Special Publication 24 June 1992

Red Alder: Guidelines for Successful Regeneration

Glenn R. Ahrens
Alex Dobkowski
David E. Hibbs

FOREST RESEARCH LAB

College of Forestry Oregon State University

The Forest Research Laboratory of Oregon State University was established by the Oregon Legislature to conduct research leading to expanded forest yields, increased use of forest products, and accelerated economic development of the State. Its scientists conduct this research in laboratories and forests administered by the University and cooperating agencies and industries throughout Oregon. Research results are made available to potential users through the University's educational programs and through Laboratory publications such as this, which are directed as appropriate to forest landowners and managers, manufacturers and users of forest products, leaders of government and industry, the scientific community, and the general public.

The Authors

Glenn R. Ahrens is research assistant, Department of Forest Science, Oregon State University, Corvallis, Oregon. Alex Dobkowski is research forester, Weyerhaeuser Co., Longview, Washington. David E. Hibbs is associate professor, Department of Forest Science, Oregon State University, Corvallis, Oregon.

Legal Notice

Disclaimer

Acknowledgment

This guide was generated in part during a workshop held by the Hardwood Silviculture Cooperative, Oregon State University (October 5, 1989; Kelso, Washington). Researchers and land managers from the Pacific Northwest participated in the workshop and in the development of this guide. Y. Tanaka (Weyerhaeuser Co.), M.A. Radwan (USDA Forest Service), and W. Fangen (Washington State Department of Natural Resources, Webster Nursery) provided additional valuable information on seedling production technology and outplanting performance.

To Order Copies

Copies of this and other Forest Research Laboratory publications are available from:

Forestry Publications Office
Oregon State University
Forest Research Laboratory 227
Corvallis, Oregon 97331-5708

Please indicate author(s), title, and publication number if known.

Red Alder:
Guidelines for Successful Regeneration

Glenn R. Ahrens
Alex Dobkowski
David E. Hibbs

Contents

English/metric conversions

1 foot x 0.305 = 1 m

1 inch x 2.54 = 1 cm

0.555 (°F - 32) = 1°C

1 acre x 0.405 = 1 ha

1 ft^2/acre x 0.23 = 1 m^2/ha

1 mile x 1.609 = 1 km

Introduction

Regeneration of red alder (*Alnus rubra*) has engendered great interest in the last 5 years. The value of alder has increased for several reasons; for example, red alder can produce high-value "furniture grade" lumber in a relatively short rotation (35-40 years) in the Pacific Northwest. Landowners also have been seeking alternatives to conifers for planting in a variety of situations, including sites infected by laminated root rot (*Phellinus weirii*) and areas where a mix of hardwoods and conifers is desired.

Red alder can be regenerated intentionally from coppices, seed, or seedlings. Alder coppices with rotations of 4 to 6 years have been managed successfully (DeBell *et al.* 1977, Harrington and DeBell 1984). However, alders more than 10 years old do not sprout well after cutting (Worthington *et al.* 1962, Harrington 1984), and regenerating alder from older existing stands by coppicing is not feasible. This paper therefore treats only regeneration from seed and seedlings.

Kenady (1977) has summarized published and unpublished information pertaining to alder regeneration. This paper synthesizes more recent research and extensive observations derived from the practical experience of land managers. Because our knowledge base is small and long-term trials are few, the guidelines presented here are conservative and general.

Selecting Sites Suitable for Alder Regeneration

Evaluation of potential site productivity is key to determining the relative profitability of alder and conifer management. Managers planning to regenerate with alder should first evaluate the suitability of the specific site for alder establishment and growth. When representative alder trees are present, site index should be estimated by the methods described by Harrington and Curtis (1985) or Worthington *et al.* (1960). Harrington (1986) gives good general rules for evaluating site factors and estimating site index for red alder in the absence of representative site trees.

Criteria for determining acceptable levels of stocking, growth rate, or stem form depend on management objectives. Our recommendations are based on timber production as a primary objective. On some sites, the high risk of excessive seedling mortality or persistent damage precludes regenerating alder for timber production. These risks are determined by physical site factors, such as climate, slope, aspect, and soils, in combination with biotic factors, such as competing vegetation and animal damage. The importance of specific hazards also depends on the potential management intensity; appropriate management may reduce some hazards to acceptable levels.

Physical Factors

Elevation

Management of red alder in western Oregon should generally be restricted to sites of 0 to 2,500 feet in elevation. At higher latitudes, the upper elevational limit decreases to as low as 1,500 feet in northwestern Washington and 1,000 feet in northwestern British Columbia.

Aspect

Near the coast, high humidity and soil moisture may provide favorable conditions on any aspect. Inland, mortality is increased on southerly aspects (135–225 degrees azimuth) as the result of drought, heat, and sunscald. These problems are exacerbated on steeper slopes (>40 percent) inland of the Sitka spruce (*Picea sitchensis*) zone, which generally is limited to 5 to 10 miles from the coast. The effects of aspect are reduced on gentle slopes (<10 percent).

Soil drainage

Prolonged flooding or poor soil drainage can greatly reduce survival and growth of alder. Development of the root system is severely restricted by poor drainage, particularly when soil saturation coincides with periods of maximum potential root growth. Poorly developed root systems increase the susceptibility of seedlings to summer drought stress; this effect is compounded by competition from heavy herbaceous cover that typically develops on poorly drained sites. Red alder does tolerate short-term winter flooding.

