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Madrone Duff and the Natural Regeneration of Douglas-fir

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Abstract

Excellent natural regeneration of Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) often occurs under canopies of Pacific madrone *(Arbutus menziesii* Pursh), but the effects of madrone duff on regeneration are poorly understood. A field experiment was conducted in a thinned Douglas-fir stand in southwestern Oregon to see if madrone duff benefits natural regeneration or reduces the cover of species that compete with Douglas-fir. No significant differences in conifer regeneration and growth or in the cover of competing species occurred among seedbeds of madrone duff, conifer duff, and mineral soil during 10 growing seasons. Douglas-fir regeneration may be affected less by madrone duff than by other influences of madrone trees.

Keywords: Duff, regeneration (natural), Douglas-fir, madrone.

Introduction

Pacific madrone *(Arbutus menziesii* Pursh) often competes with Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco). Several components of that competition have been studied: madrone growth rates (Roy 1955, Tappeiner and others 1984); leaf area and biomass (Harrington and others 1984); transpiration (Bentson 1983); and effects of madrone sprouts on light, moisture, and temperature (Minore 1986). The allelopathic effects of madrone are inconsistent, however, and the influence of madrone duff on the natural regeneration of Douglas-fir is poorly understood.

Del Moral and Cates (1971) used extracts of leaves and litter to show that madrone produces allelopathic chemicals capable of inhibiting the radical elongation of germinating Douglas-fir seeds on extract-soaked sponges in the laboratory. They compared the number and cover of species beneath madrone canopies with the number and cover of species beyond the canopies and concluded that madrone reduces subordinate vegetation in the field.

Tinnin and Kirkpatrick (1985) also examined the allelopathic effect of madrone on early seedling growth of Douglas-fir. Their leaf extracts did not significantly reduce the radical elongation of germinating Douglas-fir seeds on extract-soaked sponges. Tinnin and Kirkpatrick germinated and grew Douglas-fir for 4 weeks in a mixture of sponge rock and vermiculite; mean seed germination time nearly doubled and root growth time was halved when leaf material was added to the artificial soil mixture. Madrone leaf material had no significant effect on Douglas-fir growth when it was added to soils collected from the field, however, and germination was slowed in only one of three soil trials. Tinnin and Kirkpatrick concluded that allelopathy is not the primary factor affecting the regeneration of Douglas-fir in southwestern Oregon.

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Rose and others (1983) found that madrone litter extracts stimulate the growth of some mycorrhizal fungi and inhibit others when applied to pure cultures in the laboratory. Inhibition varies with the concentration of the extract. They found that madrone litter leachate reduces the mycorrhizae formed on roots of Douglas-fir seedlings grown in the greenhouse on forest soil from southern Oregon, but it does not reduce root growth or shoot weight.

Laboratory experiments using extracts of ground leaves or leaf litter and artificial substrates are useful in isolating the effects of allelopathic chemicals, but they do not indicate the importance of those effects in the field. Similarly, laboratory and greenhouse experiments that use soils collected from the field for short-term bioassays of allelopathic effects neither prove nor disprove the importance of allelopathy in nature. If allelopathic effects occur, their cause or causes may be very difficult to isolate. Nevertheless, it is important to determine the presence or absence of those effects under natural conditions.

Alvarez and others (1979) determined that white fir *(Abies concolor* [Gord. & Glend.] Lindl. ex Hildebr.) seedlings survive and grow better in mineral soil alone than in mineral soil with organic layers in the north-central Sierra Nevada. They concluded that both seedling growth and the presence of mycorrhizae are favored by the absence of organic layers.

Organic layers derived from madrone litter are present under most madrone trees, and these local areas of madrone duff may affect the survival and growth of naturally established Douglas-fir seedlings. Pacific madrone competes for light, moisture, and nutrients, but it often forms a nurse cover for Douglas-fir in southwestern Oregon (Gratkowski 1961). Excellent natural regeneration of Douglas-fir sometimes occurs under madrone canopies (fig. 1).

I conducted an experiment in the field to determine if madrone duff benefits the natural regeneration of Douglas-fir or reduces the cover of species that compete with Douglas-fir seedlings. I conducted another experiment in the laboratory to determine if madrone duff affects Douglas-fir seed germination. There were three null hypotheses:

- Madrone duff does not affect the natural regeneration of Douglas-fir.
- Madrone duff does not affect the cover of competing species.
- Madrone duff does not affect the germination of Douglas-fir seeds.

