NATURAL REGENERATION

Douglass F. Roy

Retired, USDA Forest Service Pacific Southwest Forest and Experiment Station, Redding, California.

ABSTRACT

Successful regeneration of ponderosa pine and Jeffrey pine by natural seedfall requires the fortunate combination of several elements. Necessary conditions are:

1. A good seed crop.
2. A mineral-soil seedbed.
3. No more than a sparse population of seed-eating rodents.
4. No competing vegetation.
5. One or more favorable growing seasons immediately following seedfall.

This sequence of favorable conditions seldom takes place in the Interior Ponderosa Pine Type. One of the principal barriers to obtaining natural reproduction is irregular seed crops. From 1942 to 1953, ponderosa pine and Jeffrey pine on the Blacks Mountain Experimental Forest produced only four light to good seed crops as follows:

Year	Seedfall per acre through October
	(thousands)
1942	42
1945	4
1948	77
1952	33

Examinations of seed traps in the fall and again each spring showed that seeds shed before the first of November comprise 60 to 75 percent of a seed crop. Remaining seeds fall during the winter.

In spite of heavy seed crops, few seedlings become established unless other conditions are suitable. Providing mineral-soil seedbeds, reducing seed-eating rodent populations, and reducing or eliminating competing vegetation are viable cultural treatments.

INTRODUCTION

The ecology of seedlings concerns factors falling into three categories--biotic, climatic, and edaphic. Generally, edaphic conditions are not heroic, in the sense of involving risk. Consequently, soils will not be discussed beyond the need for loose, mineral-soil seedbeds to enhance reproduction by natural seedfall.

Obviously, conditions affecting regeneration by seeds differ between natural seeding and artificially placed seeds. Nevertheless, the possible fate of natural seedlings can be deduced to considerable degree by results from seedspotting studies. Let's look at the results of a seedspot study on the Blacks Mountain Experimental Forest (Roy 1962).

In the fall of 1950, ground was prepared and seeds were placed in 250 ponderosa pine and 250 Jeffrey pine spots which were protected by 1/4-inch mesh dome screens. Preliminary tests indicated the following seed lot characteristics:

	Ponderosa pine	Jeffrey pine
Sound seeds by cutting tests--percent	78	99
Germination in petri dishes--percent	69	88
Germination in sand and peat moss--percent	73	83

Germination in the seedspots began by April 23, 1951. Germination of Jeffrey pine seed was considerably higher than that for ponderosa pine, reflecting the original difference in seed lot viability and the differential vigor of germination resulting from the inherent difference in seed sizes of the two species. Germination was almost complete by June 5.

Almost 50 percent of the seedspot seedlings died in the first growing season. Although mortality began early, the major losses came during the period from mid-May to mid-June. The mortality pattern indicates that Jeffrey pine seedlings are hardier than ponderosa pine seedlings.

Physiological drought caused over 44 percent of the total mortality and was, by far, the most destructive element (Table 1). Most of this mortality was suffered between May 28 and June 4 and resulted from a period of unseasonal low relative humidity. Soil moisture at this time was abundant, but lateral seedling roots had grown no more than 1/8 inch.

Wireworms (Ctenicera pruinina Horn), the larvae of click or elaterid beetles, were the second most destructive agent. These insects work underground and sometimes attack the seedlings before they emerge from the soil. Wireworms often eat grooves up the hypocotyls and into the seeds where they feed, but the cutting of hypocotyls also is common. Since wireworms work under the soil surface, an accurate estimate of total damage caused by them is impossible. Nevertheless, observed mortality caused by wireworms amounted to 9.5 percent of the germination. Most of this damage took place between April 30 and June 5.

Dark-sided cutworms (Euxoa messoria [Harris]) were the third most destructive factor. These larvae killed 5.1 percent of the seedspot seedlings. Cutworms frequently damage natural and planted seedlings seriously. In California, seedlings are damaged most seriously during the first 2 months after germination, although some injury to planted stock has been observed. Cutworm larvae emerge from the soil at night and, characteristically, cut seedling stems and pull the severed seedling into the soil. During the day, the larvae lie on the interface between moist and dry soil and can feed on the seedlings as the insects pull the seedlings farther into the soil.

The remaining mortality (11.3 of the mortality of ponderosa pine seedlings and 10.8 percent of the mortality of Jeffrey pine seedlings) was caused by a potpourri of factors. Rodents destroyed 1.3 percent of the seedlings by stem cutting. Most of the stem-cutting damage took place between May 5 and June 30. Approximately 3 percent of the seedspot seedlings were killed by foliage damage. This damage began near the end of May and continued beyond mid-August. Cutworms, rodents, grasshoppers, and webworms (Zalleria spp.) were suspected as causal agents. Ponderosa pine was defoliated more often than Jeffrey pine.

