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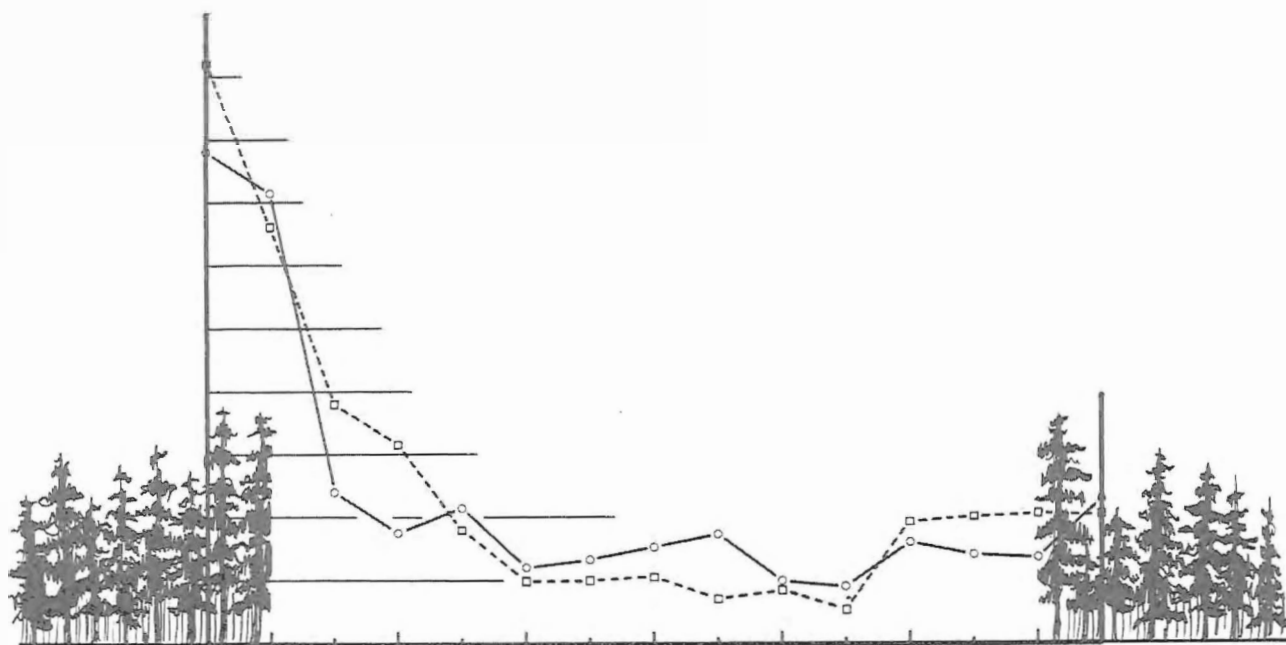
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Seedfall and Establishment of Engelmann Spruce in Clearcut Openings: A CASE HISTORY

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Seedfall and Establishment
of Engelmann Spruce in Clearcut Openings:

A CASE HISTORY

by

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Robert R. Alexander

Prompt establishment of new stands of spruce following timber harvesting is a major objective in the management of the Engelmann spruce-subalpine fir type in the central Rocky Mountains. Although planting has increased in the past decade and is expected to continue to increase, it will not be economically possible to plant at the rate at which spruce-fir forests will be cutover. Natural reproduction must therefore be depended upon to restock most clearcut areas.

An adequate supply of viable seed, a receptive seedbed, and an environment favorable to germination and seedling establishment are the basic elements necessary for successful natural regeneration. Most spruce regeneration problems have been thought to be related to environmental factors influencing germination and survival success. However, recent studies and observations have indicated that seedling establishment is limited to the margins of clearcut openings—usually 1 to 2 chains from seed source.² Rae and Schmidt³ reported similar results from a survey of seedling establishment in the spruce-fir type in the Intermountain Region; few seedlings became established at distances greater than 3 chains from the seed source.

If the limited distribution of seedlings on clearcut openings is the result of lack of viable seed, more information is needed on seed production and dispersal before spruce cutovers can be successfully restocked to natural reproduction. Good seedbed

situations and favorable environmental conditions are of little value if an adequate amount of viable seed is not available.

Engelmann spruce has been rated as a moderate seed producer. The seed is light and is dispersed long distances.⁴ Spruce seed production and dispersal have been studied in only a limited way in the Rocky Mountains, however.