Soil fertility

Soils low in available phosphorus (P) may greatly limit establishment and growth of alder (Radwan 1987). If P deficiency is suspected, a soil test is advisable. Although specific criteria for determining deficient P in soils have not been developed for alder, concentrations less than 5 to 10 ppm (Bray P1, NH_4F/HCl extractable P; Olsen and Sommers 1982) generally indicate P deficiency (N. Christensen and J. Hart, 1991, personal communication); values of 10 to 30 ppm may indicate deficiency, depending on other factors. Foliar P concentrations less than 0.16 percent indicate P deficiency in alder (Hughes *et al.* 1968).

Because alder forms a symbiotic association with the N-fixing actinomycete *Frankia*, deficiency in soil nitrogen (N) is of lesser concern. Alder can compensate for deficiencies in soil N through increased N fixation in *Frankia* nodules (Zavitkovski and Newton 1968, Koo 1989).

Moisture supply

In general, excessively dry sites should be avoided. Droughty conditions may result from inadequate annual or seasonal precipitation, low moisture-holding capacity of the soil, or high evapotranspiration, together or singly. Annual precipitation should exceed 25 inches. The low water-holding capacity of coarse soils (sandy loams or sands) or soils with rock fragment contents greater than 40 percent by volume can produce drought. Coarse soils with subsurface moisture supplies may be acceptable. This situation is usually restricted to flood plains and riparian areas, and drought hazards may still be high during stand establishment, particularly if competing vegetation is present. Poor infiltration of summer rains into fine-textured surface soils may increase drought hazards.

Frost hazard

Red alder should not be planted in areas with severe frost hazard. Such hazards are produced by topographic features that generate local frost pockets or draw cold air from large cold-air drainages. Cumulative effects of periodic frosts produce poor quality stands, and both late spring and early fall frost can be disastrous to young plantations. For example, on a plantation with poor cold-air drainage near Doty, Washington, a frost in May (air temperature 28°F for 5 hours) killed tops and damaged foliage on 50 percent of the trees. Although these trees recovered well during the growing season, an early frost in October (20°-27°F for 8 hours) severely damaged 75 percent of the trees in the plantation. Stems were killed to ground level on many trees 90-150 cm (3-5 ft) tall (A. Dobkowski, 1989, unpublished data).

Wind exposure

Frequent exposure to high winds can greatly reduce height growth and stem quality. Areas exposed to periodic high winds (>50 miles per hour) and coastal sites that are not protected from onshore winds should not be planted with alder.

Biotic Factors

Competing vegetation

Heavy cover of competing vegetation (90-100 percent cover[1] with overtopping in the first year) can greatly reduce seedling growth and increase seedling mortality. Potential competition from residual vegetation, invading forbs and grasses, or both should be evaluated on prospective sites. Prescribed burning, application of herbicides, or both, can prevent excessive competion (see Site Preparation and Vegetation Management, p. 8).

Animal damage

Browsing, rubbing, and trampling by deer and elk can greatly decrease survival, vigor, and growth. Severe browsing by big game can predispose seedlings to mortality or to reduced growth caused by competing vegetation. The impact of heavy or moderate browsing is best reduced by planting large, healthy stock that will rapidly exceed a susceptible size.

Both mountain beaver (*Aplodontia rufa*) and fur beaver (*Castor canadensis*) can substantially damage young plantations. Broadcast burning after harvest drastically reduces resident mountain beaver populations, but local populations often increase rapidly during plantation establishment. Planted seedlings may be the major potential food for mountain beavers during the first years after burning or chemical site preparation. If mountain beavers

1 Values given for cover in this report are the sum of percent cover for shrubs, grasses, forbs, and ferns present and may exceed 100 percent for a site.

appear to be increasing in the unit, preventive measures such as trapping should be considered within the unit and up to 100 feet into adjacent forests. Fur beavers prefer alder to conifer seedlings and can cause extensive mortality up to 150 feet from streams. If beavers are present in streams adjacent to a planned plantation, trappings should be considered or another site should be chosen.

Voles (*Microtus* sp.), mice (*Peromyscus* spp.), and other small rodents often damage seedlings severely, particularly in grassy or marshy areas. Basal netting or plastic tubing can protect seedlings in such areas.

Local outbreaks of defoliating insects (particularly the western tent caterpillar, *Malacosoma californicum*; the alder leaf beetle, *Chrysomela mainensis*; or the alder flea beetle, *Altica ambiens*) can also be very hazardous to new plantations. If new plantations are threatened, spraying or delaying planting should be considered. Such outbreaks are usually infrequent and seldom cause tree mortality in older plantations.

Seed Collection

Commercial supplies of alder seed are limited at this time. An adequate supply of seed from a suitable source should be secured in advance of the first season after site preparation. If a continuing program is anticipated, large collections should be made from a range of seed zones. Dried alder seed (less than 10 percent moisture by weight) remains viable for at least 5 years when stored in a freezer (8°–10°F).

Collecting seed from appropriate seed zones ensures that seedlings are adapted to conditions at a specific site and allows flexibility in planning regeneration. Complete guidelines and protocol for collection, extraction, and storage of alder seed are given in *Red alder: guidelines for seed collection, handling, and storage* (Hibbs and Ager 1989).

Regeneration from Seed

Success of Natural and Artificial Regeneration

Very little work has been done to develop methods and define conditions for effective operational regeneration of alder from seed. Examples of dense natural regeneration of alder are abundant. Alder seed is very light, and dissemination by wind commonly results in some colonization by alder after soil disturbance over a wide range of conditions. As is the case for many tree species, conditions favorable for natural regeneration of alder often produce an overabundance, requiring early precommercial thinning. Typical stand densities in natural alder thickets often exceed 100,000 stems/acre 1 to 2 years after establishment (DeBell 1975).

