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ABSTRACT: Records of 5 and 6 years' cone crops in old-growth redwood (*Sequoia sempervirens* [D. Don] Endl.) stands in northern California were studied for silvical facts. They show that (a) the principal trees in both cut and uncut stands bore fair to good cone crops for 5 consecutive years, (b) maximum seed dispersal of both total and sound seed occurred in winter, (c) overtopped trees under 30 inches d.b.h. produced almost no cones, and (d) about 86 percent of sound seed germinated, with most seed germinating in 12 days. The findings are applicable to redwood stands at medium to lower elevations.

RETRIEVAL TERMS: *Sequoia sempervirens*; seed tree selection; seeding characteristics; cone crops; seed production; seed dispersion; germination behavior; northern redwoods.

OXFORD: 174.7 *Sequoia sempervirens* --232.311:174.7 *Sequoia sempervirens* --181.523/5.

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Cone production, seed dispersal, germination in. . .

Old-Growth Redwood Cut and Uncut Stands

Kenneth N. Boe

After harvesting old-growth redwood (*Sequoia sempervirens* [D. Don] Endl.) stands, forest managers want to get new stands started as quickly as possible. They need to know to what extent they can count on natural regeneration to do all or part of this job. In planning for new stands, they need information on the prospects of good cone crops, amount of seed likely to be produced, and when seed is dispersed.

On reserved trees in partially cut and in uncut old-growth redwood stands in northern California, many co-dominant and dominant trees initially produced good cone crops, and after 6 years, the same trees continued to produce good crops. The most seed was dispersed from November through February. A high proportion of sound seed germinated. Under the test conditions, most seed germinated in 12 days. In the same stands, overtopped-intermediate crown class trees under 30 inches d.b.h. produced almost no cones. After 4 and 5 years following cutting, cone production was slightly greater than in uncut stands.

These are the major findings in a study on the Station's Redwood Experimental Forest, near Klamath, California. They supplement and support silvical information reported earlier.[1] The cone production and seeding characteristics reported here apply to northern redwoods at medium to lower elevations.

This information will provide guides for silvicultural practices in choosing the best seed trees, getting the most from seedfall by timing site preparation, and scheduling cone collection ahead of seedfall.