In one of the earliest studies in Colorado, Bates and Roeser⁵ found that the average annual production on the White River Plateau for an 18-year period (1914-31) was 83,000 sound seeds per acre, while on the Uncompahgre Plateau, annual production for a comparable 15-year period (1914-28) averaged 350,000 sound seeds per acre. Large crops (100,000 or more sound seeds per acre) were produced on the White River only at 5- to 7-year intervals, with complete failures about every 2 years. On the Uncompahgre, large crops were produced every 2 to 4 years, with complete failures at about 3-year intervals.

Boe⁶ analyzed seed records in Montana between the years 1908 and 1953. He reported data separately for the areas east and west of the Continental Divide. West of the Divide, 22 crops observed during the 45-year period were rated as 5 good,

⁴Alexander, Robert R. *Silvical characteristics of Engelmann spruce*. U.S.D.A. Forest Serv. Rocky Mt. Forest and Range Exp. Sta. Sta. Pap. 31, 20 pp., illus. 1958. (Fort Collins, Colo. 80521)

⁵Bates, C. G., and Roeser, J. *Investigative reports for the Rocky Mountain Region*. U.S.D.A. Forest Serv. Rocky Mt. Forest and Range Exp. Sta. Mimeo. Rep., 72 pp. 1933. (Fort Collins, Colo. 80521)

⁶Boe, K. N. *Periodicity of cone crops in five Montana conifers*. Mont. Acad. Sci. Proc. 14: 5-9. 1954.

²Unpublished data on file at Rocky Mountain Forest and Range Exp. Sta., U.S.D.A. Forest Serv., Fort Collins, Colo. 80521.

³Roe, A. L., and Schmidt, W. C. *Factors affecting natural regeneration of spruce in the Intermountain Region*. U.S.D.A. Forest Serv. Intermountain Forest and Range Exp. Sta. Mimeo. Rep., 68 pp., illus. 1964. (Ogden, Utah 84401)

8 fair, and 9 poor. East of the Divide, seed production was considerably poorer: only 2 good, 4 fair, and 15 poor crops were reported for a 21-year period. Throughout Montana, 1926 and 1952 were exceptionally good spruce seed years, but only the 1952 crop was heavy throughout the Rockies.

Squillace⁷ estimated that about 953,000 seeds per acre were produced in 1952 in an uncut stand along the perimeter of a large clearcut area in western Montana. Furthermore, he showed that a substantial number of sound seeds (60,000 per acre) were dispersed as far as 9 chains from the timber edge. However, this wide dispersal was during an infrequent "bumper" seed year. Seed crops produced in the other 4 years of his study (1949, 1950, 1951, 1953) were considered failures.

Roe⁸ studied seed production and dispersal on three areas in the Intermountain Region. Production in uncut stands along the edge of clearcut openings in a good seed year (1964) ranged from 200,000 to 2 million sound seeds per acre. Although large quantities of seed were released at the timber edges, less than 5 percent were dispersed as far as 10 chains into the openings. The pattern of seed dispersal was quite similar on all areas, except for quantitative differences that were attributed to differences in seed sources.

Current studies of seed production and dispersal on five National Forests in Colorado⁹ show that average seedfall in uncut stands along the perimeters of clearcuts, 1962-66, could be rated good about 1 out of the 5 years. Furthermore, most of the seed dispersed into the clearcut openings fell within 1 chain of the source.

Study

This paper reports the results of a study of seed production, dispersal, and seedling establishment after clearcutting in the spruce-fir type on Fool Creek, Fraser Experimental Forest, Colorado.

⁷Squillace, A. E. *Engelmann spruce seed dispersal into a clearcut area*. U.S.D.A. Forest Serv. Intermountain Forest and Range Exp. Sta. Res. Note 11, 4 pp., illus. 1954. (Ogden, Utah #4401)

⁸Roe, Arthur L. *Seed dispersal in a bumper spruce seed year*. U. S. Forest Serv. Res. Pap. INT-39, 10 pp., illus. 1967. (Intermountain Forest and Range Exp. Sta., Ogden, Utah #4401)

⁹See footnote 2, p. 1.

Description

The study was located in two 6-chain-wide clearcut openings—each approximately 3.5 acres in size—at 10,500 feet elevation. All trees 4.0 inches d.b.h. and larger had been removed in logging. To eliminate any internal seed source, residual trees large enough to bear cones were also cut on the study areas after logging was completed in 1956.