Mortality of seedspot seedlings during the second growing season was light, amounting to less than 8 percent of the observed germination. Pocket gophers accounted for half the second-year mortality. The second and third most important recognized causes were stem cutting by rodents - 6.4 percent, and drought - 4.3 percent. Over 33 percent of the second-year mortality could not be identified, however, generally because no trace of seedlings could be found. Browsing damage was suspected as the major factor involved.

With one dramatic exception, climatic factors had no negative effects. Soil surface temperatures generally become critical for conifer seedlings between 120° and 140° F. However, lethal temperatures range between 96° and 180° F, depending upon species, age of seedlings, and length of exposure. Sometimes seedlings can survive short periods when temperatures reach the highest limit.

Ponderosa pine seedlings seem able to tolerate high soil-surface temperatures, probably because rapid growth and early development of stem tissues provide better protection than most species have against excessive heat. Ponderosa pine also is able to cool itself. Even at an extremely young age, this species can increase quickly its transpiration when insolation becomes great (Roeser 1932).

Few of the Blacks Mountain seedspot seedlings were killed in 1951 by high soil temperatures. Seedlings survived soil surface temperatures greater than 140° F on June 18, and 153° F on July 22.

Soil moistures for each plot were sampled weekly from three depths below the ground surface--2 to 4 inches, 6 to 8 inches, and 12 to 14 inches. Every soil sample taken was over 230 milliliters in volume, and the average sample was about 240 milliliters.

The water content of all soils remained abundant throughout the first growing season. Soil moisture remained above the wilting coefficient in soils deeper than 6 inches (fig. 1).

Table 1--Causes of mortality to pine seedlings during first year, Blacks Mountain Experimental Forest, 1951

Cause of mortality	Ponderosa pine			Jeffrey pine		
	Seedlings dying (number)	Portions of mortality (percent)	Part of observed germination (percent)	Seedlings dying (number)	Portions of mortality (percent)	Part of observed germination (percent)
Unknown	79	13.9	8.3	35	6.7	3.2
Drought	250	44.3	26.2	267	51.0	24.4
Wireworms	102	18.0	10.7	134	25.6	12.3
Cutworms	71	12.5	7.4	31	5.9	2.8
Foliage damage	30	5.3	3.1	28	5.4	2.6
Rodents - stem cutting	18	3.2	1.9	8	1.5	0.7
Gophers	4	0.7	0.4	3	0.6	0.3
Root fungus	5	0.9	0.5	--	--	--
Sunscald	4	0.7	0.4	10	1.9	0.9
Rodents - stem girdling	2	0.3	0.2	--	--	--
Cattle trampling	1	0.2	0.1	1	0.2	0.1
Washed out	--	--	--	3	0.6	0.3
Cotyledons aborted	--	--	--	2	0.4	0.2
Smothered by spider web	--	--	--	1	0.2	0.1
Basis:	566	100.0	59.2	523	100.0	47.9
Number of seedspots			250		250	
Number of seeds placed (7 per spot)			1750	(6 per spot)	1500	
--percent			55		73	
Observed germination - number of seedlings			956		1091	