However, both experimental evidence and extensive field observations suggest that reliable, uniform regeneration from naturally or artificially sown seed is restricted to a relatively narrow range of conditions (described under Cultural Requirements, immediately following). In studies of direct seeding, rates of establishment have been low and variability has been high, depending on site factors. Seedling survival after the first growing season may range from 0 to 3 percent of seed sown (Ruth 1968, Haeussler 1988; B. Maxwell, 1989, unpublished data). Predation of seeds and germinants by rodents, birds, and insects substantially reduces rates of establishment from seed. Establishment rates are 2 to 4 times higher for seed protected from predation (Ruth 1968, Haeussler 1988).

Cultural Requirements

Seedbed and site preparation

Alder requires open conditions for establishment from seed. Site preparation for seed regeneration also should produce an even distribution of bare mineral soil; alder seedlings become established on organic substrates only under very moist conditions (Haeussler 1988). Broadcast burning, piling and burning, or mechanical scarification will produce such sites under most conditions.

Timing of establishment

Since most seed dispersal occurs during the winter, sites should be prepared in the fall to allow first-year establishment from seed. Whether regeneration from seed is artificial or natural, adequate establishment of seedlings in the first year may be critical to acceptable stocking. In the field, average height of a 1-year-old seedling is often 2 to 6 inches (Ruth 1968, Haeussler 1988). On many sites, competing vegetation will greatly inhibit such small seedlings if they are established more than 1 year after site preparation.

Surface soil moisture and temperature

Excessive heating or drying of the soil surface at any time during the growing season greatly limits establishment of alder from broadcast seed. The range of surface moisture and temperature conditions over the growing season on a prospective site must be evaluated.

Higher soil moisture and humidity near the coast may provide favorable soil moisture and temperatures on almost any aspect. On southerly aspects, seedling establishment may be limited to sheltered microsites shaded by debris, stumps, mounds, and so forth. In the interior Coast Range or foothills of the Cascade Mountains, rates of establishment from seed are practically zero on southerly aspects; establishment of alder from seed is usually limited to wet microsites and protected lower slopes on north aspects.

Unit size and distance from seed source

A seed source adjacent to the selected unit is most effective in producing adequate natural seeding. On smaller units (<20 acres) with a seed source on at least two sides, alder regeneration can be dense and relatively well distributed. Units that are larger and more distant from seed sources tend to have lower, less uniform seedling densities.

Little information on distances of effective seed dispersal exists. In one study, 8,000 seedlings/acre became established 33 feet from a seed wall in the first year; density decreased steadily to 0 seedlings 82 feet from the seed wall (B. Maxwell, 1989, unpublished data). In the Pacific Northwest, drying north winds in the late fall and winter may accomplish much of the seed dispersal. Thus, seed sources on the north side of a unit are preferable.

Regeneration from Seedlings

Planting of seedlings allows greater control over site selection, spacing, stocking, and seed source than does regeneration from seed. Since seedlings do not require bare mineral soil, costs and potential adverse impacts of site preparation are reduced. During the critical first year, vigorous planted alder will also have greater resilience to damage or predation, a substantial advantage over competing vegetation. On well-prepared sites, planted alder may be 4 to 7 feet tall at the end of the first growing season.

In order to realize these potential advantages of planting seedlings, appropriate guidelines must be developed for alder stocktypes, nursery culture, storage and handling, site preparation, and outplanting. The following guidelines are a synthesis of research and observations on red alder and the general lessons learned with other species.

Stocktypes

Vigorous plantations have been successfully established (>90 percent survival) from a variety of stocktypes. However, plantation success has depended on the stocktype and outplanting environment specific to a site and year.

Unlike cottonwood (*Populus* spp.) or willow (*Salix* spp.), red alder cannot be established easily from unrooted cuttings (Kenady 1977). Cuttings can be rooted in order to clone desirable genotypes (Monaco *et al.* 1980, Radwan *et al.* 1989), but tests of operational regeneration from rooted cuttings have been minimal.

Alder seedlings of acceptable size and quality (Figure 1) have been grown in 1 year by the following methods:

- *Open-bed bare-root seedling culture.* Seed is sown directly into outdoor nursery beds and grown in the open.
- *Plug + 0.5 open-bed plug-transplant.* Seed sown in small containers is grown to transplantable size in the greenhouse or shelter-house; seedlings are then transplanted to open nursery beds.
- *Bed-house bare-root.* Seed is sown directly into outdoor nursery beds and grown under partial shade and shelter (shade cloth + clear polyethylene plastic).
- *Greenhouse plugs.* Seed sown in any of a variety of container types and sizes is grown in the greenhouse.

Survival and growth of open-bed stock is generally superior to that of bed-house stock or greenhouse plugs. In field tests at six locations in southwestern Washington, 92 percent of open-bed stock, 80 percent of plugs, and 75 percent of bed-house stock survived after 2 years. Average height growth was 7 feet for open-bed stock, 5.8 feet for plugs, and 5.4 feet for bed-house stock (A. Dobkowski, 1989, unpublished data).