One opening is on a gentle north-facing slope; the other on a moderate northwest slope. Wind records taken at 10,500 feet on the west ridge of Fool Creek indicate that the prevailing winds in the study area are from the west and southwest. The openings are oriented approximately at right angles to these winds.

The uncut stand of timber adjacent to the clearcut openings is mature to overmature—250 to 300 years old—Engelmann spruce (*Picea engelmannii* Parry) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), intermixed with various amounts of old-growth lodgepole pine (*Pinus contorta* Dougl.). Spruce makes up about 60 to 80 percent of the basal area in trees 10.0 inches d.b.h. and larger.

Methods

Quantity of seed produced and distance of dispersal were measured with seed traps. In each clearcut opening, fifteen 0.25-milacre seed traps were placed along each of two parallel transect lines about 2 chains apart and approximately at right angles to the windward timber edge. The traps in each transect were placed at 0.5-chain intervals beginning 0.5 chain into the uncut stand on the windward edge of the openings and ending 0.5 chain into the uncut stand on the leeward side (fig. 1). The placement of traps permitted an estimate of (1) seed production in the uncut timber stand and at the timber edge on both the windward and leeward sides of the openings, and (2) seed dispersal at intervals across the openings.

Seed trap contents were collected in early summer annually, 1956-65. All seeds collected were cut to determine soundness. Only filled seeds that appeared to be sound were counted.

Seedling survival in each opening was measured on 52 plots. Paired milacre quadrats were established at each seed trap location except in the uncut stands. One randomly selected quadrat of each pair was scarified to mineral soil; the other

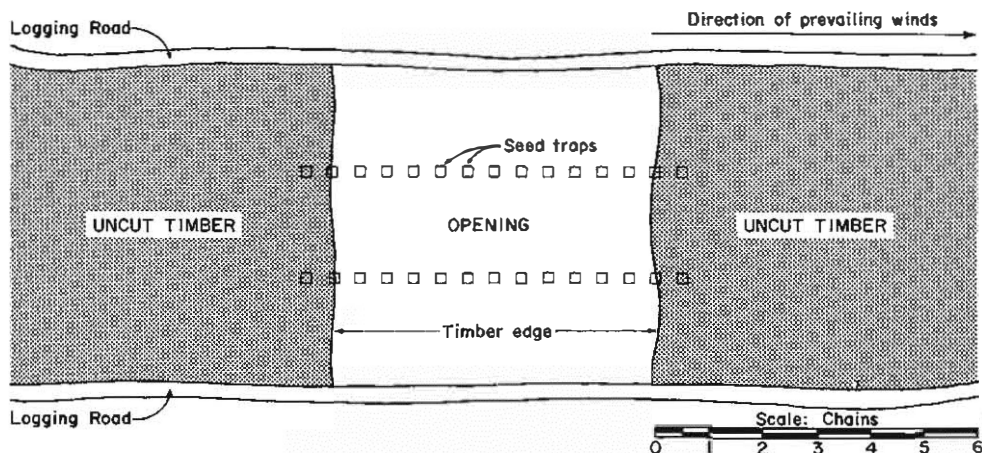


Figure 1.--Diagrammatic sketch of study plot layout.

was left untreated as a control. Seedlings were counted annually in the late summer beginning in 1958. Only seedlings that had survived 2 growing seasons were tallied. Seedlings were not marked to indicate the time of establishment; seedlings surviving at the time of the last tally in 1967 varied, therefore, from 2 to 12 years of age.

Analysis of Data

Annual seed count data for each aspect were stratified into fifteen 0.5-chain-wide zones, beginning 0.5 chain into the timber stand on the windward side of the openings. Seed count data were plotted by 0.5-chain intervals for (1) individual years—when enough seeds were caught to make comparisons, (2) the 10-year (1956-65) average, and (3) the average for the three most productive years (1959, 1961, and 1963). No differences were apparent between aspects in either the quantity of seed produced or the amount of seed dispersed into the openings (figs. 2, 3).

The number of seeds caught under stands—leeward and windward sides of the openings on both aspects—was compared with the number, basal area, and average diameter of all spruce trees 10.0 inches d.b.h. and larger growing in those stands. No significant relationship could be established, however, between the quantity of seeds caught under the timber stands and any of the variables measured to characterize the seed source.