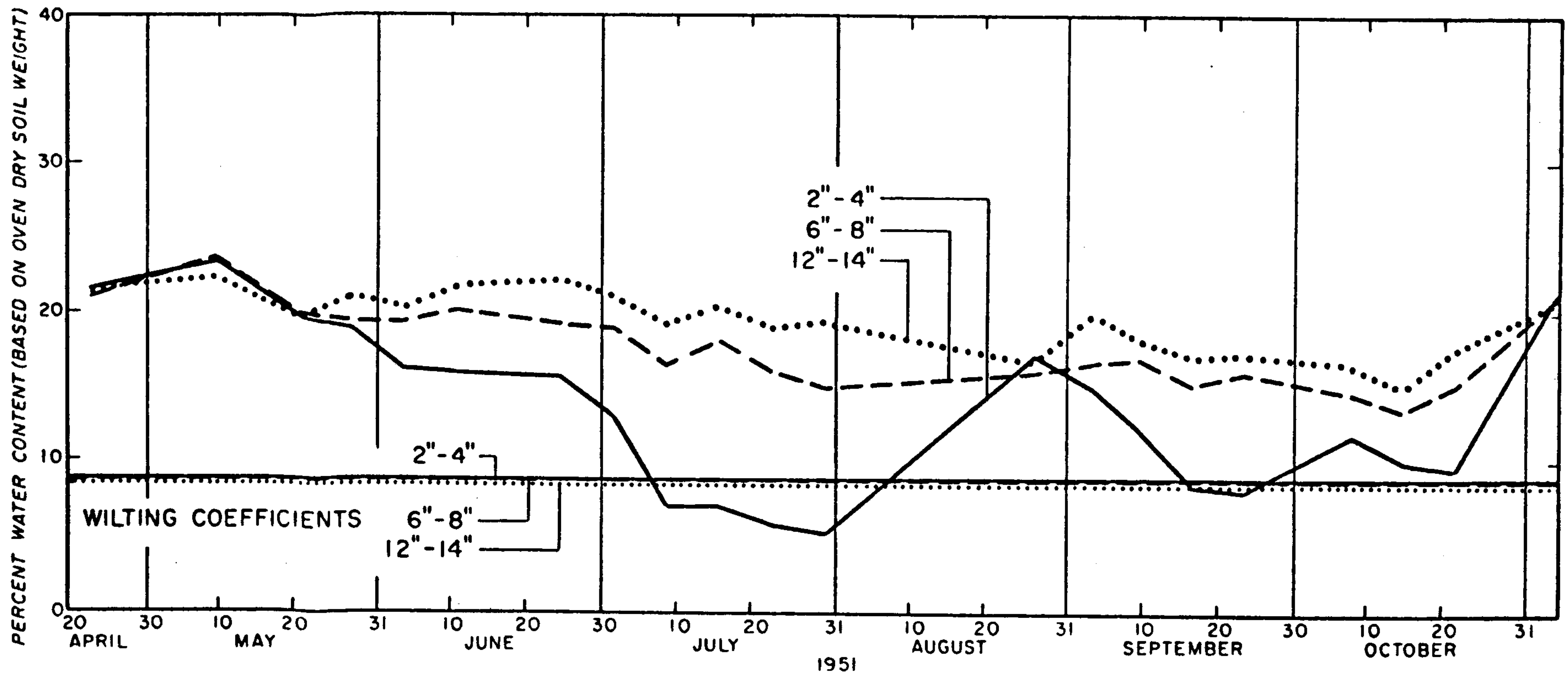

Figure 1.--Soil moisture content expressed as percent of oven-dry soil weight, Blacks Mountain Experimental Forest, 1951.

Total precipitation for 1951 was about average (Table 2 and fig. 2). The distribution was abnormal, however, with deficient rainfall during the period March through August, as shown in the following tabulation:

	Precipitation during March through August 1951 (inches)
Year with most precipitation	8.14
1951	3.75
16-year average (1936 to 1951)	6.77
Year with least precipitation	4.43

Precipitation falling during the most critical months of the first growing season was almost half that falling in the same period of a normal year. In fact, rainfall in March through August 1951 was 0.68 of an inch less than in the same period of the driest year of record. Consequently, pine reproduction in this test was subjected to soil moisture conditions which were as severe as might be expected any year.

The climatic factor which was highly significant to seedling mortality in 1951 concerned moisture held in the air. A great part of seedling mortality in the first year resulted from unseasonable low relative humidities and high vapor pressure deficits. During the 6-day period of May 29 to June 3 relative humidity peaked at 100 percent only once, remaining there only 2 hours before dropping sharply. Previously, and immediately following this period, relative humidity reached 100 percent every night and generally remained there for several hours.

Accumulated vapor pressure deficits reached a high period on May 25 and 26 when vapor pressure deficits were certainly a factor in the "drought" mortality of seedlings. As with relative humidity, seedlings survived more severe vapor pressure deficits which culminated in mid-July. These high vapor pressure deficits were associated with low wind movements and high air temperatures.

Twenty "drought-killed" seedlings were lifted carefully from the soil. Lengths of tap roots varied from 5.2 to 7.3 inches and averaged 6.6 inches. However, lateral roots, altough numerous, had just begun to develop and ranged in length from only 0.05 to 0.16 inches. Since soil moisture was abundant, and since the dead seedlings were those with the most vigorously developed tops, death was attributed to untimely low relative humidities and high vapor pressure deficits. Seedlings had been subjected to an almost continuous stress for a 10-day period at a time when young root systems were insufficiently developed to absorb enough soil moisture to replace transpiration losses.

Surface disturbance of the forest floor by mechanical means is recognized as a cultural measure for aiding establishment of conifer seedlings. Harvesting practices in the ponderosa pine type create favorable seedbed conditions to a limited extent during the normal course of logging, but purposeful seedbed preparation has not been the rule. Information on the effect of competing vegetation on germination and early establishment of pine aids greatly in planning treatments for adequate restocking.

