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Thinning Slash Affects Foliar Nutrient Concentrations in Residual Douglas-fir Trees

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ABSTRACT

At an average eight years after thinning, foliar nutrient concentrations of residual Douglas-fir trees were significantly different by thinning slash category. Potassium, nitrogen, and iron concentrations were significantly lower in situations where thinning slash was not left on the site after thinning. Other elements showed similar trends but were not statistically different.

Additional keywords: Soil parent material, nitrogen, phosphorus, potassium, boron, copper, iron.

Introduction

The mineral nutrition of forests is an important consideration for intensive forest management. Many physiological processes regulating tree growth and vigor are influenced by essential nutrients. Critically low nutrient levels or imbalances can result in reduced growth, greater susceptibility to frost, insects and disease, and reduced fertilization response and nutrient cycling rates. The ability to recognize and ameliorate nutrient deficiencies is crucial to maintaining or enhancing site productivity.

Stand management practices can have substantial impacts on nutrient levels, distribution and cycling (Cole et al. 1967, Miller et al. 1976, Stark 1979, Harvey et al. 1987). However, little is known about the effects of intermediate treatments such as thinning and associated slash treatments on the nutrient status of the residual stand, particularly over a wide geographic area. The objective of this study was to quantify the relationships between thinning slash amounts left on a site and post-thinning foliar nutrient status of the residual stand. Data collected by the Intermountain Forest Tree Nutrition Cooperative (IFTNC) includes foliar nutrient levels for Douglas-fir (*Pseudotsuga mensiesii* var. *glauca* [Beisen] Franco) for a variety of stand treatment types throughout the Inland Northwest of the United States. These data were examined for relationships between thinning slash levels and foliar nutrient status of residual trees. The results should be useful in developing silvicultural prescriptions to maintain long term site productivity.

Methods

The study area of the IFTNC encompasses much of Idaho, western Montana, northeast Oregon, and eastern Washington. Ninety-four research sites were established in managed, natural second-growth stands with at least 80% of the basal area comprised of Douglas-fir. Questionnaires were sent to local managers to obtain information on time and type of thinnings, slash treatment methods and other pertinent stand history data. The majority of the stands selected had been thinned 5 to 12 years prior to plot establishment. Some of the sites are located in unthinned, well-spaced stands, but these are not included in this analysis. Two unfertilized control plots were installed at each research site. The plots were normally one-tenth acre in size, although some were larger depending on stand density and tree size. Part of the data collected at the time of plot establishment included a systematic ocular estimate of the proportional area coverage of boles and large branches left on each plot after thinning. Soil parent material was determined from one or more soil pits dug at each site.

One year after plot establishment foliage samples were collected by climbing two undamaged dominant or co-dominant Douglas-fir trees located on each plot at 85 sites and thus, were potentially available for analysis in this study. The foliage sample trees were selected from the 65th to 90th percentile of the diameter distribution. Samples were collected from the third whorl after dormancy (from mid-September to mid-November). Current year shoots were clipped with pruners. The samples were placed in plastic bags and stored in insulated coolers with ice while in the field and during transport to the laboratory. In the laboratory, samples were stored at -18 degrees C until dried. Shoots were oven-dried at 70 degrees C for 24 hours. The needles were separated from the twigs, redried at 70 degrees C for 24 hours, weighed, and then ground in a Wiley mill in preparation for chemical analysis.

Foliar nitrogen was determined using the standard micro-Kjeldahl procedure (Bremner and Mulvaney 1982). Needles were digested with sulfuric acid and the digestate distilled with steam. Total nitrogen concentration was recorded as a percentage per unit of dry needle weight. Phosphorus was determined after digestion in sulfuric acid with a Technicon Auto Analyzer II (Black 1965, US-EPA 1979) providing estimates of concentration. Foliar concentrations of boron, calcium, copper, iron, magnesium, manganese, potassium, and zinc were determined by perchloric acid digestion, followed by DC-argon plasma emission spectrometery (Blanchar et al. 1965, Sommers and Nelson 1972).

