# Survival and Growth of Planted Yellow-Cedar Seedlings and Rooted Cuttings (Stecklings) near Ketchikcn, Alaska

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ABSTRACT

The survival and growth of yellow-cedar *((homoecyporis nootkotensis)* seedlings and rooted cuttings (stecklings) were monitored for 6 years after planting at three sites near Ketchikan in southeast Alaska to determine whether stecklings could serve as a suitable planting stock. Survival for both seedlings and stecklings was >85% at the three sites. Survival, final diameter, and finol height differed by site but not by the use or absence of Vexar as protection from browsing by Sitko block-tailed deer *(Odocoileus hemionus sitkensis)*. Vexar produced a lower rate of browsing but contributed to form problems (especially leaving trees leaning and prostrate on the ground). Seedlings had significantly greater diameters than stecklings even though they experienced a higher rate of browsing at one site. Differences in diameter and height likely were due to genetic variation rather than seedling or steckling stock type. Steck lings appear to be a suitable source of planting stock; when used for large-scale reforestation efforts, genetic considerations are essential. Planting recommendations for maximizing yellow-cedar establishment during regeneration are given.

**Keywords:** Alaska-cedar, *(hamoecyporis nootkotensis,* artificial regeneration, browsing

Yellow-cedar *(Chamaecyparis nootkatensis* [D. Don] Spach) [1] is culturally, ecologically, and commercially important in southeast Alaska, The maritime climate with year-round precipitation in the region favors abundant natural regeneration of most conifers after timber harvesting. As a result, only a modest tree-planting program exists in the region, with a primary focus of increasing the number of trees of favored species. There is a concern, however, that yellow-cedar does not regenerate in sufficient numbers following natural disturbances or timber harvests in some areas. Reasons for poor or sporadic natural regeneration in these areas are not understood and could relate to the 2-year cone maturation, low seed production, poor germination rates, competition, or heavy browse on seedlings by deer.

A widespread mortality problem, called "yellow-cedar decline," has resulted in about 200,000 ha of concentrated mortality in yellow-cedar throughout southeast Alaska. Recent research on the problem indicates the cause is a form of freezing injury to roots induced by warmer winters, reduced snowpack, and periodic freezing events in early spring (Beier et al. 2008, Hennon et al. 2006, Schaberg et al. 2005, Schaberg et al. 2008). A management strategy is being developed that recommends promoting yellow-cedar regeneration through planting and thinning on sites considered to be free of the decline problem now and into the future (Hennon et al. 2008). The combined losses from the decline problem and continued timber harvest suggest that successful regeneration of yellow-cedar is needed to ensure the susrainability of this valuable species. The management of stock quality; control of competition from herbs, shrubs, and conifers; and protection from browsing will be important components in a successful regeneration program.

Hennon (1992) conducted a small planting of yellow-cedar seedlings on Etolin Island in Alaska and reported good survival (>85%) and growth (heights of approximately 110 cm) after 5 years on productive, well-drained soils. Competing vegetation was noted as limiting survival and growth, particularly where planting was not performed promptly after harvest. There are no other reports in the literature of yellow-cedar planting results in Alaska; however, the T ongass National Forest did have an active yellow-cedar planting program in the *1990s.*

Research and operational experience with yellow-cedar artificial regeneration in British Columbia is probably applicable in southeast Alaska, Difficulty in collecting cones and low seed germination rate due to seed-coat-imposed dormancy (Pawlik 1993, Raimondi and Kermode 2004, Bonner and Karrfalt 2008) led to the development of yellow-cedar stecldings-planting stock produced by rooted cuttings rather than from seed (Karlsson 1974, 1981). Interestingly, vegetative reproduction is common for yellow-cedar in unmanaged forests. Parish and Antos (2006) contend that many mature yellow-cedar trees in natural stands originate from layering, the rooting of lower branches. Antos and Zobel (1986) noted the occurrence of layering in natural stands of the Cascade Mountains in Oregon and Washington. Hennon et al. (1990) reported the same phenomenon in Alaska and suggested that vegetative reproduction occurred more

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This article uses metric units; the applicable conversion factors are: millimeter (mm): 1 mm = 0.039 in.; meters (m): 1 m = 3.3 ft.

**Table 1. Site information for three locations in a study of yellow-cedar artificial regeneration near Ketchikan, Alaska.**

| | Site | | |
|---|---|---|---|
| | Whistle | MB 8075 | MB 8077 |
| Location | Ward Cr. Valley | Margaret Bay | Margaret Bay |
| Elevation (m) | 190–215 | 195–230 | 510–590 |
| Aspect | Northeast | East-Northeast | East |
| Slope (%) | 30 | 40 | 70 |

frequently in poorly drained sites where persistent lower branches contact the ground. Genetic testing has not been done to confirm the proportion of regeneration from seed and from layering in unmanaged forests. The current planting program in British Columbia includes up to 750,000 yellow-cedar annually since 1975; about 70% of the planting stock are stecklings produced by rooting side branches taken from hedges (Russell 1993).

