Research Note

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A COMPARISON OF THE NUTRIENT CONTENT OF ROCKY MOUNTAIN DOUGLAS-FIR AND PONDEROSA PINE TREES

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ABSTRACT

Data on the content of nitrogen, phosphorus, sulfur, sodium, potassium, calcium, and magnesium in Douglas-fir and ponderosa pine trees are presented for the Silver Creek Study Area, in the southwestern Idaho batholith. Suppressed, intermediate, and dominant trees of each species were cut and sampled from two habitat types in the study area. Needles (stratified by age), bark, heartwood, and sapwood (stratified by bole size), and branches (stratified by branch size), were analyzed for the elements of interest. No significant differences in chemical content between habitat types were detected for either species. Interspecific differences in chemical concentration were found in one or more elements for each plant part. Trends in elemental concentration over needle age, bole size, and branch size were also suggested by the data.

KEYWORDS: plant chemistry, forest nutrition, *Pseudotsuga menziesii*, *Pinus ponderosa*

INTRODUCTION

We are currently conducting research in the Silver Creek Study Area, southwestern Idaho batholith, to assess the effects of timber harvesting on the environment. The Silver Creek Study Area, located approximately 70 miles (110 km) north of Boise, Idaho, is typical of a large portion of the Idaho batholith. The area has steep slopes and coarse-textured soils formed from granitic parent materials. As a result, moderate-to-high erosion potentials exist following disturbances associated with logging and road construction.

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One study involves computation of nutrient losses from the watersheds as a result of logging. For this study, we require data on the nutrient content of ponderosa pine (*Pinus ponderosa* Laws), and of Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *glauca* [Beissn.] Franco), the two major timber species harvested. In this paper, we present data on the nitrogen, phosphorus, sulfur, sodium, potassium, calcium, and magnesium content of these two species.

OBJECTIVES

This study was conducted to quantitatively describe and compare the aboveground chemical content of nutrient elements in ponderosa pine and Douglas-fir trees, stratified by plant part and habitat type. In addition, this study will provide a data base needed for computing nutrient budgets for the experimental watersheds following various logging treatments.

METHODS

Ponderosa pine and Douglas-fir are the two principal tree species in the Silver Creek Study Area. They generally coexist in mixed stands and in a variety of habitat types. We stratified our sampling to reflect the driest and moistest habitats as indicated by the common habitat types in Silver Creek. (For a discussion of habitat types and their nomenclature as used here, see Daubenmire and Daubenmire 1968, or Pfister and others 1977.)

Site I is a Douglas-fir/elk sedge (PSME/CAGE) habitat type, ponderosa pine phase, a relatively dry type. Site II is a subalpine fir/blue huckleberry (ABLA/VAGL) type, a relatively moist type. This site contains ponderosa pine and so is probably warmer than the typical subalpine fir/blue huckleberry site that does not support this species. Steele and others (in press) estimated that the yield capability for the PSME/CAGE type ranges from 40 to 95 ft^3/acre/yr (2.8 to 6.7 m^3/ha) with a mean of 70 ft^3/acre/yr (4.9 m^3/ha). Similarly, they estimated the yield capability for the ABLA/VAGL type to range from 60 to 90 ft^3/acre/yr (4.2 to 6.3 m^3/ha) with a mean value of 75 ft^3/acre/yr (5.3 m^3/ha). These differences principally reflect the differing moisture and temperature characteristics of the two habitat types.

Soils on the two sites are morphologically similar. Both soils are classified as cryorthents: weakly developed soils with A and C horizons over bedrock at 20 to 30 inches (50 to 76 cm). Gravelly loamy sand and sandy loam textures predominate.

At each site, we selected three trees of both species, one in each of the following crown dominance classes: suppressed, intermediate, and dominant. The actual size and age for each tree are shown in table 1.

Table 2.--*Size and age of each tree sampled. Age was determined by ring count at stump height*

Species	Habitat type			
	PSME/CAGE		ABLA/VAGL	
	d.b.h.	age	d.b.h.	age
	Inches	*Years*	*Inches*	*Years*
Ponderosa pine				
Suppressed	8	59	12	86
Intermediate	16	160	19	100
Dominant	26	197	31	232
Douglas-fir				
Suppressed	11	67	14	89
Intermediate	19	76	23	145
Dominant	20	134	30	235

Each tree was cut and sampled in August 1977 in the following manner:

1. At 1/8, 3/8, 5/8, and 7/8 of the total length of the tree bole, we cut a 3-inch-thick cross section and separated heartwood and sapwood.