Seedling survival data for 1967 from each study area were stratified into thirteen 0.5-chain-wide

zones, beginning at the windward timber edge. Only data from the scarified seedbeds were used because too few seedlings became established on the control plots to make any comparisons. The number of seedlings and percent of stocked microsites were plotted over zones. The resulting scatter diagrams indicated that there were no substantial differences in seedling survival data between the two areas.

Those preliminary tests suggested that the seed count and seedling survival data from the two aspects could be combined. The combined data were stratified as before. Differences in seedfall and number and stocking of seedlings between zones were tested by analysis of variance and Duncan's multiple range tests with appropriate transformations.

To estimate seed dispersal in relation to seedfall under stands and distance and direction from source, the seed count data for 1959, 1961, and 1963—seedfall was too light or erratic to determine the dissemination pattern in other years—were plotted over distance from windward source by 0.5-chain intervals. Smooth curves were fitted to the resulting distribution for each of the 3 years.

Results and Discussion

Seedfall

Production (under stands).—Numbers of sound spruce seed caught under stands appeared to be

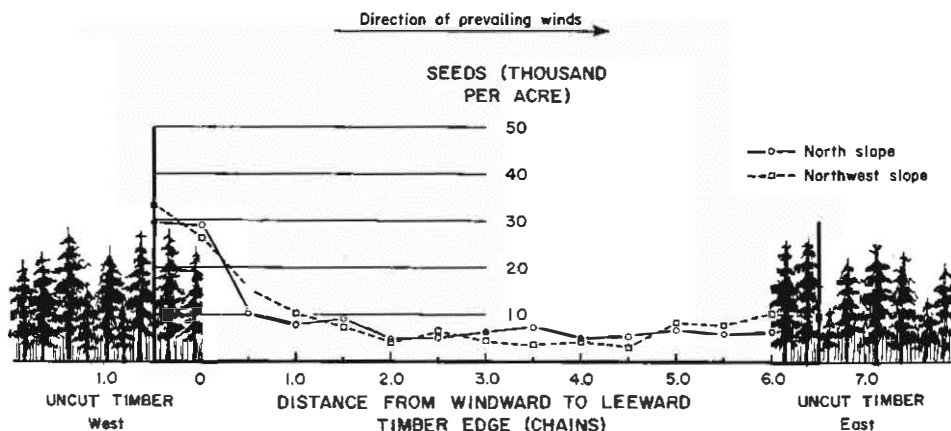


Figure 2.--
Average 10-year
dispersal of sound
Engelmann spruce
seeds into clear-
cut openings on N
and NW aspects
in relation to
distance from wind-
ward timber edge.

