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Plant moisture stress patterns in planted Douglas-fir: a preliminary study of the effects of crown and aspect

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Plant moisture stress (PMS) regimes over the summer were determined in planted Douglas-fir seedlings in clearcut and partial-cut blocks. On the south slope clearcut, PMS reaches levels that after June could seriously reduce seedling growth. The PMS of the clearcut plots exceeds 15 atmospheres at midmorning in June, but partial-cut plots do not exceed this level until September. The greater PMS of the south clearcut plot has not retarded height growth of the Douglas-fir. This is the only plot, however, on which regeneration stocking is not adequate.

Oxford: 174.7 Pseudotsuga menziesii: 422.2: 181.31: 182.28.

Retrieval Terms: Douglas-fir; moisture stress; aspect (plant cover); crown cover; canopy; regeneration.

Plant moisture stress (PMS) is an integrated measure of the balance between available soil moisture, climatic environment, and the physiological status of plants. Because moisture stress is a key element in regeneration, PMS may serve as an index to evaluate potential for seedling survival and growth. On many sites in northwestern California, moisture stress during the summer deters successful stand regeneration. Forest Survey statistics for Humboldt County indicate a conversion of commercial conifer sites to noncommercial brush as the result of poor regeneration following harvest.[1] The microenvironment after harvest is undoubtedly important to successful stand regeneration; lessening moisture stress by leaving a partial canopy may be expected to improve the survival of planted Douglas-fir.

On hot dry sites a residual canopy should ease the moisture stress by reducing temperatures, slowing wind movement, and increasing relative humidity. As a result, planted or natural seedlings should have a greater probability of survival. This study looks at the effect of a residual crown canopy and aspect on seasonal and daily PMS trends of some well-established Douglas-fir.

EARLIER STUDIES

The amount of soil water available for plant physiological processes is an important controller of plant growth. Plant water conditions, not soil water, should be studied, and according to Kramer,[2] in experiments dealing with water and plant growth, the PMS should be measured. In a laboratory study by Cleary,[3] the photosynthetic rate of Douglas-fir seedlings dropped from 66 percent at a PMS of 15 atmospheres (atm.) to 36 percent at 20 atm. In addition, a water deficit is seen by Slatyer[4] to reduce plant growth because stomata closure reduces carbon-dioxide uptake,

Table 1—*Characteristics of 1-acre plots selected to sample plant moisture stress of planted Douglas-fir, Six Rivers National Forest, California*

Characteristics	Clearcut block				Partial-cut block			
	South plot		North plot		South plot		North plot	
	Avg.	*S.D.*	*Avg.*	*S.D.*	*Avg.*	*S.D.*	*Avg.*	*S.D.*
Slope ....pct	67		39		22		55	
Basal area ....ft²/acre	0		0		72		97	
Brush cover ....pct	53	10	43	13	46	5	48	18
Sunlight ....pct of full	90	19	57	43	50	13	28	23
Regeneration:								
Douglas-fir ....trees/acre[1]	0		400		100		300	
True fir ....trees/acre[1]	0		1600		100		2200	

[1] Trees per acre × 2.47 = trees per hectare

and as a consequence, all biochemical processes. Waring[5] reported that at approximately 18 atm. of PMS, growth ceased in Douglas-fir 1 to 2 m tall.

Microclimate of a stand directly influences plant PMS, especially if the soil moisture is low. Waring and Cleary[6] found that PMS may be as many as 6 atm. lower on shaded than unshaded trees. Reducing the radiation by increasing shade will reduce temperatures and evaporation; increased shade resulted in higher survival of natural Douglas-fir, in a study by Tappeiner and Helms.[7] This study also showed that soil moisture stress on all test sites reached 15 atm. by summer's end, but the reduced evaporation allowed seedlings to survive the late summer drought. Shade also improved the survival of planted Douglas-fir, in a study by Minore.[8]