Yellow-cedar stecldings have been the subject of considerable physiological research in British Columbia, including photosynthesis (Grossnickle and Russell 1989), transpiration and water stress (Grossnickle and Russell 1990, 1996), gas exchange (Grossnickle and Russell 1991, Folk et. al, 1995), nutrient response (Hawkins 1992), and frost hardiness (Davradou and Hawkins, 1998, Hawkins 1993, Hawkins et al. 2001, Puttonen and Arnott 1994). Karlsson and Russell (1990) found no significant differences in survival, height, diameter, or form between plantings of seedling and steckling origins 13 years after planting. Also, there was no evidence of plagiotropism (i.e., horizontal leader growth, which might be expected in rooted side shoots) in stecklings.

Our work was conducted to expand the body of knowledge resulting from these studies in British Columbia and extend the applicability northward by about 5 degrees of latitude. The objective of this study was to evaluate the survival and growth of stecklings relative to seedlings in southeast Alaska to determine whether stecklings are a suitable planting stock type. A secondary objective was to evaluate the use of Vexar [2] tubing against Sitka black-tailed deer *(Odocoileus hemionus sitkensis)* browsing to enhance seedling survival, growth, and form.

## Methods

Seedlings and stecldings were planted in the spring of 1998 at three locations (Table 1; Figure 1) within 1 year of clearcut timber harvesting on Revillagigedo Island, near Ketchikan, Alaska. Two sites are representative of areas that supported yellow-cedar; the Margaret Bay 8077 site is at higher elevation, and yellow-cedar was not common at the time of harvesting.

Seedlings were grown from a local seed source on Revillagigedo Island at the Western Forest Products Limited nursery in Saanichton, Be. Stecklings were produced from two different genetic origins with approximately half from Twin Creek on Mitkof Island (to the north) and half from Bowbyes Creek on Queen Charlotte Islands (to the south). Stecklings were produced from juvenile side branches of hedges that were between 3 and 6 years old. These side branches were dipped in the hormone indole butyric acid and grown in the Campbell River nursery in Campbell River, BC. All planting stock, whether seedling or steckling, were grown in Styroblock containers, where they received normal watering and fertilization for 1 year before being lifted and shipped to Alaska in a refrigerated container.

Seedlings and stecklings were planted at a 4.3 m (14 ft) spacing in alternating rows oriented along the slope gradient (e.g., a seedling row, then a steckling row) 4.3 m (14 ft) apart. Every other seedling and steckling in each row was fitted with a Vexar tube supported by a bamboo stake to provide protection from deer. In total, 300 seedlings and 300 stecklings were planted at each of the three sites. The experiment was implemented as a complete block (site), split-plot design with stock type (seedling or srecklings) as the whole-plot treatment and Vexar (present or absent) as the split-plot treatment.

Seedlings and stecklings were measured immediately after planting (1998) and again in the spring of 1999, 2000, 2001, and 2004. Seedlings and stecklings were judged to be live or dead and were assumed dead if missing after the initial measurement. Stem diameter was measured at ground level with calipers and recorded to the nearest-millimeter. Total height was measured to the nearest centimeter. Defective form (forked or broken top, lean, prostrate on the ground) and any evidence of browse by animals was noted at each measurement. Browse rates are reported, but they were not tested statistically for differences between seedlings and stecldings or by the use of Vexar.

Student's t-test was used to evaluate initial differences in height and diameters between seedlings and stecklings at the time of planting. Survival of seedlings and stecklings was calculated for each year of field sampling. Analyses of variance (SAS Institute, Inc., 2004; General Linear Model) were used to test for differences in the final diameters, heights, proportion of trees surviving, and proportion of crowns without any type of defect. Planting stock type (seedling or steckling) was the whole plot factor and presence or absence of Vexar was the split plot factor. The analysis of variance was performed using the means of each site $\times$ stock type $\times$ Vexar combination, yielding 12 degrees of freedom. The error mean square for whole plots was used in the $F$ test of the stock type effect, and the error mean square for split plots was used in the $F$ test of the Vexar effect. All differences were judged to be significant at $a = 0.05$.

## Results

A small number of seedlings and stecklings were not found at the first measurement, and more were destroyed at the Margaret Bay 8077 site by road construction. These were removed from the analysis. More than 270 seedlings and stecklings (>90% of those planted) measured at each site were used for analysis. At the time of planting (1998), seedlings were shorter than stecklings (20.3 $\pm$ 0.1 and 25.5 $\pm$ 0.1 cm, respectively) but had larger basal diameters (3.02 $\pm$ 0.02 and 2.89 $\pm$ 0.02 mm, respectively). Although these differences were highly significant (both, $P = 0.001$), the actual differences between seedlings and steclclings were small relative to the final heights and diameters in the study.

The plantations had high survival rates, approximately 87% after 6 years, which did not differ by the use of Vexar or type of planting stock (i.e., seedling or steckling; Figure 2). The generally high rate of survival varied by site; the Margaret Bay 8077 site had greater survival (94%) than the other two sites (85%).