2. From the suppressed and dominant trees, we took a bark sample at the same four locations along the bole.

3. From the subordinate trees, we sampled several limbs of two size classes, <1/4-inch diameter and 1/4- to 1-inch diameter. From the intermediate trees, we sampled several limbs 1 inch to 3 inches in diameter. From the dominant trees, we sampled several limbs 3 to 6 inches in diameter.

4. From the intermediate trees, we sampled needles from that year (1977) and from the two previous growing seasons (1976 and 1975). (In the rest of this paper, needles will be referred to as 1-year-old, 2-year-old, or 3-year-old needles.) All samples were placed in plastic bags and brought back to the laboratory for sample preparation and chemical analysis.

LABORATORY TECHNIQUES

In the laboratory, the samples were allowed to dry in the air for 2 weeks. At the end of this period, the samples were dried in an oven for 24 hours at 167°F (75°C). Subsamples were taken from each ovendried sample and ground in a Wiley[2] mill to pass a 40-mesh screen.

Samples of heartwood, taken from four locations along the tree bole, were batched before grinding. The same subsampling and batching was done on sapwood and bark samples prior to grinding.

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[2]The use of trade, firm, or corporation 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 or service to the exclusion of others which may be suitable.

Samples were digested in a perchloric acid-nitric acid mixture (Johnson and Ulrich 1959) and analyzed for calcium, magnesium, potassium, sodium, and total phosphorus. Calcium and magnesium were analyzed by atomic absorption; sodium and potassium by flame emission; and total phosphorus by the molybdate blue-ascorbic acid method. A Kjeldahl digestion was used for total nitrogen and detected by a titrimetric procedure. Dried and ground tissue was analyzed for sulfur using a Leco induction furnace by the technique of Tiedemann and Anderson (1971).

DATA ANALYSIS

Data presented are mean values of two analyses run on each digest. In addition, each plant part (for example, 1-year-old needles and branches <1/4 inch in diameter) was digested in duplicate. Duplicate analyses of each digest were reanalyzed if the reported values varied by more than 5 percent for all elements except nitrogen and sulfur. Nitrogen analyses were reanalyzed if values varied by more than 8 percent; sulfur was reanalyzed if values differed by more than 10 percent.

We analyzed the data initially by graphical observation in the following manner: (1) for needles, plots of concentration over needle age were made for both species and and both habitat types; (2) for sapwood, heartwood, and bark, concentrations were plotted over tree diameter for both species and for both habitat types; (3) for branches, concentrations were plotted over branch diameter for both species and for both habitat types.

Apparent differences between species and between habitat types were tested by Student's T-test. In some cases, apparent differences in the slope of concentration over age (needles), or in tree size (heartwood, sapwood, and bark), or in branch size were tested by covariance analysis.

RESULTS AND DISCUSSION

Mean nutrient concentrations for both species by plant part are summarized in tables 2 and 3. The values given in these tables are stratified by needle age and by tree bole or branch size. Differences in nutrient concentrations of Douglas-fir and ponderosa pine that were significant at the 0.01 or 0.10 percent level are presented in table 4. The concentration of phosphorus in Douglas-fir branches is apparently greater than that in ponderosa pine branches, but this assumption was not tested because phosphorus content of the larger pine branches was below our detection limit.

Sodium concentrations in all plant parts for both species and for both habitat types are remarkably similar, ranging from approximately 0.037 to 0.056 percent by weight (tables 2 and 3).

Concentrations of potassium, calcium, and magnesium are consistently higher in sapwood of Douglas-fir than in heartwood. Comparisons of these same elemental concentrations in sapwood and heartwood of ponderosa pine did not show the same trends (tables 2 and 3).

