An Engelmann Spruce Seed Source Study in the Central Rockies

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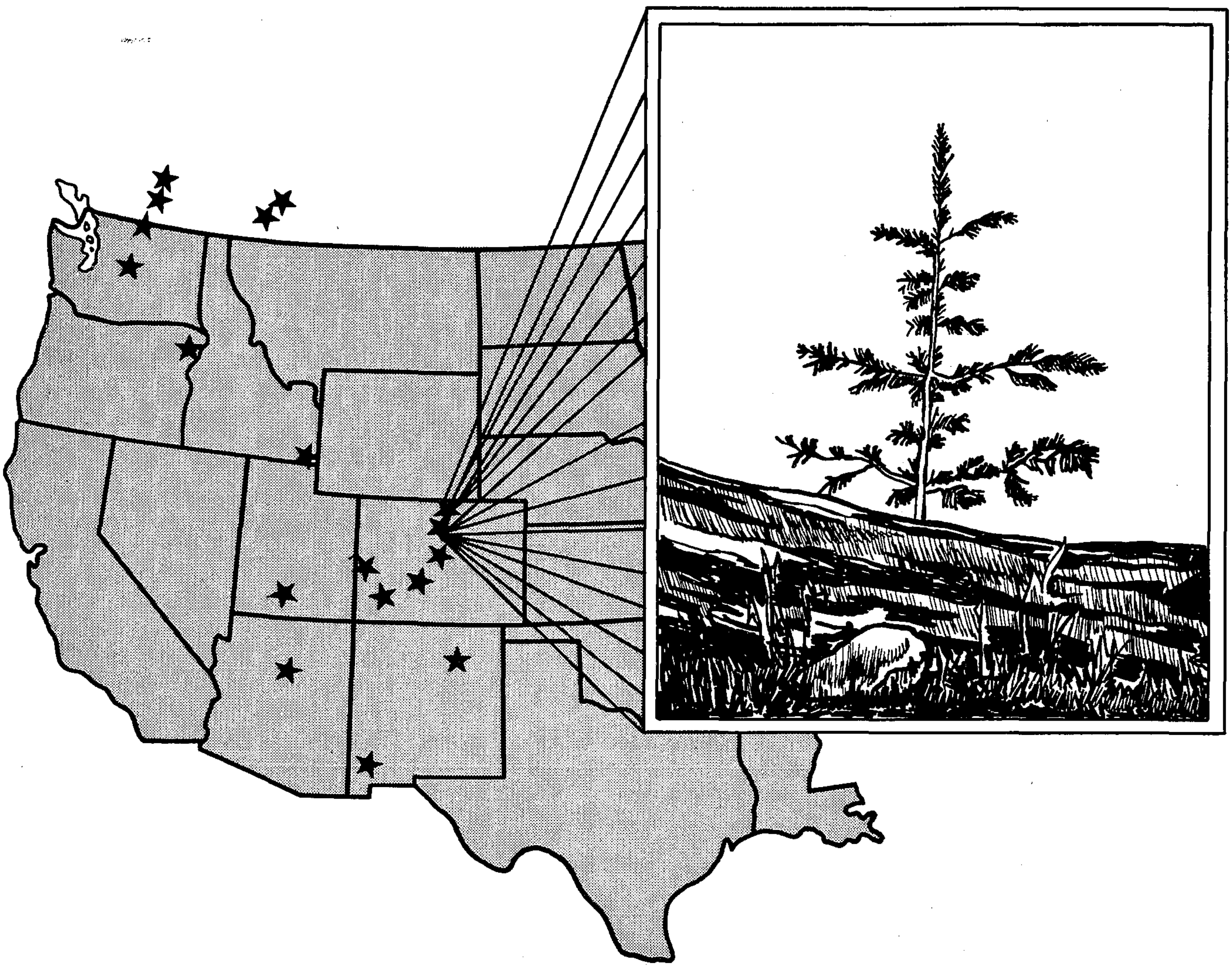

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Planted Englemann spruce seedlings from 20 sources throughout North America were field tested in the central Rockies at 9,600 feet (2,930 m) elevation. Overall survival was 73% after 10 years. Significant differences in height were evident among several sources. Sources from northern latitudes and lower elevations grew best. The results demonstrate that Englemann spruce planted at high elevations can survive when proper planting techniques and yearly maintenance procedures are used.