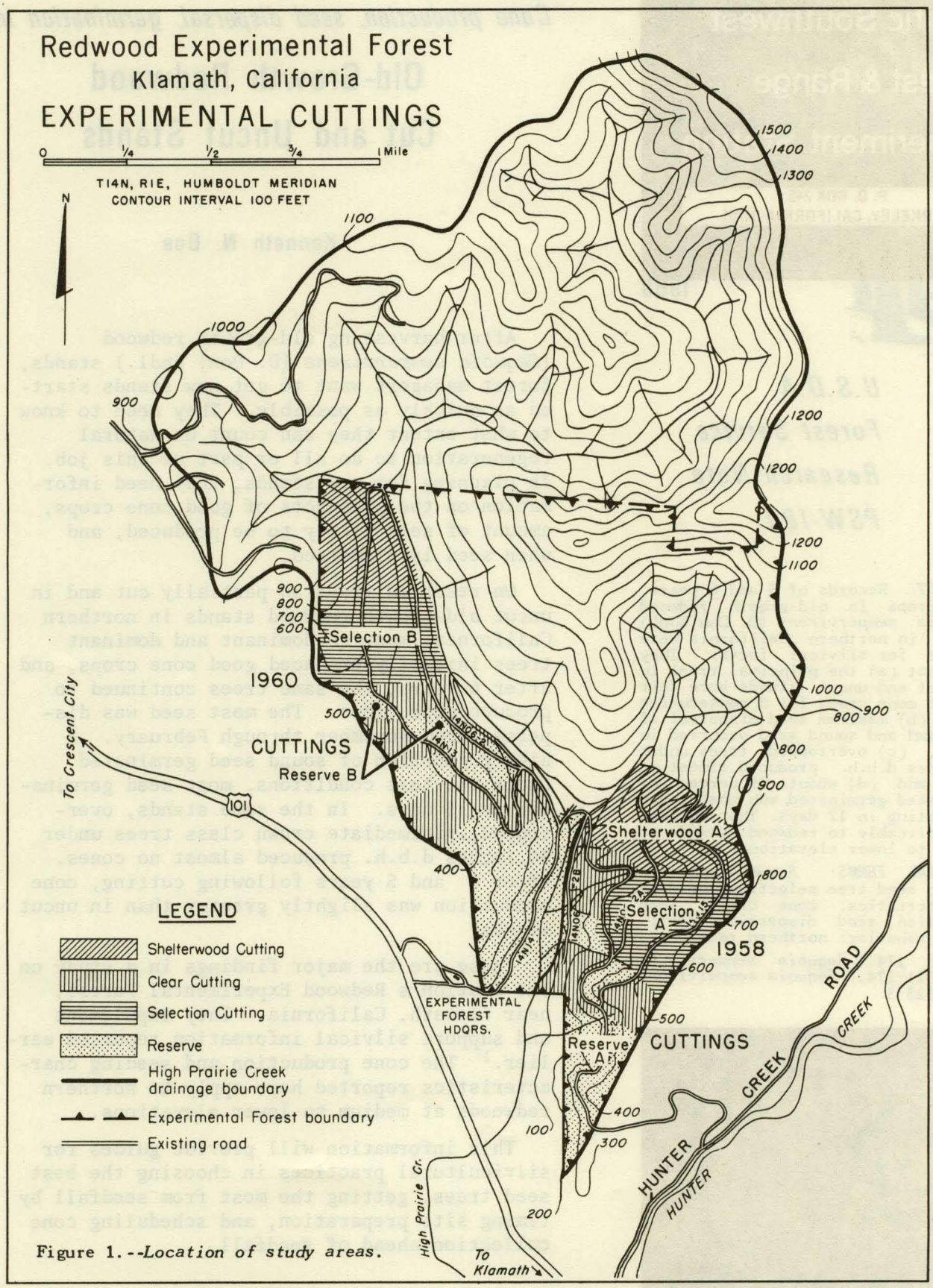

Figure 1.--*Location of study areas.*

THE STUDY

In 1958, a series of harvest cutting experiments were started on the Redwood Experimental Forest (fig. 1). Included were studies of cone bearing, seed dispersal, and seed germination. On each permanent sample plot, I observed the new cones on reserved trees by using high-powered binoculars. Six years later new cones on living trees were again subjectively rated. The subjective ratings were: (a) no cones; (b) few--cones hard to find in crown; (c) many--cones scattered throughout crown; (d) abundant--noticeably heavy crop of cones.

Seed fall was sampled in each of the different cuttings and in uncut reserved stands (fig. 1) by 1-foot square wire seed traps placed randomly. The seed traps were moved at scheduled times to different cuttings throughout this study.

At regular intervals the contents of the traps were examined. For each trap we recorded data on species, number of seed, and number of sound seed as determined by cutting tests.

From the 1960 seed crop, seeds were saved and refrigerated for germination tests beginning in April 1961. Each seed lot was identified by month and by cutting unit. From each lot, 100 or more apparently sound seeds were selected for testing. They were dusted with Arasan before being placed on the moistened filter paper in covered petri dishes. Germinators were set on open shelves in a room lit by natural and artificial means about 11 hours per day. Room temperature remained fairly constant at 70°F. throughout the test. It reached 74°F. for only 1 or 2 hours on sunny days. At each daily inspection, germinated seeds--those with radicles protruding 1/8 inch or more--were removed. After reasonable assurance that germination had ended, the remaining seeds were cut to determine those that were sound, i.e., fully developed.

RESULTS

CONE BEARING CHARACTERISTICS

Old-growth redwood is not even-aged, but in this study, trees were separated by crown classes into their relative positions in the closed canopy. The chronological age spread between overtopped and codominant-dominant trees often is 300-500 years. Physiologically, however, the entire stand may be considered mature-overmature.

Codominant and dominant redwood were the principal cone-bearers in the old-growth stands (fig. 2). On 35 to over 70 percent of these trees the cone crop ratings were "many" to "abundant"--the dominant trees rated consistently highest. Only 14 percent or less had no cones.

Elsewhere, in generalized areas of the redwood type, cone production in virgin stands has been reported as from "many" to "loaded."[2] This classification corresponds generally with ratings of "many" to "abundant" on the codominant-dominant trees on the Redwood Experimental Forest.

Cone crop ratings made on the sample trees 6 years after the study began (4 and 5 years after the shelterwood-selection cutting) showed little change in the ratings on codominant and dominant trees--13 percent or fewer had no cones, and 48 to 67 percent had "many" to "abundant" cones. Codominant and dominant trees on the partial cuttings when compared to those on uncut stands apparently did not benefit by release.

In both cut and uncut stands, redwood trees classified as overtopped and intermediate crown classes were poor cone producers. More than 70 percent of these trees had no cones (fig. 2). After 6 years, cone crops continued to be poor. But on the partial cuttings, trees showed slight increases in cone crops rated as "many" to "abundant," when compared to those in uncut stands. Release by cutting may have benefited some of these overtopped and intermediate-crown class trees.

