedlings might also be improved by manipulating fertilizer regimes (see chapter 7, this volume). Evidence suggests that the ratio of nitrogen to potassium influences cold hardiness [63].

24.4 Conclusions

The genetic, morphological, and physiological characteristics of planting stock should be designated for individual planting sites. Biologically, the goal is to plant seedlings that will most fully utilize site resources and will be least constrained by animals, vegetation, debris, or other factors. Operationally, the goal is to maximize the present net value of the plantation. Using the correct planting stock will ensure that returns on other reforestation investments. such as site preparation and maintenance also are maximized.

Planting-stock prescriptions can only be based on results from past field performance. Prescriptions will change as seedling production techniques improve and as more is learned about the interactions of seedlings with their environment. As foresters become more confident of their needs, they must alert nursery managers so that the best seedling may be produced at the lowest cost.

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