Keywords: Genetics, *Picea engelmannii*, provenance testing, seedling growth, regeneration

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Management Implications

Although the results of this study showed that Engelmann spruce seedlings from sources in more northerly latitudes and lower elevations grew better than those from other sources when planted in central Colorado, using seed from any source other than that of local seed zones is not recommended. Long-term studies are needed to determine the performance of seed from nonlocal sources. This study demonstrated, however, that proper planting techniques and follow-up operations can result in successful regeneration of Engelmann spruce in the central Rockies.

Introduction

Engelmann spruce (*Picea engelmannii* Parry) is widely distributed from Arizona and New Mexico to Alberta and British Columbia. Its habitat is characteristically cold and humid. The species grows at elevations ranging from about 1,960 feet (600 m), in the northern part of its range, to timberline, at over 11,800 feet (3,600 m), in the central and southern Rocky Mountains (Fowells 1965). It occurs on a wide variety of soils but grows best on moderately deep, well-drained silt and clay loam soils developed from basalt, andesite, rhyolite, shale, and limestone.

In British Columbia, southwestern Alberta, and northwestern Montana, the range of Engelmann spruce overlaps that of white spruce (*P. glauca* (Moench) Voss). In the areas of overlap, white spruce typically grows at low elevations and Engelmann at high elevations, while at intermediate elevations these two species hybridize naturally, particularly on cool, moist sites. Hybridization followed by backcrossing and natural selection within the hybrid swarms has resulted in populations with intermediate physiological and morphological characteristics (Daubenmire 1974).

With its wide geographical and elevational distribution, ability to grow on a wide range of soils, and natural hybridization with white spruce, a considerable amount of genetic variation can be expected in Engelmann spruce. Except for studies designed to evaluate genetic variation in British Columbia and western Alberta, and in the northern Rockies, little is currently known about genetic variation over the entire range of the species.

Results reported here are from the sole surviving field plantation of a nationwide Engelmann spruce seed source study, established in the late 1960's by the USDA Forest Service, North Central Forest Experiment Station. The purpose of the original study was to determine the nature and range of genetic variation in Engelmann spruce. The current study was a cooperative effort between the North Central Forest Experiment Station, the Rocky Mountain Forest and Range Experiment Station, and the Rocky Mountain Region 2, USDA Forest Service. The objective was to determine the adaptability of nonlocal seed sources to a central Rocky Mountains site.

The plantation, located near Vail, Colo., is typical of the subalpine environment, characterized by a 3-month growing season subject to climatic extremes, where both high surface temperatures and frost can be expected anytime (Alexander 1974, Noble and Alexander 1977). In addition, light intensities at these elevations can be damaging to young, unprotected spruce seedlings (Ronco 1970).

Successful regeneration of burns and large clearcut blocks has been a problem in the central Rockies for some time. Some sites have been planted several times without success. Long-range survival and growth records of Engelmann spruce plantations do not exist in the literature. This established plantation provided a unique opportunity to evaluate a number of seed sources, over a long period of time, in an extremely harsh environment.

Methods and Materials

Seed was collected between 1959 and 1964, from 20 stands of Engelmann spruce in British Columbia and the United States (table 1), by personnel of the British Columbia Forest Service, and the USDA Forest Service. The North Central Forest Experiment Station provided transplants (2:3 stock) produced at the Hugo Sauer State Nursery, Rhinelander, Wisc.

