Growth response and nutrient balance of Douglas-fir under fertilization on different soil parent materials, northern Idaho, USA

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Introduction

Tree growth can be limited by a number of resources, including light, water, temperature and nutrients. When nutrients limit tree growth, that limitation is often an artifact of the soil parent materials. In order to identify nutrient limitations imposed by the soil parent materials of northern Idaho on Douglas-fir (*Pseudotsuga menziesii*), the Intermountain Forest Tree Nutrition Cooperative (IFTNC) conducted fertilizer screening trial experiments. Besides growth response, the foliar nutrient balance is examined.

Our objectives were as follows:

1. determine which soil parent materials influence Douglas-fir growth under N and N+K+S+B fertilizers,
2. use that information along with foliar analysis to suggest nutrient growth limitations, and
3. determine K balance of fertilized and unfertilized Douglas-fir.

Methods

Sites, data collection and variables

- Three Douglas-fir x 5 replications were selected from 18 different sites in northern Idaho as part of nutrient screening trial experiments (Fig. 1).
- So, a total of 270 trees were included (18 sites x 3 trees x 5 replications).
- The soil parent materials were classified into nine categories, which are listed in Fig. 3.
- Three fertilizer levels were applied, control, N-only, or NKSB, randomly to individual Douglas-fir within each replication.
- Bole diameter and tree height were measured at the time of fertilizer application, and then again two years later.
- Diameter and height were used to estimate tree volumes by employing an allometric equation given by Wykoff et al. (1982).
- Growth rates of the individual trees were computed with the volumes.
- Foliar samples were clipped from the top whorls of each tree one year after fertilization and analyzed for nutrient concentrations.