Analysis

Although the IFTNC experiment was not designed to test the effects of thinning slash on foliar nutrient concentrations and the post-facto "experiment" is unbalanced, means and ranges by thinning slash class for variables that could influence nutrient status were similar (Table 1). The data were stratified into two slash level classes, two parent material groups, and pre-thinning density classes. A sub-set of stands from the entire fertilization experiment was selected for analysis in this study such that the pre-thinning density of the two slash level classes were comparable (Table 1). Previous work indicated that nutrient concentrations were usually higher on basalt and sandstone derived soils (Moore et al. 1987). Therefore, a discrete parent material variable was included in the analysis to account for variation due to parent material rather than slash level. The two parent material classes were: (1) basalt/sandstone and (2) all others. The two slash level classes were defined as ≤50% coverage and >50% coverage of boles and large branches (>1" in diameter) on a plot. These two slash categories are broadly defined; however, the two classes essentially distinguish between two operationally applied treatments: leaving most small boles and branches on the site versus removal of this material. Mean foliar concentrations for all ten nutrients were calculated for each class. Only trees located on untreated control plots at each site were included in this analysis to avoid fertilizer effects on nutrient concentrations; therefore, the analysis was based on 152 trees from 38 stands (i.e., 76 plots). The most noticeable difference between the pre-thinning characteristics of stands in the two slash categories is the proportion of sites occurring on basalt/sandstone parent materials (Table 1). Proportionally more of the stands in the low residual slash category were located on basalt/sandstone soils. If Douglas-fir growing on these soils do normally have higher foliar nutrient concentrations (Moore et al. 1987), then the pre-thinning concentrations for the low residual slash category may have been somewhat higher than those for the high slash category. Actual assessment of pre-thinning nutrient levels was not possible since the operational thinnings were conducted well prior to the initiation of this study.

Analysis of variance was used to test for differences in foliar nutrient concentrations between slash levels across all sites and within parent material groups. Tests for significance were based on least square means adjusted for differences in sample size between classes.

Results and Discussion

For all nutrients, except Ca and Zn, concentrations were higher in the >50% slash coverage category (Table 2). The differences for K, Fe, and N were significant ($\alpha = .05$). The overall trends are illustrated in Figure 1. For clarity and easier comparisons among nutrients, ratios of mean foliar concentrations by residual slash category for each element were computed in the following manner: FNC_L/FNC_H = slash category nutrient ratio (Figure 1) where:

FNC_L = average foliar concentration of a nutrient in the low residual slash category.

FNC_H = average foliar concentration of a nutrient in the high residual slash category.

Ratios less than one indicate that average concentration in the low residual slash category is less than for high residual slash.

The basalt/sandstone parent material group consistently showed higher foliar concentrations in the category of heavy residual slash left on a site. Differences between slash categories within the basalt/sandstone parent material group were larger than for the "all others" parent material group. However, the emphasis of this study is not nutritional differences between soil parent materials but rather between residual slash categories. Parent material was included in the analysis as a "covariate" to account for extraneous variation in nutrient concentrations.

The trend of lower average foliar nutrient concentrations for most nutrients in the low residual slash category is evident. The fact that most nutrients were lower in the low residual slash category suggests that the nutrient pool was somewhat reduced by removing slash during thinning operations, or made more available where large amounts of thinning slash were left. Perhaps both influences operate to produce the foliar nutrient differences in thinning slash categories. Potassium, iron, and boron showed the largest differences between the two slash categories (Table 2 and Figure 1). Baker et al. (1989) found that after one year potassium and boron showed the greatest leaching from Pinus radiata needles for any micro and macronutrients they tested. In our study, only nitrogen and potassium are below or near inadequate levels suggested by van den Driesche (1979) or Webster and Dobkowski (1983) and of the two, potassium was most different for the two residual slash categories. Mean foliar K concentrations were 7471 ppm in the high residual slash class versus 6776 ppm for the low slash class. A concentration of 6000 ppm is considered to be inadequate and 8000 ppm is marginal for Douglas-fir. Some individual installations that were marginal for potassium concentrations before thinning may have decreased below inadequate levels after removal of slash from the site.

The distribution of nutrients within components of an ecosystem (forest, subvegetation, forest floor, soil) varies significantly among elements. A study of a second-growth coastal Douglas-fir forest by Cole and others (1967) revealed that the forest component contained 44.6% of the available K in the ecosystem as compared to 9.7%, 1.7%, and 27.3% for N, P, and Ca, respectively.

The proportion of nutrients contained in different parts of an individual tree also differs by element, in turn affecting the rate of elemental transfer within the forest ecosystem. Over one-half of the N, P, K, and Ca within a tree is located in the branches, twigs, and foliage. The remainder is in the wood and bark. Therefore, elements which have a high proportion of the ecosystem's total within the tree, such as potassium, would be more sensitive to management practices involving high residual biomass removals. Furthermore, if potassium is readily available to a plant, much more is absorbed and stored than is needed for optimum growth (Brady 1974). This luxury consumption results in a much faster nutrient drain if material is removed from the site than for elements that are absorbed by plants only in amounts necessary for optimum growth. The distribution of potassium within a forest ecosystem and within individual trees, as well as its mobility, probably account for the relatively large differences in residual tree foliar concentrations between the two slash categories.

