Survival and Growth of Planted Alaska-cedar Seedlings in Southeast Alaska

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Seedlings of Alaska-cedar (Chamaecyparis nootkatensis *(D. Don.) Spach) were planted on Etolin Island in southeast Alaska and measured annually for 5 years to evaluate their survival and growth on different types of sites and microsites. Seedling survival and growth were best where light exposure and soil drainage were adequate but were poor in heavy shade or soils with impeded drainage. Burned and unburned clear-cut sites supported the best survival, height growth, and diameter growth among site types. Shoot blight, caused by the fungus* Apostrasseria *sp., was common on sites where natural vegetative reproduction of Alaska-cedar was present nearby. Grazing by deer was common on some site types, but deer only consumed new growth and few seedlings were killed. Results illustrate that Alaska-cedar seedlings planted on productive sites may have good survival and early growth.*
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Alaska-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) has outstanding wood characteristics (Harris 1990) and is consistently the most valuable wood grown in Alaska. Its natural distribution spans from Prince William Sound in Alaska to Northern California (figure 1). The species is known locally as yellow-cedar or yellow-cypress in British Columbia and Alaska because of the bright yellow color of its heartwood. Some wood is used domestically in these regions but most of the harvested volume is exported to Japan, where it is used as a substitute for the native hinoki-cedar (*C. obtusa* (Siebold and Zaccurini) Endlicher), which is in short supply there. In Alaska, the wood and bark of Alaska-cedar was an integral part of traditional Alaska Native culture (Hennon 1992a).

A large-scale forest decline has caused concentrated mortality on at least 200,000 hectares (500,000 acres) (USDA Forest Service 1992) in southeast Alaska since about 1880 (Hennon et al. 1990b). Alaska-cedar is the principal victim in this decline, which is concentrated on sites with poor and moderately poor drainage (Hennon et al. 1990a). The primary cause of this decline is not known, but all recent research indicates that it is naturally occurring and not caused by any contagious biological agent (Hennon 1990, Hennon et al. 1990c). In fact, the decline has apparently not spread to any new sites since its onset more than 100 years ago (Hennon et al. 1990a, b). Thus, the mortality factor, even though still unknown, will not threaten plantations of this valuable species on sites where decline does not now occur.

Despite the great value of Alaska-cedar, little is known about its regeneration requirements in Alaska. The species reproduces naturally on wet sites by vegetative layering (Hennon et al. 1992) but generally does not reproduce prolifically by seed. Forests with a large Alaska-cedar component that are clear-cut in southeast Alaska frequently regenerate naturally to western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce *(Picea sitchensis* (Bong.) Carr.) with regeneration of Alaska-cedar often being minimal or absent (Hennon 1992a).

Thus, losses of Alaska-cedar population due to forest decline and timber harvesting do not appear to be offset by natural regeneration in many areas. For reasons including biodiversity and commercial value, the planting of Alaska-cedar or some silvicultural method for attaining natural regeneration will be needed to replace these losses. Information on regeneration of Alaska-cedar is needed as harvesting becomes more common on sites with moderately poor drainage; frequently these are sites where Alaska-cedar is abundant. The objectives of this study are to perform a preliminary evaluation of general site requirements for planted seedlings of Alaska-cedar and to determine biotic factors that may limit their survival and growth in southeast Alaska. This is the first known planting study of Alaska-cedar seedlings in Alaska.

