

Seed Dispersal of Engelmann Spruce in the Intermountain West

Abstract

The amount and distance Engelmann spruce seed dispersed into openings was found strongly related to total seed production and quantity of spruce basal area in the adjacent windward stand. This study, conducted at 10 locations in the Intermountain West, showed that spruce seeds were dispersed as far as 201 m from the windward edges of openings, but the amount of seed decreased rapidly from 0 to 120 m. At 120 to 201 m from seed source, the number of dispersed seeds stabilized at a low level. Nearly 95 percent of all spruce seeds dispersing into openings fell within 120 m of the windward seed source. Two models were developed to illustrate these dispersal characteristics. Seed dispersal information is an important factor in making knowledgeable decisions concerning natural and artificial regeneration in the spruce forest type.

Introduction

Insufficient stocking of Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) natural regeneration on cutover areas has been a persistent problem in the Intermountain area since the 1950's. Cone production varies by year, and even in the best cone producing years, seed production can be reduced by cone and seed insects, rodents, birds, and other natural factors such as frost (Roe and Schmidt 1964, Schmidt *et al.* 1976, Shearer 1959). Even large numbers of first-year germinants resulting from heavy seed crops do not guarantee sufficient spruce establishment. Most established seedlings are usually found near timber edges rather than farther into openings (Noble and Ronco 1978).

Seed-dispersal information provides us with knowledge of how much and how far spruce seed disseminates from a source. Reliable dispersal information and a knowledge of seed:seedling ratios on varying site conditions help silviculturists make sound biological decisions concerning size and shape of cutting areas. Seedling ratios vary considerably in relation to seedbed condition and environmental and biotic factors (Alexander 1983).

The amount and distance of Engelmann spruce seed dissemination was largely unknown in the Intermountain area when this study was initiated. First-year results from a bumper seed crop indicated that quantity of sound spruce seed dispersed into Intermountain clearcuts decreased

rapidly as distance from the seed source increased, and then remained at low levels (Roe 1967). Because the data were from a single bumper seed crop, dispersal equations developed by Roe (1967) provide a much higher estimate of the quantity of spruce seed dispersed into clearcuts than yearly averages would indicate. Spruce produce good to bumper seed crops about once every 2 to 10 years depending on geographical location (Boe 1954, USDA in press).

The inverse relationship of seed dispersed in relation to distance from the seed source has been quantified for Engelmann spruce in the southern Rockies by Noble and Ronco (1978) and Alexander and Edminster (1983). White spruce (*Picea glauca* [Moench] Voss) and black spruce (*Picea mariana* [Mill.] B.S.P.) seed dispersal information is available for the northern Rockies in Canada by Dobbs (1976) and Payendeh and Haavisto (1982), respectively. This paper reports seed dispersal information for Engelmann spruce in the Intermountain area.

Methods

This study, designed to investigate seed dispersal characteristics of Engelmann spruce, was established on five National Forests in the Intermountain area—the Ashley, Dixie, and Uinta in Utah, the Teton (now Bridger-Teton) in Wyoming, and the Payette in Idaho. Ten study sites—one clearcut on each of two districts on each National Forest—were used to examine the seed dispersal.

Traps were used to collect spruce seeds dispersed in the uncut timber and into clearcuts. Seed traps were rectangular boxes approximately 0.61 m wide, 0.91 m long, and 10.2 cm deep. Each trap was covered on top by metal hardware cloth, which allowed spruce seed to fall into the traps, and by a tightly woven screen on the bottom, which held seeds in the trap but allowed air to flow through for drying seeds.

At each study site, two parallel rows of seed traps with 10 traps in each row were approximately 40 m apart at right angles to the windward timber edge (Fig. 1). The first seed trap in each row was 20 m inside the windward timber edge, and the second trap in each row was at timber edge. In each row, seed traps three to eight were placed at 20 m intervals into the clearcut from the timber edge, and traps 9 and 10 were placed at 40 m intervals beyond trap 8.

Dispersed seeds for the seed years of 1965 through 1968 were collected the spring following fall and winter seedfall. Collected seeds were cut and examined for soundness. Quantity of spruce seed on a per-hectare basis was calculated by multiplying the number of sound spruce seeds found in each trap by a per-hectare conversion factor. All further references to seed in this paper will be for sound spruce seed.

Stand basal area of Engelmann spruce was used as a measure of the seed production capability of the spruce seed source within the windward stand. Basal area values in square meters per hectare were determined for spruce trees 25.4 cm and larger in diameter at breast height (dbh). Spruce trees of this size were assumed to be sufficiently mature to produce seed. Basal area values for the 10 study locations ranged from 3.9 m² per ha up to 45.9 m² per ha (Table 1).