A SITE PREPARATION EXPERIMENT

A study to obtain information was designed as a preliminary test in securing natural regeneration of ponderosa pine (Pinus ponderosa Laws.) and Jeffrey pine (P. jeffreyi Grev. and Balf.) in the eastside pine region of California (Tackle and Roy 1953). Ground scarification simulated fresh logging disturbance on bare ground and removed vegetation elsewhere.

The specific factors chosen for study were:

1. Germination and survival of seedlings as related to ground cover density on scarified seedbeds.
2. Comparative height growth of seedlings on areas of varying ground cover density.

The experiment was conducted on the Blacks Mountain Experimental Forest in northeastern California during the years 1948 to 1952.

Selection of Study Areas

In 1948, six areas--each of varying ground cover density--were selected for scarification and rodent poisoning. These areas satisfied

Table 2--Precipitation records, Blacks Mountain Experimental Forest, 1936 to 1951

Precipitation statistic and year or period	Amount of precipitation when the month was--											
	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
	Inches											
Monthly precipitation												
Year with most precipitation	2.15	4.68	5.29	2.01	6.97	4.29	1.65	0.56	0.32	1.32	0.00	trace
1951	2.49	2.53	2.71	3.36	3.13	0.55	1.59	0.52	0.50	0.00	0.59	1.33
16-year average (1936 to 1951)	1.34	1.79	2.20	2.23	2.87	2.37	1.40	1.44	1.06	0.24	0.26	0.44
Year with least precipitation	1.39	0.62	0.28	1.27	0.45	1.99	0.28	0.85	0.27	0.50	0.54	0.65
Accumulated monthly precipitation												
Year with most precipitation	2.15	6.83	12.12	14.13	21.10	25.39	27.04	27.60	27.92	29.24	29.24	29.24
1951	2.49	5.02	7.73	11.09	14.22	14.77	16.36	16.88	17.38	17.38	17.97	19.30
16-year average (1936 to 1951)	1.34	3.13	5.33	7.56	10.43	12.80	14.20	15.64	16.70	16.94	17.20	17.64
Year with least precipitation	1.39	2.01	2.29	3.56	4.01	6.00	6.28	7.13	7.40	7.90	8.44	9.09