Application of the plug-transplant system to alder is a new approach developed by the Olympia Forestry Sciences Laboratory (USDA Forest Service) and the Washington Department of Natural Resources, Webster Nursery (Radwan and Fangen 1990). A report describing the production system and outplanting performance of alder plug-transplants is in preparation (M.A. Radwan *et al.*, in press). The plug-transplant method allows greater control of germination and establishment conditions and of spac-

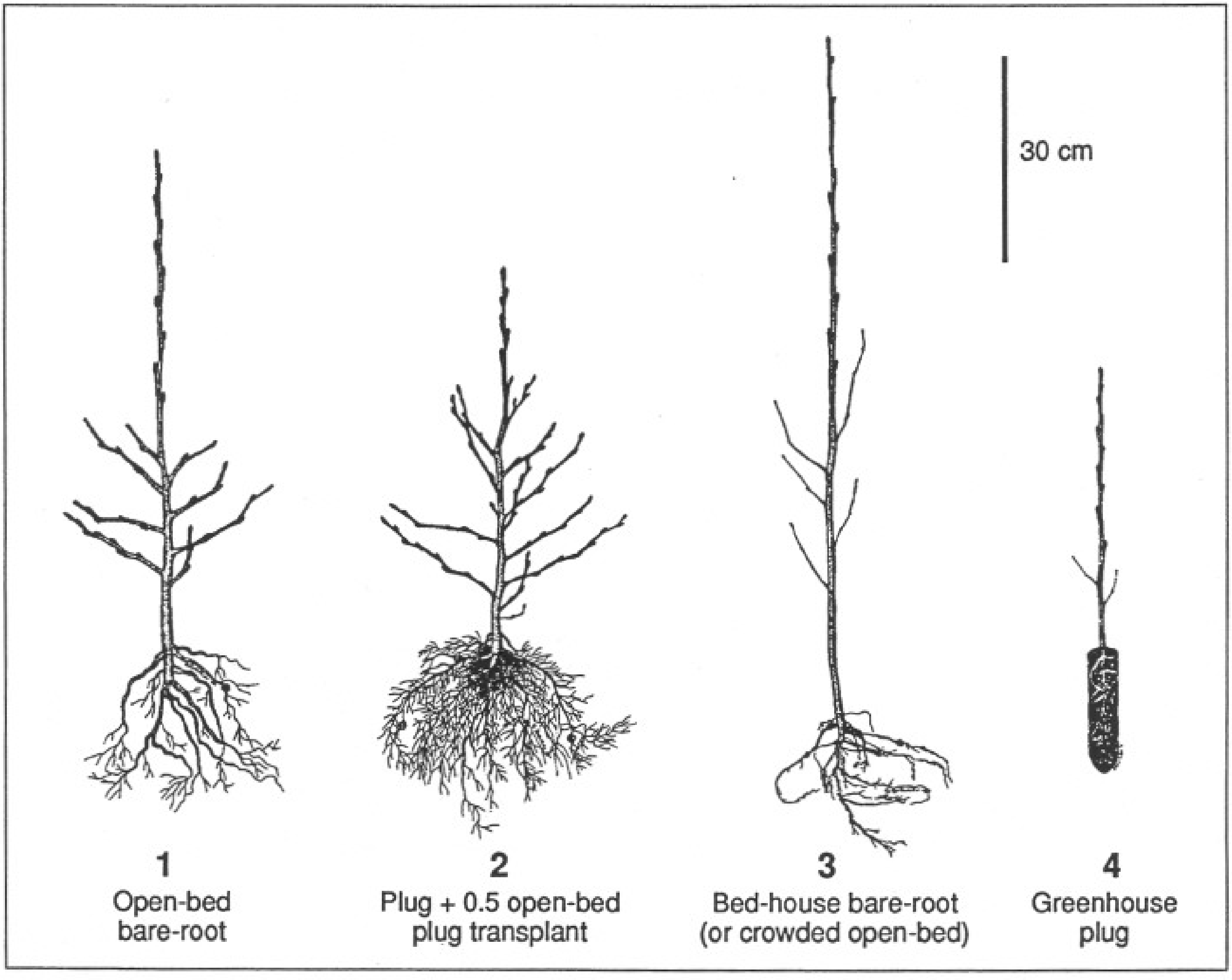

Figure 1. Typical red alder seedling stocktypes (grown in 1 year). Stocktypes 1 and 2 generally have the best range of characteristics (see p. 7).

ing in the nursery bed than does direct sowing into nursery beds (see Nursery Culture, below).

Ultimately, the ranking of different stocktypes on the basis of success rate and cost will depend on site-specific hazards. Small plug and tall bedhouse stock have performed well in some circumstances. Plug stock does well when competing vegetation, extreme heat and cold, and animal damage are negligible. Tall seedlings may do better than shorter stock where there is shrubby competition and the hazard of stem exposure to sun or cold is low. However, when outplanting conditions are variable or unpredictable, planting stocky seedlings grown in open nursery beds minimizes risks.

Nursery Culture

Seed germination and seedling establishment

Good estimates of viability, germination, and establishment rates are needed to allow efficient use of seed and control over spacing with direct seeding in nursery beds. Red alder has shown high variability among seed lots in these characteristics (Kenady 1977, Elliot and Taylor 1981, Berry and Torrey 1985). Many nurseries have reported substantially higher or lower germination rates in the field than in standard germination tests (68°F for 16 hours, 86°F for 8 hours).

More reliable estimates of seedling yield are obtained by monitoring the performance of a given seed lot under specific nursery conditions. This requires repeated use of a large seed lot under consistent conditions. Better estimates of germination and initial establishment rates may also be obtained by sowing directly into sand flats, counting only those seedlings that survive the cotyledon stage (Berry and Torrey 1985). Further development of germination tests that better predict field performance is needed.

