Influence of Soil Parent Material on the Nutrition and Health of Established Conifer Stands in the Inland Northwest

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Introduction

Initial efforts of the Intermountain Forest Tree Nutrition Cooperative (IFTNC) concentrated on studying the effect of nitrogen fertilization on Douglas-fir *(Psuedotsuga menziesii* var. *glauca)* growing in the inland Northwest (eastern Oregon, eastern Washington, Idaho, and western Montana). The IFTNC established ninety-four experimental sites in managed, second growth Douglas-fir stands. This paper presents results showing that tree growth response to N fertilization and tree mortality rates are significantly influenced by the underlying rocks on which the stand is growing.

Results

Moore et al. (1990) provide details on the experimental design and statistical analysis of the region-wide Douglas-fir experiment. Foliar N concentrations collected from Douglas-fir growing on untreated plots were very low, averaging about 1.1%, well below published critical levels for Douglas-fir. Essentially all of the experimental stands were N deficient. One year after applying 200 lbs. of N per acre, average foliar N concentration increased to about 1.35%; similarly, after applying 400 lbs. of N per acre, foliar N increased to about 1.65%. As if to confirm the foliar diagnosis, essentially all of the Douglas-fir stands showed significant growth response for the first few years after treatment. The conclusion seemed easy: N is universally limiting and fertilizing with N produces substantial growth response. However, after a few more years' growth, response to N fertilization changed dramatically. Douglas-fir stands showed significantly different N response depending on the foliar potassium (K) concentration and foliar K/N ratio at the time of treatment (Mika and Moore 1991). The good pre-treatment K-status sites (foliar K>6000 PPM and K/N>65) showed good net response to the 200 lbs. N treatment and a significant additional growth increase from the 400 lbs. N treatment (Figure 1). This is exactly the response pattern expected in strongly N limited forest systems. However, while the

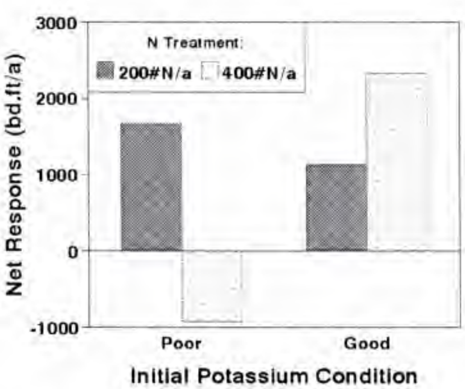

Figure 1. Ten-year growth response of Douglas-fir stands to nitrogen fertilization by pre-treatment foliar potassium status.

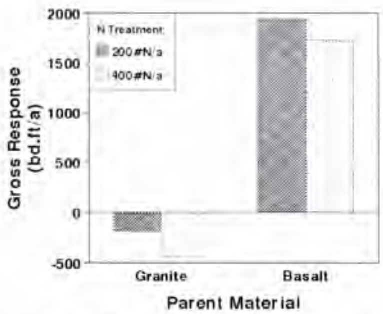

Figure 2. Ten-year growth response of Douglas-fir stands to nitrogen fertilization for granite and basalt parent materials.

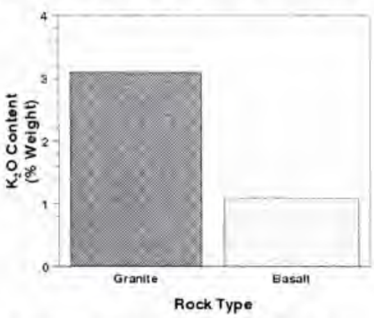

Figure 3. Potassium content of rocks on which Douglas-fir study stands were growing.

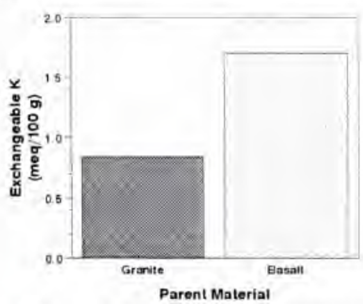

Figure 4. Soil exchangeable potassium for unfertilized Douglas-fir stands growing on granite and basalt parent materials.

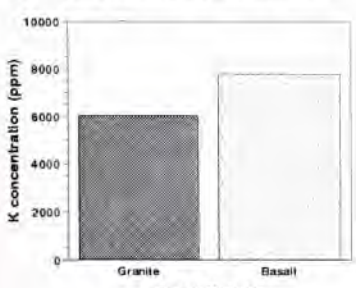

Figure 5. Foliar potassium concentration for unfertilized Douglas-fir stands growing on granite and basalt parent materials.

poor K-status sites (foliar K<6000 PPM and K/N<50) showed good growth response to the 200 lbs. N treatment, the average response to the 400 lbs. N fertilization was negative. There was significant treatment induced tree mortality from the 400 lbs. N treatment.