Data from all 10 study sites were combined to develop a seed dispersal model for Engelmann spruce, applicable to the Intermountain area. Seed dispersal data from individual study sites were pooled because of a large amount of yearly variation within and between study areas. We assumed that 1965 to 1968 represented an average four-year period because seed crops ranged from failure to bumper. Seed crop production was good in 1965, a failure in 1966, bumper in 1967, and fair in 1968. The four-year average number of spruce seeds found in each seed trap on a per-

hectare basis was used as a measure of expected seed dispersal.

TABLE 1. Engelmann spruce basal area in the windward stand at each study area location.

National Forest	Location name	Basal area (m ² /ha)
Ashley	North Brownie Creek	3.9
Ashley	Paradise Peak	15.2
Dixie	Griffin Top	13.1
Dixie	Midway Summit	45.9
Payette	Corral Creek	26.6
Payette	Fisher Creek	8.3
Bridger-Teton	Mosquito Creek	6.2
Bridger-Teton	Togwotee	44.3
Uinta	Cold Springs	15.6
Uinta	Hidden Lake	20.7

Stepwise regression techniques were used to develop a seed dispersal model that best explained dispersal of spruce seeds into openings from the windward timber. Other dependent and independent variables tested during the development of a seed dispersal model include the following:

Dependent—The natural logarithm of the four-year average number of spruce seeds that dispersed into clearcuts at specific distances from the windward edge.

Independent—The number of spruce seeds that fell into seed traps 20 m inside the windward stand edge.

—The natural logarithm of the distance each seed trap was located from the windward stand edge.

The constant 40.2 m was added to all measurements in the analyses to avoid negative or zero distance values for traps at 1 chain into the timber and at timber's edge, respectively. The standard regression model used was:

$$Y = b_0 + b_1X_1 + b_2X_2 + \dots + b_nX_n$$

Results and Discussion

Seed dispersal of Engelmann spruce into openings in this Intermountain area was positively correlated with spruce basal area and with the quantity of spruce seeds dispersed at the windward stand edge, and was negatively correlated with distance from seed source. These results

correspond with other findings from this Inter-mountain area (Roe 1967; Shearer 1985). A similar Colorado study also showed that numbers of sound spruce seeds falling at different distances into openings was highly correlated with distance from the source and the amount of seed falling under the uncut stand (Alexander and Edminster 1983). Measures of the spruce seed source were not used in the Colorado seed dispersal models, but estimates of seed production were examined on the basis of live crown and basal area of dominant and codominant spruce (Alexander *et al.* 1982).

In this study, the basal area of the spruce seed source was a strong determinant of the amount of seed dispersed (Fig. 2). For example, doubling the spruce basal area of the seed source from 15 to 30 m² quadruples the amount of seed dispersed at the timber edge. This relationship of basal area to seed dispersal held true at all distances up to 200 m from the windward seed source. However, in Colorado Noble and Ronco (1978) found no correlations between seed production and basal area, but they did find a positive relationship of seed production in the windward seed source with number of seeds dispersed at all distances from the source. They related differences in seed numbers at different distances to the quantity of seed produced in the adjacent stand, but not to the spruce basal area.

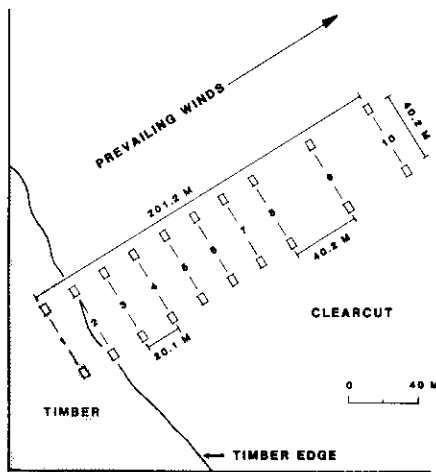


Figure 1. Seed trap locations in relation to windward stand edge—Engelmann spruce seed dispersal study.