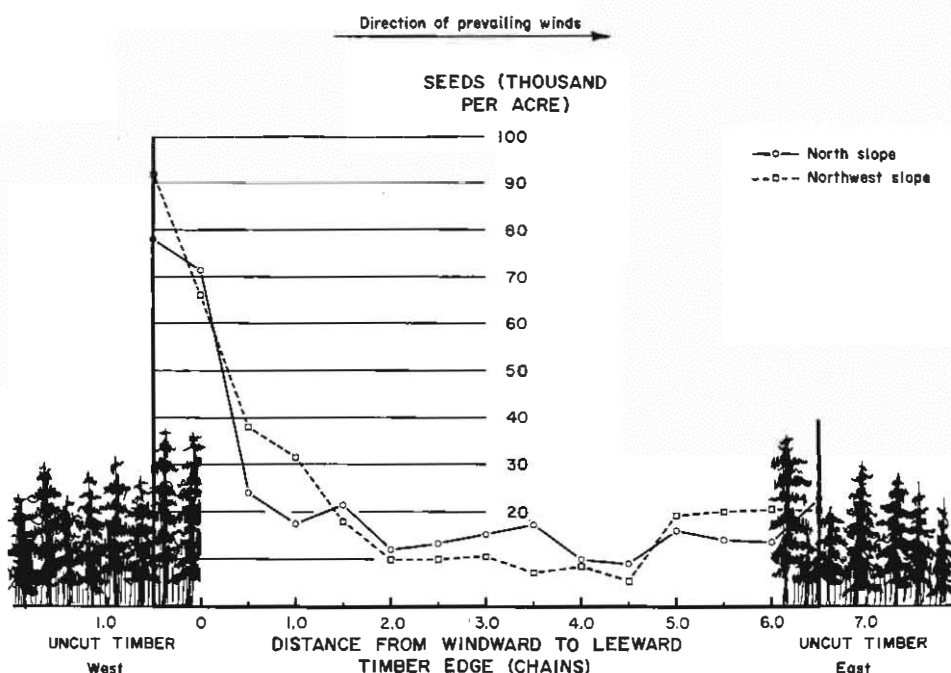


Figure 3.--
Average number of
sound Engelmann
spruce seeds dis-
persed into clear-
cut openings on N
and NW aspects
during the three
most productive
years in relation
to distance from
windward timber edge.

influenced more by the location of the stand with respect to prevailing winds than by any measured characteristic of the seed source. Average seed production was significantly greater under the stand on the windward side of the openings in years of both high and low seed production (table 1). Since traps were placed only 0.5 chain into the timber stands, fewer seeds caught under the leeward stand probably reflects the influence of wind movement across the openings; wind probably blew some seeds away from the leeward edge of the openings. Esti-

mates of seed production under stands are based, therefore, on seedfall under the windward stand.

During the 10-year period 1956 through 1965, total under-stand seedfall was 321,000 sound seeds per acre. Annual seedfall varied considerably from year to year (table 1). The 1961 seed crop contributed about 40 percent of the total under-stand seedfall. Moderate crops (50,000 to 100,000 sound seeds per acre) were produced in 1959 and 1963. In the other 7 years of the study, seed crops were rated poor to nearly complete failures.

Table 1.--Average sound spruce seedfall under and at the edge of the timber stands adjacent to clearcut openings, Fool Creek study area, Fraser Experimental Forest, Colorado, 1956-65

Year	Windward side		Leeward side	
	Under stand	Timber edge	Under stand	Timber edge
- - - - - Number per acre - - - - -				
1956	6,000	2,000	2,000	7,000
1957	6,000	10,000	0	3,000
1958	24,000	10,000	17,000	8,000
1959	64,000	55,000	23,000	24,000
1960	12,000	19,000	6,000	6,000
1961	133,000	128,000	25,000	23,000
1962	6,000	5,000	0	1,000
1963	55,000	24,000	18,000	5,000
1964	13,000	15,000	6,000	6,000
1965	2,000	2,000	0	1,000
Average	32,100	27,000	9,700	8,400

Dispersal (into openings).—Seed dispersal was influenced by the size of seed crop, distance from source, and direction and velocity of prevailing winds.

Seedfall into the clearcut openings was greater in years of heaviest seed production. About 35 percent of the total number of seeds falling to the ground in the openings were dispersed in 1961. An additional 35 percent were dispersed in the moderate seed years of 1959 and 1963.

Seedfall was not uniformly distributed over the openings, but decreased in an exponential manner as distance from source increased. Furthermore, most of the seed falling to the ground in the openings appeared to have been dispersed from the stand on the windward timber edge. About half of the total number of seeds dispersed during the 10-year period, and in each of the 3 years of moderate to good seed production, fell within 1.5 chains of the windward edge. Seedfall then either leveled off or gradually continued to diminish until about two-thirds of the way across the openings. The average number of seeds falling at that distance from source was about 10 percent of the under-

windward-stand seedfall, regardless of the size of the seed crop. Beyond 4.5 chains, seedfall gradually increased until the leeward timber edge was reached (fig. 4).

The numbers of sound seed falling to the ground between windward timber edge and 1.5 chains into the openings decreased most rapidly in 1961—the year of highest seed production—but between 1.5 and 4.5 chains, the slope of the 1961 seed dispersal curve was similar to the 1959 curve (fig. 5). That suggests that differences in seedfall between windward timber edge and 4.5 chains in 1959 and 1961 were largely associated with differences in seed production.

Seed production was similar in 1959 and 1963, but seedfall in 1963 decreased more rapidly between windward timber edge and 1.5 chains into the openings (fig. 5). Furthermore, about the same amount of seed fell to the ground at 4.5 chains from source in 1963 as fell at 1.5 chains. Differences between seed dispersal curves for 1959 and 1963 suggest that velocity and perhaps direction of winds were different at the time seed was shed.