Most studies have shown that stratification is not necessary for germination of alder; soaking seeds in water at room temperature for 16 to 24 hours before sowing usually provides an adequate pregermination treatment (Radwan and DeBell 1981, Berry and Torrey 1985). Physiological dormancy has been indicated only in rare instances (Schopmeyer 1974; Elliot and Taylor 1981). However, stratification can increase germination rate under lower temperature regimes representative of field conditions in the spring (Tanaka *et al.* 1991). Thus, four weeks of wet, cold stratification are recommended for consistent performance with field sowing in the spring. Presoaking at room temperature is recommended when warmer germination conditions can be maintained (greenhouse culture or field sowing in summer).

Alder seeds require light after hydration in order to germinate (Kenady 1977, Berry and Torrey 1985). Seeds should be surface-sown and held in place by a light covering of fine gravel (not soil), sawdust, or peat secured by Reemay cloth (Ken-Bar Inc., 24 Gould St., Reading, Massachusetts 01867), burlap, or plastic netting. Warm daytime temperatures are best for rapid germination.

Inoculation with *Frankia*

Inoculation with the nodulating actinomycete *Frankia* can increase consistency in establishment and growth, particularly in fumigated nursery beds or sterilized soil in the greenhouse (Berry and Torrey 1985, Hilger *et al.* 1991). Nodulated seedlings generally perform better after outplanting (Dommergues 1982, McNeill *et al.* 1989). Alder compensates for low soil N with higher N-fixation rates (Koo 1989); in some cases, failure to inoculate may result in very poor performance (Koo 1989, Martin *et al.* 1991).

Applying pure culture of *Frankia* in dilute suspension directly to the germination medium is the most consistently successful method for inoculation (Perinet *et al.* 1985). Inoculum is most effective when it is mixed with peat or another carrier before being incorporated in nursery beds or containerized media (Martin *et al.* 1991). Preparing a slurry from fresh alder root nodules in a blender and applying dilute extracts from this slurry to nursery beds or containerized media before sowing is also effective.

Seedling density

Alder seedlings grow very rapidly under nursery conditions; seedling densities must be relatively low to prevent overcrowding. Open-bed seedlings grown at densities of 5-15 seedlings/ft^2 are more acclimated to cold, heat, and sun than are more crowded or partially sheltered seedlings. Partial shade or excessive crowding produces tall, spindly seedlings that have only small buds low on the stem. Taller seedlings are also more prone to damage in handling and storage. Alder grown in styroblock containers are often small, spindly, or both as the result of crowded conditions, and they are generally more susceptible to damage.

Other nursery practices

Adequate irrigation is very important for establishment and growth of alder in the nursery or greenhouse. In general, alder requires more frequent watering to reduce heat stress and maintain soil moisture during early establishment and growth than do conifers.

Nitrogen fertilization regimes should be low for alder in order to promote development of N-fixing nodules (Koo 1989, Martin *et al.* 1991). Because alder is sensitive to P deficiency, maintaining adequate P is essential for establishment, growth, and nodulation (Hughes *et al.* 1968, Radwan 1987, Koo 1989).

Alder grows very rapidly under favorable conditions, and excessively large seedlings are common. Seedling size can be controlled by sowing late, in order to shorten the growing season, and by reducing irrigation. Top pruning is not recommended, because it promotes multiple tops and increases susceptibility to disease. Root pruning (undercutting) may effectively limit the size of both shoot and root and produce a more compact and fibrous root system.

Aggressive disease control is recommended for all culture methods. *Septoria alnifolia*, which causes stem cankers, and *Botrytis* spp., which cause top-kill, can significantly decrease nursery yields. Both of these fungi can be controlled with periodic application of fungicides throughout the growing season.

Seedling Characteristics and Grading Standards

Regardless of the cultural method, alder seedlings having the best survival, growth, and damage resistance over a range of conditions are characterized by the following traits (A. Dobkowski and Y. Tanaka, 1989, personal communication):

- Height should be 12 to 36 inches and basal diameter at least 0.16 inches. Stocky, rather than tall thin, seedlings are preferable. (Diameter is more important than height.)
- Buds and branches should be located along the entire stem.
- Fibrous root systems should be full and undamaged. Damage to larger roots (>0.08 inches) is particularly undesirable.

Examples of these traits in typical seedling types are shown in Figure 1 (p. 5).

Nursery grading practices are very important for ensuring good outplanting performance and reducing culling of seedlings in the field. All marginal seedlings should be culled at the nursery. Resistance of low-grade seedlings to damaging agents after outplanting is much lower than that of high-grade seedlings.

Criteria for identifying marginal or low-grade seedlings depend on conditions in the nursery beds. If crowding has suppressed seedlings, *relative* size should be considered in addition to the *minimum* size standard. For example, in a crowded bed of larger seedlings, a 50-cm by 5-mm seedling may be suppressed and low in vigor. Root systems and general seedling health should also be assessed during grading at the nursery. Any seedlings showing symptoms of nursery diseases such as *Septoria* or *Botrytis* should be culled.

Handling and Outplanting Seedlings

Nursery stock should be lifted in January and stored at either 28.4°F or 35.6°F until planting. Storage below freezing is recommended, since seedlings stored above freezing break dormancy more readily. Seedlings should be stored in sealed bags to prevent desiccation and physical damage to exposed parts.

Outplanting from March 15 to April 15 is recommended. This "window" provides the optimal balance between frost and drought hazards; the best time for any specific site depends on local conditions. Seedlings planted from December through February can sustain severe winter top-kill. February plantings also can break bud when the risk of killing frost is still very high (Figure 2); this risk is minimized by planting in late March. Seedlings must also have ample time to achieve adequate root growth while soil moisture is favorable before summer drought. By early summer, seedlings planted in mid-March can have nearly four times as many new roots as those planted in mid-May (A. Dobkowski, 1990, unpublished data).

