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Field Performance in Southeast Alaska of Sitka Spruce Seedlings Produced at Two Nurseries

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Abstract

A study of nursery stock performance was conducted on four sites in the Tongass National Forest in southeastern Alaska: two sites at Fire Cove (Ketchikan Ranger District [R.D.]) and one each at Anita Bay (Wrangell R.D.) and Eight Fathom (Hoonah R.D.). Containerized Sitka spruce seedlings used in the study were grown at USDA Forest Service nurseries in Petersburg, Alaska, and Coeur d'Alene, Idaho, from seed sources appropriate for each of the three locations. Seedlings from the Petersburg nursery were taller (33 centimeters versus 18 centimeters) and had greater shoot dry weights (1.51 grams versus 0.67 gram) than those from Coeur d'Alene; however, seedlings from Coeur d'Alene had a more favorable shoot-to-root ratio (2.1 versus 4.3). Survival after the first growing season exceeded 96 percent for all seed sources and sites. After three growing seasons, survival for the local seed source at each site ranged from 71 to 98 percent for the trees from Petersburg and 52 to 93 percent for trees from Coeur d'Alene. Cause of mortality differed among sites: animal damage was most important at the Fire Cove sites and frost damage was most important at the Eight Fathom site. Initial seedling height was greater for the Petersburg seedlings, a difference that still existed after three growing seasons. Third-year height growth of the Coeur d'Alene seedlings was equal to or greater than that of the Petersburg trees; thus, the difference in mean total height between seedlings from the two nurseries decreased during the 3 years. Our preliminary conclusion is that seedlings intended for outplanting in southeast Alaska can be grown in nurseries in the Pacific Northwest if appropriate Alaska seed sources are used.

Keywords: Artificial regeneration, frost damage, animal damage, seedling survival, seedling growth, *Picea sitchensis.*

Introduction

The Tongass National Forest in southeastern Alaska relies almost exclusively on natural regeneration to restock cutover stands. Although this is successful in almost all cases, situations arise where planting may achieve objectives not possible with natural regeneration. These objectives include improving stocking and distribution of selected species, rapid restocking of difficult to regenerate sites (for example, river terraces, flood plains, and high-elevation sites) or sites prepared by slash burning, and to introduce genetically improved stock (Harris and Farr 1974). Planted seedlings can develop rapidly on some sites; thus, artificial regeneration may be used to reduce rotation length.

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Production of high-quality nursery stock is critical in a successful planting program. Seedlings with high growth potential are essential if any advantage is to be gained over natural regeneration. The primary source of seedlings for southeast Alaska has been the USDA Forest Service's B. Frank Heintzelman nursery in Petersburg, Alaska. Because of relatively low demand for seedlings, however, it was never possible to achieve the economies of scale found in large nurseries that can spread fixed costs over many more units of production. Because of high costs, the question was asked, Would it be cost effective to grow trees in the large forest nurseries of the Pacific Northwest (that is, Idaho, Oregon, and Washington) for outplanting in southeast Alaska? To be successful, seedlings grown outside Alaska must have potential for survival and growth equal to or better than that of seedlings grown in Alaska. To address this question, a cooperative study involving the Alaska Region and the Pacific Northwest Research Station of the USDA Forest Service was begun in 1986. This note presents 3-year results of the planting done in 1986. The 1986 planting, consisting of stock of Sitka spruce {*Picea sitchensis* (Bong.) Carr) from two container nurseries, was an exploratory study done before a larger planting in 1987. The 1987 planting included two species, Sitka spruce and western redcedar {*Thuja plicata* Donn ex D. Don), trees from three nurseries, and two stock types (plug and plug+1 seedlings). Results from the 1987 planting will be presented in a future report.

