Inhibiting Effect of Ponderosa Pine Seed Trees on Seedling Growth

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ABSTRACT—Ponderosa pine seed trees, numbering 4, 8, and 12 per acre, were left standing for 9 years after harvest cutting on the Challenge Experimental Forest, Calif. Seedling heights were measured at ages 5, 9, and 14, and for all ages were poorest if within 20 feet of a seed tree. Seedlings 20 feet or less from a seed tree at the ages given lost the equivalent in years of height growth: 5(4.1); 9(6.8); 13(10.6). Seed-tree density greatly affected seedling height—the greater the density, the poorer the height growth. The inhibitory effect of the seed trees extended outward at least 40 feet, and persisted 4 years after their removal.

The seed-tree cutting method is a desirable even-aged alternative to clearcutting for many species and situations. The method has particular appeal to owners of small forest parcels who often do not have capital for artificial regeneration or for buying and planting trees. Many of them will depend on natural regeneration. An effective way of achieving adequate regeneration in young-growth ponderosa pine (*Pinus ponderosa* Laws.) stands in north central California is to apply the seed-tree cutting method (Corbett 1962).

Once stocking reaches or exceeds the desired regeneration standard, the trees can be removed in a second cutting or left indefinitely. If left, the seed trees have several positive and negative attributes. They can serve as insurance for providing another seed crop. And if large and plentiful enough, they may provide an interim monetary return before the next harvest. But seed trees constitute a source of income which the landowner has forgone. In addition, they risk mortality and total loss from climatic and biotic agents, and use essential resources (light, moisture, and nutrients) which nearby seedlings need.

How much do seed trees inhibit growth of the seedlings near them? Seed trees hamper seedling growth

Figure 1. A representative view of a seed-tree harvest area on the Challenge Experimental Forest, Calif. Four seed trees per acre remain. Slash has been piled but not yet burned.

(Smith 1962), but little information is available that quantifies the phenomenon or how long it lasts.

This paper reports a study conducted in cooperation with the Soper-Wheeler Company, on the Challenge Experimental Forest, Yuba County, Calif. The results can be applied to about 1.5 million acres of highly productive timber land along the lower west slopes of the Sierra Nevada. And the silvicultural principles described are applicable wherever the seed-tree method is practiced.

An important attribute of the Experimental Forest is its high site. The dominant species, ponderosa pine, will average 140 feet in height in 100 years (Arvanitis et al. 1964). Soils often are over 100 feet deep, the mean annual temperature is 55 degrees F. and precipitation averages over 66 inches annually.

Timber stands on the experimental forest were about 90 years old when this study began. Although ponderosa pine dominates in terms of volume, other more tolerant conifers and hardwoods are more abundant, particularly in the smaller diameter classes. They often grow in dense thickets and in general are poorly distributed. Consequently, a combination site preparation-slash disposal operation is necessary to clear the ground of these and competitive brush species to prepare seed beds for conifer establishment.

The Seed-Tree Cuttings

Harvest cuttings in 1959, 1960, and 1962 left two levels of seed-tree stocking—4 and 8 trees per acre (*fig. 1*). A related cutting with 12 seed trees per acre was made in 1958. Altogether, 127 acres in 16 irregular compartments, ranging from 3 to 13 acres, comprised the study site. Slash on each compartment was piled with a bulldozer and later burned. In so doing, much of the remaining vegetation also was piled, creating seedbeds of bare mineral soil.

The ponderosa pine seed trees were the best phenotypes possible. They were large in diameter, full-crowned, tall, vigorous, and in some instances showed evidence of past cone production. They were spaced evenly throughout each compartment.

Ponderosa pine produced heavy seed crops in 1960 and 1964. Seed trees were removed in 1969 after the regeneration standards of 1,000 seedlings per acre and 50 percent milacre stocking were achieved on all compartments. Thus, seedlings grew for 5 and 9 years with seed trees present. Additional data, taken 5 years after seed-tree removal, ascertained if the effect of the seed trees continued to influence seedling height growth.

Sampling for seedling height was by fixed plots and temporary transects. Data for 5- and 9-year-old seedlings were taken from previously established milacre regeneration plots designated by a random start-systematic design. Each plot was referred to nearby seed trees by compass bearing and distance.