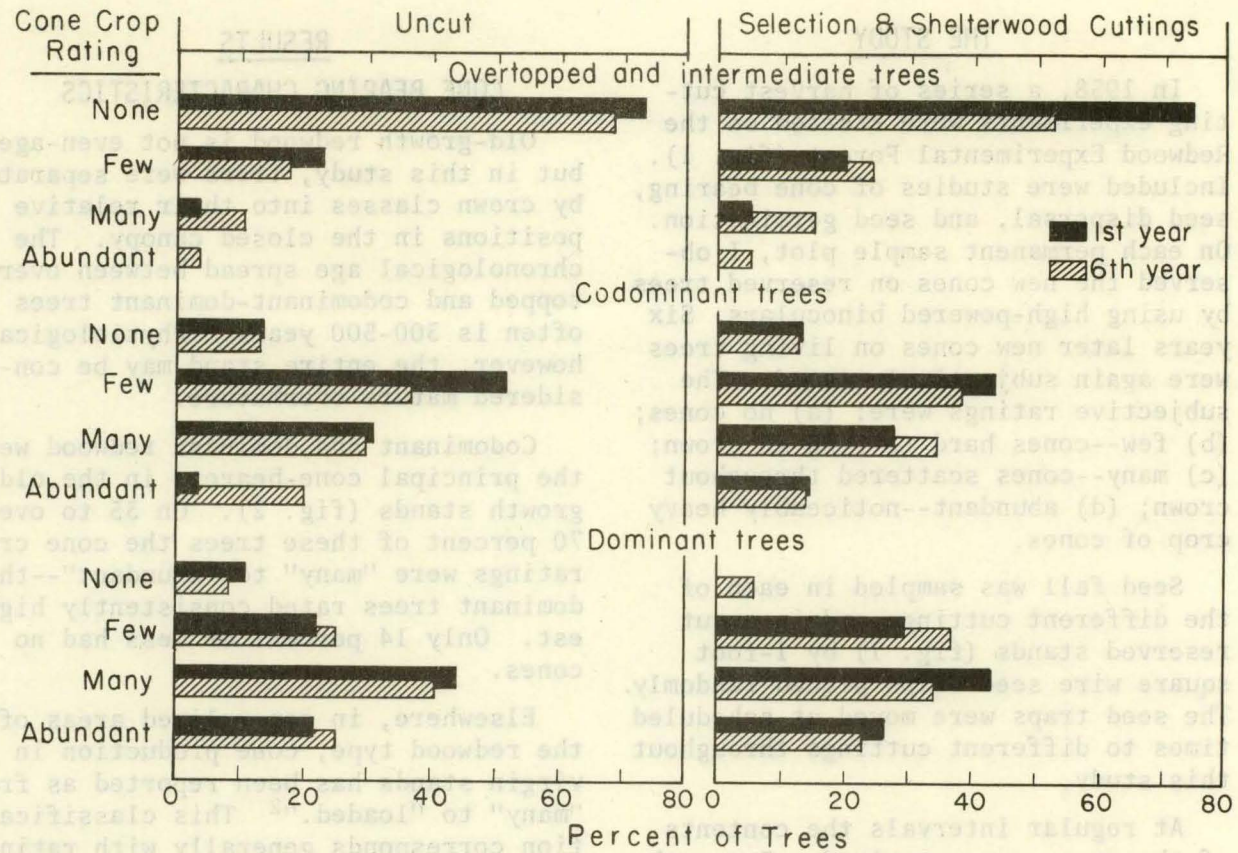

Figure 2.--*Comparison of cone bearing within crown-class groups of trees, initially, and after 6 years on cut and uncut stands, by percent of trees by class.*