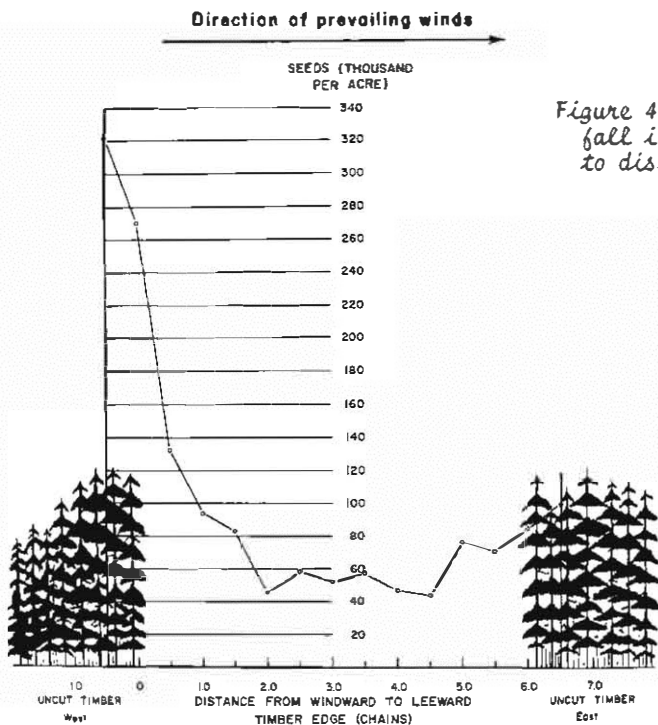


Figure 4.--Total 10-year Engelmann spruce seedfall into the clearcut opening in relation to distance from windward timber edge.

Fewer, but satisfactory, numbers of seedlings became established within 1 chain of the leeward timber edge (fig. 6). About one-fifth of the total seedfall into the opening occurred here. Those seedbeds were also shaded part of the time by the leeward timber stand, but they were exposed to the prevailing winds.

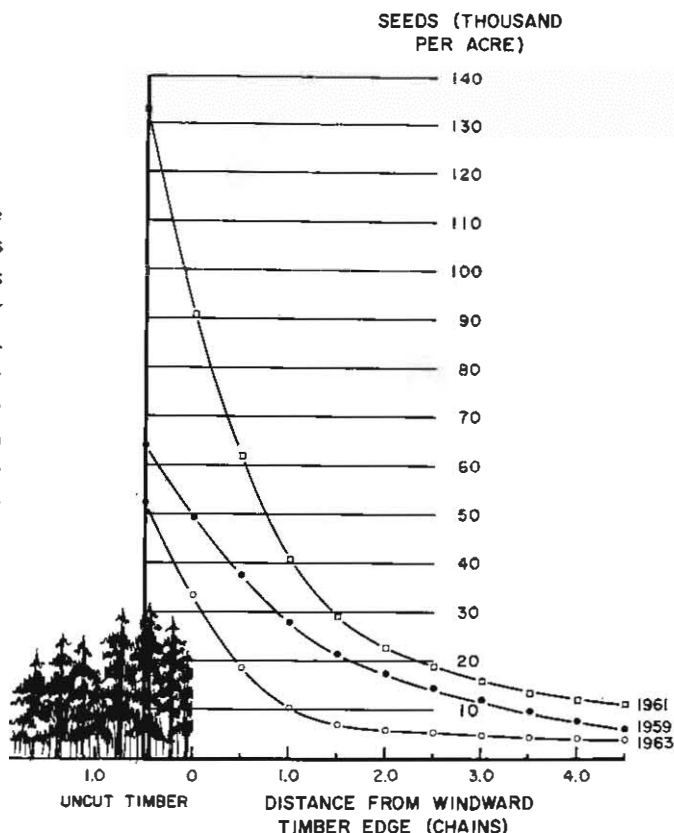
In the clearcut openings—between 1 and 5 chains from the windward edge—the number of surviving seedlings per acre ranged from 0 to 1,000, but only two zones contained more than 250 seedlings per acre (fig. 6). Fewer seeds fell into the openings beyond 1 chain from standing timber, and seedbeds located there were exposed to more adverse environmental conditions.

Seedling Survival

Number of spruce seedlings 2 years old and older surviving in 1967 were related to quantity of 10-year seedfall into the clearcut opening, seedbed type, and environmental conditions.