As relocating the milacre plots after seed-tree removal proved impracticable, a system of temporary transects was established to sample 14-year-old seedlings. The transects radiated outward from cut stumps in eight cardinal and intercardinal directions (every 45 degrees). Each transect was 40 feet long, 4 feet wide,

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Figure 2. Height of 14-year-old ponderosa pine seedlings increased as distance from the former seed tree increased.

and divided into 10-foot zones. For example, zone 1 extended outward from the stump a distance of 10 feet; zone 2 from 11 to 20 feet; zone 3, 21 to 30 feet; and zone 4, 31 to 40 feet. Thus at the seed-tree intensity of 12 per acre, where trees are 60 feet apart, sampling overlapped in the 21- to 40-foot portion of the transect. Significantly smaller overlapping was present at the intensity of eight seed trees per acre, spaced 74 feet apart. If perfectly distributed, four seed trees per acre are spaced 104 feet apart and sampling does not overlap.

On this site, on prepared ground, the first seed crop produces seedlings that become dominant. Subsequent seed crops contribute fewer seedlings, and those that become established are dominated by seedlings from the earlier crop. Height growth of the younger seedlings is retarded greatly. In this study, data for 5-year-old seedlings were from the first seed crop in several compartments, and 9-year-old seedlings were from the seed crop in nearby, but different compartments. Data for 14-year-old seedlings were from the same compartments as the 9-year-olds, and in a few instances may have been from identical seedlings.

Each milacre plot was searched carefully for ponderosa pine seedlings. Occasionally, rapidly-growing hardwood sprouts would suppress seedlings. These, plus browsed or damaged seedlings, were rejected as height-growth data.

Large variations in seedling heights were anticipated, so many seedlings were sampled:

Seedling age	*Milacre plots*	*Measured seedlings*
5	336	345
9	270	645
14		1600

Fourteen-year-old seedlings were sampled near 18 ponderosa pine stumps. To satisfy a standard for selection, stumps had to be surrounded by a reasonable number of pine seedlings and be free of dense thickets of hardwood sprouts and advance conifer reproduction.

Five- and 9-year-old seedling heights were plotted against distance from seed trees, and compared to a plotting of mean seedling height by zones. Only minor differences were observed. Thus these data were grouped into zones by cardinal and intercardinal directions for comparison to 14-year-old seedlings.

Data were examined graphically and statistically to determine differences in seedling heights. Seedling height growth was then tested to determine relationship with size of seed tree, direction of seedling from seed tree (especially north versus south), density of seedlings, distance of seedling from seed tree, and number of seed trees per acre for the three time-spans studied.

Results and Discussion

Seed-tree diameter and seedling location (cardinal or intercardinal direction from seed tree) did not affect

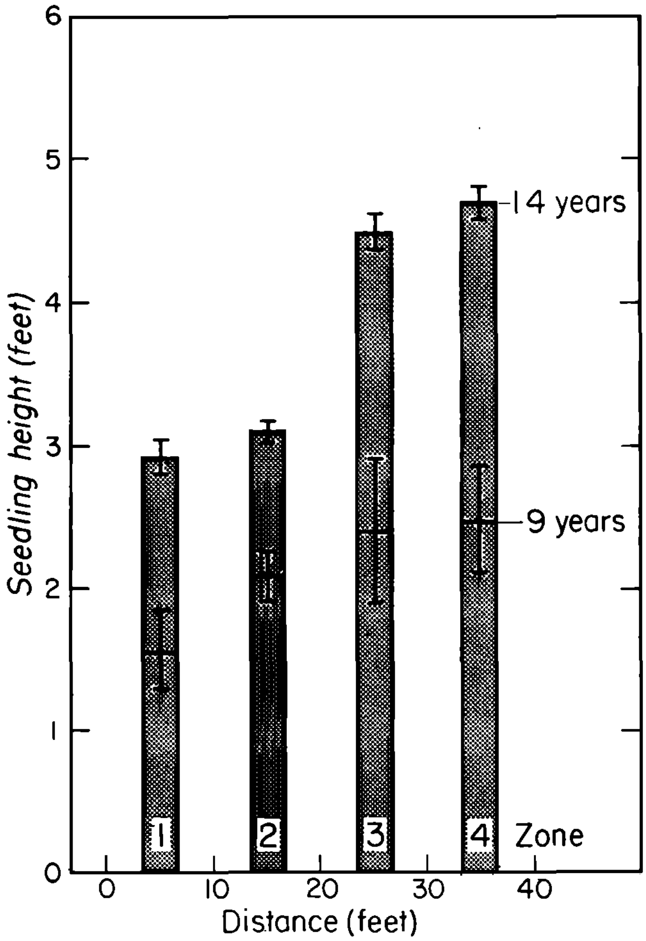

Figure 3. Distance from seed tree greatly affects seedling height. Stocking was 12 seed trees per acre. Mean seedling height and standard error are shown for each 10-foot zone.