Table 2.--*Nutrient content of ponderosa pine, data combined from two sites. All values are reported as percent by weight*

Plant part	Element						
	Sodium	Potassium	Calcium	Magnesium	Phosphorus	Nitrogen	Sulfur
Needles							
Current year	[1]0.047	0.829	0.108	0.109	0.191	1.48	0.114
1 year old	.035	.722	.194	.114	.136	1.58	.106
2 years old	.031	.642	.225	.098	.151	1.60	.105
Mean	.037	.739	.176	.107	.159	1.55	.108
Sapwood							
Suppressed tree	.044	.057	.076	.026	[2]	0.524	.007
Intermediate tree	.060	.045	.049	.017		.286	.015
Dominant tree	.059	.053	.056	.014		.304	.011
Mean	.054	.052	.060	.019		.371	.011
Heartwood							
Suppressed tree	.050	.033	.141	.032	[2]	.291	.005
Intermediate tree	.054	.039	.089	.028		.323	.005
Dominant tree	.051	.026	.092	.024		.315	.007
Mean	.051	.033	.100	.028		.313	.005
Branches							
<1/4-inch diameter	.043	.250	.383	.095	.043	.829	[3]
1.4 to 1 inch dia.	.049	.135	.296	.080	.033	.794	[3]
1 to 3 inches dia.	.047	.070	.604	.038	[2]	.381	.012
>3 inches diameter	.064	.066	.493	.035		.389	.008
Mean	.051	.130	.444	.061		.585	.010
Bark							
Suppressed tree	.055	.253	.349	.078	.033	.734	.052
Dominant tree	.056	.034	.323	.018	[2]	.509	.037
Mean	.056	.137	.337	.048		.621	.045

[1]Each data point is the mean value of two separate digestions and duplicate analyses.

[2]Values were below the detection limit (0.01 percent) for all samples of sapwood and heartwood and for some branch and bark samples.

[3]Samples were not analyzed.

Table 3.--*Nutrient content of Douglas-fir, data combined from two sites. All values are reported as percent by weight*

Plant part	Element						
	Sodium	Potassium	Calcium	Magnesium	Phosphorus	Nitrogen	Sulfur
Needles							
Current year	[1]0.043	0.750	0.423	0.117	0.133	1.20	0.088
1 year old	.070	.631	.888	.147	.120	1.01	.090
2 years old	.037	.582	1.05	.153	.115	1.28	.082
Mean	.050	.655	.786	.139	.123	1.16	.087
Sapwood							
Suppressed tree	.042	.038	.059	.008	[2]	0.409	.011
Intermediate tree	.043	.033	.052	.006		.306	.018
Dominant tree	.042	.037	.057	.006		.296	.007
Mean	.042	.036	.056	.007		.337	.012
Heartwood							
Suppressed tree	.047	.016	.029	.003	[2]	.268	.005
Intermediate tree	.066	.013	.027	.003		.264	.013
Dominant tree	.050	.011	.022	.002		.269	.011
Mean	.055	.013	.026	.003		.267	.010
Branches							
<1/4-inch diameter	.055	.199	.578	.061	.073	.978	[3]
1/4 to 1 inch dia.	.044	.137	.928	.051	.049	.758	[3]
1 to 3 inches dia.	.072	.065	.541	.023	.017	.393	.011
>3 inches diameter	.050	.077	.646	.029	.021	.407	.012
Mean	.055	.120	.674	.041	.040	.628	.012
Bark							
Suppressed tree	.055	.126	1.38	.041	.036	.625	.015
Dominant tree	.055	.107	1.37	.034	.026	.727	.011
Mean	.055	.115	1.38	.038	.031	.676	.013

[1]Each data point is the mean value of two separate digestions and duplicate analyses.
[2]Values were below the detection limit (0.01 percent) for all samples of sapwood and heartwood.
[3]Samples were not analyzed.

Table 4.--*Comparison of nutrient levels for plant parts of ponderosa pine and Douglas-fir tested by Student's T-test. Data taken from tables 2 and 3*

Plant part	Element	Concentration greater in	Significance level
Needles	Calcium	Douglas-fir	0.01
	Magnesium	Douglas-fir	.01
	Nitrogen	Ponderosa pine	.01
	Sulfur	Ponderosa pine	.01
Sapwood	Potassium	Douglas-fir	.01
	Magnesium	Douglas-fir	.01
Heartwood	Calcium	Ponderosa pine	.01
	Magnesium	Ponderosa pine	.01
Branches	Magnesium	Ponderosa pine	.10
	Calcium	Douglas-fir	.01
Bark	Calcium	Douglas-fir	.01
	Sulfur	Ponderosa pine	.01

For both species, relationships exist between the nutrient content and the age of needles. Calcium increases with needle age for both species (fig. 1). In addition, the rate of increase in calcium content with increasing needle age is greater for Douglas-fir than for ponderosa pine. This increase is apparent by inspection and was highly significant when tested by covariance analysis. For the common model (habitat type not considered), $F = 22.94$, $f = 1, 20$. Potassium and phosphorus decrease with the age of the needles for both species (figs. 2 and 3). There appears to be no difference in the slope or mean concentration between the two species.