Seedlings survived in significant numbers only on scarified seedbeds. Furthermore, seedlings were largely confined to the margins of the openings (fig. 6). The largest number of seedlings was established within 1 chain of the windward timber edge where nearly half of the seed dispersed fell. Those seedbeds were also protected from the prevailing winds and shaded part of the time by the trees along the windward timber margin, which created an environment more favorable to germination and establishment than elsewhere in the openings.

Figure 5.--Estimated Engelmann spruce seedfall from windward timber edge to 4.5 chains into the opening for years of significant seed protection.



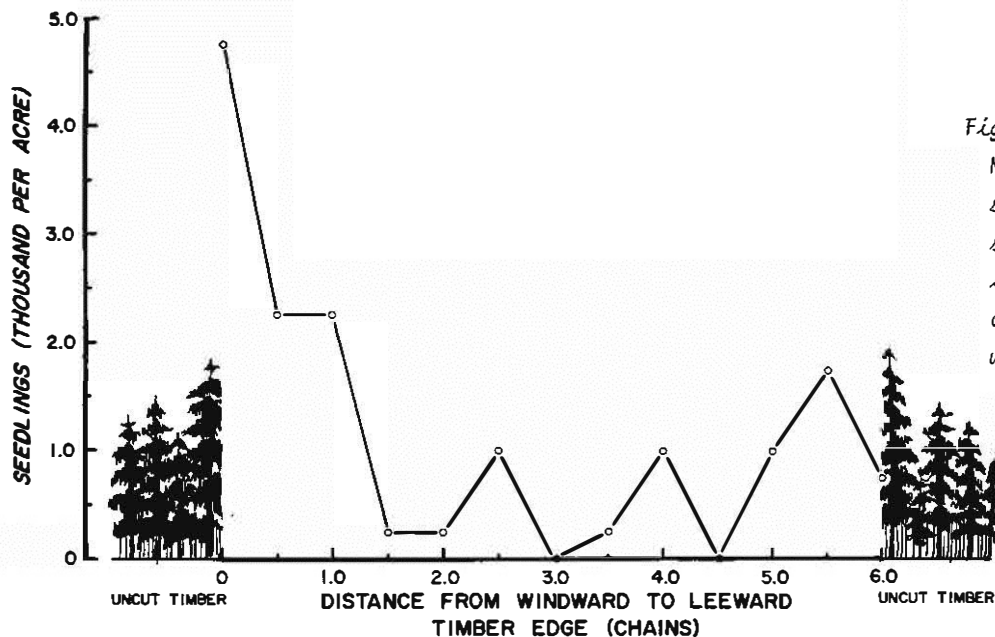


Figure 6.--
Number of Engelmann
spruce seedlings on
scarified seedbeds
in relation to
distance from wind-
ward timber edge.

The number of stocked milacres on scarified seedbeds was greater near the seed source where seedlings were more abundant. Fifty percent or more of the milacre plots within 1 chain of standing timber were stocked with from two to six seedlings. Beyond 1 chain from the timber edge, only two zones were more than 25 percent stocked, and none of the stocked milacres in those zones contained more than one seedling.

Seedlings did not become established on undisturbed seedbeds; only three out of 52 plots were stocked after 10 years, and each contained only one seedling.

Few spruces 2 years old and older became established on scarified seedbeds until 1961, when a large number of new seedlings from the 1959 seedfall survived the second growing season (fig. 7).¹⁰ Many of those seedlings were not alive, however, at the end of the next growing season. There were small increases in seedling numbers in 1963 and 1964 from seed cast in 1961, but losses incurred in 1962 were not recovered. Seeds cast in 1963 produced few second-year seedlings, and

the number of surviving seedlings gradually decreased after 1964, although seedling density was the same on all plots in the last 2 years of the study.

Large numbers of seed cast in 1961 and in 1963 were observed to germinate on scarified seedbeds, but most did not survive the first growing season. Although no weather records are available from the study areas, the survival data suggest that climatic conditions after the 1959 seedfall were more favorable to establishment than after seedfall in either 1961 or 1963. Furthermore, seedbed conditions on scarified plots were not as favorable to regeneration success after the 1961 and 1963 seedfall because of the increased competition from herbaceous vegetation.

Stocking to spruce was related to seedling density the first few years of observation, but stocking in 1967 was about the same as in 1961. The yearly variation in seedling density after 1961 generally resulted in changes in the number of seedlings per stocked milacre, but not in the number of stocked milacres.