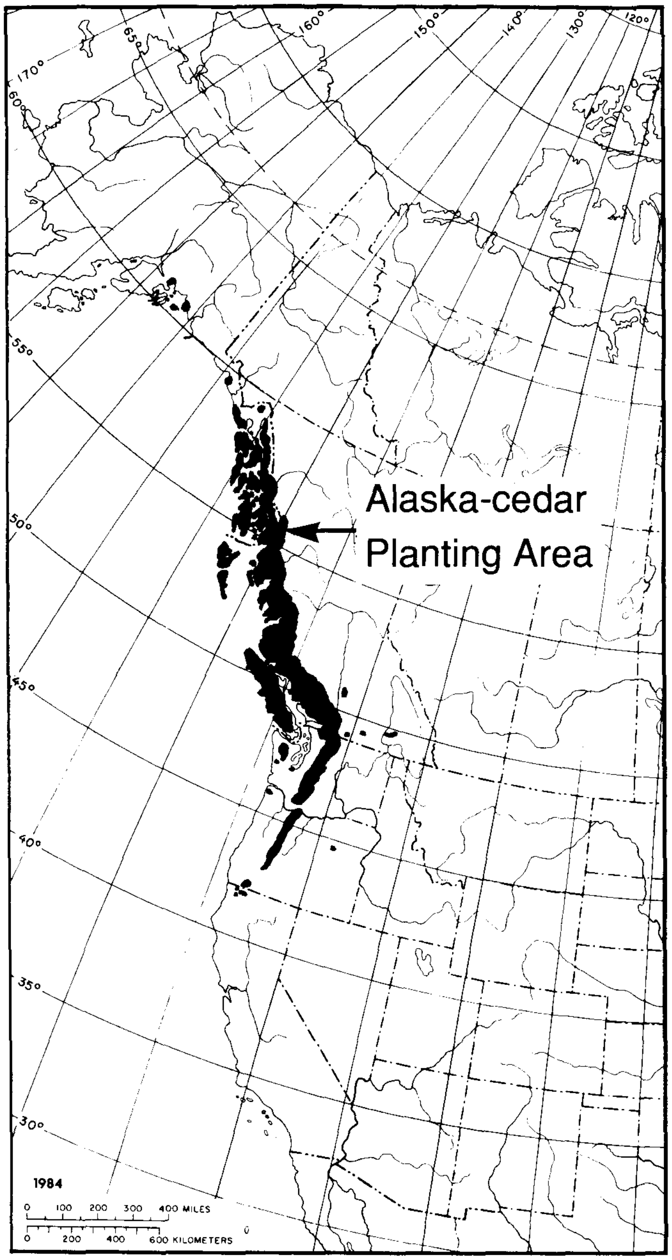

Figure 1—*Natural range of Alaska-cedar (modified from Harris (1990)); the planting site at Anita Bay, Etolin Island, Alaska is noted.*

Materials and Methods

Study location and seedlings. Seedlings were planted at 16 locations near Anita Bay at about latitude 56° N on Etolin Island in southeast Alaska (figure 1). All locations were below 150 m (500 feet) elevation and on slopes less than 20%. Seedlings were planted using hoedad tools during several days of warm, dry weather in June 1986. A numbered aluminum tag attached to a stake flag was placed in the ground adjacent to each seedling for relocation.

All Alaska-cedar seedlings used in this study were grown at the USDA Forest Service nursery in Petersburg, Alaska. Seeds for the seedlings were various, mixed collections from trees on Mitkof and adjacent islands, all within about 80 km (50 miles) of the eventual planting location. Seedlings were grown in Styrofoam cell containers in the greenhouse for 2 years before planting. Seedlings averaged 40.8 ± 0.19 cm and 4.0 ± 0.03 mm (means ± standard errors) in height and diameter, respectively, at the time of planting.

Study design. A total of 800 seedlings of Alaska-cedar were planted, 50 seedlings at each of 16 sites. At each site, seedlings were planted in 5 rows of 10 seedlings. Spacing was 4 m (13 feet) within and between rows. Seedlings were not fertilized or protected from deer. Each planting site represented one of the following conditions:

1. Open bog
2. Low-volume (scrub) stand of Alaska-cedar
3. A stand similar to the low-volume stand (#2) that had recently been clear-cut
4. High-volume, productive stand that was uncut (heavily shaded under canopy)
5. High-volume productive stand that was cut and not burned
6. High-volume productive stand that was cut and burned

Table 1—*General conditions of soil moisture drainage and exposure to light at each type of planting site*

Site type	No. sites	No. seedlings	Exposure to light	Soil moisture drainage
1. Bog	2	100	Exposed	Wet
2. Scrub, uncut	4	200	Moderately shaded	Moderately wet
3. Scrub, cut	2	100	Exposed	Moderately wet
4. Productive–uncut (dark)	2	100	Shaded	Drained
5. Productive–cut–unburned	2	200	Exposed	Drained
6. Productive–cut–burned	4	100	Exposed	Drained
Totals	16	800		

Each site had some combination of poor, moderate, or good soil drainage and poor, moderate, or good exposure to light. For example, bogs generally had poor drainage and good light exposure. Light exposure and soil drainage were noted for the specific planting location as each seedling was planted. The physical appearance of the planting substrate for each seedling was examined during planting and classified as abundant rotten wood, disturbed soil (mineral soil exposed), adjacent to a stump, or undisturbed duff. A similar classification was used previously (Sidle and Shaw 1983) in describing planting microsites of clear-cuts in southeast Alaska (table 1).