Similar relationships can be drawn when nutrient content is compared with tree diameter. In sapwood, magnesium and nitrogen tend to decrease as tree diameter increases (figs. 4 and 5). For bark samples, the potassium and total phosphorus tend to decrease as tree diameter increases (figs. 6 and 7). These relationships were not tested for significance because the sample size was small and this study was not designed to test this hypothesis.

When nutrient content and size class of branches are compared, magnesium, potassium, and nitrogen all decrease with increasing size class (figs. 8, 9, and 10). Magnesium, potassium, and nitrogen appear to reach a base level at from 0.02 to 0.04 percent, 0.05 to 0.10 percent, and 0.3 to 0.5 percent, respectively, when branch diameter exceeds 1 inch (figs. 8, 9, 10).

There were no apparent differences in chemical composition of tree parts of the same species when comparison was made between habitat types. The slightly greater yield capability in the more moist ABLA/VAGL type suggests that the standing crop nutrient content, expressed in kilograms per hectare, would be greater in this habitat type than in the drier PSME/CAGE habitat type. Such a conclusion is likely to be valid only for stands of mature trees that have attained maximum nutrient content.

Extraordinarily high concentrations of potassium were found in bark of the small ponderosa pine from Site I. The results were consistent for two separate digestions and duplicate analyses. Contamination is possible, but would have had to have happened to the bulk sample prior to subsampling, grinding, and digestion.

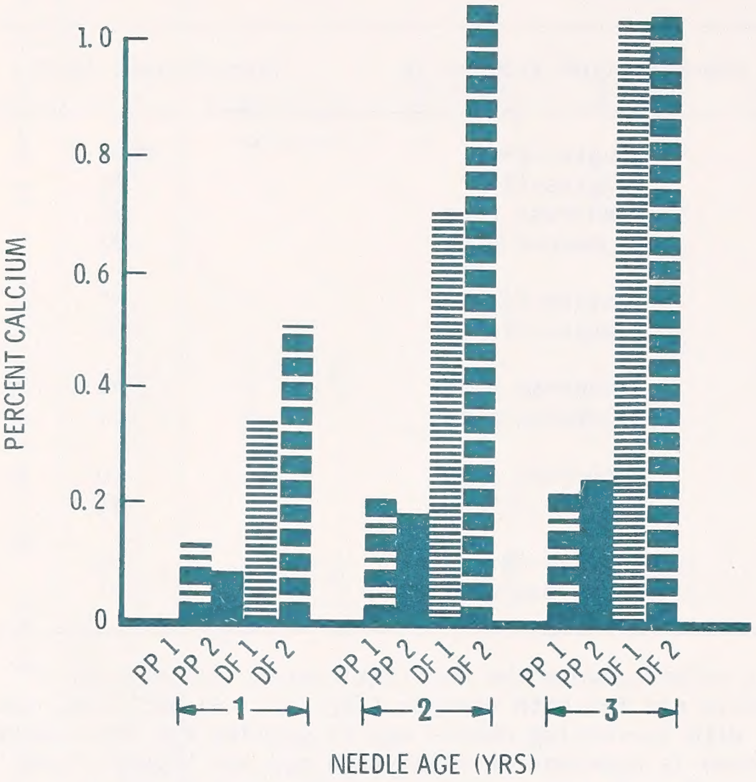


Figure 1.--Percent calcium in needles plotted over needle age, where 1 = current year (1977) needle growth. Data are presented for both species and both habitat types; I = PSME/CAGE and II = ABLA/VAGL. Each point represents the mean value of two separate digestions and duplicate chemical analyses.