Figure 1—Natural regeneration of Douglas-fir under a madrone canopy.

Methods

Field Experiment

The field experiment was established in a Douglas-fir stand at an elevation of 945 meters (3,100 ft) in the Tiller Ranger District, Umpqua National Forest. Similar stands are common in the Cascade Range of southwestern Oregon. This stand was thinned in 1974. Average light intensity under the thinned stand at noon on September 12 was 410 microeinsteins meter^{-2} second^{-1} -about 25 percent of full sunlight. [1/] Soil under the stand was a well-drained sandy loam in the Straight series. The site had a west aspect and was on a 40-percent slope. An array of 12 seedbed plots was established in May 1975. Each plot was a 2- by 1-meter (6.6- by 3.3-ft) rectangle, and the plots were spaced about 3 meters (9.8 ft) apart.

[1/] A Li-Cor model LI-185A quantum/radiometer/photometer and quantum sensor registering in the 400 to 700 nm waveband were used to measure radiation at 1 meter (3.3 ft) above the soil surface at 120 systematically located points. (The use of trade names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others that may be suitable.)

Three treatments were randomly assigned to these 12 plots. In the first treatment, all duff was removed from four plots. In the second treatment, all duff was removed from four plots and immediately replaced. In the third treatment, all duff was removed from four plots and replaced with madrone duff. Four 2- by 1-meter (6.6- by 3.3-ft) areas under a nearby madrone stand were scraped bare to provide the duff for this third treatment. Thus, there were four replications of three seedbeds: mineral soil, conifer duff, and madrone duff. Sides of 1.3-centimeter (0.5-in) hardware cloth were constructed around each plot to reduce litter movement and raveling. The sides were 15 centimeters (6 in) high and supported by length of 1.3-centimeter (0.5-in) diameter aluminum tubing driven into the soil at regular intervals.

I revisited the plots in June 1976, May 1977, July 1978, September 1979, September 1980, and September 1984. Fresh litter from the previously scraped areas under the madrone stand was removed and scattered on the madrone duff plots in 1976, 1977, 1978, and 1979. Douglas-fir seedlings of natural origin were counted and measured on each of the 12 plots at each visit. Vegetative cover was measured in 1976, 1977, 1978, 1979, and 1984 by recording the length occupied by each species present along two systematically located, 2-meter (6.6-ft) line intercepts on each plot. Numbers of seedlings, heights of the tallest seedling on each plot, and total vegetative cover were evaluated in split-plot analyses of variance by treating seedbed treatments as the whole plots and measurement periods as the subplots.

Laboratory Experiment

Surface material was collected from each of the 12 field plots and brought to the laboratory in September 1984. The field samples were moistened and placed in 12 plastic sandwich boxes. Sixty Douglas-fir seeds were sown on the surface in each box, and the boxes were closed and placed in random order in a cooler at 1 °C (34 °F). After an 8-week stratification period, the closed boxes were removed from the cooler and placed in random order in a growth chamber at 10 °C (47 °F) with a 12-hour photoperiod. Germinating seeds were counted and removed daily. I used the techniques described by Campbell and Sorensen (1979) to calculate days to peak germination, mean germination rate, and the standard deviation of mean germination rate. Germination percentages were transformed to arc sines. Completely random analyses of variance were used to examine all differences associated with seedbed substrates.

Results

Field Experiment

Douglas-fir regeneration was slow at first, but there was an average of 2.7 seedlings/square meter (0.25 seedlings/ft^2) after the first six growing seasons (table 1). Regeneration continued during the last four growing seasons to produce an average of 10 seedlings/square meter (0.93 seedlings/ft^2) in September 1984 at the end of the 10th growing season. This is equivalent to 100,000 seedlings/hectare (40,469 seedlings/acre). Variation among seedbed replicates was large, however, and the conifer duff, mineral soil, and. madrone duff averages were not; significantly different.

The Douglas-fir seedlings grew slowly. Seedling heights increased with every measurement but the increases were small and not significantly different among seedbeds (table2).

Table 1—Average number of naturally established Douglas-fir seedlings on conifer duff, mineral soil, and madrone duff seedbeds in the field, by measurement date[1/]

Seedbed	June 1976[2/]	May 1977[2/]	July 1978[2/]	September 1979[2/]	September 1980[2/]	September 1984[2/]
			Seedlings per square meter[3/]			
Conifer duff	0.1	1.1	2.0	3.1	2.8	7.1
Mineral soil	.1	1.1	1.9	2.5	2.5	9.8
Madrone duff	.1	.4	2.8	3.1	2.9	13.2

[1/] Each value is the average obtained from 4 randomly located, 2- by 1-meter rectangular plots under a thinned Douglas-fir stand. The plots were established in May 1975.