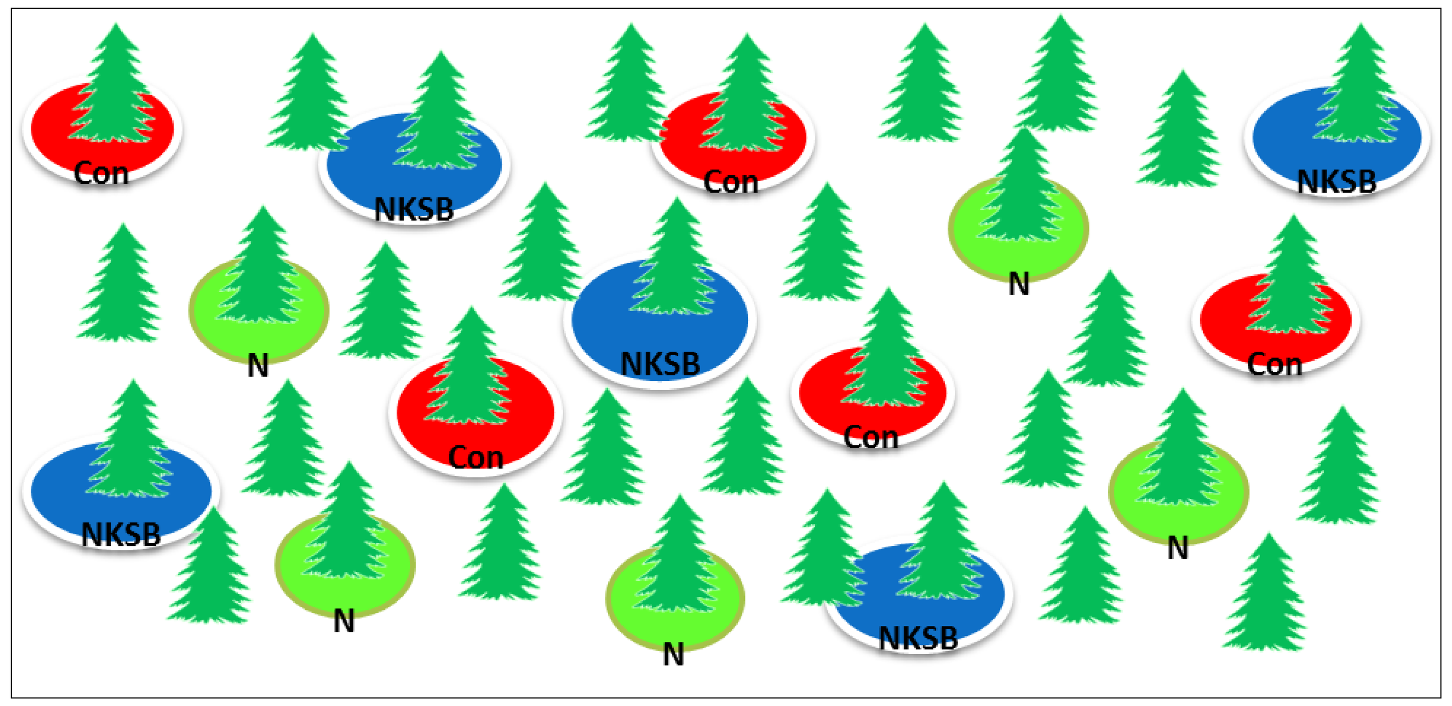


Figure 1 A generic layout of a site, the whole plot unit.

Experimental design and data analysis

- To test the simple effects of fertilizer within levels of soil parent material and interaction of soil parent material and fertilizer on Douglas-fir growth rate, a replicated split-plot design was employed.
- Besides K:N, nutrient ratios were selected for examination by multiple regression.
- Foliar data means and standard errors were analyzed graphically.
- A ratio of 0.5 was used as a reference critical values for K:N; although 0.65 is considered optimal (Ingestad 1971).

Results and Discussion

The results of the growth analysis are given in Table 2 and Figure 2, and plots of the foliar data are given in Figures 3 and 4.

- Growth responses to the fertilizers depended on the soil parent material (Soil Parent Material x Fertilizer interaction).
- Only three of the nine soil parent materials in this study exhibited differences among fertilizer simple effects on growth rates; although trends among means suggested that nutrient addition impacted tree growth on other soil parent materials.
- Typically, there were increases in growth under N-only and/or NKSB relative to the controls, but on some materials there was no fertilizer effect.

Table 1 Type 3 Effects of the growth response model

Effect	F	Pr<F
Fertilizer	13.37	<.0001
Soil Parent Material	10.87	<.0001
Fertilizer x Soil Parent Material	2.51	0.0017
Ln Initial Tree Volume	95.65	<.0001
Site within Soil Parent Material	11.09	<.0001
Site x Fertilizer within Soil Parent Material	2.66	0.0006