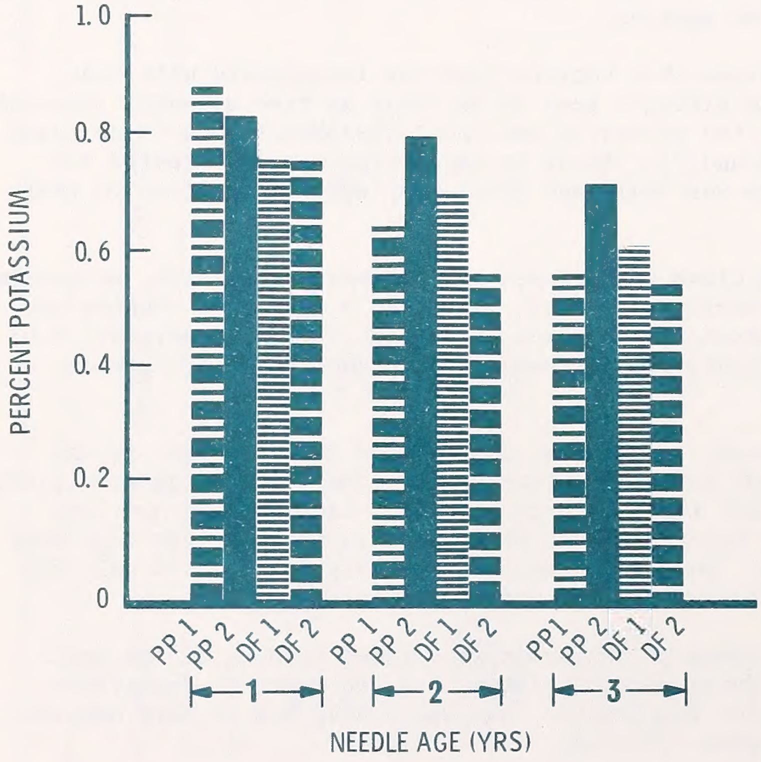


Figure 2.--Percent potassium in needles plotted over needle age, where 1 = current year (1977) needle growth. Data are presented for both species and both habitat types; I = PSME/CAGE and II = ABLA/VAGL. Each point represents the mean value of two separate digestions and duplicate chemical analyses.

Figure 3.--Percent total phosphate in needles plotted over needle age, where 1 = current year (1977) needle growth. Data are presented for both species and both habitat types; I = PSME/CAGE and II = ABLA/VAGL. Each point represents the mean value of two separate digestions and duplicate chemical analyses.

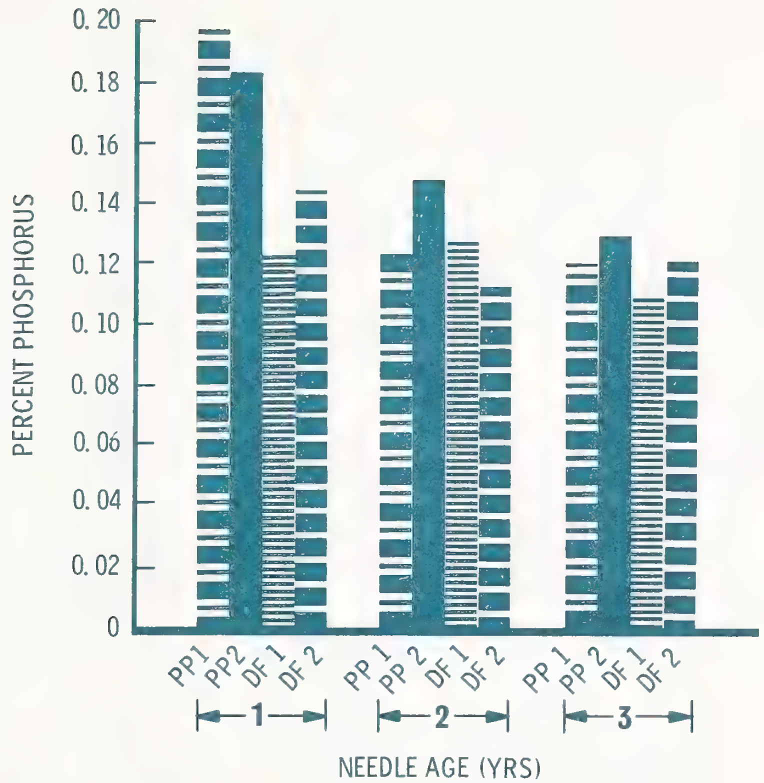
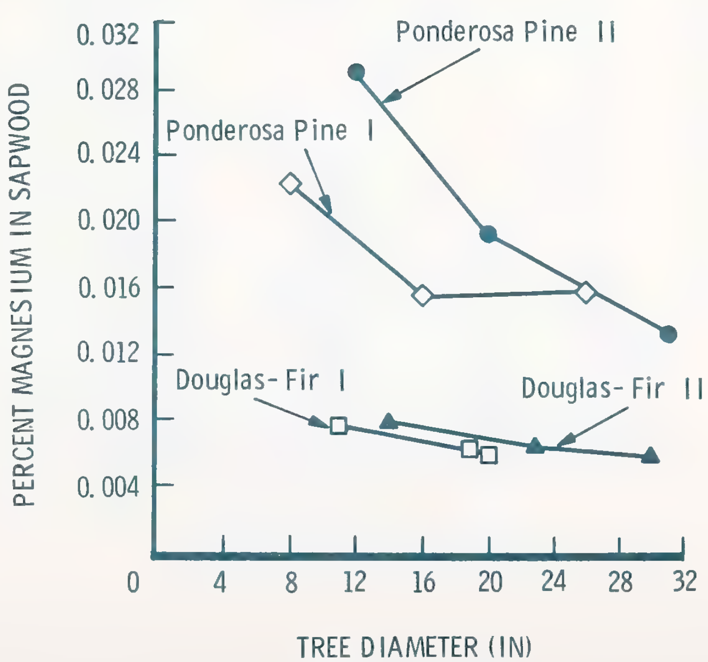