Since the data from our study are observational rather than experimental, there are other possible explanations for the results reported here rather than residual slash levels. However, we feel that potential confounding influences have been reduced because observations were collected from a fertilization experiment designed around age, site quality, and stand density resulting in pre-thinning conditions that were similar for the two slash categories. Still, experiments directly designed to manipulate slash levels should be conducted to test the relationships reported in this paper. Additionally, the observations on thinning slash levels (>50% or ≤50% coverage) are obviously imprecise. Improved precision derived from an experiment would likely reduce the error term in the statistical analysis, and perhaps more of the nutritional differences observed between the slash categories would then be statistically significant.

The data in the present study was collected five to twelve years after the stands were thinned, suggesting that these effects are long term. Results of this study suggest that leaving thinning slash on a site can result in a "fertilization" effect for the residual stand. Conversely, removal of the slash, particularly the crowns, may result in a significant reduction in the nutrient budget of a site. Since the stands in this study remained well-stocked after the thinnings, these results represent a "minimum impact" scenario. Thinning slash is usually relatively minor compared to the amount of slash produced during commercial harvest operations. Therefore, careful treatment of logging residues to maintain a site's nutrient budget is warranted. Needles, twigs, and branches should be left on a site after thinning or harvesting if operationally feasible.

Literature Cited

Baker, T.G., G. M. Will, and G.R. Oliver. 1989. Nutrient release from silvicultural slash: leaching and decomposition of *Pinus radiata* needles. For. Ecol. Manage., 27:53-60.

Blanchar, R.W., G. Rehm, and A.C. Caldwell. 1965. Sulphur in plant materials by digestion with nitric and perchloric acid. Soil Sci. Soc. Amer. Proc. 29:71-72.

Brady, N.C. 1974. The Nature and Property of Soils. 8th Edition. MacMillan Publishing Co., New York, New York. 637 p.

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen-Total. pp. 595-624. *In* methods of soil analysis, Part 2, 2nd Edition. *Edited by* A.L. Page. Am. Soc. Agron., Madison, Wisconsin.

Cole, D.W., S.P. Gessel, and S.F. Dice. 1967. Distribution and cycling of nitrogen, phosphorus, potassium, and calcium in a second-growth Douglas-fir ecosystem. *In* Symposium on primary productivity and mineral cycling in natural ecosystems. p. 197-213. Univ. Maine Press, Orono.

Harvey, H.E., M.F. Jurgensen, M.J. Larsen, and R.T. Graham. 1987. Decaying Organic Materials and Soil Quality in the Inland Northwest: A Management Opportunity. General Technical Report INT-225. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 15 p.

Moore, J.A., P. G. Mika, and J.L. Vander Ploeg. 1987. Seventh annual report. Intermountain Forest Tree Nutrition Cooperative. College of Forestry, Wildlife and Range Sciences. Univ. of Idaho. 38 p.

Miller, R.E., D.P. Lavender, and C.C. Grier. 1976. Nutrient Cycling in the Douglas-fir Type - Silvicultural Implications. In Proceedings, 1975 Annual Convention, Society of American Foresters, p. 359-390.

Sommers, L.E. and D.W. Nelson. 1972. Determination of total phosphorus in soils: A rapid perchloric acid digestion procedure. Soil Sci. Soc. Am. Proc. 36:902-904.

Stark, N.M. 1979. Nutrient Losses From Timber Harvesting in a Douglas-fir Forest. Research Paper INT-231. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 41 p.

US-EPA. 1979. Handbook for Analytical Quality Control in Water and Wastewater Laboratories. Environmental Monitoring and Support Laboratory, Office of Research and Development, EPA, Cincinnati, Ohio.

Webster, S.R. and A. Dobkowski. 1983. Concentrations of foliar nutrients for trees and the dosage and frequency of fertilizer trials. Weyerhaeuser Res. Rtp. No. 1, Project No. 050-3920/3. 25 p.

Table 1. Distribution of selected site and stand characteristics by residual thinning slash category.

	--Slash ≤ 50%--	--Slash > 50%--
	Mean and (Range)	
Number of Plots	45	31
Proportion of plots occurring on basalt/sandstone	.356	.226
Age	65 (32 to 89)	57 (27 to 81)
Quadratic Mean Diameter	9.5 (6.3 to 12.7)	9.9 (5.2 to 15.4)
Basal Area (sq. ft./ac.)	125 (56 to 211)	125 (17 to 217)
Stand Density before thinning (T.P.A.)	1298 (800 to 3070)	1540 (410 to 3240)
Site Index	67 (39 to 98)	75 (40 to 105)