Stock was planted during June 1970, in the Moniger Creek area of the Holy Cross Ranger District, White River National Forest. The plantation was at 9,600 feet (2,930 m) elevation, on a nearly flat slope, with a northeastern aspect. The site was originally occupied by a mature Engelmann spruce—subalpine-fir (*Abies lasiocarpa* (Hook.) Nutt.) forest, containing occasional lodgepole pine (*Pinus contorta* Dougl.). Because of recent logging and a subsequent fire, no vegetation existed on the site at the time of planting. Soils are shallow, poorly developed, and quite rocky. Annual precipitation averages 30 inches (76 cm), most of which falls as snow.

Trees were planted in a randomized, complete block design, with 4-tree linear plots and 12 replications. Each planting spot was staked and labeled with seed source, block, and subsample to facilitate relocation of test trees. To provide protection against high light intensity, all trees were planted in the shade of stumps and logs, or shade was provided using suitable natural material (Ronco 1972). Spacing was irregular because

Table 1.—Origins, survival, and height growth of Engelmann spruce seed sources

Seed source	State or province	Location	Latitude	Elevation	Survival after 10 years	Total height after 10 years	Height growth 5-10 years
			° N	feet	percent	inches	inches
3231	BC	Kidd Creek	49	4,700	67	[1]47.6	24.8
3232	BC	Inlet Creek	50	4,600	70	44.5	20.9
3235	BC	Cutting Permit 31	50	5,125	68	44.5	23.2
3261	OR	Wallowa-Whitman NF	45	4,650	91	39.8	18.5
3229	BC	Powers Creek	50	4,100	77	39.8	18.1
3250	NM	Santa Fe NF	36	9,500	69	39.4	16.5
3253	ID	Payette NF	45	6,200	77	39.4	18.9
3258	WA	Okanogan NF	48	4,200	77	36.2	16.9
3629	CO	Grand Mesa-Uncompahgre NF	39	10,500	71	32.3	14.6
3259	WA	Wenatchee NF	48	2,550	52	31.9	13.8
3252	AZ	Coconino NF	35	9,400	67	31.5	13.4
3248	CO	San Juan NF	37	10,600	69	31.1	15.7
3246	CO	Roosevelt NF	40	9,000	77	30.7	15.7
3249	CO	Gunnison NF	39	10,400	90	29.5	13.8
3621	CO	Larimer County #1	41	7,900	66	29.1	13.8
3247	CO	Pike NF	39	8,900	77	28.3	12.6
3256	UT	Dixie NF	37	9,900	85	26.8	14.2
3622	CO	Larimer County #2	41	9,400	83	26.4	13.0
3630	NM	Gila NF	33	8,200	62	24.0	5.9
3255	ID	Cache NF	42	8,500	67	21.3	10.6
Plantation Mean					73	33.9	15.7

[1]*Source means scored by the same line are not statistically different at the 5% level.*

of shade requirements, but an approximate 8- by 8-foot (2.4- by 2.4-m) grid was maintained.

During the first growing season, tree condition and survival observations were taken monthly. General vigor, presence and condition of new growth, and condition of old foliage were noted. Dead trees were dug up, and root condition was recorded.

Beginning in 1971, survival counts were taken twice yearly—once after snowmelt in the spring, and again in late fall after the onset of dormancy. Trees were reshaded at each visit until they outgrew the shading material.

Total height of each tree was measured to the nearest centimeter in the fall of 1974 and 1979, at the conclusion of the 5th and 10th growing seasons after planting. Ten-year height and survival were compared, using a randomized block analysis of variance.

Results

Survival

Survival of trees from all seed sources averaged 73% after 10 years (table 1). And, although survival among individual seed sources ranged from 52% for the Wenatchee source to 91% for the Wallowa-Whitman source, there were no statistically significant differences among sources in survival.

Initial rates of mortality were similar for all seed sources. Most mortality occurred during the first 2 years after planting. Survival rates for sources exhibiting the best, poorest, and average performance for all sources are illustrated in figure 1.