Parent Material Effects

The soil parent material largely supplies mineral nutrients such as K. Therefore, we analyzed the ability of parent material to predict Douglas-fir N growth response. Our most common parent materials were plutonic rocks (mostly granites) and volcanic rocks (mostly basalts), with about 20 of the Douglas-fir sites occurring on each of these rock types. Stands growing on granite-derived soils showed negative average response to both nitrogen treatments (Figure 2), while stands on soils derived from basalt produced large average growth response to N fertilization but no significant difference between the 200 and 400 lbs. N treatments. By locating our study sites on existing geologic maps compiled by the United States Geologic Survey (USGS), we estimated the K content of the rocks at each Douglas-fir study site. The granite rocks were estimated to have about twice the K content of the basalts (Figure 3), which initially seems counter to explaining the observed N response results for the two rock types. However, K availability to trees depends on more than just rock K content. Buol et al. (1989) show that granite rocks weather into coarse, sandy soils with low base status, while basalts weather into fine, clay soils with high base status. Buol et al.'s observations are confirmed by analysis of soil samples collected from the unfertilized plots of the IFTNC Douglas-fir study sites. Soils derived from basalts had about twice the exchangeable K of soils derived from granites (Figure 4). This difference in soil exchangeable K translated into significantly different foliar K concentrations for the unfertilized Douglas-fir trees growing on these sites (Figure 5). Douglas-fir growing on basalt soils averaged foliar K concentration of about 8000 PPM, while those growing on granite soils averaged about 6000 PPM. Statistically significant, these concentration differences are likely to be biologically significant as well: research indicates that 8000 PPM is an adequate foliar K concentration for Douglas-fir, while 6000 PPM is inadequate (Webster and Dobkowski 1983).

We believe that soils developed from certain parent materials, granites in this example, are unable to supply sufficient K to meet the demands of the stand. Potassium deficiencies became very apparent, resulting in significantly increased mortality rates ("square death" within plot boundaries) after N deficiencies were eliminated by N fertilization. Potassium deficiency has been shown to affect plant resistance to insects and diseases (Moore et al. 1994, Mandzak and Moore 1994, Huber and Arny 1985).

Forest Health and Potassium Deficiencies

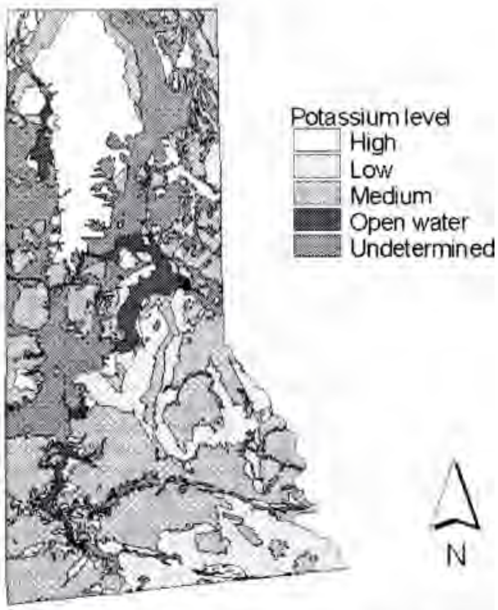

Figure 6. Rock potassium content map for the five northern Idaho counties.

Based on these experimental results, the IFTNC member organizations began to wonder if the substantial forest health problems in the inland Northwest could be associated with wide-scale K deficiencies. As an initial test of this idea, we obtained digital geology maps for the inland northwest from the USGS, and used published lithology descriptions, geochemical data, and input from geologists to construct a rock K content map for the 5 northern counties of Idaho (Figure 6). This area was selected because digital maps of root rot "hot spots" in this area were available from the Forest Pest Management (FPM) group in Region 1 of the Forest Service and the Idaho Department of Lands (IDL). We overlaid the "root rot" digital maps on the rock K content map using a computer-based Geographic Information System. The results from these analyses are shown in Figures 7 and 8. The FPM "root rot" map data (Figure 7) shows that "hot spots" occur more frequently (45%) on low K content (< 1.5% K_2O) rocks compared to the estimated land area comprised of low K content rocks (22%). The IDL "root rot" map data shows (Figure 8) an even stronger association of root rots and rock type, with about 70% of the "hot spots" occurring on low K content rocks while only 22% of the land area is comprised of this rock type.

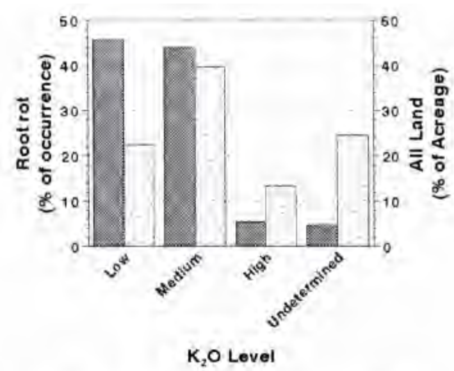

Figure 7. Percent of land area occurring on rock potassium content classes and percent occurrence of root rot hot spots identified from Forest Service digital maps for the five northern Idaho counties.