Alder stems are brittle and sensitive, requiring careful handling during transport and outplanting.

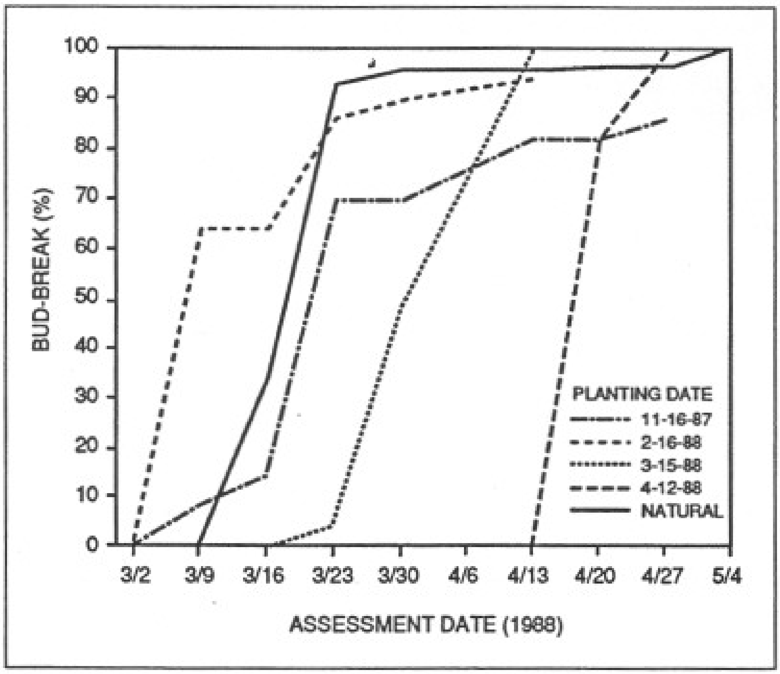

Figure 2. Seasonal progress of bud-break for red alder seedlings planted at different dates on a site at 800-foot elevation. One hundred seedlings were sampled for each planting date and for the natural seedlings. Planting stock was 1-year-old Styro-8 cc. plug seedlings; natural seedlings were 1 to 2 years old. Stock for November planting was taken directly from greenhouse; other stock was lifted in mid-January and stored in the freezer until outplanting. Data from a Weyerhaeuser Co. planting date study by A. Dobkowski and Y. Tanaka (1989).

The following recommendations for outplanting are based on numerous outplanting trials with a variety of stocktypes.

- Planting holes should be opened with a shovel in order to ensure holes large enough for the entire root system.
- Seedlings should be planted deeply, with the root collar buried at least 1 inch. Deep planting prevents exposure of shallow roots and promotes greater root development.
- Planting spots should not be scalped more than necessary to open the hole; large scalps increase hazards of sun and cold exposure.
- Seedlings should be planted in shelter of moderate debris when possible.
- Roots should be in mineral soil.
- Soil should be packed carefully around roots, and the planter's boot should not touch the stem. Alder stems are very sensitive to bruising.

Maintaining desired spacing can be difficult; the bare stems of newly planted alder are difficult to see on all but the most barren sites. Crews experienced in planting alder should have less trouble with this. Scalping makes planted spots more visible but can increase the incidence of sun-scald and heat-girdling. Planting stock taller than 18 inches are easier to see than small stock.

Site Preparation and Vegetation Management

Site preparation offers the best opportunity to control competing vegetation on alder plantations; after planting, chemical methods are restricted and manual control is very costly. Evaluation of potential problems from competing vegetation during regeneration should begin before the previous stand is harvested. Open stands with dense shrubby understories present high levels of competing vegetation after harvest. Dense overstories with sparse ground vegetation diminish competing vegetation. Final evaluation of site-preparation needs should be done early in the spring prior to planting.

When competing vegetation is less than 90 percent cover with no overtopping during the first year, rapid growth of healthy alder seedlings will generally ensure a high proportion of free-to-grow seedlings with little or no site preparation. Seedling growth may be affected when the cover of competing vegetation during the first year exceeds 90 percent with overtopping. Survival may be reduced by vegetative cover of 125 to 150 percent with overtopping during the first year and 150 to 200 percent in the second year. At these levels of competition, site preparation is required in order to achieve adequate plantation stocking and performance.

Broadcast burning often provides adequate site preparation, particularly where levels of slash, shrub cover, or both, are high. Moderate amounts of slash, debris, and vegetation shelter first-year seedlings and may improve establishment. However, excessive slash may reduce planting quality, compromise the uniformity and quantity of stocking, and increase the incidence of rodent damage.

On some burned or scarified sites, competition from herbaceous weeds can greatly reduce alder survival and growth in the first and second years. In these situations, herbicide treatments before planting can make the difference between success and failure. The results from one red alder test plantation with heavy herbaceous weed competition provide a good example (Table 1).

Weed control can also benefit established alder plantations, particularly at wider spacings. Closely spaced plantations (<9 feet) or dense natural regeneration effectively dominate a site within 2 to 3 years. Alder seedlings at wider spacings (>10 feet) appear to be more vulnerable to prolonged effects of vegetative competition. At these wider spacings, maintenance of relatively weed-free conditions during and after plantation establishment can double to quadruple alder growth in comparison to unweeded conditions (M. Newton *et al.*, 1990, unpublished report). Figueroa (1988) has summarized effective chemical treatments for preparing sites to be planted with red alder.

