PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U.S.DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

GERMINATION AND SURVIVAL OF DOUGLAS-FIR IN NORTHERN CALIFORNIA...

effects of time of seeding, soil type, and aspect

Rudolph O. Strothmann

USDA Forest Service
Research Note PSW-245
1971

Abstract: For best results, direct-seeding of Douglas-fir in northern California should be done in November or December. In trials on two National Forests, sowing in those months resulted in significantly more seedlings than sowing in February or March. Also, more seedlings became established on fine-textured red soils than on coarser gray-brown soils. On red soils, more seedlings developed on south aspects; on gray-brown soils, more developed on north aspects. Some seeds—particularly on spring-sown plots—did not germinate until the second growing season.

Oxford: 174.7 *Pseudotsuga menziesii* (794):232.335.
Retrieval Terms: Pseudotsuga menziesii; regeneration (artificial); California (northwestern); direct-seeding; seedling survival; loam soils; aspect; seeding date.

Direct-seeding as a forest regeneration technique holds wide appeal for forest managers. This attraction is especially strong in places where rugged terrain and limited accessibility make planting costly and difficult, as in portions of the Douglas-fir region of northwestern California. The development of aerial seeding techniques has made it possible to seed large acreages much quicker and easier and relatively cheaper than planting. The number of regeneration failures which still occur on direct-seeded areas is ample evidence, however, that we need to learn much more about the factors which influence success.

To find out if the number of Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii)* seedlings which become established after direct-seeding in northern California is significantly affected by soil type, aspect, or time of seeding, studies were conducted on two National Forests. The two general types of soils tested were loams or clay loams of predominately reddish color, and coarser, stony, gray-brown loams. The two aspects tested were northerly and southerly. The seeding times were the latter parts of November, December, February, and March. A seeding had also been planned for January, but deep snow forced its cancellation.

From the results of this study, I can offer two main recommendations to forest managers in northern California who are contemplating direct-seeding of Douglas-fir: (1) seed in November or December (January also may be satisfactory); (2) if seed is in short supply, and clearcuts on several soil types must be regenerated, give preference to seeding the red soils.

STUDY SITES

Seeding was done between November 1965 and March 1966 in two separate localities in northwestern

California: one group of four study sites was near the town of Happy Camp on the Klamath National Forest; the other four sites were near Willow Creek (about 60 miles south) on the Six Rivers National Forest. In each locality two sites were on the red soil type (one on a north and one on a south aspect) and two sites, similarly paired, were on the gray-brown soil type.

Elevations of the study sites ranged from 2,100 to 3,100 feet. For the most part, slopes averaged between 30 and 45 percent, but on the gray-brown soil in the Happy Camp area the slope averaged between 65 and 70 percent.

All clearcuts used had been logged within 2 years and slash-burned within 1 year of seeding. On all blocks, Douglas-fir had been the main species present at time of logging, although tanoak *(Lithocarpus densiflorus* [Hook & Arn.] Rehd.*)* and madrone *(Arbutus menziesii* Pursh.*)* were also present in varying amounts. On several of the clearcuts, small amounts of sugar pine *(Pinus lambertiana* Dougl.*)* and ponderosa pine *(Pinus ponderosa* Laws.*)* were present.

The soils in both study areas have developed from schistose parent material. Neither area has yet been included in published soil survey reports, but on the basis of reports for nearby areas, the soils resemble those in the Josephine, Sites, Masterson, and Sheetiron series.[1]

In the Happy Camp area the reddish-brown soil resembles the Sites soil series. It is a deep, relatively stone-free clay loam with a pH of 5.6 for the surface layer. The gray-brown soil in this area resembles the Sheetiron series. It is relatively shallow, with small areas of the underlying, fractured bedrock just breaking the surface in a few places. The surface soil has a loamy texture and a pH of 5.7.

In the Willow Creek area, the reddish-brown soil probably belongs to either the Sites soil series or the Josephine series. The surface layer has a loamy texture and a pH of 5.8. It is slightly stonier and less red than the reddish-brown soil in the Happy Camp area.

The gray-brown soil at Willow Creek may be intermediate between the Sheetiron and the Masterson series. It occurs on less steep topography than its counterpart at Happy Camp and is a deeper soil. Like the Happy Camp soil, it is quite stony *(fig. 1).* The surface soil has a loamy texture and a pH of 5.5.