First season tree condition records indicate several factors responsible for initial mortality. Improper planting clearly contributed to 17% of the first season mortality, while poor root system development resulted

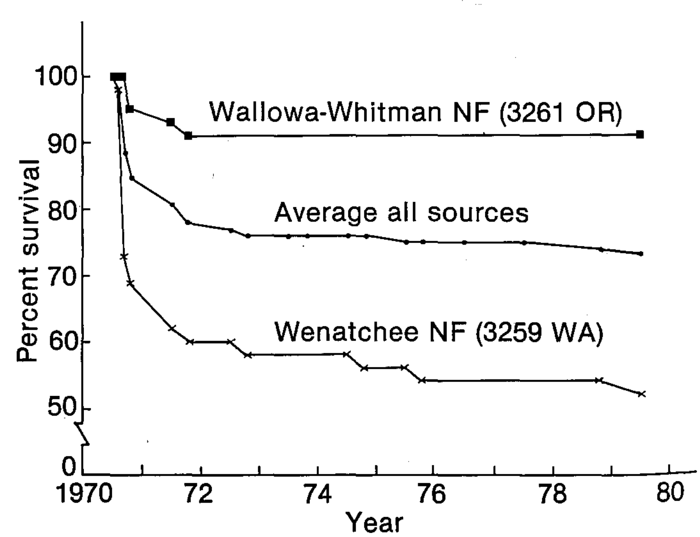

Figure 1.—Best, worst, and average survival by year.

in 15% of the first season losses. A combination of the above factors caused an additional 10% loss. Initial condition of the trees when planted may have been responsible for some of these losses. Only 11% of the trees which died the first growing season exhibited good vigor one month after planting. The remaining losses were due to unknown causes.

The lack of new foliage after planting also indicated which trees were under stress and most likely to die. Only 12% of the trees with healthy new growth one month after planting died during the first growing season, whereas new growth was dead on 34% of the trees which eventually died. In addition, 38% of the first season mortality had lost needles from the lower branches within 1 month after planting.

Height Growth

Average total height of trees, from all seed sources, after 10 years, was 33.9 inches (86 cm) (table 1). There were significant differences in total height among the 20 seed sources at 5 and 10 years after planting. After 10 years total height among individual seed sources ranged from 21.3 inches (54 cm) for the Cache NF source (3255) from Idaho to 47.6 inches (121 cm) for the Kidd Creek source (3231) from British Columbia. Individual tree heights ranged from 5.9 to 79.1 inches (15 to 201 cm) (fig. 2).

The four British Columbia seed sources did quite well, averaging from 39.7 to 47.6 inches (101 cm to 121 cm) in height. Significant differences in height were found between the top British Columbia seed source and the Cache, Gila, Larimer County, and Dixie sources. The Cache source was also significantly shorter than the Payette, Santa Fe, Wallowa-Whitman, and all British Columbia sources (table 1).

Latitude and elevation of the seed sources were both related to height growth. Analysis of variance of grouped data revealed significant differences in height between low and high elevation sources and between northern and southern sources (figs. 3 and 4). In contrast, there were no significant differences in survival of sources grouped on the basis of latitude or elevation of seed source. Because seed from all sources from below 6,900 feet (2,100 m) elevation were also from northern latitudes (≧ 45° N), it is impossible to determine if either or both of these variables are responsible for differences in height growth among groups of sources.

Relative height growth for most sources has not changed much during the course of this study. In general, northern sources grew relatively well throughout the entire study period. The most notable of these are the four sources from British Columbia, and the sources from the Wallowa-Whitman NF (3261) in Oregon, and from the Payette NF (3253) in Idaho. These sources were ranked between 3rd and 15th out of 20 in total height in the nursery. However, their relative height growth improved after planting and the same sources were ranked between 1st and 7th position at 5 and 10 years after planting. While height growth of

Figure 2.—This tree from the Wallowa-Whitman seed source was 79 inches (201 cm) tall, 10 growing seasons after planting.