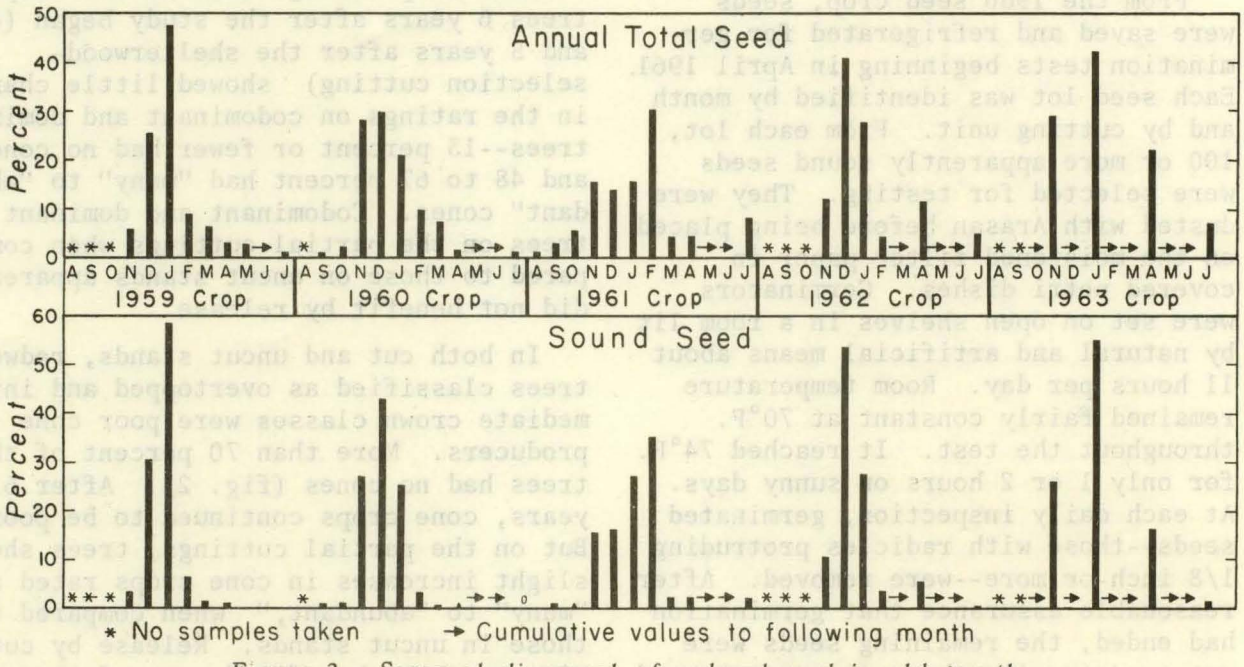

Figure 3.--*Seasonal dispersal of redwood seed in old-growth stands, Redwood Experimental Forest.*

We therefore rated the cone crops of redwoods of overtopped and intermediate crown classes, by diameter classes (table 1), to examine relationships with tree size. We found that 75 to 100 percent of trees 28 inches d.b.h. and under had no cones when first observed, in 1958; 25 to 35 percent of trees above this size--mostly in the intermediate crown classes--had "few" to "many" cones. After 6 years (4 and 5 years after cutting) ratings on all sample trees in both cut and uncut stands showed better cone crops than in previous observations. On the trees 28 inches d.b.h. and under, however, the increase was slight. Release by cutting apparently had small impact--cut and uncut stands showed no differences.

Redwood cones persist on the trees for many months. This characteristic allows old and new cones to be observed together. The 1 year of record suggests a close correlation between the new and the old:

	Old	New
	(percent)	
Cone rating per tree:		
None	45.0	45.3
Few	31.9	30.1
Many	17.8	17.6
Abundant	5.3	7.0

Past and present crops, therefore, can be useful indicators in choosing potential seed trees.

SEED DISPERSAL

In this study, old-growth redwood produced fair to abundant amounts of sound seed every year for 5 consecutive years (1959-1963) (table 2). Each year the amount of sound seed was a small and a variable percent of total seed dispersed. It ranged from only 2.5 percent in the fair seed-year to 12 percent in good seed-years.

The seasonal dispersal pattern for the seed year beginning August 1 indicated the most seed fell from November through February, when 85 percent or more of total seed was dispersed (fig. 3).

The greatest amounts of sound seed also were dispersed in winter (fig. 3). Therefore, the best quality coincided with maximum seedfall. Practically no sound seed was dispersed in late spring and in summer.

GERMINATION

Under the test conditions, first germination required from 5 to 8 days, and peak germination was reached in 7 to 12 days (table 3). Days to last germination ranged from 16 to 45 days, and averaged 25 days. These results confirm findings reported earlier.[1] But the seed tested required fewer days to reach peak germination than Metcalf had reported.[3] There was no trend that the rate of germination of seed dispersed in one winter month was better than that of any other month.

Real germination is the percent of sound seed germinating. It ranged from 75 to 94 percent and averaged 85 percent (table 3). The viability of sound seed was not much greater in one winter month as compared to the others.