STUDY AREA AND METHODS

The study area is in eastern Humboldt County, on the Six Rivers National Forest on the granitic Ironside Mountain batholith. Plots ranged from 4500 to 5000 feet (1370 to 1525 m) in elevation, where snow cover is common, especially on north-facing slopes. Of the average annual precipitation of 50 to 60 inches (127 to 152 cm), 80 percent falls between November and March. Soils of all the plots are in the Neuns series[9]—well-drained, coarse, lateritic soils derived from igneous parent materials. Neuns soils generally develop on steep slopes above 4000 feet (1220 m) and often have a high erosion hazard following logging.

The daily and seasonal patterns of PMS were determined on four 1-acre (0.405 ha) plots laid out on north and south slopes of partial-cut and clearcut blocks *(table 1)*. All cutblocks were planted in 1963 with 2-0 seedlings of Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco). On each plot, six Douglas-fir between 3 and 10 feet (1 to 3 m) were selected for PMS sampling, which was scheduled at monthly intervals starting in mid-June and ending in September. Trees of this size were chosen so that they would not be seriously defoliated by repeated foliage clipping.

Brush cover was estimated at five points (determined at random azimuths and distances) around each plot center. A 20- by 20-foot subplot was established at each location. Brush crown diameters were mapped on the subplots; the percentage of crown cover was estimated from these maps *(table 1)*.

Regeneration of the 1-acre plots was sampled with two milacre quadrats in each of the brush subplots *(table 1)*. No planted Douglas-fir were found on the 10 random milacre quadrats of the south clearcut plot. However, Douglas-fir were found on the larger brush plots, outside the quadrats, at a survival rate of 44 per acre (17.8/ha). All plots except the south clearcut have natural true fir seedlings, and the south partial cut plot also showed 196 planted ponderosa per acre (79.4/ha).

Percent of full sunlight *(table 1)* was estimated at one corner of each of the five subplots, using the anthracene-benzene solution method.[10] The five random points in each plot were sampled on four consecutive days in August 1974. Each day a vial of solution was placed at each point and exposed for 24 hours. Buff-colored towels were used as a standard background for the field and calibration vials. The calibration curve used to estimate light was a linear regression of transmittance values of the solution and light meter readings under 0, 1, 2, 4, and 6 layers of window screen.

The PMS of each sample tree was determined before dawn, at midmorning (after 9:00 a.m.), and again at midday (after 12:00 p.m.). Each tree was subjected to the full day sequence of tests twice during a 4-day period in June, July, August, and once in September. Foliage samples were small twigs 2 to 4 inches (5 to 10 cm) long, which were immediately placed in the pressure chamber.[11] Pressure was applied to the foliage of the twig at a rate of 1 to 2 atm. per second. The tree PMS recorded was that pressure at which a bead of moisture appeared on the exposed cut end of the twig. Trees in the sun were sampled on the shady side.

RESULTS

By mid-June, when the first PMS determinations were made, trees on the north-facing slopes had not begun leader growth. At the same time, the trees of the south clearcut plot had virtually completed their leader growth. At the June predawn test PMS was less than 8 atm. on all the plots *(table 2)*. An analysis of predawn results indicates very little difference between plots during the June tests. In contrast, the July, August, and September predawn PMS rates show increasing differences between plots: during these 3 months the PMS on the south clearcut plot is always much higher than on the other three plots. By July only trees on the south slope clearcut show a substantial increase in predawn PMS. By August these same trees show an increase in PMS to a level more than twice that of June. Predawn PMS rates of trees on the north clearcut and partial cuts do not increase appreciably until the September tests. Over the summer both south aspect plots show an appreciable increase between July and August. The north-facing plots do not increase in PMS at such a rate until September.