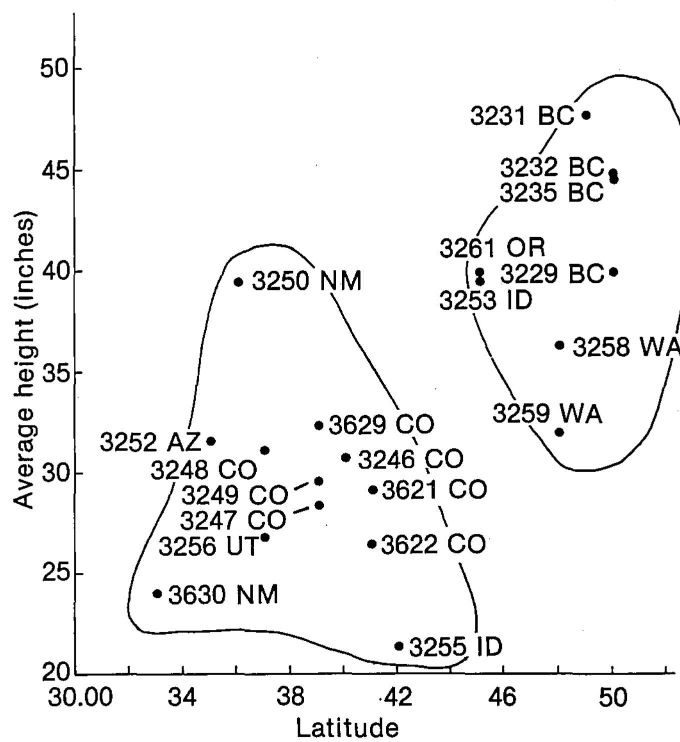

Figure 3.—Average height growth by latitude of seed source. Northern sources were significantly taller than southern sources (circled areas).

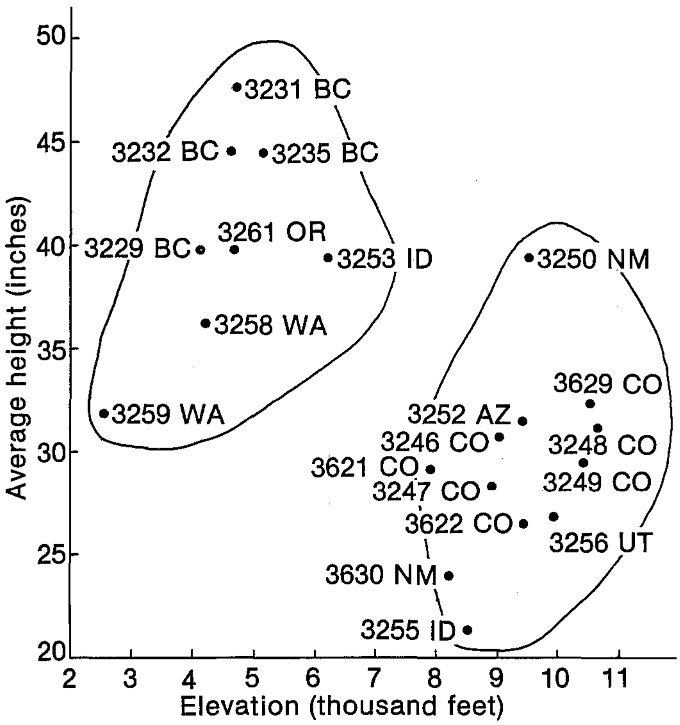

Figure 4.—Average height growth by elevation of seed source. Low and high elevation sources (circled) were significantly different.

trees from all sources averaged 15.7 inches (40 cm) (table 1) for the period between 5 and 10 years after planting, height growth of trees from the six sources above averaged between 18.1 and 24.8 inches (46 and 63 cm) during the same period.

In contrast to the northern sources, most of the southern (less than 43° N latitude) sources have grown slowly during the entire study period. Height growth during the last 5 years, for 9 of the southern sources, averaged between 5.9 and 14.6 inches (15 and 37 cm). The most notable exception to the generalization that southern sources have shown consistent slow growth during the study period is the Gila NF source (3630) from New Mexico. This source ranked first out of 20 in height in the nursery, but dropped to 11th after 5 years in the field, and to 19th after 10 years.