METHODS

Within each soil type, and as close to one another as possible, two recent clearcuts at similar elevations were chosen—one on a north aspect and the other on a south aspect. Finally, on each clearcut, three blocks (replications) to test seeding date were laid out. Seeding dates were randomly assigned to the five plots within each block (the January plots were never seeded). A plot consisted of a row of 10 seedspots. Each spot was sown with 10 untreated, aluminum-coated seeds, and subsequently covered with a dome-shaped hardware-cloth screen to prevent seed losses

Figure 1—*Characteristic stoniness of gray-brown surface soil on north aspect at Willow Creek, in northern California. The Douglas-fir seedling in front of hard-hat is in its third growing season, but has been heavily browsed.*

to rodents and birds.

To evaluate seed quality, stratified seeds were tested for germination in the laboratory concurrently with the last of the field sowings. Laboratory germination averaged 91 percent after 32 days. The field sowings were made with unstratified seed to permit natural conditioning. The laboratory tests served to indicate the germination potential of the seed under ideal conditions.

The effects of time of seeding, soil type, and aspect on germination and survival were tested by analysis of variance of seedling counts at the end of the first and second growing seasons. The analysis treated certain factors as "nested" within others because each site had a fixed combination of factors that cannot be assigned independently of the others. The eight sources of variation tested were: (1) locality, (2) soil/locality, (3) aspect/soil/locality, (4) block/aspect/soil/locality, (5) date of seeding, (6) date X locality, (7) date X (soil/locality), and (8) date X (aspect/soil/locality). Results of seedings in March were excluded from the analysis because of their complete failure the first year.

RESULTS

The sources of variation statistically significant at the 1 percent level *(table 1)* were:

soil/locality
aspect/soil/locality
block/aspect/soil/locality
date of seeding
date X (soil/locality).

The interaction of date X locality was significant at the 5 percent level. The interaction of date X (aspect/soil/locality) was significant at that level the first growing season, and at the 1 percent level the next season. Locality alone was not a significant factor.

Time of Seeding

The November and December seedings were the most successful—particularly those on red soil with a southerly aspect *(table 2)*. Differences between seedings in November and December were not significant, but both produced significantly more seedlings than seedings in February. The seedings in March were a complete failure the first year. Seedings during November and December on red soil and southerly aspect produced more than 30 first-year seedlings per 300 seeds sown at Happy Camp, and 25 or more seedlings per 300 seeds sown at Willow Creek. Also, on the north aspect of the red soil at Happy Camp, the December seeding produced more than 30 first-year seedlings per 300 seeds sown. The superiority of seeding in November or December is demonstrated by the number of live seedlings counted at the end of both the first and second growing seasons *(table 3)*.

In general, more live seedlings were present in April than during later months, although in a few instances the peak count was attained in May. Neither count represents total germination, however, since new seedlings continued to appear on most plots as late as June, and in some cases, even later. The decreasing numbers after April simply show that mortality exceeded germination as the growing season progressed.

Table 1—*Analysis of variance of Douglas-fir seedling counts at end of the first and second growing seasons*[1]

Source of variation	Degrees of freedom	F value	
		First growing season	Second growing season
Locality	1	3.321	4.078
Soil/locality	2	17.812**	24.388**
Aspect/soil/locality	4	7.193**	8.855**
Block/aspect/soil/locality	16	2.934**	3.414**
Seeding date	2	39.869**	5.668**
Date X locality	2	3.904*	4.148*
Date X (soil/locality)	4	4.672**	4.434**
Date X (aspect/soil/locality)	8	2.893*	4.033**
Error	32	–	–
Total	71	–	–

[1]March seeding results excluded because of complete failure the first year.
*Significant at 5 percent level.
**Significant at 1 percent level.

Table 2—*Germination and survival of Douglas-fir seedlings during the first growing season, by date of seeding, soil type, and aspect (all replications combined)*

Date seeded	Happy Camp Area						Willow Creek Area					
	Apr.	May	June	July	Aug.	Sept.	Apr.	May	June	July	Aug.	Sept.
	Number per 300 seeds											
RED SOIL/NORTH ASPECT												
Nov. 1965	32	30	22	20	17	14	15	13	12	10	10	9
Dec. 1965	77	54	37	35	35	31	6	4	4	5	5	4
Feb. 1966	7	6	6	5	5	5	0	2	1	2	2	2
Mar. 1966	0	0	0	0	0	0	0	0	0	0	0	0
RED SOIL/SOUTH ASPECT												
Nov. 1965	43	36	33	33	32	31	60	39	31	31	31	25
Dec. 1965	66	57	47	43	40	33	58	39	38	37	33	29
Feb. 1966	0	0	0	0	0	0	0	1	1	1	1	1
Mar. 1966	0	0	0	0	0	0	0	0	0	0	0	0
GRAY-BROWN SOIL/NORTH ASPECT												
Nov. 1965	17	17	9	9	7	5	13	21	19	19	19	19
Dec. 1965	35	33	19	16	16	16	4	9	9	9	9	9
Feb. 1966	10	10	10	8	5	4	1	5	5	5	5	4
Mar. 1966	0	0	0	0	0	0	0	0	0	0	0	0
GRAY-BROWN SOIL/SOUTH ASPECT												
Nov. 1965	28	18	11	11	9	7	18	7	7	7	7	7
Dec. 1965	17	10	8	8	6	3	10	5	5	4	3	3
Feb. 1966	0	0	0	0	0	0	0	0	0	0	0	0
Mar. 1966	0	0	0	0	0	0	0	0	0	0	0	0