Midmorning PMS values in June and July are similar, but a strong upward trend develops in the south clearcut plot after July. The north clearcut and partial cut plots do not show this amount of PMS increase until September. The June midmorning PMS plot averages are not very different, but throughout the rest of the summer there are greater differences between plots *(table 2)*. A comparison of averages between plots showed that in August and September the south clearcut plot is much higher in PMS than the other plots. Across months, the PMS of the partial cuts does not change much until September. Midmorning PMS of both clearcut plots exceeds 15 atm. in June; and except for the June north partial cut, the partial cuts do not reach this level until September.

The midday PMS values have a narrow range throughout the summer, and except for the south clearcut, a rather small increase from June to September. The June midday values of all plots are not much different. By September the south clearcut plot has increased somewhat more than the other plots. Note, however, that by September all plots reach a PMS of nearly 20 atm. or more by the middle of the day.

Table 2–*Summary of plant moisture stress of planted Douglas-fir on four logged plots, Six Rivers National Forest, California, summer 1974*

Month	Clearcut block				Partial cut block			
	South plot		North plot		South plot		North plot	
	Avg.	S.D.	Avg.	S.D.	Avg.	S.D.	Avg.	S.D.
	Atmospheres							
	Predawn							
June	7.7	1.1	7.0	0.8	7.1	1.0	7.9	0.9
July	10.4	1.2	8.0	1.5	8.2	1.5	7.5	1.4
August	15.6	1.4	8.0	0.9	10.5	1.9	9.0	1.9
September	21.0	1.4	12.4	1.8	15.5	1.4	17.4	2.2
	Midmorning							
June	15.7	2.0	17.1	1.4	14.6	2.3	15.8	2.7
July	15.6	2.0	15.1	1.2	12.6	2.1	14.8	2.0
August	21.7	1.4	15.3	2.1	13.2	2.0	14.7	3.6
September	24.0	0.8	20.4	1.5	20.1	1.9	19.0	1.7
	Midday							
June	16.8	1.4	16.4	1.0	17.8	1.3	16.9	1.8
July	17.6	0.8	16.0	0.9	15.6	1.3	17.2	2.7
August	21.0	0.9	17.5	1.2	19.7	2.2	20.1	1.4
September	24.2	2.2	19.2	2.1	20.7	0.8	21.1	1.6

Average total height and height growth values for the selected PMS trees are highest on the south clearcut plot *(table 3)*. There are no strong differences between the average total heights, but the current height growth of the south clearcut plot is much greater than that of the other plots. The north partial-cut plot height growth is also shown to be much less than that of the north clearcut, but not different from that of the south partial cut.

Table 3–*Height and growth of the planted Douglas-fir sample trees, Six Rivers National Forest, California*

Plot	Total height		Height growth	
	Avg.	S.D.	Avg.	S.D.
	Inches[1]			
Clearcut block:				
South plot	68.3	5.9	6.8	0.6
North plot	58.5	11.2	5.1	1.9
Partial-cut block:				
South plot	62.2	21.3	4.0	0.7
North plot	49.7	8.2	1.8	0.7

[1] Inches × 2.54 = height in cm.

The regeneration survey on these acre plots indicates that stocking of only the south clearcut is inadequate *(table 1)*. The principal problem of this clearcut plot is poor seedling survival, not height growth. The south partial-cut plot and both north slope plots have adequate survival of planted seedlings plus a component of naturally seeded true fir.

DISCUSSION

Predawn PMS reflects the cumulative seasonal use of the available soil water. After sunrise the PMS represents a tree's complex reaction to the soil water, and its increased transpirational activity. By September all predawn PMS values exceed the 18 atm. that Cleary[3] found cut Douglas-fir photosynthesis to nearly 50 percent of its maximum at 8 atm. By midmorning both clearcut plots reach approximately 95 percent of their midday levels, while partial cuts reach about 85 percent. The effect of shade is most apparent in the midmorning tests, when shaded trees were often 5 to 6 atm. less than trees in the sun. As a consequence PMS variation is somewhat greater on the partial cut plots.