Discussion and Conclusions

It is not uncommon for high altitude Engelmann spruce plantations in the Rockies to fail dismally because of environmental and biotic factors. However, in this study none of the sources had less than 50% survival after 10 seasons of growth. The survival trends observed thus far indicate that it is possible to predict the eventual success of a plantation as early as 2 years after planting (fig. 1). The condition of the planting stock 1 month after planting also seems to be an indicator of eventual survival, but is less reliable. Such evidence suggests that trees in which new growth is absent or dead, or which shed needles shortly after planting, are not likely to survive the first growing season under the harsh conditions found on high altitude planting sites.

The lack of significant differences in survival of the 20 seed sources may not continue much longer. The physical appearance of trees from some sources indicates that more trees may die during the next few years. Trees from sources such as the Gila (fig. 5) seem to be gradually declining, as indicated by dead tops, lack of any well defined terminal leader, and poor growth form. It is possible that trees from some of the sources cannot adapt to environmental conditions of the site once they have grown beyond the protection of shading material.

Height growth of trees in this plantation is not exceptional by standards used in other parts of the country. However, growth of many of the sources can be considered quite good for high altitudes in the central Rockies, where it is generally accepted that 20-40 years are necessary to achieve breast height of 4.5 feet (1.4 m) (Alexander 1967).

Height growth patterns found in this plantation probably are strongly correlated with phenological patterns such as time of flushing, and time of height growth cessation of individual seed sources. The dramatic change in height growth ranking of the Gila NF source (3630) is probably because the source is the southernmost in this study, and trees from this source have suffered repeated severe winter damage (fig. 5). Height growth of trees from this source has averaged only 5.9 inches (15 cm) during the past 5 years. Other studies of the Engelmann-white spruce complex have shown that high elevation spruce sources are the first

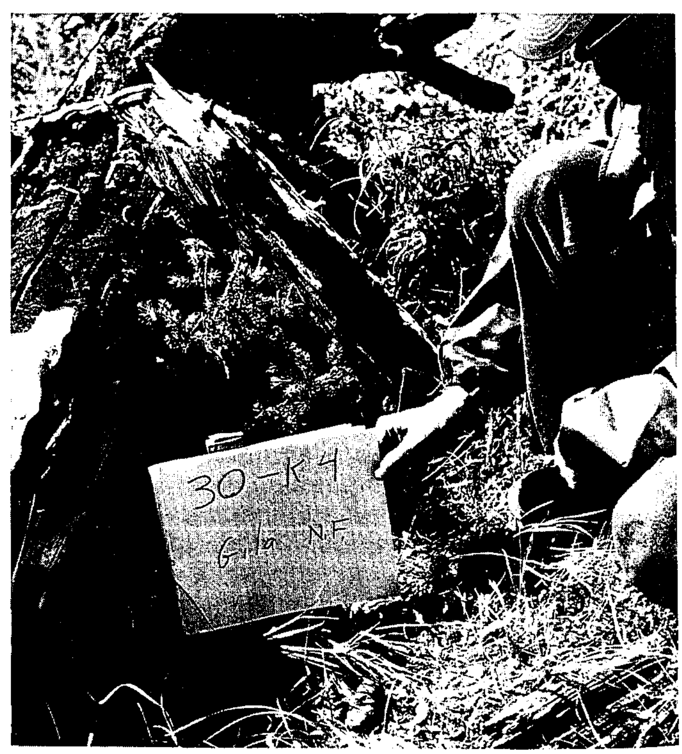

Figure 5.—Trees from the Gila seed source, with dead tops, dying foliage, and poor form, are surviving, but do not appear to be well adapted to the site.

to flush in the spring (Dietrichson 1971), the first to set bud in the fall (Roche 1969 and Dietrichson 1971), and are the slowest growing (Roche 1969, Dietrichson 1971, Nienstaedt et al. 1971). These studies appear to explain the slow growth of high elevation sources planted in this study. However, it should be noted that sources termed low elevation in this study are actually from the same elevation as the higher elevation sources in Roche's (1969) study, and that the study site is at a higher elevation and lower latitude than the earlier study sites. Additional research is needed in this plantation to determine the relationship between height growth and phenological variables.