Seedlings had significantly greater final diameters ($P = 0.007$) than stecldings (Figure 3). Greater heights for seedlings followed the same pattern, but differences were not quite significant ($P = 0.06$) (Figure 3). There was no interaction effect detected between site and stock type on final heights or diameters. The higher growth rate of seedlings over stecklings was apparent at each sampling interval after the first year at each of the sites (Figure 4), suggesting that initial

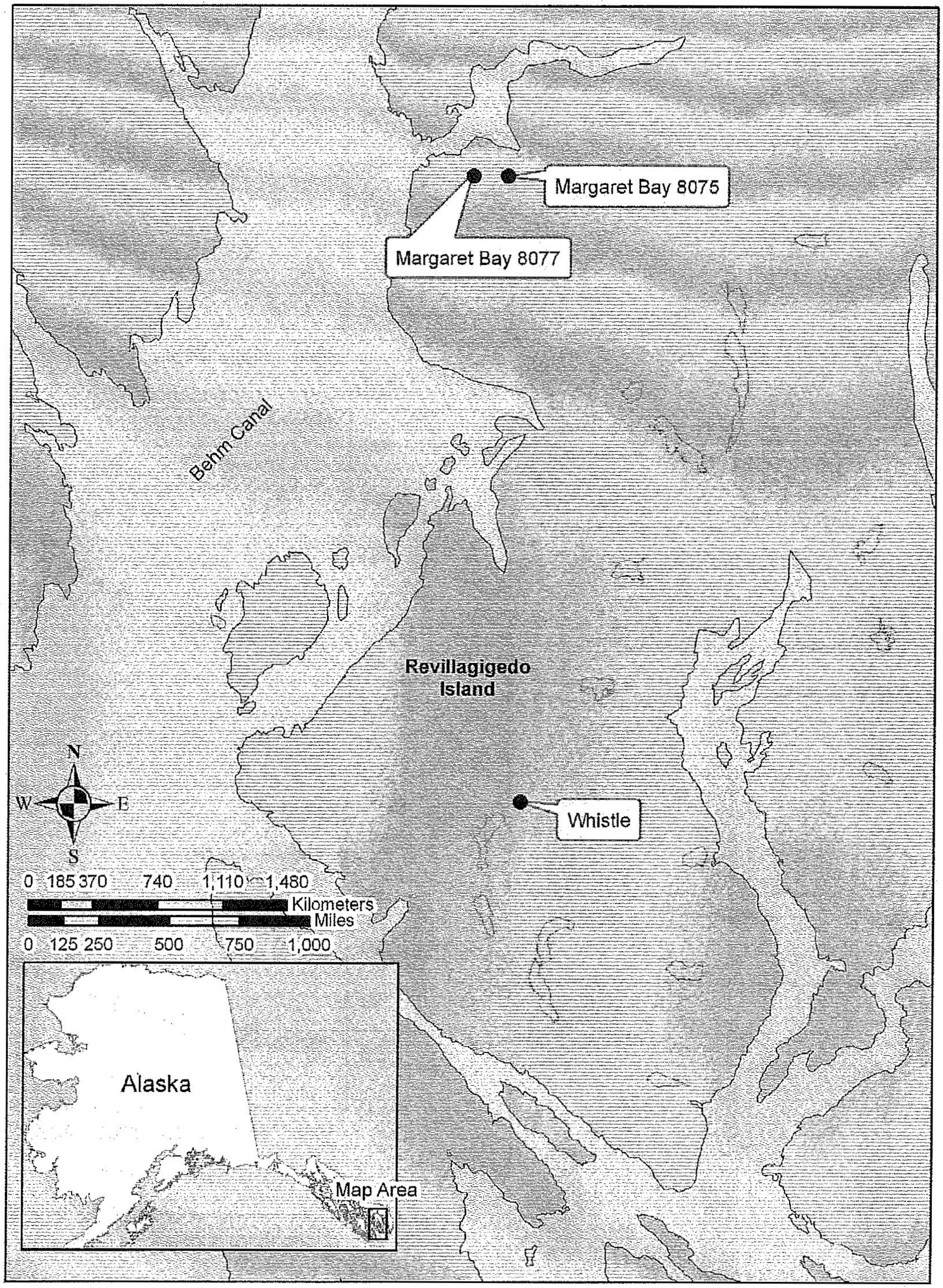


**Figure 1. Map of three sites where yellow-cedar seedlings and stecklings were planted and measured for survival and growth near Ketchikan on Revillagigedo Island, Alaska.**

differences in diameters between seedlings and stecklings were not responsible for this difference. Site was also a major factor in determining final heights ($P$ = 0.0004) and diameters ($P$ = 0.0002). Heights and diameters at the two low elevation sites were greater than at the higher-elevation Margaret Bay 8077 site. Final mean height and diameter at the higher elevation site lagged approximately 30 em and 4 mm, respectively, behind those at the two lower-elevation sites.

Browsing by deer was noted on fewer than 2% of the trees at the Margaret Bay 8077 and Whistle sites (Table 2). The Margaret Bay 8075 site had considerably more browsing, where 34% of the trees were browsed in at least one of the measurement periods. The highest rates of browse at that site in individual years were found in the 2000 (17%) and 2001 (24%) measurements.

Seedlings tended to experience a higher rate of browsing (41%) than stecklings (27%) at the Margaret Bay 8075 site (Table 2).