Effects of the residual crown canopy on the plot PMS trends are not entirely clear because the north clearcut often had a lower PMS than the partial cuts. Except for June, the predawn values of the south clearcut plot PMS are always greater than the south partial cut. Although basal area is not a direct measure of canopy cover, it is an easily measured index of the stand density, and sunlight is shown to decrease rapidly on both north and south aspects as basal area increases *(table 1)*. An important factor of the effect of crown cover on the PMS is the duration of time during daylight that the PMS might reach levels that could inhibit tree photosynthesis. Cleary[3] found that an increase from 16 to 20 atm. reduced the rate of Douglas-fir photosynthesis from 59 to 35 percent of its maximum. Midday PMS of all plots exceeded 16 atm. in June, so the growth rate was probably less than 60 percent of maximum after noon. By mid-August the PMS of the trees on the south clearcut plot exceeded 20 atm. by mid-morning, so photosynthetic rate was perhaps less than 35 percent for the rest of the day. On the other three plots we would not expect the rate of photosynthesis to be less than 50 percent until September. By late August most trees had ceased growth on both north and south slopes.

Any advantage that a lower PMS has on the partial-cut plots and the north slope clearcut is not apparent in the results of the tree height growth measurement *(table 3)*. The south clearcut has the best height growth rate. On this plot the growing season (a function of soil and air temperatures) coincides with the period of high soil moisture, increasing the site growth potential. Warm temperatures in May and June provide an opportunity for early seasonal growth at these high elevations. Trees of both north slope plots showed no evidence of bud expansion by early June, indicating temperatures were still too low to start tree growth. Later, when the temperatures on the north slopes increased sufficiently to trigger growth, the daily PMS rates had begun to reach levels that reduced the rate of photosynthesis.

The results of this study have two important implications for stand management. On hot dry slopes, a partial cut to increase shade will moderate the PMS and improve the survival of planted Douglas-fir. This partial crown cover could be hardwood or marginal conifers that would be removed after the planted seedlings become well established. On the cooler north slopes clearcutting may be required to obtain the maximum light and heat to start tree growth before water stress becomes limiting.

NOTES

[1] Oswald, Daniel D. 1968. *The timber resources of Humboldt County, California.* USDA Forest Serv. Resour. Bull. PNW-26, 42 p.

[2] Kramer, Paul J. 1963. *Water stress and plant growth.* Agric. J. 55:31-35.

[3] Cleary, Brian D. 1970. *The effect of plant moisture stress on the physiology and establishment of planted Douglas-fir and ponderosa pine seedlings.* Ph.D. thesis. Oreg. State Univ., Corvallis. 85 p.

[4] Slatyer, R. O. 1967. *Plant-water relationships.* 366 p. Academic Press, New York.

[5] Waring, Richard H. 1969. *Matching species to site. In* Regeneration of ponderosa pine, Symposium proceedings, Oreg. State Univ., Corvallis. p. 54-61.

[6] Waring, Richard H., and B. D. Cleary. 1967. *Plant moisture stress: evaluation by pressure bomb.* Science 155:1248-1254.

[7] Tappeiner, J. C., and J. Helms. 1971. *Natural regeneration of Douglas-fir and white fir on exposed sites in the Sierra Nevada of California.* Am. Midl. Nat. 86:358-370.

[8] Minore, Don. 1971. *Shade benefits Douglas-fir in southwestern Oregon cutover area.* Tree Planters' Notes 22:1. 2 p.

[9] Personal communication, Wilmer L. Colwell, Jr., Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 1974.

[10] Marquis, D.A., and G. Yelenosky. 1962. *A chemical light meter for forest research.* USDA Forest Serv. Northeast Forest Exp. Stn., Station Paper 165. 25 p.

[11] Pressure chamber model 600 from the PMS Instrument Company of Corvallis, Oregon. Trade names are mentioned for information only and do not imply endorsement by the U.S. Department of Agriculture.

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