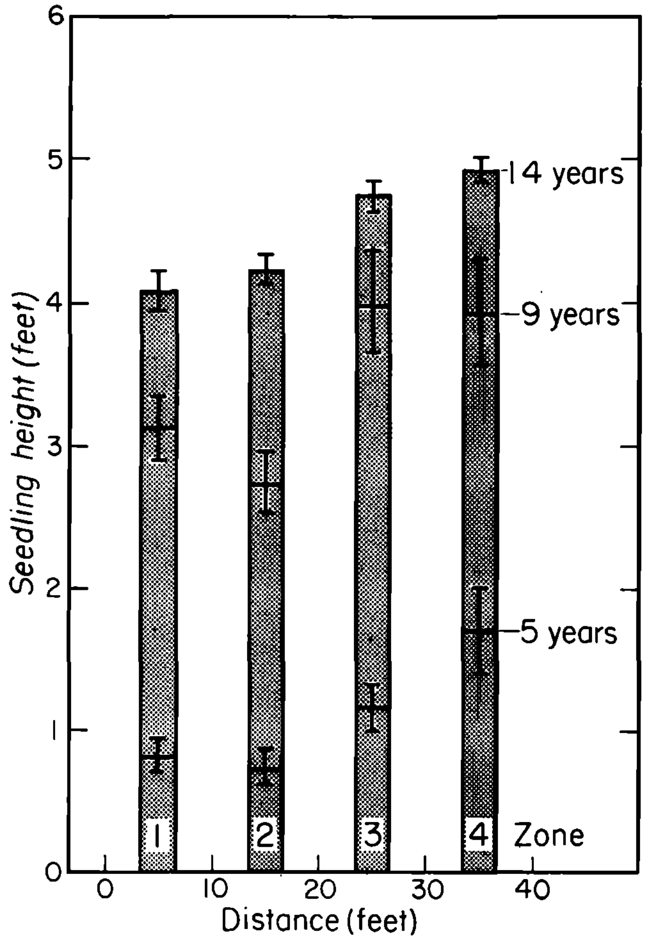

Figure 4. Distance from seed tree greatly affects seedling height. Stocking was 8 seed trees per acre. Mean seedling height and standard error are shown for each 10-foot zone.

Table 1. Effect of ponderosa pine seed-tree spacing on seedling height, Challenge Experimental Forest, Calif.

Seed trees per acre	Seedling age	Heights of seedlings when distance from seed-tree locations was . . . 0-10 feet	11-20 feet	21-30 feet	31-40 feet
No.	*Years*			*Feet*	
4	5	0.8	0.8	1.6	2.2
8	5	0.8	0.7	1.2	1.7
12	5	...	...	...	...
4	9	3.3	3.2	4.6	4.7
8	9	3.1	2.7	4.0	4.0
12	9	1.6	2.1	2.4	2.5
4	14	5.1	5.6	7.3	8.4
8	14	4.1	4.2	4.8	5.0
12	14	2.9	3.1	4.5	4.7

seedling height. Apparently, light and moisture gradients are reasonably similar on all sides of the various-sized seed trees. A "t" test indicated that seedling height was not related significantly to seedling density ($p = .05$).

Distances of seedling from seed tree was an important variable (*fig. 2*). Analyses of variance indicated that seedling height differed significantly ($p = .05$) by zones for 5- and 14-year-old seedlings (*figs. 3, 4, 5*). Differences among zones were not significant for 9-year-old seedlings, primarily because large differences between zones 2 and 3 were offset by close similarity in zones 1 and 2 as well as 3 and 4. Similarity of seedling heights in zones 3 and 4 with 12 seed trees per acre is to be expected because root systems of seed trees probably overlap, and competitive effects are similar. The large difference in seedling height between zones 2 and 3 also is notable for 5- and 14-year-old seedlings.