Table 1. Alder seedling performance on a site with high potential for herbaceous weed invasion (near Castle Rock, Washington). The site was prepared by broadcast-burning with and without herbicide treatment (P. Figueroa and A. Dobkowski, 1990, unpublished data).

Treatment	Vegetative cover (%)[1]		Survival (%)	Height (m)
	(Year 1)	(Year 2)	----(Year 2)----	
Burn only	124	204	42	1.2
Burn + herbicide[2]	16	126	92	2.2

[1] Values given for cover in this report are the sum of percent cover for shrubs, grasses, forbs, and ferns present and may exceed 100 percent for a site.
[2] 2,4-D + atrazine.

Synopsis: Steps to Successful Regeneration

Site selection: Select sites based on evaluation of estimated site productivity, potential hazards, and specific management objectives. Estimate alder site index for prospective sites from existing trees or by using criteria in Harrington's (1986) site evaluation guide. Assess the potential for major hazards resulting from high elevation, poor soil drainage, deficient soil P, inadequate moisture, excessive heating, periodic frost, or high winds.

Site preparation: Site preparation is the best opportunity to control competing vegetation. Inadequate site preparation can substantially reduce survival and growth of alder. Heavy shrub cover or slash may be reduced with broadcast burning. Assess the potential for dense herbaceous vegetation in early spring, before planting. Chemical treatments before planting are recommended if herbaceous vegetation threatens to exceed 100 percent cover with overtopping in the first year.

Choosing between seeds and seedlings: Regeneration from naturally or manually sown seed can be adequate under the most favorable conditions on small areas. Artificial regeneration is recommended for consistent control over uniformity and spacing of seedling establishment.

Seed collection and seed source: Secure an adequate supply of seed from a suitable source (see Hibbs and Ager 1989). Large seed collections and long-term storage will facilitate seedling production for large-scale programs.

Seedling production: Arrange for a supply of good quality seedlings, preferably grown in open nursery beds. Target seedling characteristics are 12- to 36-inch height, 4-mm minimum basal diameter, healthy buds along the entire stem, and healthy, undamaged fibrous root systems.

Planting: Plant high-quality seedlings between March 15 and April 15. Seedling characteristics should be suitable for the specific outplanting environment. Open planting holes with a shovel and bury the root collar at least 1 inch. Take special care not to bruise or break alder stems, which are sensitive and brittle.

References

BERRY, A.M., and J.G. TORREY. 1985. Seed germination, seedling inoculation, and establishment of *Alnus* spp. in containers in greenhouse trials. Plant and Soil 87(1):161-173.

CHRISTENSEN, N., and J. HART. 1991. Personal communication. Department of Soil Science, Oregon State University, Corvallis.

DeBELL, D.S. 1975. Short-rotation culture of hardwoods in the Pacific Northwest. Iowa State Journal of Research 49 (3, Pt. 2): 345-352.

DeBELL, D.S., R.F. STRAND, and D.L. REUKEMA. 1977. Short rotation production of red alder: some options for future forest management. P. 231-244 *in* D. G. Briggs, D. S. DeBell, and W. A. Atkinson, compils. Utilization and management of alder. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-70.

DOBKOWSKI, A. 1989, 1990. Unpublished data. Weyerhaeuser Company, Longview, Washington.

DOBKOWSKI, A. and Y. TANAKA. 1989. Personal communications. Weyerhaeuser Company, Longview, Washington, and Centralia, Washington.

DOMMERGUES, Y. 1982. Ensuring effective symbiosis in nitrogen-fixing trees. P. 395-411 *in* P. Graham and S. Harris, eds. Proceedings of the International Workshop on Biological Nitrogen Fixation Technology for Tropical Agriculture. CIAT Press, Cali, Columbia.

ELLIOT, D.M., and I.E.P. TAYLOR. 1981. Germination of red alder (*Alnus rubra* Bong.) seed collected from several locations in its natural range. Canadian Journal of Forest Research 11:517-521.

FIGUEROA, P.F. 1988. First-year results of a herbicide screening trial in a newly established red alder plantation with 1+ 0 bare-root and plug seedling stock. Proceedings, Western Society of Weed Science 41:108-124.

FIGUEROA, P.F., and A. DOBKOWSKI. 1990. Unpublished data. Weyerhaeuser Company, Centralia, Washington and Longview, Washington.

HAEUSSLER, S. 1988. Germination and first-year survival of red alder seedlings in the central coast range of Oregon. M.S. Thesis. Oregon State University, Corvallis. 105 p.

HARRINGTON, C.A. 1984. Factors influencing initial sprouting of red alder. Canadian Journal of Forest Research 14:357-361.

HARRINGTON, C.A. 1986. A method of site quality evaluation for red alder. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. General Technical Report PNW-192. 22 p.

HARRINGTON, C.A., and R.O. CURTIS. 1985. Height growth and site index curves for red alder. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-358. 12 p.

HARRINGTON, C.A. and D.S. DeBELL. 1984. Effects of irrigation, pulp mill sludge and repeated cutting on growth and yield of black cottonwood and red alder. Canadian Journal of Forest Research 14:844-849.

HIBBS, D.E., and A.A. AGER. 1989. Red alder: guidelines for seed collection, storage, and handling. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 18. 6 p.

HILGER, A.B., Y. TANAKA, and D.D. MYROLD. 1991. Inoculation of fumigated nursery soil increases nodulation and yield of bare-root red alder (*Alnus rubra* Bong.). New Forests 5:35-42.