Measurements. The height and basal diameter were measured for each seedling at planting in 1986 and then measured before the initiation of shoot growth each spring through 1991. Seedling height (to the top of the straightened leader) and basal diameter (at the groundline) were measured to the nearest centimeter and millimeter, respectively. Shoot blight caused by the fungus *Apostrasseria* sp. (Hennon 1992b) and browsing by deer were also noted annually for each seedling. The color of each seedling was classified each year as green (> 91% green), green-brown (51 to 90% green), brown-green (1 to 50% green), or brown (0% green). Seedlings were judged to be surviving in 1991 if they were green or green-brown.

Because of the exploratory nature of this study and the unbalanced design, statistical analyses are not reported. Rather, data on seedling survival, height growth, diameter growth, and the incidence of grazing and shoot blight are grouped by site type and means are presented graphically.

Results

Planting sites. Exposure to light varied for seedlings planted in the scrub-uncut type, where the canopy was somewhat open and the density of brush was variable; however, exposure was more uniform at all other site types. Excessively wet soils were noted when free water was observed during planting; bog vegetation or skunk cabbage were typical of these wet microsites. Soil drainage appeared relatively consistent at a few sites (for example, poor drainage for all seedlings planted in bogs) but was variable at most other sites. Even the three productive site types had some poorly drained soils (average 6% of planting microsites).

In the clear-cut site types, the undisturbed duff was the most common soil type (61% of planting microsites), followed by almost equal frequencies of close proximity to stumps, rotten wood, and disturbed duff. Almost all planting microsites were recorded as undisturbed duff at other site types. Although vegetation and some fine woody slash were destroyed in the burned units, burning was light and duff layers generally remained intact.

Seedling survival. One year after planting, seedling survival in all site types approached 100%, except for the 81% survival in bogs (figure 2). By

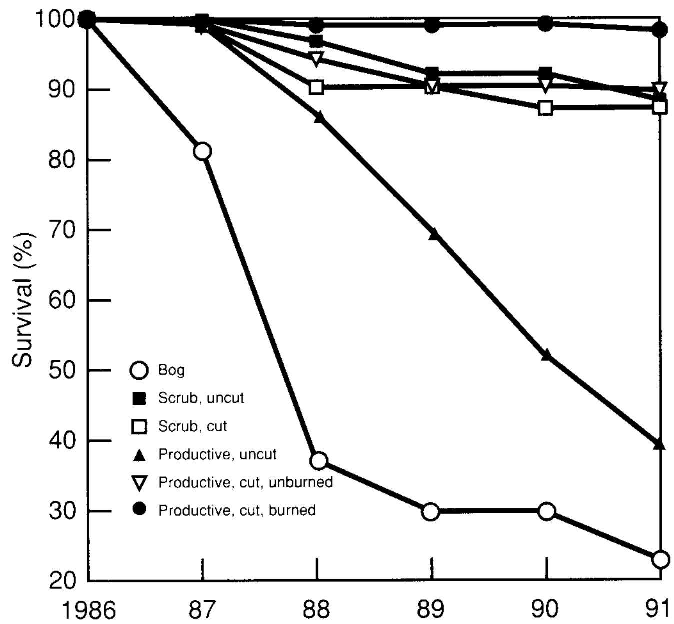

Figure 2—*Survival of Alaska-cedar seedlings in six site types from the time of planting in 1986 to 1991. See table 1 for a description of each site type.*

1991, however, seedling survival was markedly affected by site type. Seedlings in bogs continued to die in successive years after planting, leaving only 23% of the seedlings alive in 1991. Most of these surviving seedlings in bogs occurred on slightly raised areas (hummocks), but even these seedlings were off-color.

Seedlings in the productive-uncut (heavy canopy) type appeared healthy 1 year after planting (98% were green) but many seedlings appeared brown and began to die within 2 years. Only 39% were alive in 1991 and many of these had dead shoots and dead terminal leaders.

Survival after 5 years in the field was greater than 88% in all other site types. Many seedlings that died on these sites were planted in wet, poorly drained microsites. The productive-cut-burned site type had the best rate of survival (97%).