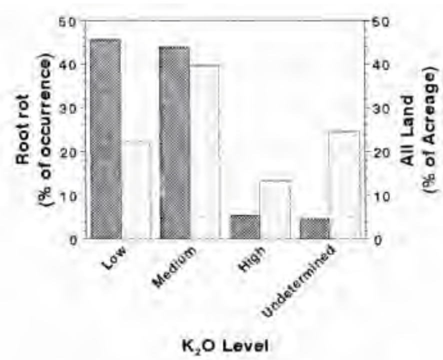

Figure 8. Percent of land area occurring on rock potassium content classes and percent occurrence of root rot hot spots identified from Idaho Department of Lands digital maps for the five northern Idaho counties.

Given the evidence presented above, Dave Hamilton and John Byrne, scientists at the Intermountain Forest Experiment Station of the USDA Forest Service, very recently undertook a reanalysis of permanent growth monitoring plots originally used in developing mortality equations for the Prognosis model (Wykoff et al. 1982). They visited the permanent sample plots to collect rock

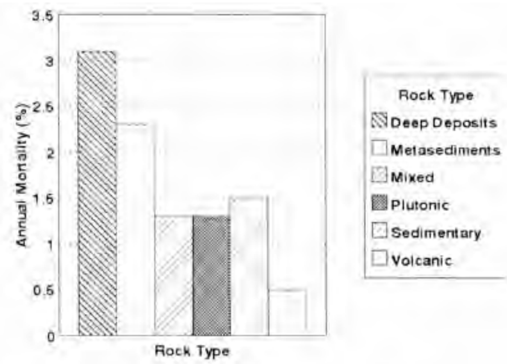

Figure 9. Average annual mortality rates from remeasured permanent sample plots across all tree species by rock type for northern Idaho, western Montana, and northeastern Washington.

samples for determination of the rock type at each location. Average annual mortality rates from these remeasured permanent plots across all tree species are summarized by rock type in Figure 9. Metasedimentary rocks were significantly higher than all other "hard rock" types, with an average annual mortality rate of 2.3%. Volcanic rocks had significantly lower average annual mortality rates (0.5%) than all other rock types. Many metasedimentary rocks have very low K content. Hamilton and Byrne's analysis provides additional independent support for the links between K availability and forest health.

Current and Future Work

The IFTNC has recently undertaken many activities to test the hypothesis that K availability affects tree mortality rates. The largest effort is a region-wide set of multi-nutrient experiments established in 1994, 1995, and 1996. In keeping with the results described earlier, parent material and forest habitat type are the two strata used in selecting the experimental locations. The experimental design and treatment combinations are provided in Table 1. Since the experiment has just been established, there are no results to report. Terry Shaw describes a new seedling nutrition experiment also being conducted by the IFTNC in a separate paper in this proceedings.

Table 1. Experimental design and fertilizer treatment regimes used in the new multi-nutrient experiment established in 1994 through 1996. Letters in parentheses indicate the set of fertilizer treatments used at each site (N = nitrogen rate, NN = nitrogen rate with repeated applications, NK = nitrogen-potassium response surface).

	Forest Habitat Series		
Parent Material	Douglas-fir	Grand fir	Western redcedar/ Western hemlock
Granite	3 (NK)	3 (NK)	3 (NK)
Basalt	1 (N), 2 (NN)	3 (NK)	1 (N), 2 (NN)
Metamorphic		1 (NK)	3 (NK)
Glacial Till	3 (N)	3 (NK)	3 (N)

(N) Nitrogen Rate Experiment

N Rate(lb/ac)	K Rate (lb/ac)
0	0
300	0
0	200
300	200
100	0
200	0
600	0

(NN) Repeated Nitrogen Rate—sites with this design include the treatments used in the nitrogen rate experiment (N) listed above as well as the following treatments repeated at the interval listed below. The design requires 14 plots.

N Rate (lb/a)	K Rate (lb/a)	Interval
100	0	8 years
200	0	8 years
300	0	8 years
600	0	8 years
100	0	4 years
200	0	4 years
300	0	4 years

(NK) Nitrogen-Potassium Response Surface—sites with this design include all the rates listed below. The design requires 14 plots.

N Rate (lb/a)	K Rate (lb/a)
0	0
300	0
0	200
* 300	200
87.9	58.6
87.9	341.4
512.1	58.6
512.1	341.4
600	200
300	400

* This treatment, the center point for the response surface, was repeated 4 times to produce the total of 14 plots.

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