Figure 4.--Percent magnesium in sapwood plotted over tree diameter at breast height for both species and both habitat types; I = PSME/CAGE and II = ABLA/VAGL. Each point represents the mean value of two separate digestions and duplicate chemical analyses.



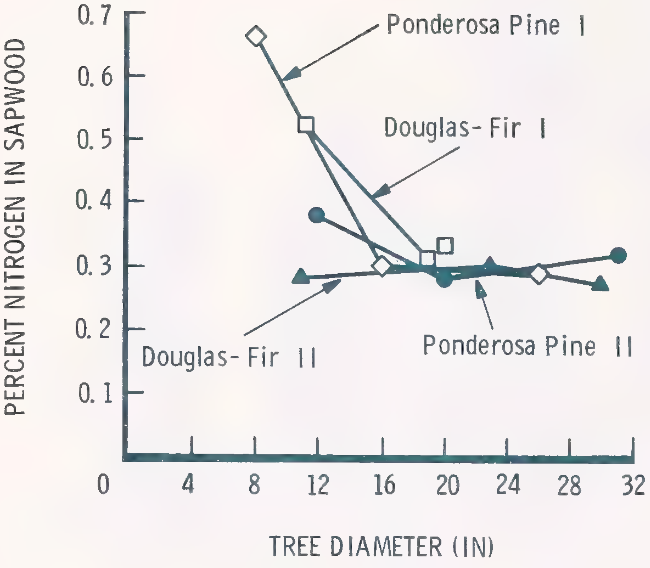


Figure 5.--Percent total nitrogen in sapwood plotted over tree diameter at breast height for both species and both habitat types; I = PSME/CAGE and II = ABLA/VAGL. Each point represents the mean value of two separate digestions and duplicate chemical analyses.

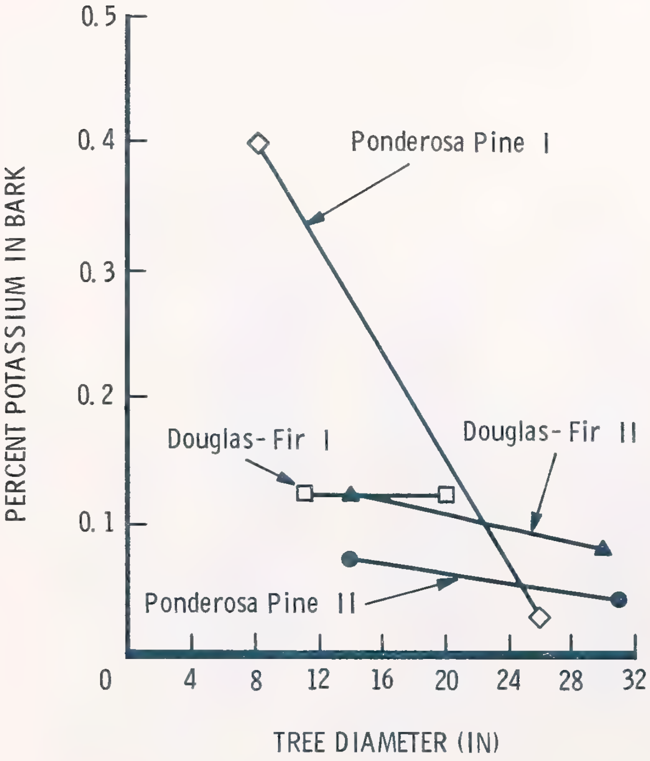


Figure 6.--Percent potassium in bark plotted over diameter at breast height for trees of both species and both habitat types; I = PSME/CAGE and II = ABLA/VAGL. Each point represents the mean value of two separate digestions and duplicate chemical analyses.