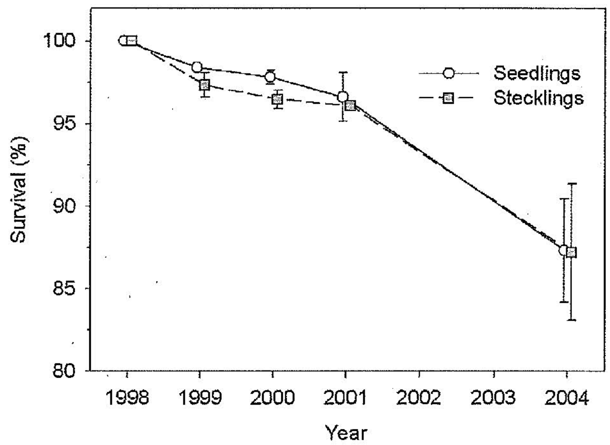


**Figure 2. Survival of yellow-cedar seedlings and stecklings. Values represent means and standard errors of the three planted sites near Ketchikan, Alaska.**

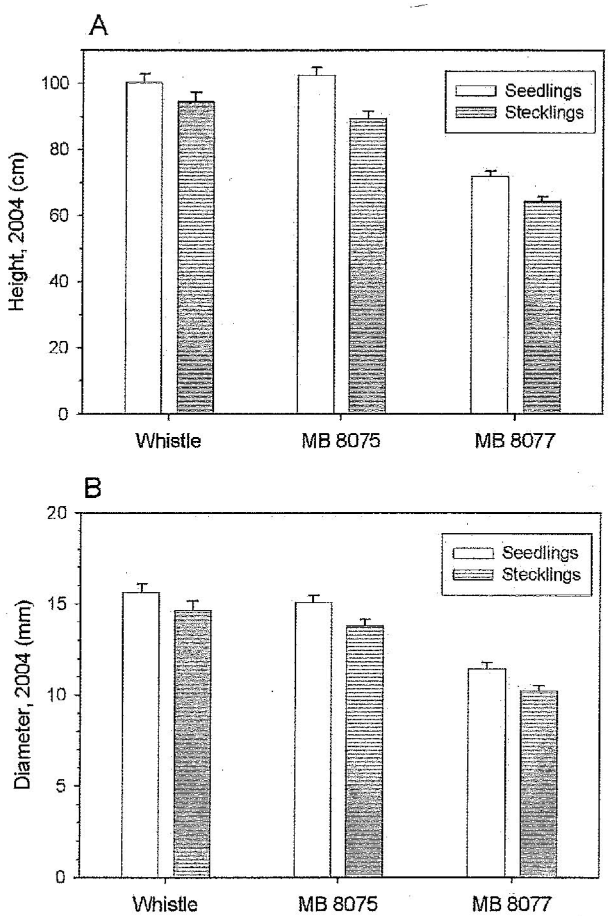


**Figure 3. Mean (A) heights and (B) diameters in 2004 of seedlings and stecklings at the three planted sites near Ketchikan, Alaska. Error bars are standard errors.**

Seedlings and stecklings protected by Vexar at this site had a lower browse rate than those without Vexar, but Vexar did not give complete protection. Similarly, plantings with Vexar tended to have less browsing of terminal leaders (16%) than without Vexar (32%).