Methods

Seedlings were produced at Forest Service container nurseries in Petersburg, Alaska, and Coeur d'Alene, Idaho. At Petersburg, seedlings were grown in Styroblock-4[r] containers (66 cubic centimeters in volume) during the normal growing season under mostly natural lighting conditions. At Coeur d'Alene, seedlings were grown in a second, late-season crop in Ray Leach Pine Cells (66 cubic centimeters in volume), with natural light supplemented by artificial light to maintain seedling growth. This schedule is normally used to grow stock for outplanting on low to moderately stressful sites. Seedlings were grown under the standard irrigation and fertilization regimes used at each nursery. At Petersburg, seedlings were removed from the containers in early February 1986 and placed in cold storage until they were shipped to the field for planting in June 1986. The trees grown at Coeur d'Alene were packaged in early February and shipped via air freight to Petersburg where they were placed in cold storage and shipped to the field sites with the Petersburg trees.

Three seed sources were used in the study (table 1). Outplanting sites in each of the seed zones were selected after consultation with Ranger District personnel (table 2). Planting was done in June 1986—the normal planting time for southeast Alaska.

The experiment was a randomized block design with three blocks per site. Within each block, each combination of seed source and nursery was represented by a row of 30 trees. At the Fire Cove sites, only trees from the local seed source were available. At the Anita Bay and Eight Fathom sites, all seed source-nursery combinations were planted; thus, each block contained six rows of 30 trees.

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Table 1—Seed sources used for nursery comparison study[a]

Seed lot number	Source area	Latitude	Longitude	Elevation	Year collected
				Meters	
57	Revilla Island, Ward Cove	55°21' N.	131°39' W.	0-155	1981
102	Mitkof Island, Petersburg	56°49' N.	132°57' W.	0-155	1982
85	Chichagof Island, Hanging Valley	58°00' N.	135°58' W.	850	1981

[a] The Ward Cove and Mitkof Island sources were mass collections and represent a wide range of aspects. The Hanging Valley source was collected on a south-southeast aspect.

Table 2—Study sites In the Tongass National Forest, southeast Alaska, planted In 1986 and used In nursery comparison study

Area	Ranger District	Elevation	Slope		Aspect	Year harvested	Site preparation
			Percent	Position			
		Meters					
Fire Cove (two sites)	Ketchikan	115-150	60-70	Mid	N	1984	None
Anita Bay	Wrangell	50-75	60-70	Mid	S	1985	Burned in 1986
Eight Fathom	Hoonah	18	0	Bottom		1983	One manual cutting of salmonberry at time of planting

Planting rows were staked, and the planting spot for each seedling was marked with a numbered metal pin. Trees were planted in a suitable microsite within 0.5 meter of the pin. If no suitable microsite was found, the spot was skipped and the length of the row increased to accommodate the skipped spot. Seedlings were planted at a spacing of 1.8 meters.

A subsample of 25 randomly selected seedlings from each seed source-nursery combination was taken at the planting site. These seedlings were used to determine height, diameter, number of branches, length of the longest branch, and root and shoot dry weight of each nursery lot.

After planting, the height of sach seedling was measured and its condition determined by a visual inspection. In fall 1986, and each fall in the next 2 years, seedling total height to the nearest centimeter and stem diameter to the nearest millimeter at 15 centimeters above ground line were measured. In 1988, third-year height increment was measured. Total seedling height and height increment were measured for all trees; diameter was measured on every third tree. Seedling condition was determined to be one or more of the following: healthy, animal damage, frost damage, abnormal needle color (mainly chlorotic), mechanical damage, presence of overtopping vegetation, and a miscellaneous category where physical appearance was not normal but no cause of the abnormality could be determined. Animal and frost damage were most common, and those data are summarized in this note.

Initial and third-year seedling height and diameter and third-year height increment and survival were analyzed by analysis of variance. An arc sine square root transformation was used for seedling survival data. Only seedlings whose current terminal was not damaged by animals were included in the analysis of height growth. For the seedlings selected at planting time for destructive sampling, means and 95-percent confidence intervals were determined for each seed source-nursery combination.