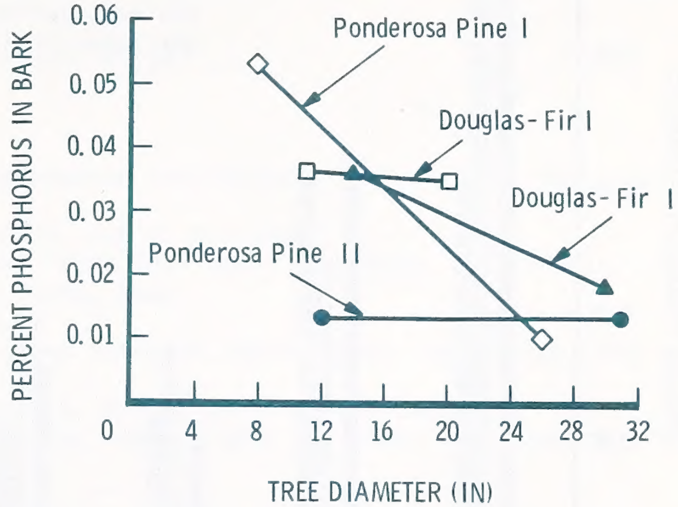


Figure 7.--Percent total phosphorus in bark plotted over diameter at breast height for trees of both species and both habitat types; I = PSME/CAGE and II = ABLA/VAGL. Each point represents the mean value of two separate digestions and duplicate chemical analyses.

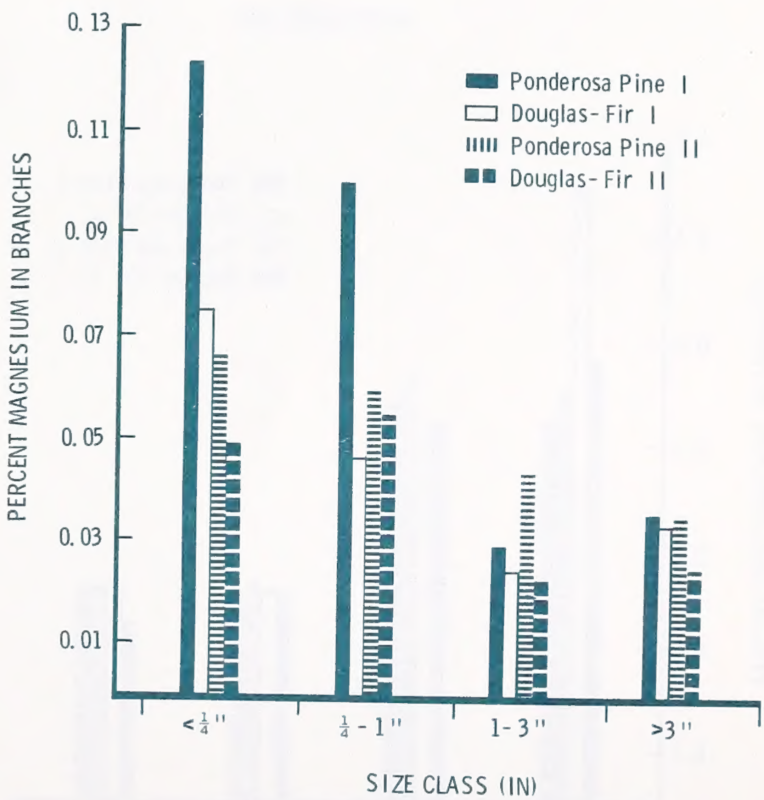


Figure 8.--Percent magnesium in branches plotted by branch size class. Each point represents the mean value of two separate digestions and duplicate chemical analyses. Site I is a PSME/CAGE habitat type and site II is a ABLA/VAGL habitat type.