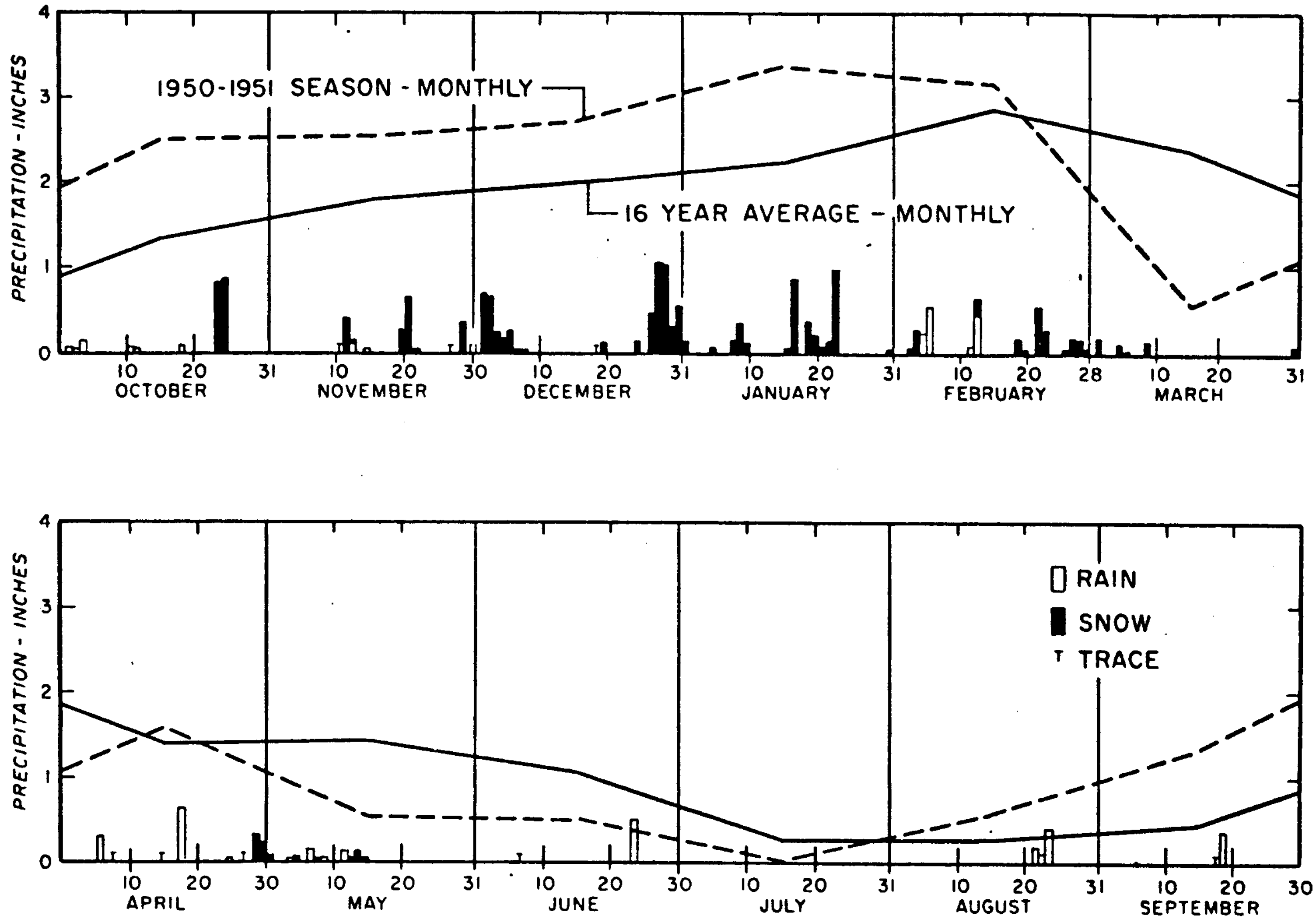

Figure 2.--Daily and monthly precipitation, Blacks Mountain Experimental Forest, 1950-1951 season.

certain conditions. First, each represented a natural regeneration area. Second, the areas were sufficiently large and properly shaped--generally larger than 0.2 acre and any shape except extremely long and narrow. Third, the trees bordering the areas were bearing a satisfactory cone crop during seedbed preparation so that seed would be supplied soon after.

Scarification

The forest floor on the plots was scarified 2 weeks before seedfall with an offset disk-harrow pulled by a wheeled farm tractor. The disk-harrow had two sets of disks with 22-inch blades. By adjusting the rear set of disks to cut between the furrows made by the forward set, maximum disturbance was attained. This machine scarified strips 4½ feet wide. It performed well on open bare areas and on areas with only light cover of low vegetation. However, it was not heavy enough to break through and tear up a duff layer or thick bunchgrass roots, and in slash the equipment hung up on limbs and chunks. Suitable scarification equipment must cope with these impediments as well as the stony soil surfaces of the eastside type.

Rodent Poisoning

Poisoning was aimed at three seed-eating rodents: ground squirrels (Citellus spp.), chipmunks (Eutamias spp.), and white-footed mice (Peromyscus spp.). Control of pine squirrels (Tamiasciurus spp.) and California gray squirrels (Sciurus griseus griseus Ord.) was not attempted since activity of these animals in the study areas was negligible during cone development. Rodent populations were not determined by trapping, but observations indicated that each of the target rodents was present before seedfall in substantial numbers on all study areas.

The lethal bait was oat groats treated with sodium fluoroacetate, also known as "1080." Three ounces of "1080" were added to every 100 pounds of groats. In all, 810 acres were treated at a cost of 26 cents per acre (Cosens and Tackle 1950).

Seedfall

Abundant seed fell in 1948. Seedfall was not measured on the study areas, but 120 8.2 square-foot seedtraps on three comparable logged plots nearby caught sound pine seed at the rate of 130,000 per acre.

Germination and Survival Counts

Seedling germination and survival were sampled on millacre quadrats arranged in transects. These transects ran through all degrees of ground cover density present on the six locations.

Each millacre quadrat was classified by the type and visible surface density of ground cover. If the quadrat had one-tenth or less of its surface covered, it was classified as bare; if more than one-tenth but not greater than four-tenths, light; more than four-tenths but not over seven-tenths, medium; and if more than seven-tenths, heavy.

Germination, survival, and height growth were analyzed by the original quadrat classifications. In 1951, each quadrat was reclassified to detect any changes in surface density. No appreciable change was found for either vegetation or duff. On some quadrats, slash had settled nearer the ground but the overall density remained unchanged.

Height Growth Measurements

If stocking is adequate, seedling vigor determines how soon, if ever, the desired reproduction will dominate competing vegetation and establish a forest cover. Therefore, seedling vigor, best measured by height growth, is another measure of regeneration success. To obtain comparisons, heights of all seedlings not damaged by deer, rodents, cattle, or other agents, were recorded for a randomly selected sample of quadrats from each of the four ground cover density groups.

RESULTS

Germination

The greatest number of seed per acre germinated on seedbeds described as bare. Here, over 33,000 seed germinated per acre. As ground cover density increased, germination decreased, with greater disparity between germination on bare and light densities of cover than between germination on medium and heavy densities. Seedbeds with light, medium, and heavy ground cover had 11,420 seedlings, 3,816 seedlings, and 2,914 seedlings per acre, respectively. Roughly similar trends are indicated for the density range within each type of ground cover (Table 3). For example, 5,062 seed per acre germinated on quadrats with light squaw carpet cover, 3,091 seed per acre on medium squaw carpet, but only 1,774 seed per acre germinated on heavy squaw carpet.