Results

Seedling Characteristics at Time of Planting

Seedlings from the Ward Cove and Hanging Valley seed sources grown at Petersburg were, on average, appreciably taller, larger in diameter, and heavier than those from the same seed sources grown at Coeur d'Alene; the number of branches was also greater for the Petersburg trees, but branch length was not different (table 3). Shoot-to-root ratio was greater for trees grown at Petersburg.

Seedlings from the Mitkof Island seed source produced in Petersburg were grown in 1984 and left in the containers but outdoors in 1985, the year that seedlings from the other sources were grown. At the time of planting, these seedlings were 30 to 40 percent shorter than those from Ward Cove and Hanging Valley sources and had lower height-to-diameter and shoot-to-root ratios. Seedlings grown from the Mitkof Island source at Petersburg were taller and heavier than those from Coeur d'Alene (table 3), but shoot-to-root ratio was the same, and the physical appearance of Mitkof Island seedlings from both nurseries was more alike than that of seedlings from the Ward Cove and Hanging Valley sources.

Seedling Survival and Damage

Survival was 96 percent or greater at all sites during the first growing season. The greatest decrease in survival occurred between the first and second growing seasons at all sites. The primary cause of mortality differed among the sites (table 4).

The most meaningful nursery comparison was for the local seed sources planted at each of the study sites. Third-year survival was higher for Petersburg trees grown from the local seed sources at each site than for similar Coeur d'Alene trees. The probability that these differences were real was higher (p = 0.01) at the Fire Cove sites than at Anita Bay and Eight Fathom (p = 0.30 or greater).

The greatest amount of anima! damage occurred at the Fire Cove site's,, and the Coeur d'Alene trees had a higher percentage of damage than the Petersburg trees (table 4). Most of the mortality appeared to be either directly or indirectly related to browsing. Anima! damage at Fire Cove was clipping of the top and lateral branches.

Table 3—Selected Sitka spruce seedling characteristics for trees grown at the Petersburg and

Nursery	Seed source	Height[a]	Diameter	Height/ diameter	Branches: Number	Branches: Max. length	Dry weight: Shoot	Dry weight: Root	Shoot/root
		Cm	*Mm*			*Cm*	*Gram*	*Gram*	
Petersburg	Hanging Valley	31.1(1.4)	2.5(.1)	123(9)	15.8(1.4)	6.9(.8)	1.47(0.19)	0.38(0.06)	4.0(0.4)
Coeur d'Alene	Hanging Valley	18.0(1.1)	1.8(.1)	101(7)	10.8(.7)	5.9(.5)	.61(.06)	.33(.03)	1.8(.1)
Petersburg	Ward Cove	35.5(1.8)	2.6(.1)	136(8)	15.8(1.2)	7.0(1.0)	1.56(.21)	.33(.06)	4.7(.4)
Coeur d'Alene	Ward Cove	18.3(1.1)	1.8(.1)	102(5)	10.4(1.3)	6.1(.8)	.73(.10)	.31(.05)	2.4(.2)
Petersburg	Mitkof Island	22.4(1.8)	2.7(.2)	83(9)	12.6(2.0)	3.9(.6)	1.33(.16)	.62(.05)	2.1(.2)
Coeur d'Alene	Mitkof Island	18.4(1.6)	1.9(.1)	97(10)	11.4(1.1)	6.9(1.0)	.76(.07)	.34(.04)	2.2(.1)

[a] Mean followed by 95-percent confidence interval.