HUGHES, D.R, S.P. GESSEL, and R.B. WALKER. 1968. Red alder deficiency symptoms and fertilizer trials. P. 225-237 *in* J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen, eds. Biology of Alder. Proceedings of a Symposium. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

KENADY, R.M. 1977. Regeneration of red alder. P. 183-192 *in* D. G. Briggs, D. S. DeBell, and W. A. Atkinson, compils. Utilization and Management of Alder. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. General Technical Report PNW-70.

KOO, C.D. 1989. Water stress, fertilization, and light effects on the growth of nodulated mycorrhizal red alder seedlings. Ph.D. thesis. Oregon State University, Corvallis. 113 p.

MARTIN, K.J., Y. TANAKA, and D.D. MYROLD. 1991. Peat carrier increases inoculation success with *Frankia* on red alder (*Alnus rubra* Bong.) in fumigated nursery beds. New Forests 5:43-50.

MAXWELL, B. 1989. Unpublished data. Forestry Sciences Laboratory, Corvallis, Oregon.

McNEILL, J.D., M.K. HOLLINGSWORTH, W.L. MASON, A.J. MOFFAT, L.J. SHEPPARD, and C.T. WHEELER. 1989. Inoculation of *Alnus rubra* seedlings to improve seedling growth and forest performance. Forestry Commission Research Division, United Kingdom. Research Information Note 144. 3 p.

MONACO, P.A., T.M. CHING, and K.K. CHING. 1980. Rooting of *Alnus rubra* cuttings. Tree Planters' Notes. 31:22-24.

NEWTON, M., E.C. COLE, and S.R. RADOSEVICH. 1990. Competitive interaction among western hemlock, red alder and riparian salmonberry. Unpublished progress report. Department of Forest Science, Oregon State University, Corvallis.

OLSEN, S.R. and L.E. SOMMERS. 1982. Phosphorus. P. 403-430 *in* A.L. Page, R.H. Miller, and D.R. Keeney, eds. Methods of Soil Analysis, part 2. Agronomy. Monogr. 9, American Society of Agronomy, Madison, Wisconsin.

PERINET, P., J.G. BROUILLETTE, J.A. FORTIN, and M. LALONDE. 1985. Large scale inoculation of actinorhizal plants with *Frankia*. Plant and Soil 87(1):175-183.

RADWAN, M.A. 1987. Effects of fertilization on growth and foliar nutrients of red alder seedlings. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-375. 14 p.

RADWAN, M.A., AND D. S. DEBELL. 1981. Germination of red alder seed. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Note PNW-370. 4 p.

RADWAN, M.A., and W.V. FANGEN. 1990. Production of quality red alder planting stock. Abstracts, 63rd Annual Meeting of Northwest Science Association. Northwest Science 64:91.

RADWAN, M.A., T.A. MAX, and D.W. JOHNSON. 1989. Softwood cuttings for propagation of red alder. New Forests 3:21-30.

RADWAN, M.A., Y. TANAKA, A. DOBKOWSKI, AND W. FANGEN. Production and assessments of red alder planting stock. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW. In press.

RUTH, R.H. 1968. First season's growth of red alder seedlings under gradients in solar radiation. P. 99-106 *in* J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen, eds. Biology of Alder, Proceedings of a Symposium. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

SCHOPMEYER, C.S., technical coordinator. 1974. *Alnus* B. Ehrh. P. 206-211 *in* Seeds of Woody Plants in the United States. USDA Forest Service, Agriculture Handbook 450. Washington, D.C.

TANAKA, Y., P.J. BROTHERTON, A. DOBKOWSKI, and P.C. CAMERON. 1991. Germination of stratified and non-stratified seeds of red alder at two germination temperatures. New Forests 5:67-75.

WORTHINGTON, N.P., F.A. JOHNSON, G.R. STAEBLER, and W.J. LLOYD. 1960. Normal yield tables for red alder. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper 36. 3 p.

WORTHINGTON, N.P., R.H. RUTH, and E.E. MATSON. 1962. Red alder: its management and utilization. USDA Forest Service, Washington, D.C. Miscellaneous Publication 881. 44 p.

ZAVITKOVSKI, J., and M. NEWTON. 1968. Effect of organic matter and combined nitrogen on nodulation and nitrogen fixation in red alder. P. 209-224 *in* J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen, eds. Biology of Alder, Proceedings of a Symposium. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Ahrens, G.R., A. Dobkowski, and D.E. Hibbs. 1992. RED ALDER: GUIDELINES FOR SUCCESSFUL REGENERATION. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 24. 11 p.

Intentional efforts to regenerate red alder (*Alnus rubra* Bong.) in the Pacific Northwest have been successful in many cases. Natural or artificial regeneration from seed may be adequate under the most favorable site conditions. However, planting is recommended for better control over spacing and uniformity of establishment. Consistent success over the range of conditions in the Pacific Northwest requires careful site selection, adequate site preparation, and good quality seedlings.

Ahrens, G.R., A. Dobkowski, and D.E. Hibbs. 1992. RED ALDER: GUIDELINES FOR SUCCESSFUL REGENERATION. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 24. 11 p.

Intentional efforts to regenerate red alder (*Alnus rubra* Bong.) in the Pacific Northwest have been successful in many cases. Natural or artificial regeneration from seed may be adequate under the most favorable site conditions. However, planting is recommended for better control over spacing and uniformity of establishment. Consistent success over the range of conditions in the Pacific Northwest requires careful site selection, adequate site preparation, and good quality seedlings.