Because seedlings were counted only once per month, it was not possible to identify accurately the causes of mortality. General observations of the dead seedlings suggested that the main causes were damping off, drought, and cutworms.

The February seedings, with one exception, failed to produce any first-year seedlings on south aspects, although a few did become established on north aspects.

Second growing-season results showed some success for February and March seedings because of delayed germination (many second-year germinants could be positively identified by traces of aluminum powder still present on the seedcoats). A few of the seeds sown in November and December also showed delayed germination, but these few comprised only a small percentage of the total number sown in those months.

Type of Soil

Soil type exerted a significant influence on the number of seedlings which were produced. Seedings on the red soils resulted in far more seedlings in both localities the first growing season than did seedings on the gray-brown soils *(table 3)*. This difference continued throughout the second growing season at Happy Camp, but not at Willow Creek because of a sizable amount of delayed germination on the gray-brown soils there.

Aspect

The influence of aspect on establishment of seedlings appears more complex, with neither aspect being consistently superior to the other. Response apparently varied with soil type, as evident from the first-season results *(table 3)*. On the red soil in both areas, the south aspects produced the most seedlings; whereas on the gray-brown soils, the north aspects produced the most. These same relationships generally prevailed during the second growing season, except that on the red soil in the Happy Camp area, delayed germination was considerably greater on the north aspect than on the south. Therefore, by the end of the second season, seedling counts were nearly identical (73 vs. 72).

Table 3—*Number of live Douglas-fir seedlings at end of first and second growing seasons, by soil type, aspect, and month of seeding (all replications combined)*

Soil type and aspect[1]	Month of seeding[1]				Total
	Nov.	Dec.	Feb.	Mar.	
HAPPY CAMP (149)-FIRST GROWING SEASON					
Red Soil (114):					
North aspect	14	31	5	0	50
South aspect	31	33	0	0	64
Gray-brown soil (35):					
North aspect	5	16	4	0	25
South aspect	7	3	0	0	10
WILLOW CREEK (112)-FIRST GROWING SEASON					
Red soil (70):					
North aspect	9	4	2	0	15
South aspect	25	29	1	0	55
Gray-brown soil (42):					
North aspect	19	9	4	0	32
South aspect	7	3	0	0	10
Total	117	128	16	0	–
HAPPY CAMP (189)-SECOND GROWING SEASON					
Red soil (145):					
North aspect	13	30	15	15	73
South aspect	30	29	5	8	72
Gray-brown soil (44):					
North aspect	5	15	12	7	39
South aspect	4	1	0	0	5
WILLOW CREEK (132)-SECOND GROWING SEASON					
Red soil (60):					
North aspect	6	3	11	4	24
South aspect	14	20	2	0	36
Gray-brown soil (72):					
North aspect	24	9	14	9	56
South aspect	9	1	2	4	16
Total	105	108	61	47	–

[1]Figures in parentheses show total number of live seedlings.

In spring of the first growing season, I noted that germination on both soils occurred sooner on south aspects than on north. This difference undoubtedly was chiefly a temperature response, with temperatures suitable for germination occurring later on north slopes than on south.

This slower warm-up on the north slope, however, benefited the February sowings by giving the seeds more time to undergo the pre-chilling needed to break dormancy. At the end of the first growing season, a few seedlings were present on each of the four north aspects for the February seeding. By contrast, three of the four south aspects had no seedlings at all. And the fourth (red soil at Willow Creek) had only one. The number of seedlings on both aspects increased the second year, owing to delayed germination. But seedlings on north aspects still outnumbered those on south aspects by almost six to one (52 vs. 9).