Seed dispersal patterns show that as distance from the seed source increases, quantity of spruce seed decreases. In this study, Engelmann spruce seed was found to disperse up to 201 m from the windward edges of openings, but the quantity of sound seed decreased rapidly from 0 to 120 m from the windward stand edge and then remained at low levels or decreased slightly from 120 to 201 m. Almost 70 percent of all seed that dispersed into openings fell within 30 m and 95 percent fell within 120 m. This is similar to findings in the central Rocky Mountains where about 67 percent of the spruce seed dispersing into openings fell within 30 m of the windward stand edge and nearly 95 percent fell within 107 m (Alexander and Edminster 1983). This rapid decline in seedfall leveled off with only 1 percent of the spruce seeds falling under uncut stands dispersing as far as 183 m from the windward stand edge. In another Colorado study, about 50 percent of the seeds falling into clearcuts fell within 30 m of the windward edge (Noble and Ronco 1978). Numbers of seeds continued to decrease for a distance of 60 to 80 m from the windward stand edge, and then leveled off in the wider openings.

Two dispersal models were developed from these data to predict the number of spruce seeds that disperse into openings at varying distances from a windward seed source. The three-variable model requires a measure of spruce basal area and number of seeds dispersed at the windward edge, but the two-variable model only needs the basal area of the spruce seed source. Both models estimate the quantity of sound spruce seeds that can be expected at varying distances from a seed source. Yearly variation in seed-crop size is unaccounted for in the two-variable model. The quantity of spruce seeds dispersed is the expected yearly average over 4 years. The models and descriptions of the variables are shown for the three-variable and the two-variable models:

Three-variable model:

$$Y = [36.4481 + 0.0194 (T * 1/D) + 350.5242 (B * 1/D)]^2$$

$$R^2 = .84; \text{MSE} = 19312.56; n = 190$$

Two-variable model:

$$Y = [38.1525 + 792.3007 (B * 1/D)]^2$$

$$R^2 = .69; \text{MSE} = 36317.32; n = 190$$

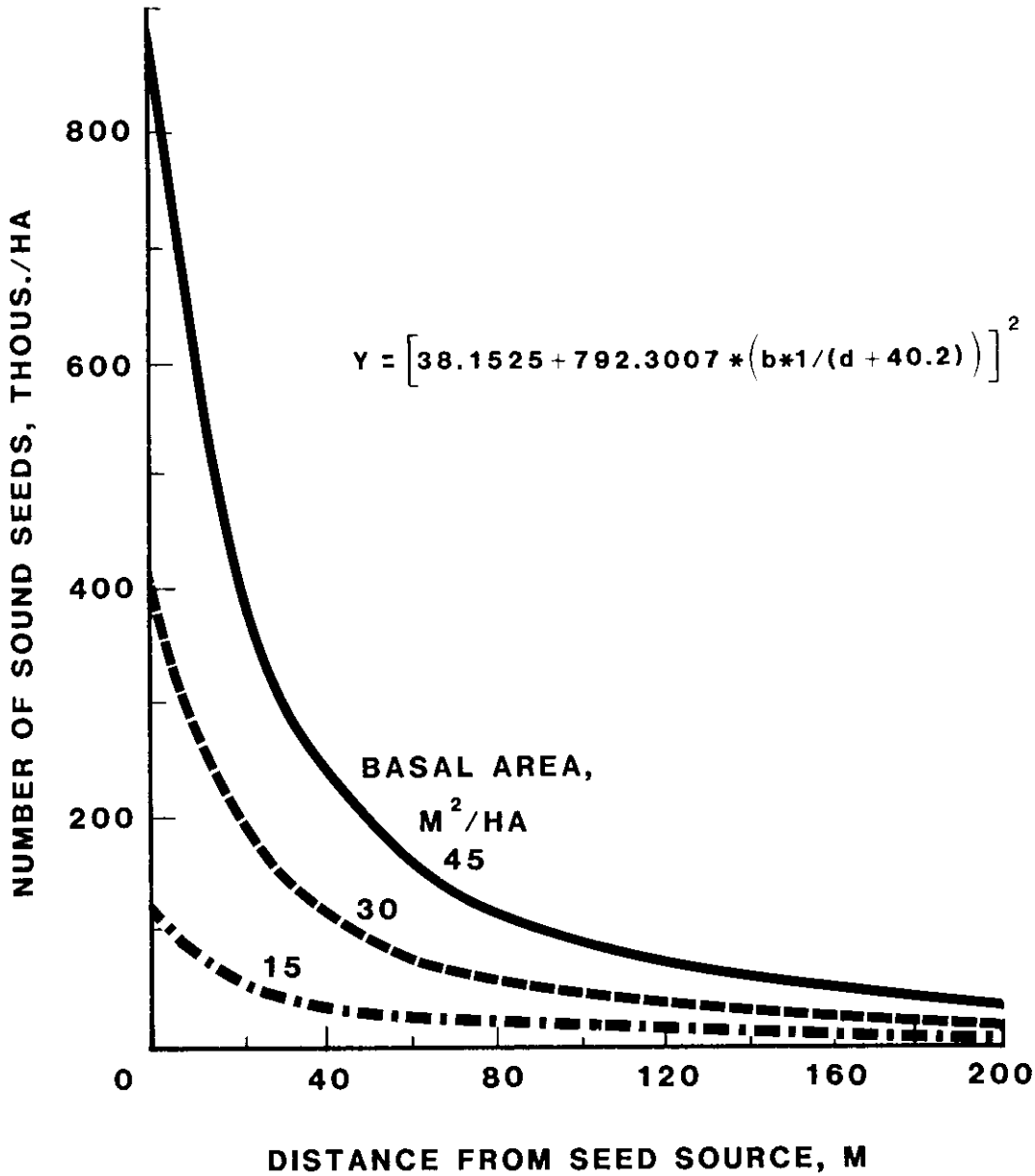


Figure 2. Seed dispersal patterns of Engelmann spruce at different distances from the seed source in relation to basal area of windward stand.

Variables:

Y = The 4-year average number of spruce seeds that disperse into clearcuts at specific distances from the windward stand edge.

B = The stand basal-area-per-hectare value of spruce trees in the windward timber that are 25.4 cm or larger at d.b.h.

T = The number of spruce seeds per hectare dispersed at the windward stand edge.

D = The distance each seed trap is located from the windward stand edge plus 40.23 m.

MSE = Regression mean square error.

n = Number of observations.

Table 2 was developed from the two-variable equation to show estimates of the number of spruce seeds dispersing into openings in relation to the basal area of spruce in the windward stand. The high mean square error indicates that a large amount of variability is not accounted for by the variables within the models.

The three-variable model provides a good prediction of seedfall into openings when spruce basal area of the windward stand and the amount of seed falling at timber edge are known. Its primary advantage over the two-variable model is that it adjusts for seedfall of a particular year. Simply measuring the basal area of spruce trees 25.4 cm and larger and reading seed traps at timber edge provide a good estimate of how much seed was dispersed at varying distances from timber edge. The primary disadvantage of the three-variable model is that it is a measure after seedfall.

The simpler two-variable model also has advantages and disadvantages. On the advantage side, it requires only a measurement of the basal area of spruce 25.4 cm and larger to provide an estimate of what might be expected in terms of amounts and distances of seed dispersal for an average year. As such, it provides an approximation before the fact, while the three-variable model depends on some measure of seed production for a given year. The primary disadvantage of the two-variable model is that it does not provide a good estimate for any given year, rather just an average. This is particularly important when predicting dispersal from a bumper seed crop.

There was no attempt in this study to measure seed dispersal from the leeward edge of cuttings nor to relate the quantity of sound spruce seeds to the number of resulting seedlings.

Knowledge of seed dispersal is an important factor in making defensible decisions concerning natural regeneration in the spruce forest type. Seed dispersal information coupled with knowledge of seed:seedling ratios for specific site conditions help managers in decisions on cutting shape and timing and method of site preparation. For example, Colorado studies (Alexander 1983) showed that, depending on site conditions, it may take from 32 to 417 spruce seeds to obtain one five-year-old spruce seedling. Seedling establishment of spruce is generally higher on scarified than on nonscarified sites (Alexander 1984, Fiedler and others 1985). Estimates of the quantity of seed dispersed at varying distances from the seed source and the seed:seedling ratios for various site preparation methods may suggest intensive scarification at the center of a clearcut and practically none near timber edge. It may also show that a large proportion of a proposed clearcut holds little prospect for successful natural regeneration, and that artificial regeneration will be needed if the manager proceeds with the cutting. As a result, both natural and artificial regeneration costs can be minimized by selecting proper silvicultural practices. Seed dispersal information helps make these silvicultural determinations.

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TABLE 2. Predicted number of spruce seeds dispersed into openings at selected distances from the windward edge of stands of different basal area (estimates from two-variable model¹).

Windward stand basal area (m ² /ha)	Distance from windward stand edge (meters)						
	0	40	80	80	120	160	200
	----- Thousands of seeds per hectare -----						
5	19	8	5	4	3	3	
15	111	35	19	13	10	8	
25	281	81	41	26	19	15	
35	529	147	72	45	31	24	
45	855	233	112	68	47	35	

¹Y = [38.1525 + 792.3007 (B * 1/(D + 40.2))]².

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