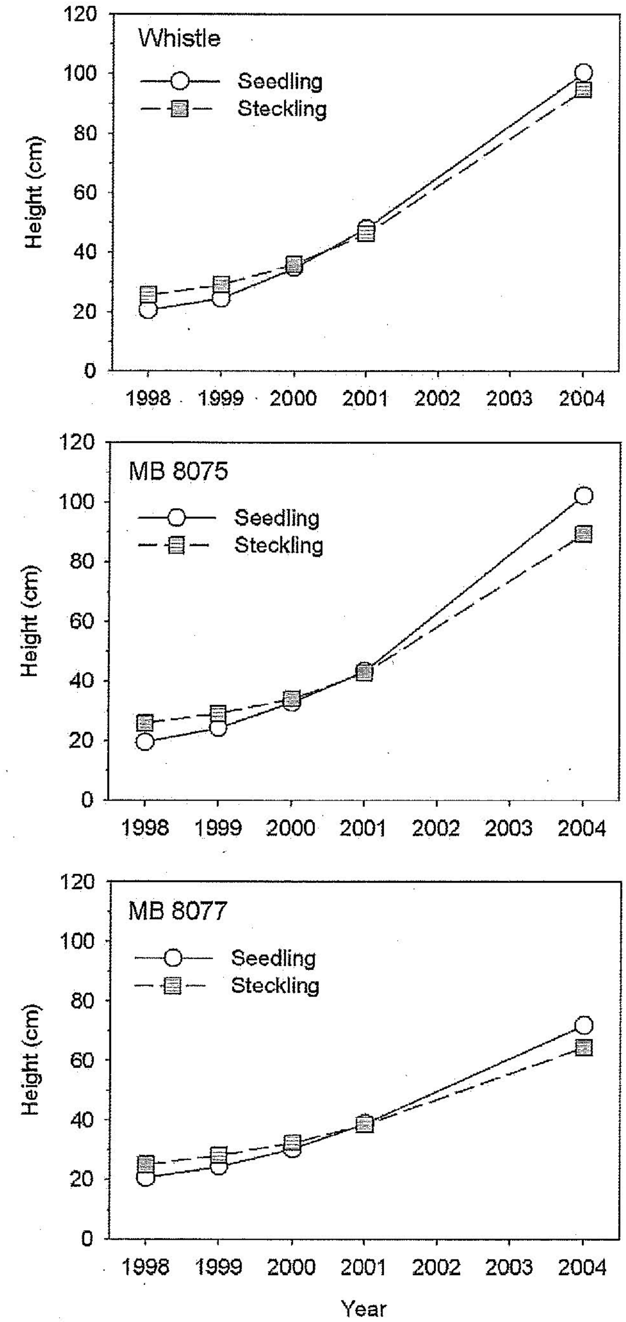


**Figure 4. Height growth at each of the sampling intervals for seedlings and stecklings planted at three sites near Ketchikan, Alaska.**

Planting-stock type and browse history had little influence on final form of surviving trees in 2004. Vexar, however, significantly increased ($P = 0.01$) the frequency of form problems (Table 3). Overall, more unprotected plantings (79%) had a normal form than with the use of Vexar (63%). Trees that were leaning (27%) or prostrate on the ground (8%) were the most common form problems associated with Vexar. These form problems were also found in trees without Vexar, although in reduced frequencies (18% and 2%, respectively). We did not detect a difference in the final diameters or heights of unprotected trees or those with Vexar at the three sites (Figure 5).

Table 2. **Percentage of cumulative browsing of seedlings and stecklings for three locations in a study of yellow-cedar artificial regeneration near Ketchikan, Alaska. $n \geq 133$ for all combinations of site, planting stock, and use of Vexar.**

| | Seedlings | | | Stecklings | | |
|---|---|---|---|---|---|---|
| Site | Vexar | No Vexar | Overall | Vexar | No Vexar | Overall |
| | ..............(%).............. | | | ..............(%).............. | | |
| MB 8075 | 33 | 49 | 41 | 24 | 33 | 27 |
| MB 8077 | 0 | 2 | 2 | 3 | 0 | 1 |
| Whistle | 1 | 1 | 1 | 2 | 1 | 2 |

Table 3. **Percentage of planted stock with normal, leaning, or prostrate stems, with and without browse protection, after six growing seasons in a study of yellow-cedar artificial regeneration near Ketchikan, Alaska. The frequency of other form problems (i.e., forked or broken tops) was minor (<2%).**

| | | | Form | | |
|---|---|---|---|---|---|
| Site | Treatment | $n$ | Normal | Lean | Prostrate |
| | | | ................(%)................ | | |
| MB 8075 | Vexar | 269 | 64 | 29 | 5 |
| | No Vexar | 259 | 80 | 17 | 0 |
| MB 8077 | Vexar | 227 | 63 | 26 | 9 |
| | No Vexar | 233 | 73 | 22 | 3 |
| Whistle | Vexar | 248 | 62 | 25 | 10 |
| | No Vexar | 248 | 84 | 14 | 1 |
| Overall | Vexar | 744 | 63 | 27 | 8 |
| | No Vexar | 740 | 79 | 18 | 2 |

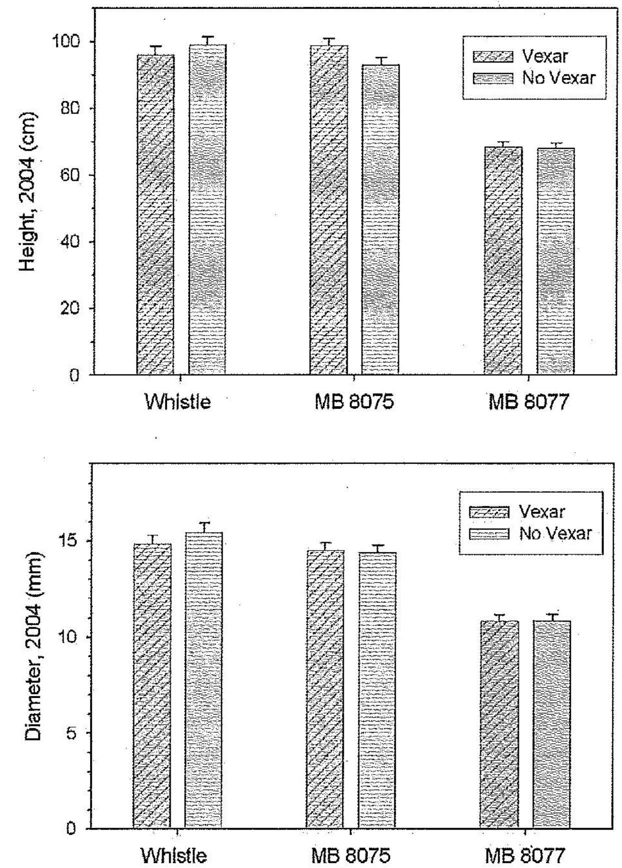


**Figure 5. Mean heights and diameters in 2004 of trees (i.e., both seedlings and stecklings) with and without Vexar at the three planted sites near Ketchikan, Alaska. Error bars are standard errors.**