Variable effects of ground cover types on germination are also shown. The most marked example of this is the germination obtained on grassy quadrats when species of bunchgrasses and sedge were distributed approximately as follows: Idaho fescue (Festuca idahoensis) - 71 percent, squirreltail (Sitanion hystrix) - 11 percent, western needlegrass (Stipa occidentalis) - 10 percent, little bluegrass (Poa sandbergii) - 4 percent, and sedge (Carex rossii) - 4 percent. Germination on the grass-dominated quadrats for any cover density class was much greater than for any other type of cover in the same density range.

First-year Survival

The effect of ground cover upon pine seedling survival was evident as early as the end of the first growing season. While 42 percent of the seedlings on bare areas survived, only 16 percent remained alive where the cover density was heavy (Table 4). The relatively low survival (26 percent) on areas with only light cover shows that even a small amount of competition is unfavorable to seedling establishment.

First-year seedling survival on a stocked quadrat basis--one or more seedlings per milacre quadrat (Table 5)--further demonstrates the effect of the density of ground cover. Stocking after the first year under medium and heavy cover by either stocked quadrats or number of seedlings per acre (Table 6) was well below that considered necessary for producing a fully stocked stand at maturity.

Survival During Early Establishment

Seedling survival diminished each year after germination (Tables 6 and 7). Reduction in survival between the first and fourth years on bare areas was decidedly lower than the reduction on areas of dense ground cover, whether measured by numbers of seedlings (Table 7) or numbers of stocked quadrats (Table 5). For number of seedlings, the reductions in survival between the first and fourth years are 9 percent for bare, 15 percent for light, 15 percent for medium, and 11 percent for heavy densities. Though these losses are about the same percentage-wise, the loss for the heavy ground cover is more significant because far fewer seedlings survived there the first season. Reductions in stocked millacre quadrats during the same period for bare, light, medium, and heavy ground cover densities were 20 percent, 33 percent, 23 percent, and 9 percent, respectively.

Height Growth

The height growth of seedlings also showed pronounced effects of ground cover density. These differences increased markedly in the fourth year, the average total heights for all seedlings on bare, light medium, and heavy cover densities being 5.6, 2.3, 3.2, and 2.5 inches, respectively (Table 8). When only the tallest seedlings (one per quadrat) were considered, the average heights became 6.7, 3.0, 3.1, and 2.4 inches (Table 9).

Differences in height growth through the fourth year were found to be highly significant between bare and light density covers for all seedlings; and significant for the tallest seedlings. The seedling height differences between light and medium cover densities were significant for all seedlings.[1/] No other differences were statistically significant.

Seedlings on bare areas were not only taller but were much more vigorous in appearance; they had greater needle complement, longer needles, and more robust stems than seedlings on areas with greater cover density.

[1/]Height differences between seedlings growing on light and medium cover densities were not significant at the end of the third year. This discrepancy in statistical significance of height growth between the third and fourth growing season is a reflection of seedling mortality and field technique and not height growth per se. During the first 3 years, heights were measured from cotyledon scars to tips of terminal buds. In the fourth growing season, the cotyledon scars became indistinct on many seedlings so heights had to be measured from ground line to tips of terminal buds.

Table 3--Germination by type and density of ground cover

Ground cover density	Squaw carpet[1]	Grass	Woolly mules-ears[2]	Duff	Slash	All	Quadrat basis
	Type of ground cover						
	- - - Number of seeds germinating per acre - - -						(number)
Bare	--	--	--	--	--	33,329	164
Light	5,062	13,472	--	5,643	--	11,420	119
Medium	3,091	5,889	5,286	1,750	2,333	3,816	38
Heavy	1,774	5,944	--	2,286	1,428	2,914	70
Basis; number of quadrats	58	116	7	36	10	--	--

[1] *Ceanothus prostratus* Benth.

[2] *Wyethia mollis* Gray.