Table 4—Seedling survival and major causes of damage to seedlings on 4 study sites in southeast Alaska

Site	Seed source	Nursery[a]	1986 Survival	1986 Animal damage	1986 Frost damage	1987 Survival	1987 Animal damage	1987 Frost damage	1988 Survival	1988 Animal damage	1988 Frost damage
			Percent								
Fire Cove 1	Ward Cove	P*	100	0	0	94	6.6	0	94	6	0
	Ward Cove	C	96	8.3	0	82	13.3	0	82	8	0
Fire Cove 2	Ward Cove	P*	99	5.6	0	78	3.3	0	71	0	0
	Ward Cove	C	97	16.8	0	61	30.0	0	52	1	0
Anita Bay	Ward Cove	P	99	3.3	0	88	0	0	88	1	0
	Ward Cove	C	99	1.1	0	69	0	0	64	0	0
	Mitkof Island	P*	100	2.2	0	90	0	0	83	0	0
	Mitkof Island	C	100	3.3	0	84	0	0	78	0	0
	Hanging Valley	P	99	1.1	0	94	0	0	91	0	0
	Hanging Valley	C	99	3.3	0	86	0	0	80	3	0
Eight Fathom	Ward Cove	P	100	0	13	40	0	39	30	0	60
	Ward Cove	C	100	0	8	64	0	57	50	11	78
	Mitkof Island	P	100	0	0	100	0	9	98	7	68
	Mitkof Island	C	100	0	15.5	91	0	48	84	6	80
	Hanging Valley	P*	99	0	6	98	0	5	97	8	44
	Hanging Valley	C	100	0	12.2	98	0	60	93	6	70

[a] Asterisk indicates local seed source for the site and nursery where seedlings were grown: P = Petersburg; C = Coeur d'Alene.

At Anita Bay, survival of the Petersburg trees from the three seed sources was similar. For the Coeur d'Alene seedlings, the poorest survival was for the southernmost, Ward Cove source. Neither animal nor frost damage was an important factor at Anita Bay (table 4).

At Eight Fathom, the northernmost site, seed source affected survival ($p = 0.01$); survival of the Ward Cove source was the lowest—50 percent or less by the end of the third growing season. Frost damage was severe at this site and occurred in varying amounts to all seed sources at some time during the 3-year study. Frost damage resulted in increased mortality in the Ward Cove source but not in the Mitkof Island or Hanging Valley sources. Animal damage, primarily girdling at the base of the stem, increased in the third year of the study after being absent during the first two growing seasons (table 4).

Seedling Development

Initial seedling height (measured after outplanting) was greater ($p = 0.01$) for the Ward Cove and Hanging Valley sources from the Petersburg nursery than for those from Coeur d'Alene (table 5). Initial height of trees from the Mitkof Island source was similar for the two nurseries. The effect of nursery environment on initial seedling height differed among the nurseries. Heights of Petersburg seedlings were different at $p = 0.01$ for Ward Cove and Hanging Valley sources, which were grown at the same time, while height of seedlings from the three seed sources grown at Coeur d'Alene differed at $p = 0.25$.

After three growing seasons, size differences were similar to those at the time of planting; that is, the Petersburg trees were tallest for Ward Cove and Hanging Valley sources, whereas the height of trees from the Mitkof Island source was similar for both nurseries. Height at time of planting for seedlings was different at $p = 0.01$, and height differences at 3 years were different at $p = 0.04$ or greater (table 6).

Third-year height increment was greater for the Coeur d'Alene trees in all but two cases. Differences in incremental height growth between nurseries were not detected at less than $p = 0.11$ (tables 5 and 6).

Seedling diameter increased from twofold to fivefold between 1986 and 1988. The diameters of 3-year-old seedlings were different at $p = 0.05$ at Eight Fathom and greater than $p = 0.24$ at the other sites. Effects of seed source on diameter were not measurable at $p = 0.30$ for the Anita Bay and Eight Fathom sites (tables 5 and 6).