Growth. Both height and diameter growth of seedlings were influenced by site type (figures 3

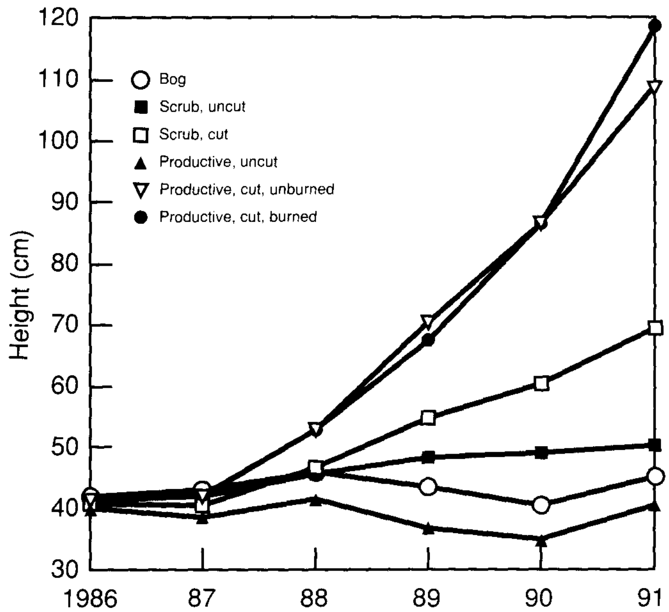

Figure 3—*Mean height growth of Alaska-cedar seedlings planted in six different site types.*

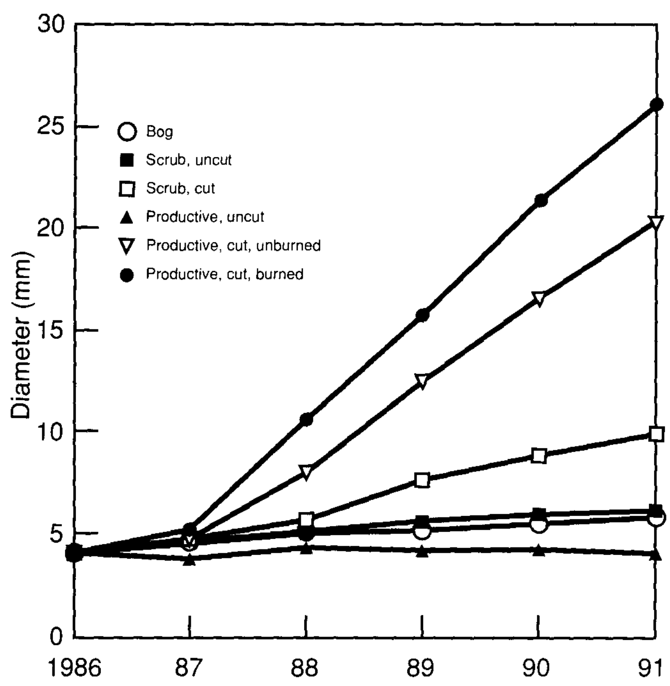

Figure 4—*Mean basal diameter growth of Alaska-cedar seedlings planted in six different site types.*

and 4). Height and diameter results presented here include only those seedlings that were alive at each annual measurement. Heights of seedlings 1 year after planting (in 1987) exhibited little growth and were similar among different site types (figure 3). By 2 years after planting (1988), however, seedlings in the burned and unburned productive clear-cut sites began rapid growth. This trend continued through 1991 with annual height growth and final heights being greatest for seedlings in the two productive-cut site types, followed by the scrub-cut type. Thus, seedling height growth was greatest in the three site types that had been harvested and had maximum light exposure. Heights of seedlings in other site types acquired only modest gains (scrub-uncut type) or some actually lost height (for example, bog and productive-uncut (dark) types). Seedlings in the latter two types frequently had dead tops, which accounted for their reduced heights.

Diameter growth of live seedlings followed the same trend as height growth (figure 4). Seedling diameters increased slightly in all site types (except the dark sites) the first year. From the second year (1988) through the fifth year (1991), seedling diameter increased rapidly in the three clear-cut site types (burned, unburned, and scrub), although seedlings in the scrub-cut type did not keep pace with those in the other two types. Seedlings in the bog, scrub-uncut, and productive-uncut site types produced little diameter growth after the second year. The largest Alaska-cedar, 5 years after planting, was 229 cm (7.5 feet) tall with a 59-mm (2.3-inches) basal diameter. This seedling/ sapling was growing an average of 37 cm in height and 11 mm in diameter per year.