Conclusions

Seed crops did not occur on Fool Creek with the same frequency observed elsewhere. Only

¹⁰The number of seedlings by years in figure 7 is for the scarified plots at the windward timber edge. Those plots were chosen to illustrate yearly variation because of the large number of seedlings, but the trend was the same on other scarified plots where seedlings became established in significant numbers

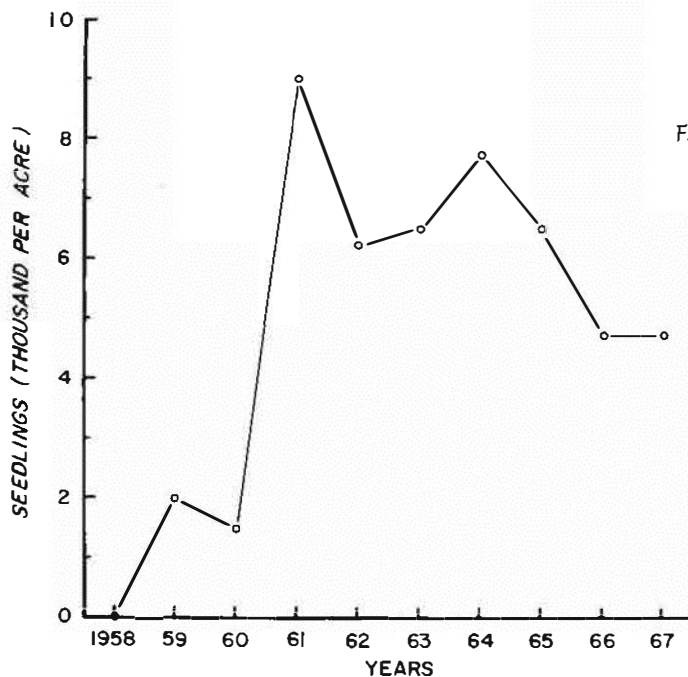


Figure 7.--Number of Engelmann spruce seedlings on scarified seedbeds at the windward timber edge in relation to years.

one good crop was produced in 10 years, and even moderate crops occurred at 4-year intervals. Seed production in other years was so low that for practical purposes it can be ignored. Infrequent seed crops means that natural reproduction cannot be expected every year.

Although most seed fell within 1.5 chains of the standing timber, sound seeds in considerable quantities were dispersed across the 6-chain-wide openings in years of moderate to good seed production. The pattern of seedfall was similar in those years, except for the quantitative differences largely associated with differences in the amount of seed produced and in wind movement across the clearings at the time seed was shed. Similar seed dispersal has been observed elsewhere in Colorado. That suggests that the pattern of spruce seedfall into clearcut openings in the central Rocky Mountains is influenced by the direction of prevailing winds as well as distance from source.

An ample seed supply is of little value, however, when seedbed or environmental conditions limit regeneration success. Seed in significant quantities and favorable seedbed conditions did not result in satisfactory restocking in the openings beyond the margins of standing timber; virtually no reproduction became established on unprepared seedbeds, even along the margins of openings where seed

was available in considerable quantities and environmental conditions appeared to be favorable.

Scarification, aimed at increasing the suitability of the seedbed for seedling establishment by reducing competition, was not as effective as expected. Overall, however, scarification increased both stocking and numbers of seedlings, even though most of the seedlings were confined to the margins of the openings—where other environmental conditions also favored regeneration success.

No recommendations can be made concerning the size of opening that will restock to natural reproduction, or the cultural practices and protective measures needed to encourage seedling establishment. This study suggests however, that (1) seed supply is not the factor limiting regeneration success in small openings; (2) some form of seedbed preparation—at least the removal of heavy accumulations of duff and litter—is needed to encourage seedling establishment, and (3) if new seedlings are to survive, they must be protected from adverse environmental factors such as intense solar radiation and high temperatures, low temperatures and frost heaving, and drying winds.

Considerably more information is needed on germination and survival under different combinations of seedbed and environment to provide estimates of the probability of seedling establishment. Additional data are also needed on the amount of seed produced, periodicity of seed crops, and dispersal distances to work out relationships between seed supply and size of opening. Once estimates of seed supply and the number of seeds required to provide an established seedling are available, the size of opening that will restock to natural reproduction can be determined for a variety of conditions.

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