Table 5—Average initial and 3d-year height of Sitka spruce seedlings planted at 4

Site	Seed source	Nursery[a]	Height		3d-year height increment	Diameter	
			Initial	3d year		1st year	3d year
			Centimeters			*Millimeters*	
Fire Cove 1	Ward Cove	P*	33.1	58.3	13.0	3	8
	Ward Cove	C	20.4	46.3	14.4	2	7
Fire Cove 2	Ward Cove	P*	36.0	49.5	9.4	3	6
	Ward Cove	C	20.7	40.8	11.3	2	5
Anita Bay	Ward Cove	P	36.4	67.6	24.3	3	13
	Ward Cove	C	19.4	53.6	25.0	2	11
	Mitkof Island	P*	17.2	48.3	23.1	3	12
	Mitkof Island	C	17.5	50.2	22.4	2	9
	Hanging Valley	P	28.8	44.7	12.8	2	10
	Hanging Valley	C	19.4	44.8	19.9	2	11
Eight Fathom	Ward Cove	P	31.6	48.4	8.2	3	6
	Ward Cove	C	16.9	35.9	12.6	2	4
	Mitkof Island	P	20.2	44.4	8.9	2	6
	Mitkof Island	C	16.2	37.6	11.9	2	6
	Hanging Valley	P*	25.2	40.2	12.4	3	6
	Hanging Valley	C	15.3	35.0	10.6	2	4

[a] Asterisk indicates local seed source for the site and nursery where seedlings were grown: P = Petersburg; C = Coeur d'Alene.

Table 6—P-values for differences in 3d-year performance among seedlings from the Petersburg and Coeur d'Alene nurseries and

Site	Source of variation	3d-year height	3d-year height increment	3d-year diameter
Fire Cove	Nursery	0.04	0.24	0.24
Anita Bay	Nursery	.37	.40	.36
	Seed source	.01	.04	.60
Eight Fathom	Nursery	.13	.11	.05
	Seed source	.41	.50	.30

Discussion

There were differences in survival and growth among trees from the two nurseries after three growing seasons, but the magnitude and occurrence of differences varied among study sites. Although additional time is needed to determine whether these differences are maintained and how they affect early stand development, it is possible to note some trends or irreversible conditions that have developed to date.

The main objective of our study was to determine if field performance of the seedlings produced in Alaska was different from that of seedlings grown at nurseries in the Pacific Northwest (that is, Idaho, Oregon, or Washington) from the same Alaska seed sources. The most meaningful differences were those occurring between nurseries with seedlings grown from local seed sources for each site. In terms of survival, there were large differences between nurseries for the two Fire Cove sites but not for the Anita Bay and Eight Fathom sites. The differences at Fire Cove were directly or indirectly related to greater browsing of the Coeur d'Alene trees and not to poor seedling performance.

The initial height differences tended to remain about the same in absolute terms. The relative increase in height from the first to the third year was greater for the Coeur d'Alene trees at the Fire Cove and Eight Fathom sites but not at Anita Bay, where seedlings from the local seed source grown at the two nurseries were more alike than was the case at the other sites. Height increment during the third growing season was similar for seedlings from both nurseries. If this trend continues, the absolute difference in size between stock from the different nurseries will decline.

We believe that the differences in performance between seedlings from the two nurseries were related to the relatively large differences in the morphology of the growing stock from the nurseries at Petersburg and Coeur d'Alene and in the different type of growing cycle used at each nursery. Even though frequent rains and mild temperatures during the southeast Alaska growing season (Farr and Hard 1987) reduces environmental stress, the more sturdy, well-balanced, and physiologically sound a seedling is, the better it will perform after outplanting. The same factor or factors that contributed to the greater occurrence of frost damage on trees from Coeur d'Alene—be it smaller size and (or) less hardiness due to late season production in the nursery—probably accounted for the differential browsing damage as well. (Note: The stock from Coeur d'Alene used in this study was not typical of their stock produced as a second crop. The stock we used was shipped in early February and stored at cool temperatures for several months. Normally, stock from their second crop undergoes a greenhouse regime to induce hardiness and larger caliper before late spring planting in the northern Rocky Mountains.)