The pronounced lack of seedling height growth in zones 1 and 2 is true of the three seedling ages studied. This could relate to use of soil moisture by the seed trees. On a similar site on the Experimental Forest, Ziemer (1968) studied soil moisture depletion on all sides of a 28-inch diameter sugar pine (*Pinus lambertiana* Dougl.). Soil moisture was depleted most in a zone 15 feet around the tree at a depth of 8 to 11 feet. This condition probably explains why the greatest depression in seedling height occurred in zone 2.

It also suggests that soil moisture is a primary limiting factor to seedling height growth beneath seed trees. It does not explain wholly, however, why seedlings beneath seed trees did not react more rapidly after the seed trees were logged. Several reasons for this lack of response are probable. Nutrients could have been depleted by the seed trees, or toxic substances could have been emitted by the decaying seed-tree roots.

A more compelling reason is that the seed trees had a cumulative weakening effect on the seedlings beneath them. These seedlings had not developed enough feeder roots below ground nor photosynthetic area above to respond quickly to the additional resources available after seed-tree removal. Seedlings farther away were able not only to gather more resources, but also to capture additional resources after seed-tree removal.

While distance from seed tree affects height of individual seedlings, number of seed trees affects their overall height response. Plainly, the more seed trees, the lower seedling height (*table 1*). And this is true for seedlings 5, 9, and 14 years old in all zones.

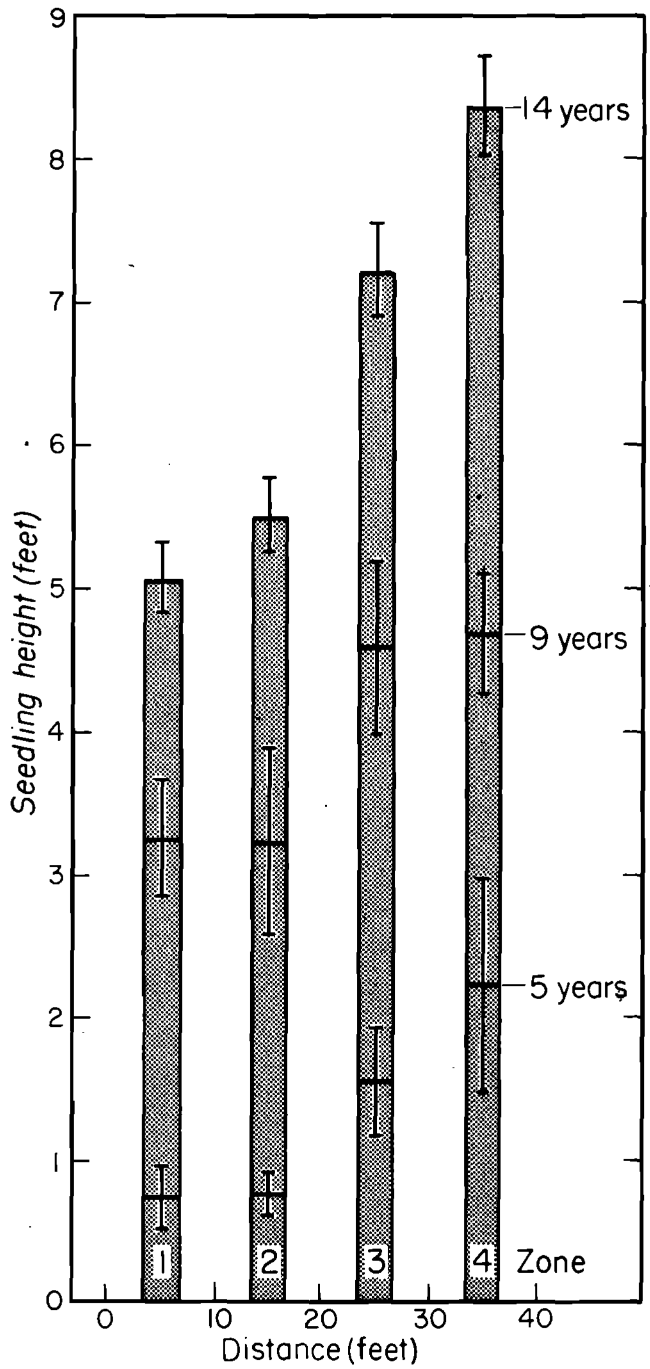

Figure 5. Distance from seed tree greatly affects seedling height. Stocking was four seed trees per acre. Mean seedling height and standard error are portrayed for each 10-foot zone.