Table 4--Percentages of seedling survival for the first and fourth years after germination by type and density of ground cover

Ground cover density	Squaw carpet	Grass	Woolly mule-ears	Duff	Slash	All[1]
FIRST YEAR						
	- - - - - - - - - - - - - percent survival - - - - - - - - - - - - -					
Bare	--	--	--	--	--	42 (41.9)
Light	31 (4.1)[2]	26 (22.8)	--	27 (3.6)	--	26 (30.5)
Medium	9 (2.8)	19 (2.3)	27 (1.8)	14 (2.0)	29 (0.8)	19 (9.7)
Heavy	11 (7.9)	16 (4.6)	--	22 (3.6)	20 (1.8)	16 (17.9)
All[1]	20 (14.8)	25 (29.7)	27 (1.8)	24 (9.2)	24 (2.6)	38[3] (100.0)
FOURTH YEAR						
Bare	--	--	--	--	--	33
Light	19	11	--	7	--	11
Medium	0	0	8	7	14	4
Heavy	0	4	--	13	0	4
All[1]	9	10	8	8	12	24

[1]Weighted by number of quadrats sampled in each category. Data are presented in this form to indicate the natural regeneration which can be expected after scarification, rodent poisoning, and seedfall as described in this report.

[2]Numbers in parentheses show the percent of ground area in each category.

Table 5--Milacre quadrat stocking percentages for first and fourth years by ground cover density

Ground cover density	Stocked quadrats		Basis	
	First year	Fourth year	First year	Fourth year[1]
	- - - - percent - - - -		- - - - number - - - -	
Bare	90	70	164	115
Light	66	33	119	101
Medium	37	14	38	36
Heavy	17	8	70	63
All	65	39	391	315

[1]Sample size reduced by logging disturbance.

Table 6--Number of seedlings surviving per acre by type and density of ground cover, and year after germination

Ground cover density and year		Squaw carpet	Grass	Woolly mules-ears	Duff	Slash	All
		Type of ground cover					
Bare	1 year	--	--	--	--	--	14,043
	2 year	--	--	--	--	--	13,122
	3 year	--	--	--	--	--	12,035
	4 year	--	--	--	--	--	11,017
Light	1 year	1,562	3,528	--	1,500	--	3,025
	2 year	1,312	2,575	--	917	--	2,178
	3 year	937	1,822	--	417	--	1,535
	4 year	937	1,493	--	417	--	1,277
Medium	1 year	273	1,111	1,428	250	667	710
	2 year	0	571	1,000	250	333	389
	3 year	0	286	571	125	333	222
	4 year	0	0	429	125	333	139
Heavy	1 year	194	944	--	500	286	457
	2 year	103	462	--	357	286	254
	3 year	34	231	--	357	0	143
	4 year	0	231	--	286	0	127
All	1 year	586	2,940	1,428	833	400	6,962
	2 year	428	2,129	1,000	529	300	5,584
	3 year	321	1,484	571	324	200	4,943
	4 year	267	1,204	429	294	200	4,473

Table 7--Seedling survival, by ground cover density

Ground cover density	First	Second	Third	Fourth
	Years after seedfall			
	percent survival			
Bare	42	39	36	33
Light	26	19	13	11
Medium	19	10	6	4
Heavy	16	9	5	4
All	38	30	27	24

Table 8--Average heights of seedlings, in third and fourth years, by ground cover density

Ground cover density	Third year				Fourth year			
	Basis				Basis			
	Quadrats	Seedlings	Average height[1]	Difference and significance[3]	Quadrats	Seedlings	Average height[2]	Difference and significance[3]
	- - - number - - -		- - - - inches - - - -		- - - number - - -		- - - inches - - -	
Bare	10	73	2.8		8	61	5.6	
				1.5 HS				3.3 HS
Light	10	38	1.3		9	26	2.3	
				0.1 N				0.9 S
Medium	6	8	1.2		4	5	3.2	
				0.1 N				0.7 N
Heavy	5	5	1.1		3	4	2.5	

[1]Measured from cotyledons to tip of terminal bud.

[2]Measured from ground line to tip of terminal bud.

[3]HS - highly significant

S - significant

N - not significant

Table 9--Average heights of tallest seedlings (one per quadrat), in third and fourth years, by ground cover density

Ground cover density	Third year: Seedlings measured	Third year: Average height[1]	Third year: Difference and significance[3]	Fourth year: Seedlings measured	Fourth year: Average height[2]	Fourth year: Difference and significance[3]
	number	- - - - inches	- - - -	number	- - - - inches	- - - -
Bare	10	3.2		8	6.7	
			1.7 S			3.7 S
Light	10	1.5		9	3.0	
			0.2 N			0.1 N
Medium	6	1.3		4	3.1	
			0.2 N			0.7 N
Heavy	5	1.1		3	2.4	

[1]Measured from cotyledons to tip of terminal bud.

[2]Measured from ground line to tip of terminal bud.