The productive-cut-unburned site type was represented by four locations, two of which were planted less than a year after harvest and two planted 2 to 3 years after harvest. Thus, the final mean height and diameter of seedlings can be distinguished as those "planted early" and "planted late" and compared to growth in burned-cut and scrub-cut sites. Seedlings planted late had smaller heights and diameters than those planted early but were larger than seedlings planted in the scrub-cut type (figure 5). For seedlings planted quickly after clear-cutting on productive sites, growth did not appear to differ on burned and unburned sites.

Soil type did not have a noticeable effect on height or diameter growth of seedlings, except that both heights and diameters tended to be smallest among seedlings planted in the rotten wood type. Frost heaving of seedlings was not a problem in disturbed soils nor did it occur in any soil type in this study.

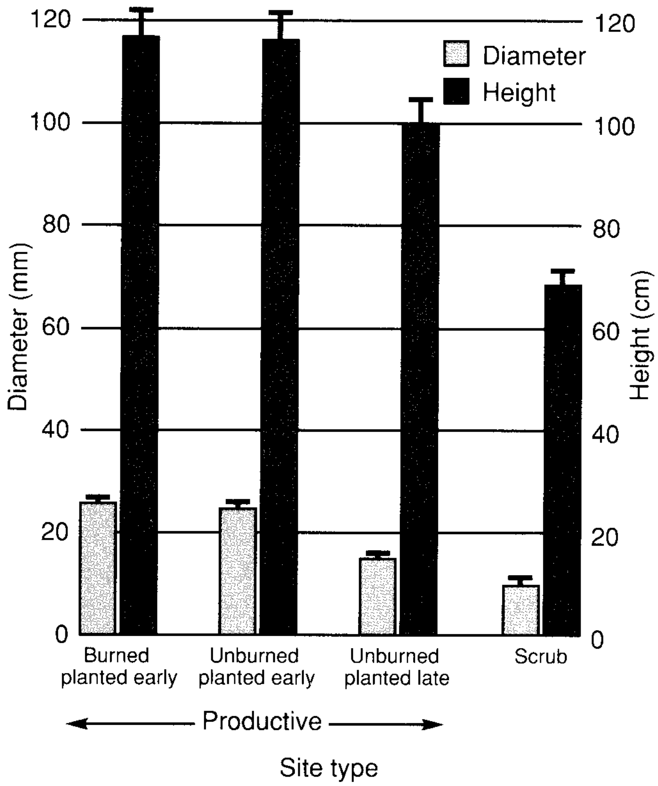

Figure 5—*Height and diameter of Alaska-cedar seedlings 5 years after planting on four harvested site types: 1. productive, burned, planted early; 2. productive, unburned, planted early; 3. productive, unburned, planted late; and 4. scrub, planted early. Values are means ± one standard error.*

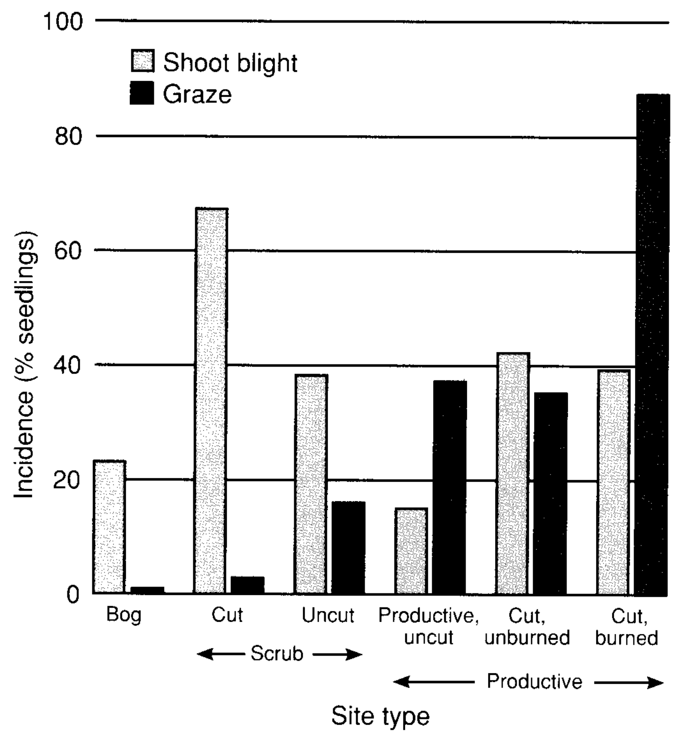

Figure 6—*Percentage of live Alaska-cedar seedlings grazed by deer or infected with shoot blight fungus (*Apostrasseria *sp.) on six different site types.*