## Discussion

Stecklings appear to be a suitable substitute for seedlings when planting yellow-cedar for reforestation. Survival rates were similar between seedlings and stecklings. Seedlings outgrew steddings, but it is not dear whether this difference can be attributed to the trees' source (seeds or cuttings) or to genetic variation. It is conceivable that greater root development before outplanting and in the first growing season in the field by seedlings compared with steddings (Folk et al. 1995) could have resulted in the greater seedling growth that we measured. Russell et al. (1990) reported slightly more root biomass and a greater root:shoot ratio in stecklings compared with seedlings, however. After the first year in the ground, the faster growth rate of seedlings over stecklings was maintained throughout the 6 years of the study. It is possible that the slower early growth of stecklings allows for greater competition from adjacent vegetation than seedlings would experience. A study similar to ours, conducted in British Columbia, found no difference in growth rate between yellow-cedar seedlings and stecklings (Karlsson and Russell 1990). Our survival rate was similar to the 88% survival observed in yellow-cedar seedlings planted at higher elevation (740-850 m) in British Columbia (Mitchell and Koppenaal 2006). Also, the 20% form defect in plantings without Vexar that we found was similar to the 10-20% in the British Columbia trial.

Rapid growth is an important factor for yellow-cedar trees. Longer-term survival will be reduced in slow-growing saplings in young stands due to competition with shrubs and other conifers. Thinning can be used as a silvlcultural tool to favor yellow-cedar over competing species; however, early growth of yellow-cedar must be sufficient to produce saplings that can be selected during the thinning.

Competing vegetation is a leading threat to successful regeneration of conifers, including yellow-cedar regeneration (Burgess et al. 2003). Site preparation that eliminates western hemlock advance regeneration and slows the establishment of shrubs may improve the establishment and growth of planted yellow-cedar, and the effect of site preparation may persist for decades. Hennon et al. (2006) remeasured a 1986 plantation of yellow-cedar seedlings on Etolin Island 20 years after establishment and found marked differences in growth of seedlings planted on burned and unburned portions of the same harvest unit. Although growth after the first 5 years was similar (Hennon 1992), planted yellow-cedar were overtopped by western hemlock on the unburned area, whereas the burned area lacked western hemlock competition and yellow-cedar were taller. Our work shows that when site preparation is not possible, planting soon after harvest may help ensure establishment of yellow-cedar. This goal of early planting cannot be met when yellow-cedar planting stock is limited; planting stock availability should coincide with harvest activities. A lower rate of establishment of planted yellow-cedar can be expected in cases where planting is delayed by several years after harvest.

Browsing by deer was minimal at two of the study sites and was moderate at the third site. Evidence of browse on western redcedar (*Thuja plicata* Donn) from British Columbia, especially on the Queen Charlotte Islands, shows that deer can drastically reduce regeneration (Martin and Baltzinger 2002, Coates et al. 1985). Deer apparently prefer to browse yellow-cedar seedlings more than yellow-cedar stecklings (Russell 1993), but this preference may apply only to recently planted stock. We also found a greater percentage of browsing on seedlings compared with stecklings at our one site with moderate browse levels. This browsing preference may be explained by lower concentrations of terpenes in the foliage of seedlings compared with steckIings, whether caused by the initially greater proportion of juvenile follage in seedlings or the longer-term influence of genetic control (Vourch et al. 2002).

Vexar caused initial form problems for individual seedlings and steckIings in our study, primarily toppling over and leaning. Leaders caught in Vexar developed a whirling growth pattern in some individual seedlings and steddings. Leaning and fully bent over trees without Vexar were found, but at lower frequencies. Snow probably pushes over trees with Vexar to produce the leaning and toppling. Leaning seedlings and saplings can right themselves and develop good form (Gourley et al. 1990); thus, this problem may be only temporary. Our data analysis did not show an overall influence, positive or negative, on survival or growth from use ofVexar. The expense of Vexar treatments is not justified in areas where a low or moderate rate of browse is expected, such as our study sites. In areas with high deer populations, Vexar or other forms of protection may be needed because deer can lead to nearly complete failure of plantations. Vexar will probably cause more planted cedar to be pushed to the ground in areas of heavy snow, and these would be the same areas where lower rates of deer browse would be expected.

The potential narrowing of the genetic base of stecklings is a concern when they are widely used for regeneration. This drawback of genetic diversity is potentially offset by genetic gains made possible through done origin, selection, effective population size, and deployment (Libby 1982, Russell 1993). The Tongass National Forest is considering the use of yellow-cedar steddings when seedlings are not available, or a mixture of seedlings and stecklings when both are available and more planting stock is required. Currently only one yellow-cedar hedge from Alaskan seed is producing steelelings. More hedgerows will need to be established from Alaskan seed sources if forest managers are to expand the use of yellow-cedar steddings for reforestation.

We suggest that these sites be thinned in a few years and that the growth of the planted yellow-cedar regeneration be monitored into the future. Whether seedlings or steckIings are used to regenerate yellow-cedar, we recommend a study to evaluate rates of growth and deer browse on the genetic stock available for use in Alaska. Genetically matched stock types with adequate genetic sampling and proper replication in field trials are necessary for these trials to obtain statistically meaningful results. Currently, the Tongass National Forest has 33 seed collections of yellow-cedar from locations scattered around southeast Alaska. Also, determining foliar terpene levels (Vourch et al. 2002) of these genetic stocks could lead to the use of particular seed sources that produce high terpene concentrations, which may minimize heavy browse in areas where deer are abundant and allow successful establishment. It is our hope that research and management experience will increase lmowledge of the silvics of yellow-cedar so that this valuable species can be maintained as a vital part of Alaska's forests.