DISCUSSION

In planning a harvest cutting for restocking by natural regeneration, the forest manager must identify and reserve seed trees. Results in this study suggest that overtopped-intermediate redwood trees under 30 inches d.b.h., in northern California, are essentially worthless as seed trees. A few trees in this group may improve their cone production after several years. But if seed is needed immediately on the freshly disturbed seedbeds, it is a poor risk to wait for larger cone crops from these small trees. A small proportion of the larger intermediate-class redwood trees appear to be fair cone producers. And some may improve cone production with time. The codominant and dominant

Table 1.--*Cone crop rating of overtopped-intermediate crown classes of redwood in partially cut and uncut stands, initally, and after 6 years, by diameter class, Redwood Experimental Forest*

SELECTION-SHELTERWOOD CUTTING

Cones per tree	Ratings of trees, by diameter classes (inches)...									
	12-16		18-22		24-28		30-34		36 +	
	First year	+6 yrs.	First year	+6 yrs.	First year	+6 yrs.	First year	+6 yrs.	First year	+6 yrs.
	Percent									
None	94	89	100	86	75	63	73	41	58	24
Few	6	11	0	0	25	31	23	41	30	32
Many	0	0	0	14	0	6	4	14	12	31
Abundant	0	0	0	0	0	0	0	4	0	13
UNCUT STANDS										
None	100	100	100	80	100	83	80	82	44	38
Few	0	0	0	20	0	0	20	9	48	33
Many	0	0	0	0	0	17	0	0	8	24
Abundant	0	0	0	0	0	0	0	9	0	5

Table 2.--*Redwood seed production, by crop years and by harvest cutting stands, Redwood Experimental Forest*

Stand	Seed[1] trees	Crop year	Estimated total seed	Estimated sound seed	
	No./acre		*M/acre*	*M/acre*	*Pct.*
Shelterwood Cutting A	3	1959	14,654	1,414	9.6
		1960	24,657	2,990	12.1
Selection Cutting A	14	1959	38,073	4,405	11.6
		1960	64,275	6,923	10.8
		1961	33,376	2,447	7.3
Reserve Stand A	20	1961	25,191	1,233	4.9
Selection Cutting B	20	1962	18,316	2,339	12.2
Reserve Stand B	30	1962	32,342	4,008	12.4
		1963	11,056	280	2.5

[1]Dominant, codominant, and intermediate redwood trees 32 inches d.b.h. and larger.

Table 3. *Germination tests of hand-selected old growth redwood seed of different lots from the 1960 crop, by month of seed dispersal, Redwood Experimental Forest*

Item	Seed dispersed during...				Average
	Nov.	Dec.	Jan.	Feb.	
SHELTERWOOD CUTTING					
First germination.....days	6	7	8	8	7.2
Peak germination.....days	7	8	12	9	9.0
Last germination.....days	19	30	26	26	25.2
Real germination.....percent	77.8	93.6	91.7	76.9	85.0
Basis.....No. sound seeds	27	47	24	13	--
SELECTION CUTTING					
First germination.....days	6	6	5	8	6.2
Peak germination.....days	7	8	9	12	9.0
Last germination.....days	37	23	16	19	23.8
Real germination.....percent	84.2	85.7	75.0	92.9	84.4
Basis.....No. sound seeds	38	42	36	14	--
UNCUT STAND					
First germination.....days	5	7	6	(1/)	6.0
Peak germination.....days	12	12	9	(1/)	11.0
Last germination.....days	19	45	19	(1/)	27.7
Real germination.....percent	81.8	92.9	81.8	(1/)	85.5
Basis.....No. sound seeds	22	42	22	--	--

[1]Not enough seed for testing.

trees produced the most cones. They can provide the seed needed for rapid replacement of the harvested trees. If trees have many persistent old cones they should be chosen for continued cone production.

Redwood seed falls chiefly during winter. This characteristic permits pre-cleanup of harvested areas to get seed on fresh mineral soil for early germination and establishment. And because the seed is the best quality, optimum seedfall and winter rains coincide to provide ideal conditions for immediate starting of new trees. Five consecutive redwood seed crops in the middle elevation zone give further assurance of seeding dependability.

Should seed be needed for direct seeding or for nursery seedling production, the information on germination will be useful. Percent of germination is low because so much of the seed is unsound. Any cleaning or separation technique that eliminates some or most of the unsound seed will result in increased viability because real germination is consistently very high. Cones collected by October, ahead of the principal seedfall, will contain most of the seed.

FOOTNOTES

[1]Boe, Kenneth N. *Redwood seed dispersion in old-growth cutovers.* U.S. Forest Serv. Res. Note 177, Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 7 p., illus. 1961.

[2]Muelder, D.W., and Hansen, J.H. *Observations on cone bearing of Sequoia sempervirens.* Univ. Calif. Sch. Forest. Calif. Forest. & Forest Prod. 26, p. 2,3. 1961

[3]Metcalf, Woodbridge. *Artificial reproduction of redwood (Sequoia sempervirens).* J. Forest. 22(8), p. 882. 1924.

The Author

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