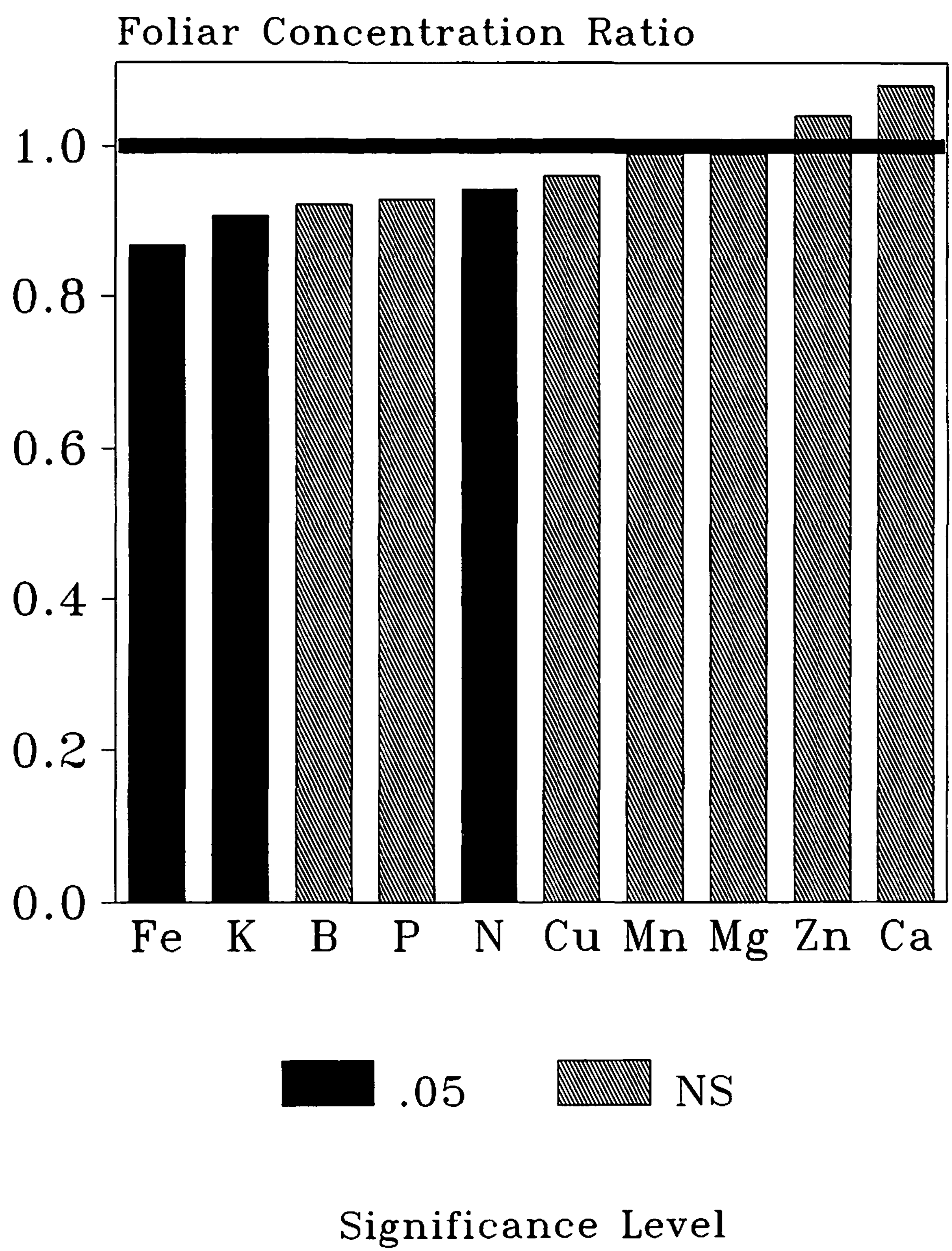
Table 2. Average foliar nutrient concentrations by thinning slash category and soil parent material group.

	-------Slash ≤ 50%-------			-------Slash > 50%-------		
	Basalt	Others	All	Basalt	Others	All
Nitrogen[1]	1.16	1.09	1.12*	1.27	1.11	1.19*
Phosphorus[1]	0.247	0.201	0.224	0.266	0.216	0.241
Potassium	7,055	6,496	6,776*	8,299	6,643	7,471*
Calcium	3,764	4,250	4,007	3,706	3,694	3,700
Magnesium	1,719	1,598	1,658	1,739	1,586	1,662
Manganese	375	373	374	395	361	378
Boron	25	27	26	29	28	29
Copper	4	4	4	5	4	4
Iron	75	68	71*	100	64	82*
Zinc	31	30	31	33	26	30

[1]Units are percents for these two elements, the remainder are parts per million.

* = Significantly different ($\alpha = .05$).

Figure 1. Ratios of mean foliar nutrient concentrations in the low residual category to the high residual slash category by element


Foliar Concentration Ratio
1.0
0.8
0.6
0.4
0.2
0.0
Fe
K
B
P
N
Cu
Mn
Mg
Zn
Ca
.05
NS
Significance Level