## Endnotes

[1] The taxonomic status of yellow-cedar is in question because of the discovery of a tree species with close phylogenetic affinity in northern Vietnam, *Xantbocyparis uietnamensis* Farjon & Hiep, (Farjon et al. 2002). Yellow-cedar joins the Vietnamese tree in this newly created genus as *Xanthocyparis nootkatensis* Farjon & Hiep. Whether that name or the older name *Callitropsis nootkatensis* (D. Don) Orest, (Little et al. 2004) is adopted will be determined at the next International Botanical Congress in 2011 (Mill and Farjon 2006).

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the US Department of Agriculture of any product or service.

## Literature Cited


ANTOS, J.A., AND D.B. ZOBEL. 1986. Habitat relationships of *Chamaecyparis nootkatensis* in southern Washington, Oregon, and California. *Can. J Bot.* 64: 1898 -1909.

BEIER, C.M., S.E. SINK, P.E. HENNON, D.V. D'AMORE, AND G.P. JUDAY. 2008. Twentieth-century climate change and the dendrochronology of declining yellow-cedar forests in southeastern Alaska. *Can. J. For. Res.* 38: 1319-1334.

BONNER, F.T., AND R.P. KARRFALT. 2008. *The Woody Plant Seed Manual* Ag. Handb. 727. US For. Serv., Washington, DC.

BURGESS, O., AK. MITCHELL, AND G. GOODMANSON. 2003. Twenty-year assessment of four species planted in the mountain hemlock zone of British Columbia. *For. Chron. 79(2):285-290.*

COATES, KD., J.C. POLLACK, AND J.E. BARKER. 1985. *The effect of deer browsing on the early growth of three conifir species in the Queen Charlotte Islands.* Research Report RR85002-PR. Ministry of Forestry, BC, Canada.

DAVRADOU, M., AND B.J. HAWKINS. 1998. Effects of plantation location and population on the seasonal freezing tolerance of yellow-cedar *(Chamaecyparis nootkatensis)* stecklings. *New For. 15:77-87.*

FARJON, A, N.T. HIEP, D.K. HARDER, P.K. LOC, AND L. AVERYANOV.2002. The new genus and species in Cupressaceae (Coniferales) from northern Vietnam, *Xanthocyparis vietnamensis. Novon 12:179-189.*

FOLK, R.S., S.c. GROSSNICKLE, AND J.H. RUSSELL. 1995. Gas exchange, water relations and morphology of yellow-cedar seedlings and stecklings before planting and during field establishment. *New For.* 9: 1-20.

GOURLEY, M., M. VOMOCIL, AND M. NEWTON. 1990. Forest weeding reduces the effect of deer-browsing on Douglas-fir. *For. Ecol. Manag.* 36: 177-185.

GROSSNICKLE, S., AND J. RUSSELL. 1989. *Rooting of yellow cypress cuttings. Part 1: Influence of donor plant maturation.* Res. Memo 083. Forest Research Development Agreement, Victoria, BC, Canada. 2 p.

GROSSNICKLE, S.C., AND J.H. RUSSELL. 1990. Water movement in yellow-cedar seedlings and rooted cuttings: Comparison of plant and root system pressurization methods. *Tree Physiol. 6:57-68.*

GROSSNICKLE, S.C., AND J.H. RUSSELL. 1991. Gas exchange processes of yellow-cedar *(Chamaecyparis nootkatensis)* in response to environmental variables. *Can. J. Bot. 69:2684-2691.*

GROSSNICKLE, S.C., AND J.H. RUSSELL. 1996. Changes in shoot water relations parameters of yellow-cedar *(Chamaecyparis nootkasensis)* in response to environmental conditions. *Can. J. Bot. 74:31-39.*

HAWKINS, B.J. 1992. The response of *Chamaecyparis nootkatensis* steddings to seven nutrient regimes. *Can. J. For. Res. 22:647-653.*

HAWKINS, B.J. 1993. Photoperiod and night frost influence the frost hardiness of *Chamaecyparis nootkatensis* clones. *Can. J. For. Res.* 23: 1408 -1414.

HAWKINS, B.J., J.H. RUSSELL, AND J. ARNOTT. 2001. Cold hardiness of yellow-cedar *(Chamaecyparis nootkatensis* (D. Don) Spach). P. 531-554 in *Conifir cold hardiness,* Bigras, F.J., and S.J. Colombo (eds.), Kluwer Academic Publishers, Dordrecht, The Netherlands.

HENNON, P.E. 1992. Survival and growth of planted Alaska-cedar seedlings in southeast Alaska. *Tree Planters' Notes. 43(3):60-66.*

HENNON, P.E., D. D'Alv[ORE, D. WITTWER, AND J. CAOUETTE. 2008. Yellow-cedar decline: Conserving a climate-sensitive tree species as Alaska warms. P. 233-245 in *Proceedings of National Siluiculture Workshop,* Deal. R. (ed.), Gen. Tech. Rep. PNW-GTR-733. US For. Serv. Pacific Northwest Res. Stn., Portland, OR.