Grazing. The incidence of grazing by deer was affected by site type; it was uncommon on seedlings in bog, scrub-uncut, and scrub-cut site types (figure 6). Grazing was more frequent on the three productive site types and reached the highest level (87%) on the cut-burned sites. Repeatedly grazed seedlings in clear-cuts frequently had bushy crowns and noticeably large diameters; however, grazing generally did not produce differences in seedling height or diameter. Ungrazed seedlings tended to be taller in the productive burned and productive uncut site types than grazed seedlings in the same site types. Grazed seedlings in productive-cut-unburned and scrub-cut site types tended to have larger diameters than ungrazed seedlings in the same site types, particularly in the former plots where average seedling diameter was 17 and 26 mm for ungrazed and grazed seedlings in 1991, respectively.

Shoot blight. Seedlings infected with *Apostrasseria* sp. had one or more dead or dying (yellow) shoots. Terminal leaders were attacked on some seedlings every year. Shoots typically died back less than 15 cm from branch tips, but three large seedlings were apparently killed by the fungus. Black fruiting bodies (acervuli) of *Apostrasseria* sp. were usually evident after tissues had been killed. Fruiting bodies of other fungi, such as *Herpotrichia juniperi* (Duby) Petr., were also frequently observed on these symptomatic tissues.

The incidence of shoot blight was associated with site type (figure 6) with the greatest incidence (67% of seedlings by 1991) occurring on seedlings in the scrub-cut site type. The productive-uncut type had the lowest incidence of shoot blight (15% of seedlings). Microsite features, such as drainage and light exposure, had no apparent effect on the incidence of shoot blight. Shoot blight had no measurable effect on height or diameter growth of seedlings.

One year after planting, numerous seedlings in exposed locations had noticeable symptoms somewhat similar to those caused by *Apostrasseria* sp. However, these seedlings lacked the fruiting bodies of the fungus *Apostrasseria* sp. Some 23% of seedlings had a scorched appearance with scattered brownish scales and dead shoot tips in 1987.

Ninety-eight percent of these seedlings occurred in exposed locations. Most scorched seedlings, particularly those on favorable sites and microsites, appeared green after another year.

Discussion

This study illustrates that planted seedlings of Alaska-cedar can successfully be established in southeast Alaska. Results also demonstrate the overwhelming effect that site factors have on survival and growth of seedlings. On sites with good light exposure and soil drainage, planted seedlings of Alaska-cedar are capable of excellent survival and growth. Survival and growth are particularly good on productive clear-cut sites where light and soil factors may be optimal and competition from other vegetation is reduced by early planting or burning.

Seedling survival and growth were diminished by heavy shade and poor soil drainage. Although Alaska-cedar has sometimes been considered to be shade tolerant, this feature of its reproduction has never been studied adequately. Results from this preliminary study suggest that planted seedlings cannot tolerate heavy shade. In a separate study, the fate of several hundred young (1- to 2-year-old), naturally regenerated seedlings of Alaska-cedar at three sites near Peril Strait, Alaska, was followed for several years (Hennon unpublished data). These small seedlings occurred in high-volume stands of mature Alaska-cedar and western hemlock with closed canopies and considerable shade. By the third year, over 99% of the seedlings had perished. Most seedlings shriveled and died without apparent attack by pests or by deer feeding, perhaps the result of too little sunlight.

In the present study, the poor survival of Alaska-cedar planted in wet, poorly drained soils may seem surprising. The species is apparently well adapted to growing in these wet soils. Many patches of prostrate, asexually reproducing Alaska-cedar were growing in the bogs where survival of planted seedlings was so poor. Perhaps the nursery-grown seedlings were not adapted to the anaerobic, infertile soil conditions of bogs.