The height growth observed in our study fell within the range observed by Shaw and others (1987) on two sites in southeast Alaska. Seedling survival in the local seed sources used in our study covered a wider range than that reported by Shaw and others (1987). They also report the occurrence of frost heaving on one of their sites but no frost damage to the stem or foliage of seedlings. They do not report any animal damage, which was a significant cause of mortality on the site in our study with the lowest survival. Sitka spruce survival over a 10-year period on six sites in the Kitimat Valley, British Columbia, was 90 percent or greater, and average annual height growth was 26 centimeters/year.[2] In a study on Vancouver Island, British Columbia, Sitka spruce survival ranged from 65 to 95 percent after one growing season; after six growing seasons, survival had decreased by 0 to 27 percent over that of the first year. Average annual height growth ranged from 32 to 45 centimeters for the 6 years (Omule 1988).

The climate in southeast Alaska is excellent for good seedling survival and early growth. Although rainfall tends to be lower during the summer, there is usually no prolonged drought, and mild temperatures mean that moisture stress is usually low (Farr and Hard 1987). Although competing vegetation can develop rapidly after harvesting (Alaback 1984), it does not create the same level of stress in seedlings that occurs in seedlings growing in areas with a prolonged summer drought period such as western Oregon.

A secondary objective of the study was to examine the performance of seed sources covering a latitudinal span on the sites selected for this study. This is by no means a thorough examination of movement of seed sources between different geographic areas of southeast Alaska. The response of the three seed sources at Anita Bay and Eight Fathom, where all seed sources were planted, provided some information on response of seedlings due to movement of seed between seed zones. A more thorough discussion of seed movement in southeast Alaska is presented by Campbell and others (1989).

The most distinct and irreversible effect of seed source on survival was at the Eight Fathom site, where frost damage seriously affected seedling performance. All seed sources were affected to some degree (some natural regeneration also sustained frost damage), but the southernmost source from Ward Cove was most affected. Frost damage to this seed source was the primary reason for the low (50 percent or less) survival at Eight Fathom. Eight Fathom was the only site where frost damage was observed. The site had all the characteristics of being a frost pocket. It is representative, however, of the river terrace situation, which has been one of the regeneration problem areas over the years (Harris and Farr 1974). Our data on frost damage to seedlings and data from Shaw and others (1987) on the occurrence of frost heaving on a river terrace site indicate that frost may be important, along with severe competition from salmonberry and other species, in making these sites regeneration problem areas. In northern coastal British Columbia, frost damage to Sitka spruce during the first year after outplanting is not uncommon; however, this damage is usually confined to the first year and does not occur repeatedly as was observed at Eight Fathom.[3]

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[2] Pollack, J.C.; van Thienen, F. 1986. Tree species trial in the Kitimat Valley. Smithers, BC: British Columbia Ministry of Forests, Research Branch. 15 p. Unpublished report for Project EP 12. On file with: British Columbia Forest Service, Smithers, BC.

[3] Personal communication, David Coates, British Columbia Ministry of Forests, Smithers, British Columbia.

At Anita Bay, the tallest trees were from the Ward Cove source, and this source also had the tallest average tree height as well as the greatest initial seedling height. In terms of relative increase in height, the local Mitkof Island seed source increased an average of 280 percent over the three growing seasons; the Ward Cove and Hanging Valley sources increased an average of 186 and 155 percent, respectively.

Campbell and others (1989) discuss microgeographic variation in Sitka spruce in southeast Alaska and the implications of this variation to seed transfer in artificial reforestation. They suggest that using local seed sources is desirable and that movement of seed even short distances may adversely affect seedling survival and growth. Our results, admittedly limited in scope, suggested that for sites where frost damage may occur, the best adapted local seed sources should be used.

Our preliminary conclusion, based on these experiments using stock from Idaho that was known to be smaller and less hardy than normal, is that seed from southeast Alaska sources can be grown in Pacific Northwest nurseries if photoperiod can be artificially lengthened to simulate conditions in Alaska. To provide a more definitive answer, we installed a second planting in 1987 that used seedlings grown during the normal growing season; we will report those results when more time has elapsed after planting.

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