Variation in height of individual trees within the sources increased as the average height of the source increased (fig. 6). This reflects individual tree behavior, in that all trees in the faster growing sources were not tall. In fact, some were as short or shorter than trees from slower growing sources. It is possible that outstanding growth of some trees in northern seed sources may be attributed to hybrid vigor resulting from introgression of Engelmann and white spruce. Dietrichson (1971), for example, attributed the outstanding vigor of British Columbia sources planted in Norway to heterosis resulting from introgression of the two species. Before testing this hypothesis, however, additional research using techniques such as those described by Fowler and Roche (1977) will be required to determine if some of the sources included in this study are of hybrid origin.

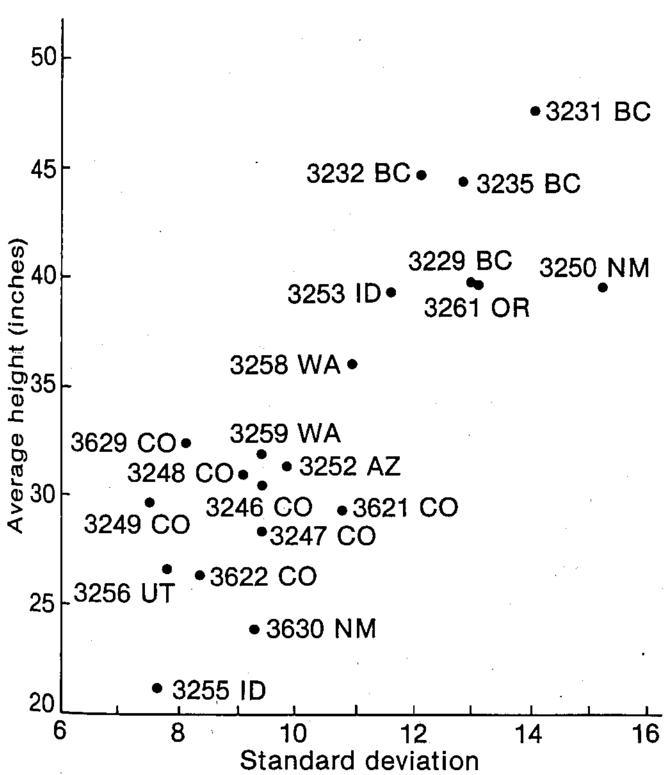

Figure 6.—Sources with taller average tree height exhibited greater variation in individual tree height.

A major factor contributing to the success of this plantation was the care taken in handling, planting, and shading each tree, and the replacement of shade during the subsequent biannual inspections. Continued protection and careful recordkeeping also contributed greatly to the success of this study.

This study demonstrates not only that Engelmann spruce planting stock may be improved genetically, but that the species can be successfully planted at high altitudes when proper procedures are carefully followed.

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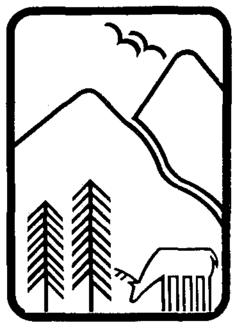
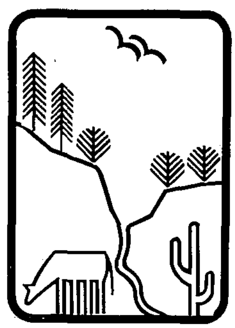
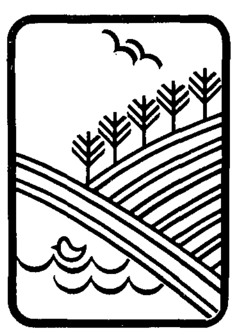


Rocky Mountains



Southwest



Great Plains

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