DISCUSSION

Seeding date for Douglas-fir has received considerable study in the Pacific Northwest. Carmichael[2] tried seeding at semi-monthly intervals from January through May in southwestern Washington. He found that seeding before mid-March resulted in substantially higher germination (greater than 17 percent) than seedings made after this time (less than 8 percent).

Dick[3] tried seeding at intervals from September 24 through March 25 in western Washington. He found that seeding date had a highly significant effect on both germination and seedling survival. Greatest success was achieved from November to mid-January. Although survival of germinants increased with later seedings, this was greatly offset by decreasing germination when seeding was done after mid-January.

Gartz[4] tried direct-seeding of stratified Douglas-fir seed in April, May, and June and on various slopes and aspects in northwestern Oregon. The April sowings produced more seedlings than those in May or June, and north and east aspects produced more than did the south and west aspects. In comparing his spring-sown plots with fall sowings, Gartz concluded that spring sowing is less desirable.

Lavender[5], also conducting studies in northwestern Oregon, achieved better results from November and December seedings than from seedings in January, February, or March. He likewise found that more seedlings germinated on north aspects than on south aspects.

Seedling counts were not recorded separately by age class in this study, but it is apparent that the seedings in November and December resulted in the greatest number of first-year seedlings and in the least amount of delayed germination. Evidently most of the seed sown in either of these two months was exposed to sufficient moist pre-chilling to break dormancy the following spring. On the other hand, seed sown as late as February or March during this single test year had insufficient natural stratification; hence germination was delayed.

Delayed germination has also been noted in other seeding trials with Douglas-fir in northwestern California.[6] Nevertheless, because of the many hazards to which seeds are exposed if they lie on the ground for a year or more before they germinate, the number of seedlings which may be produced from such seeds is highly uncertain. Thus, the best seeding dates are those which will result in the greatest number of seedlings the first year after sowing. On this basis the February and March seeding dates must be rated as poor choices.

That red soils produce more seedlings than gray-brown soils has also been reported by Cooper.[7] Doubtless this response difference is due to more than merely a difference in soil color. The red soils at Happy Camp and Willow Creek are generally more fine-textured than the gray-brown soils and therefore probably can hold more moisture. And they are less stony than the gray-brown soils. Further research on the effects of soil type characteristics on regeneration is needed.

Precipitation during the growing season (April through September) was below the 20-year average for both areas in both years that the study was in progress. The first year was particularly dry, with rainfall averaging only about half of normal for the 6-month period. And, during the critical 3-month period of May through July, both areas received less than 1 inch of rain as compared to the normal amounts of 3.05 inches at Willow Creek and 3.60 inches at Happy Camp.[8] These unusually dry conditions during this first growing season undoubtedly reduced germination and survival appreciably.

Hardware-cloth screens were used in this study to protect seed spots from animal depredation. The screens may also have slightly improved the microenvironment for germination and establishment. Therefore, in an operational job where broadcast seeding is used, the number of seeds required per established seedling may be somewhat higher than reported in this note.

Acknowledgments: I thank the Klamath and Six Rivers National Forests for providing study areas and for their help in installing study plots.

NOTES

[1]Zinke, Paul J., and W. L. Colwell, Jr. *Some general relationships among California forest soils.* In, *Forest-soil relationships in North America.* Oregon State University Paper 25, p. 353-365, illus. 1965.

[2]Carmichael, Ralph L. *Relation of seeding date to germination of Douglas-fir seed.* Northwest Sci. 31: 177-182, illus. 1957.

[3]Dick, James. *Period for direct seeding Douglas-fir in the Pacific Northwest.* Weyerhaeuser Forestry Res. Note 48, 6 p., illus. 1962.

[4]Gartz, Jack F. *Stratified Douglas fir seed sown in April, May and June.* Oregon State Board of Forestry Res. Note 19, 19 p., illus. 1955.

[5]Lavender, Denis P. *Seeding dates and Douglas fir germination.* Oregon Forest Lands Res. Center, Res. Note 34, 15 p., illus. 1958.

[6]Personal correspondence from William W. Oliver. Pacific SW. Forest & Range Exp. Sta., Redding, Calif. Oct. 10, 1965.

[7]Cooper, D. W. *Influence of soil type on reforestation in Humboldt County.* Calif. Agr. 15(7): 4, illus. 1961.

[8]Based on records at U.S. Forest Service Ranger stations in these communities.

The Author

RUDOLPH O. STROTHMANN is doing research on the silviculture of redwood and associated species, with headquarters in Arcata, Calif. He earned bachelor's (1950), master's (1951), and Ph.D. (1964) degrees in forestry at the University of Michigan, and has been on the Station's staff since 1964.

GPO 981-227