The scorched appearance of seedlings on exposed sites 1 year after planting was probably the result of warm, dry weather that occurred during, and several days after, planting. These seedlings apparently experienced a form of transplant shock due to desiccation. Their good subsequent recovery indicates their responsiveness to adverse conditions when planted on favorable sites.

Biotic factors, such as grazing by deer and infection by *Apostrasseria* sp., usually cause mortality in very young seedlings or in older seedlings that are repeatedly attacked. At its current level, shoot blight is not causing serious damage even in site types where it is common. The incidence of the disease appears to be intensifying at all sites in this study and this trend may continue for several more years. *Apostrasseria* sp. only causes disease on young trees, however, and stands of Alaska-cedar will eventually outgrow susceptibility. In a survey of pathogenic fungi on mature Alaska-cedar, the fungus was not detected (Hennon 1990, Hennon et al. 1990c).

Because only recently grown tissues of seedlings are grazed by deer, most grazing does not result in direct mortality. Terminal and lateral shoots near the tops of seedlings are most frequently grazed, which results in some grazed seedlings that are short and bushy. Grazing of seedlings on productive sites can have the effect of delaying height growth. Diameter growth is sometimes actually enhanced in grazed seedlings (presumably, so is root growth), and seedlings may attempt to resume their shoot/root balance by accelerating height growth in ensuing years. If seedlings go ungrazed for a year or two under good growing conditions, they should attain heights that will not allow deer to feed upon their terminal leaders.

Seedlings planted in areas of dense deer populations may experience intense grazing every year. By their reduced height and photosynthetic area, grazed seedlings will be at a disadvantage with competing vegetation. Such seedlings will probably not survive competition for light and nutrients with species of brush such as *Vaccinium* spp. and western hemlock. Some planted Alaska-cedar seedlings in unburned clear-cuts were grazed in consecutive years and were becoming crowded and even overtopped by hemlock and brush in 1991. This was particularly apparent on sites planted several years after harvest. The combination of deer grazing and competing vegetation may be the greatest threat to survival of Alaska-cedar seedlings on well-drained sites.

Regenerating Alaska-cedar on the most poorly drained sites would present a challenge because nursery-grown seedlings will frequently perish in the mucky soil; however, such sites are not harvested or managed. Planted seedlings in soils with somewhat better drainage (scrub sites) may have good early survival, but their growth will not be rapid. Selection of drier microsites by planters may improve seedling survival and growth. Perhaps the Alaska-cedar that exists as vegetatively-reproducing understory in some scrub stands could be encouraged to grow into trees following some stand treatment, such as salvage or overstory harvest. On wet sites that already exhibit the decline problem, some mortality of regenerated Alaska-cedar should be expected over the life of the regenerated stand. However, forest managers can plant Alaska-cedar on productive sites without fear of decline spreading to the plantation.

Private timber companies in British Columbia perceive a valuable future market for Alaska-cedar as a specialty wood. Approximately 900,000 Alaska-cedars are planted every year on productive sites in coastal British Columbia. "Stecklings," asexually reproduced rooted cuttings, account for most of the planting stock there. In the past several years, the Alaska Region of the USDA Forest Service has initiated efforts to collect seed, produce stock, and plant nursery-grown seedlings of Alaska-cedar on harvested sites. These efforts will offer opportunities to replace Alaska-cedar where it is harvested or to grow it on the many wet sites or productive sites where it is not currently found. In addition, we are exploring methods of attaining adequate natural regeneration through seed tree harvests and soil disturbance.

Uncertainties still remain with techniques of managing stands of Alaska-cedar once they have been established with natural regeneration or planting. Silvicultural information on site selection, spacing, and pruning is needed in both British Columbia and Alaska to determine their effects on wood quality and volume production.

Conclusions

Planting of Alaska-cedar may be needed to attain adequate regeneration of this valuable tree species in southeast Alaska. This study provides preliminary information on planting requirements of Alaska-cedar. Results suggest the following:

1. Seedling survival and growth appear best on sites with good soil drainage and light exposure, but early survival is also good on sites with moderately poor drainage.
2. If significant vegetation competition is expected, site preparation to retard competing vegetation (for example, burning) should be considered and/or sites should be planted promptly after harvest. Burning will likely increase browsing on seedlings if deer are present.
3. To maximize growth, seedlings can be protected (for example, by Vexar) in areas of high deer population.

Acknowledgments

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