HENNON. P., D. D'AMoRE, D. WITTWER, A JOHNSON, P. SCHABERG, G. HAWLEY, C. BEIER, S. SINK, AND G. JUDAY. 2006. Climate warming, reduced snow, and freezing injury could explain the demise of yellow-cedar in southeast Alaska, USA. *World Res. Rev. 18:427-450.*

HENNON, P., C. DOWLING, AND R. REED. 2006. Yellow-cedar regeneration demonstration area. US For. Servo Alaska Region, Juneau, AK. *Sourdough Notes* 3(2):8-9.

HENNON, P.E., E.M. HANSEN, AND C.G. SHAW III. 1990. Dynamics of decline and mortality of *Chamaecyparis nootkatensis* in southeast Alaska. *Can. J Bot.* 68:651-662.

KARLSSON,I. 1974. Rooted cuttings of yellow cedar. Vancouver, British Columbia. BCFS Int. Res. Note 66: 5 p.

KARLSSON, I. 1981. Propagation of Alaska yellow-cedar *(Chamaecyparis nootkatensis* (D. Don) Spach) by rooted cuttings for production planting. *Int. Plant Propagators' Soc.* 31:112-116.

KARLSSON, I., AND J.H. RUSSELL. 1990. Comparison of yellow cypress trees of seedling and rooted cutting origins 9 and 11 years in the field. *Can. J. For. Res.* 20:37-42.

LIBBY, W.J. 1982. What is a safe number of clones per plantation? P. 342-360 in *Resistance to disease and pests in forest trees,* Heybroek, H.M., B.R. Stephan, and K. von Weissenberg (eds.), Pudoc, Wageningen, The Netherlands.

LITTLE, D.P., A.E. SCHWARZBACH, R.P. ADAMS. AND C.F. HSIEH. 2004. The circumscription and phylogenetic relationships of *Callitropsis* and the newly described genus *Xanthocyparis* (Cupressaceae). *Am. J Bot.* 91:1872-1881.

MARTIN, J.L., AND C. BALTZINGER. 2002. Interaction among deer browsing, hunting, and tree regeneration. *Can. J For. Res.* 32:1254-1264.

MILL, R.R., AND A. FAR]ON. 2006. Proposal to conserve the name *Xantbocyparis* against *Callitropsis* Oerst. (Cuppressaceae). *Taxon* 55:229-231.

MITCHELL, A.K., AND R. KOPPENAAL. 2006. *Outplanting performance of western redcedar, yellow-cedar and Douglas-fir in montane alternative silvicultural systems (MASS).* Technology Transfer Note No. 34. Canadian Forest Service, Ottawa, ON, Canada. 4 p.

PARISH, R., AND J.A. ANTOS. 2006. Slow growth, long-lived trees, and minimal disturbance characterize the dynamics of an ancient, montane forest in coastal British Columbia. *Call. J. For. Res. 36:2826-2838.*

PAWUK, W.H. 1993. Germination of Alaska-cedar seed. *Tree Planter's Notes* 44(1):21-24.

PUTTONEN, P., AND J.T. ARNOTT. 1994. Influence of photoperiod and temperature on growth, gas exchange, and cold hardiness of yellow cypress stecklings. *Call. J For. Res. 24:1608-1616.*

RAIMONDI, N., AND A.R. KERMODE. 2004. Seedling growth and establishment in natural stands of yellow-cedar *(Chamaecyparis nootkatensis)* seedlings derived from the use of modified seed dormancy-breaking treatments. *New Forests 27:* 55-67.

RUSSELL, J.H. S.C. GROSSNICKLE, C. FERGUSON, AND D.W. CARSON. 1990. *Yellow-cedar stecklings nursery production and field performance.* Forest Research Development Agreement, Victoria, BC, Canada. 21 p.

RUSSELL. J .H. 1993. Clonal forestry with yellow-cedar. P. 188-20 in *Clonal Forestry, VoL 2: Conservation and application.* Ahuja, M.R., and W.J. Libby (eds.). Springer-Verlag, Berlin.

SAS INSTITUTE INC. 2004. *General Linear Models Procedure.* SAS Online Doc 9.1.3. SAS Institute Inc., Cary, NC.

SCHABERG, P.G., P.E. HENNON, D.V. D'AMORE, G.J. HAWLEY, AND C.H. BORER, 2005. Seasonal differences in freezing tolerance of yellow-cedar and western hemlock trees at a site affected by yellow-cedar decline. *Can. J. For. Res.* 35:2065-2070.

SCHABERG, P.G., P.E. HENNON, D.V. D'AMORE, AND G.J. HAWLEY. 2008. Influence of simulated snow cover on the cold tolerance and freezing injury of yellow-cedar seedlings. *Global Change Biol.* 14: 1282-1293.

VOURCH, G., J.H. RUSSELL, AND J.L. MARTIN. 2002. Linking deer browsing and terpene production among genetic identities in *Cbamaecyparis nootkatensis* and *Thuja plicate* (Cupressaceae). J. H*ered. 93:370-376.*