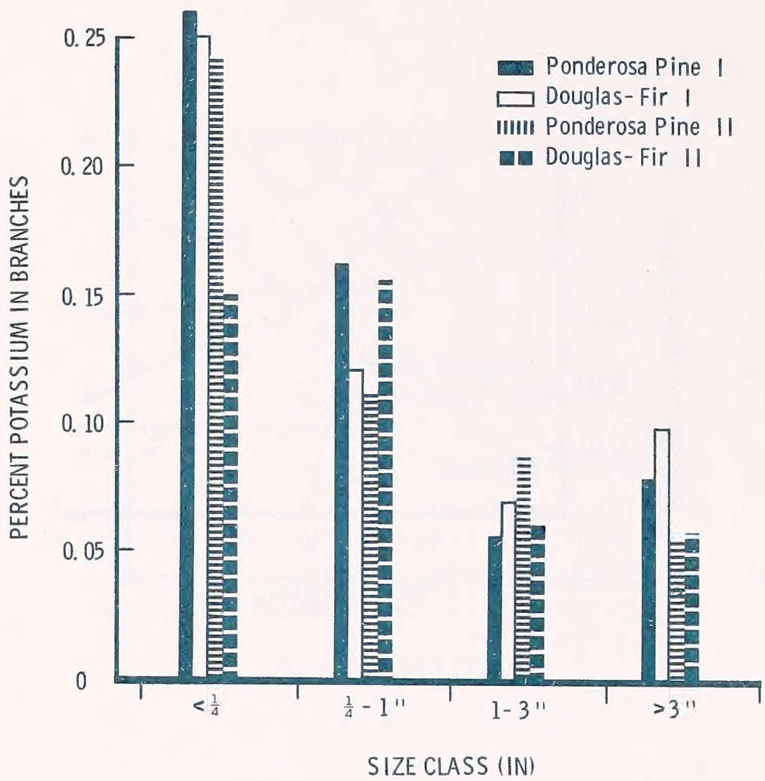


Figure 9.--Percent potassium in branches plotted by branch size class. Each point represents the mean value of two separate digestions and duplicate chemical analyses. Site I is a PSME/CAGE habitat type and site II is a ABLA/VAGL habitat type.

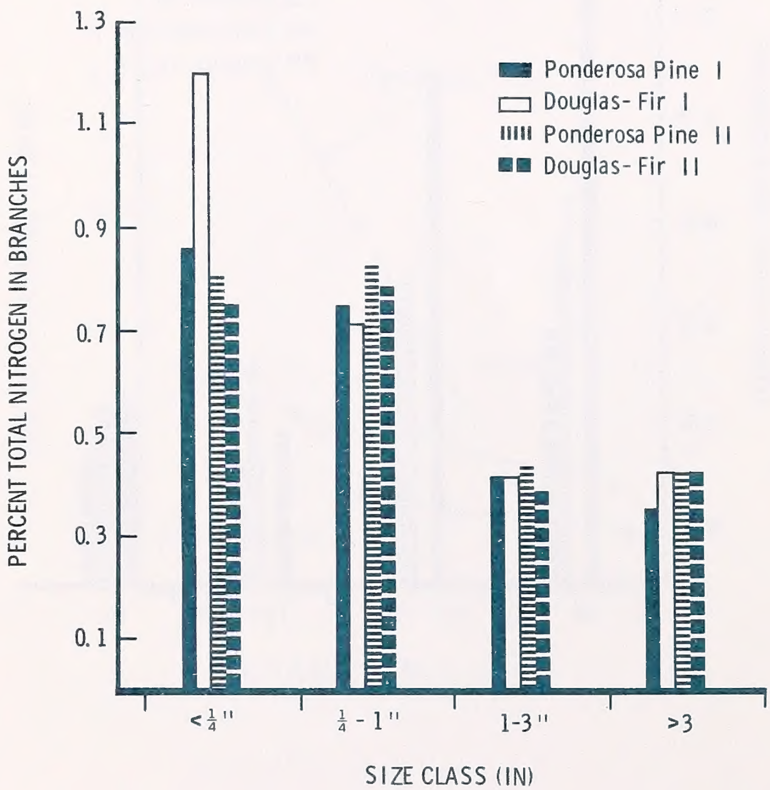


Figure 10.--Percent total nitrogen in branches plotted by branch size class. Each point represents the mean value of two separate digestions and duplicate chemical analyses. Site I is a PSME/CAGE habitat type and site II is a ABLA/VAGL habitat type.

Results of this study will provide a data base necessary for computing nutrient losses caused by removing the boles from logged units in the Silver Creek Research Area. Future plans include studies on rates of litter and slash decomposition in Silver Creek. Data from this paper will also be used to estimate nutrient gains to the soil from litter and slash decomposition when decomposition rate studies are completed.

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