[3]HS - highly significant

S - significant

N - not significant

Table 10--Results of 1952 regeneration cutting, Black Mountain Experimental Forest

Sample area	Sound seed production per acre: Fall[2]	Sound seed production per acre: Total[3]	Seedlings per acre 1953[1]: June	Seedlings per acre 1953[1]: October	Survival of June seedlings
	Number	Number	Number	Number	Percent
1	24,336	40,265	375	42	11
2	32,153	41,003	790	274	35
3	38,053	51,019	1,095	679	62
Average[4]	33,038	45,183	820	392	48

[1]Basis, 194 milacre quadrats.

[2]Through October 17, 1952.

[3]Through May 1953.

[4]Basis, 54 8.2 square-foot seed traps.

DISCUSSION

Comparison of results for various ground cover densities shows that ponderosa pine seedbed preparation should be aimed at eliminating all competing ground cover and exposing loose mineral soil, not necessarily over the whole ground surface but in enough evenly distributed spots for sufficient germination and early seedling survival to insure adequate future stocking. A search for reproduction on bare but unscarified ground within the poisoned area indicated that scarification is desirable even on bare ground. Seedbeds should be prepared in the same year as the seedfall to obtain the maximum benefit of loose mineral soil before it again becomes compacted.

Besides hindering germination and survival, small amounts of competing vegetation are detrimental to pine seedling development. Four years after seedfall, live seedlings on the bare soil averaged 1.8 to 2.4 times as tall as seedlings growing where ground cover was present. The dominant seedlings growing on bare soil were 2.2 to 2.9 times taller than dominant seedlings growing elsewhere. These differences are statistically significant. Visible surface cover density, therefore, appears to correlate well with seedling height growth, at least for the first 4 years.

Some might argue that areas with light cover density have adequate stocking (1,277 seedlings per acre) 3 years after seedfall. However, the number of seedlings per acre becomes less impressive when we see that only 33 percent of the millacre quadrats are stocked, and when the poor height growth (Tables 8 and 9) is considered. The chance for seedlings to attain full growth potential in early life has been thwarted by only a small amount of ground cover or visible competition. Excavations probably would demonstrate that the soil is occupied to a surprising degree with competing root systems. Bare soil seems the only suitable condition for early maximum stand development.

RESULTS

Results of the study allow the following conclusions:

1. Duff, slash, and competing vegetation are all detrimental to establishment and development of seedlings in the eastside pine type of California.

2. Detrimental effects of ground cover become increasingly greater with time, at least during the first 4 years.

3. Proper site preparation aids seed germination and seedling survival, and minimizes the period needed by seedlings to dominate the ground and assure a new stand of trees.

EXPLOITATION OF A MODERATE SEED CROP

Forest managers probably will have difficulty obtaining favorable conditions for establishing natural regeneration. The exacting requirements for natural regeneration in the eastside pine type are illustrated by an attempt to exploit a moderate seed crop expected for 1952 (Hallin 1959). Units varying from ¼ to 1½ acres and aggregating 11 acres were clearcut and oriented so that borders with cone-bearing trees surrounded each unit. Estimates in the spring of 1952 indicated that bordering trees would produce at least 600 cones or about 43,000 seeds per acre. After logging, slash and vegetation were removed, and rodents were poisoned before seedfall began in mid-September. Results were only moderately successful (Table 10). Lack of success was attributed mainly to ineffective rodent control.

CONCLUSIONS

What was learned from the significantly different results obtained in each of the two experimental attempts to obtain natural regeneration? First, competing vegetation can be reduced and seedbeds can be prepared by well-known methods. Second, elimination of animal-caused seed losses is uncertain. Because favorable weather for seedling establishment cannot be controlled, seedling survival is undependable. Consequently, planting is the surest method for promptly reforesting unstocked units.

LITERATURE CITED

Cosens, Richard D., and David Tackle. Costs of rodent control in pine regeneration in California. Res. Note 73. Berkeley, Calif.

Calif. For. and Range Exp. Stn., Forest Service, USDA. 1950. 5 p.

Hallin, William E. The application of unit area control in the management of ponderosa-Jeffrey pine at Blacks Mountain Experimental Forest. Tech. Bull. 1191. Washington, D.C.: USDA. 1959. 96 p.

Roeser, Jacob, Jr. Transpiration capacity of coniferous seedlings and the problem of heat injury. J. For. 30:381-395, 1932.

Roy, Douglass F. Some factors affecting establishment of pine reproduction on sagebrush-flat edges in northeastern California. Thesis submitted in partial satisfaction of the requirements for the degree of Master of Science in Forestry in the Graduate Division of the University of California, Berkeley, Calif. 1962. 134 p.

Tackle, D., and D. F. Roy. Site preparation as related to ground cover density in natural regeneration of ponderosa pine. Tech. pap. 4. Berkeley, Calif. Calif. For. and Range Exp. Stn., Forest Service, USDA. 1953. 13 p.