Table 2. Years of growth lost by seedlings near seed trees, Challenge Experimental Forest, Calif.

Seed trees per acre	Seedling age	Loss of seedling height growth when distance from seed-tree locations was . . . 0-10 feet	11-20 feet	21-30 feet	31-40 feet
No.	*Years*		*Years*		
4	5	4.1	4.1	3.1	2.4
8	5	4.1	4.2	3.6	3.0
12	5	...	...	...	...
4	9	6.2	6.3	5.1	5.0
8	9	6.4	6.7	5.6	5.6
12	9	7.7	7.2	7.0	6.9
4	13	9.9	9.6	8.4	7.7
8	13	10.7	10.6	10.1	9.9
12	13	11.4	11.2	10.2	10.0

How far does the inhibitory effect of the seed trees extend? Theoretically, it would extend a length equal to the radius of crown or root extension. Crown radii of this size of ponderosa pine on this site do not exceed 15 feet. Root radius is unknown, although Ziemer (1968) attributed slight soil moisture depletion at 40 feet to the presence of roots from a study tree. The flattened height-growth trends for 9- and 14-year-old seedlings influenced by seed trees 60- and 74-feet apart (*figs. 3 and 4*) suggest inhibition of seedling height at 40 feet. However, the trend of seedling height growth with 4 seed trees per acre (*fig. 5*), and a minimum effective radius of 52 feet, shows less inhibition and a strong upturn in seedling height at 40 feet. Thus the inhibitory effect of individual ponderosa pine seed trees extends outward at least 40 feet, but may not extend much farther.

How long do seed trees hold back seedlings? Height growth for the fourteenth year was measured on 374 seedlings. Mean leader length among the various zones and seed-tree intensities ranged from 0.56 to 1.13 feet, with a range in standard error of 0.03 to 0.09 feet. Analyses of variance indicated that seedling height did not vary significantly ($p = .05$) among zones for 4, 8, and 12 seed trees per acre. This lack of difference indicates a degree of similarity among zones and suggests that the differential effect of the seed trees is no longer operative. No additional seedling inhibition should occur. The analyses also indicated that the effect of the seed trees probably lasted through age 13.

In order to quantify the amount of height-growth lost, seedlings must be compared to an acceptable standard. Normal yield tables might provide comparisons, but are inaccurate at ages less than 20 years. A better standard is a ponderosa pine level of growing stock study on the Experimental Forest. Site quality, site preparation, seed source, high survival of planted stock, and subsequent brush regrowth are similar in both studies. Data are actual for ages 5 and 9, and projected for age 13. Thus seedling height standards are 4.3 feet at age 5, 10.5 feet at age 9, and 17.9 feet for 13-year olds.

The difference in height between the free-to-grow standards and the seedlings in the various zones reflects the hold-back effect of the seed trees. This difference was divided by the standard's growth rate. Results portray the number of years of growth lost compared to the free-to-grow rate (*table 2*).

These losses are not likely to be made up during the rotation. Therefore, they are a direct cost of leaving the various intensities of seed trees for the time spans indicated. And because the dominance potential (Newton 1973) of ponderosa pine seedlings in zones 1 and 2 is lower than that of hardwoods and brush, a more clumpy pine distribution could result. This further substantiates a previous recommendation that young-growth ponderosa pine seed trees should be removed immediately after stocking of 2-year-old seedlings reaches the regeneration standard (McDonald 1969a).

Foresters often regard natural regeneration as being less expensive than artificial regeneration with planted stock. This may or may not be so. It is largely an economic problem that needs to be evaluated. Other studies on the Experimental Forest have evaluated the periodicity and magnitude of ponderosa pine seed crops (Sundahl 1966), the negative effect of advance growth on seedling survival (Hall 1963), the decrease in stocking and density of regeneration from seed-tree removal (McDonald 1969a), and the gain in logging production rate when removing ponderosa pine seed trees (McDonald 1969b). This study quantifies another critical component that will contribute to economic analyses. ■

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