[2/] The seedbed values do not differ significantly (P<0.05).

[3/] To obtain number of seedlings per square foot, multiply by 0.0929.

Table 2—Average height of naturally established Douglas-fir seedlings on conifer duff, mineral soil, and madrone duff seedbeds in the field, by measurement date [1/]

Seedbed	May 1977[2/]	July 1978[2/]	September 1979[2/]	September 1980[2/]	September 1984[2/]
			Centimeters[3/]		
Conifer duff	2.0	4.1	5.2	6.5	11.9
Mineral soil	2.3	4.8	6.4	7.6	11.8
Madrone duff	1.5	5.3	6.7	8.2	9.1

[1/] Each value is the average obtained from the tallest seedling on each of 4 randomly located, 2- by 1-meter rectangular plots under a thinned Douglas-fir stand. The plots were established in 1975, but absence of seedlings on most replicates made height analysis impractical in 1976.

[2/] The seedbed values do not differ significantly (P<0.05).

[3/]To obtain height in inches, multiply by 0.3937.

Competing vegetation was not a serious problem on any of the seedbed plots. Indeed, seedling establishment seemed to be more common under competing plants than it was in the open. Snowberry *(Symphoricarpos albus* [L] Blake) was the most abundant species, and it accounted for about half of the vegetative cover after 10 growing seasons. Species composition was similar on the three seedbeds, and the average cover of competing vegetation did not differ significantly on conifer duff, mineral soil, and madrone duff (table 3).

Table 3—Average cover of competing vegetation on conifer duff, mineral soil, and madrone seedbeds in the field, by measurement date[1]

Seedbed	June 1976[2]	May 1977[2]	July 1978[2]	September 1979[2]	September 1984[2]
			Percent		
Conifer duff	23.2	7.2	21.8	24.0	36.0
Mineral soil	25.5	7.5	17.5	15.2	34.8
Madrone duff	21.8	3.8	13.5	12.0	32.2

[1] Each value is the average obtained from line intercepts on 4 randomly located, 2- by 1-meter rectangular plots. Snowberry *(Symphoricarpus albus* [L] Blake) was the dominant species on all 3 seedbeds.

[2] The seedbed values do not differ significantly ($P<0.05$).

Table 4—Average germination percentages, days to peak germination, and mean germination rates of Douglas-fir seeds stratified and germinated in the laboratory on conifer duff, mineral soil, and madrone duff [1]

Seedbed substrate	Germination[2]	Peak germination[2]	Mean germination rate and standard deviation[2] [3]
	Percent	*Days*	
Conifer duff	57.1	12.8	0.0643 ± 0.0231
Mineral soil	68.3	12.6	.0656 ± .0231
Madrone duff	72.5	12.4	.0666 ± .0237

[1] Each value is the average of 4 replicates.

[2] Determined by the method of Campbell and Sorensen (1979). The substrates do not differ signify-cantly ($P< 0.05$).

[3] Mean germination rate equals 1/(mean germination time in days).

Laboratory Experiment

Germination began 8 days after seeds were placed in the growth chamber; the last viable seed germinated 7 weeks later. A few more Douglas-fir seeds germinated on madrone duff than on conifer duff or mineral soil, but the differences among seedbed substrates were not significant (table 4). Differences among substrates, were also small and not significant with respect to peak germination !and mean germination rate. I. did not observe any substrate-related germination abnormalities.

Conclusions

None of the three hull hypotheses were rejected. Failure to reject a null hypothesis does not prove that null hypothesis (Parkhurst 1985), however and. the lack of significant differences among the. seedbed, substrates does not prove that the substrates were similar I have not shown that madrone duff failed to affect; natural regeneration, competing vegetation, or seed germination; It may have done so but any effects of the duff were obscured by variation among seedbed, replicates. That variation indicates that other factors were more Important than madrone duff.

If madrone duff benefits the natural regeneration of Douglas-fir, reduces competing vegetation, or affects the germination of Douglas-fir seeds, its effects probably are not very important. Douglas-fir regeneration may be affected less by madrone duff than by the influences of madrone trees on microclimate, soil moisture, seed fall, animal predation, and other unmeasured variables.

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