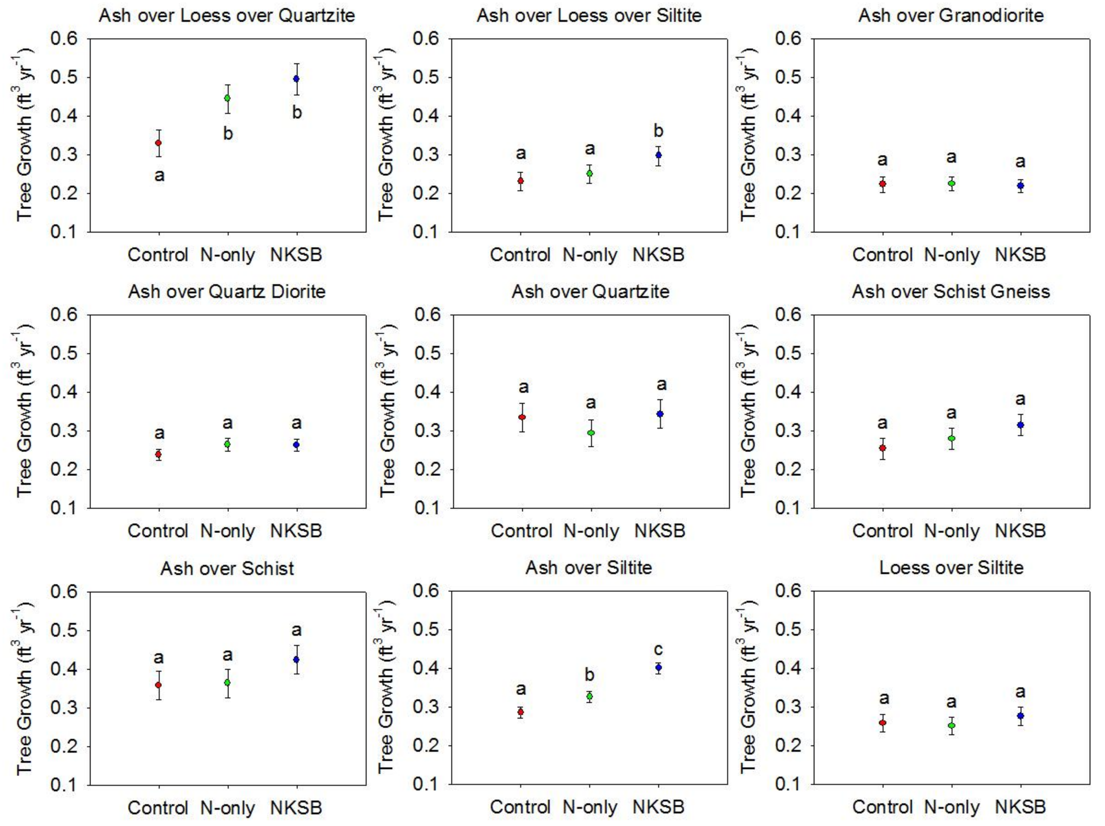
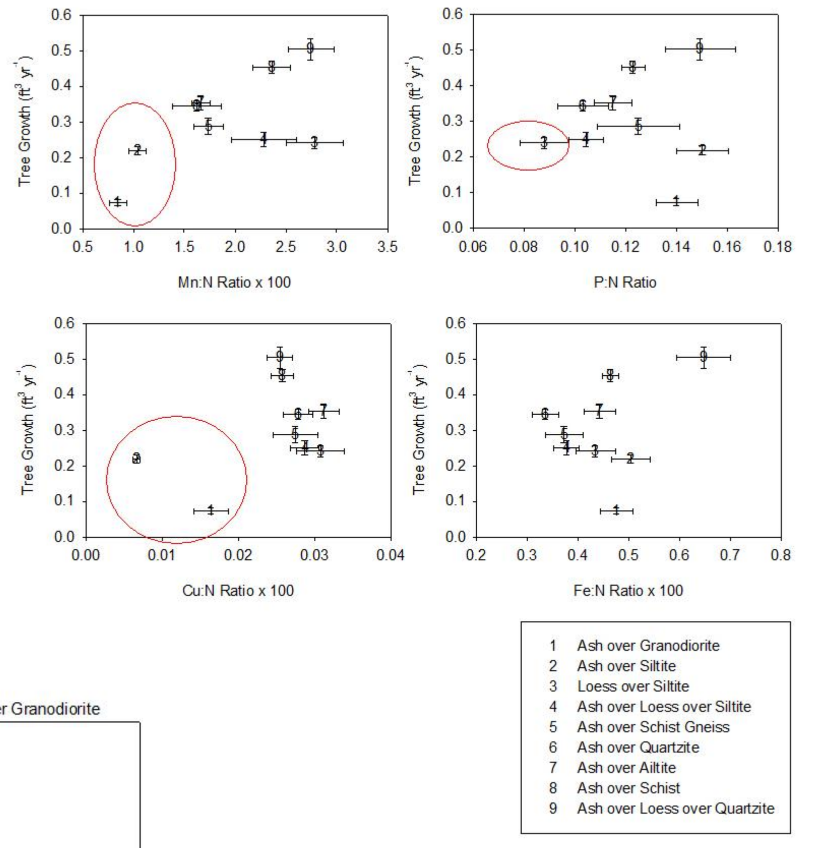


Figure 2 The least-square means of soil parent material x fertilizer treatments. Treatment means are compared as the simple effect of fertilizer within each soil parent material, and declared different at α-level .05. Shared letters indicate no significant difference between means, and error bars represent the standard error about the mean. Model results are given in Table 1.

- The growth response by fertilizer was contingent upon neither S:N nor B:N ratios; however other nutrients, P, Mn and Cu, may explain a lack of growth response to fertilizer on some soil parent materials. Additional experiments may indicate critical values for nutrient ratios for Douglas-fir in this region.

- On all soil parent materials, the tree foliage of the controls was either K-balanced or in excess of K relative to N. Potassium deficiencies were induced on some soil parent materials when N-only fertilizer was added but not on others, suggesting that soil parent material is important to K balance under N-only fertilization. Trees that are deficient in K are susceptible to insect infestations and disease (Moore et al. 1994), so fertilizing with N-only should be done with caution.

Figure 3 Tree growth against the ratios found to be important to growth by multiple regression. Red Circles suggest explanations for the lack of growth response to fertilization. Error bars represent the standard errors.



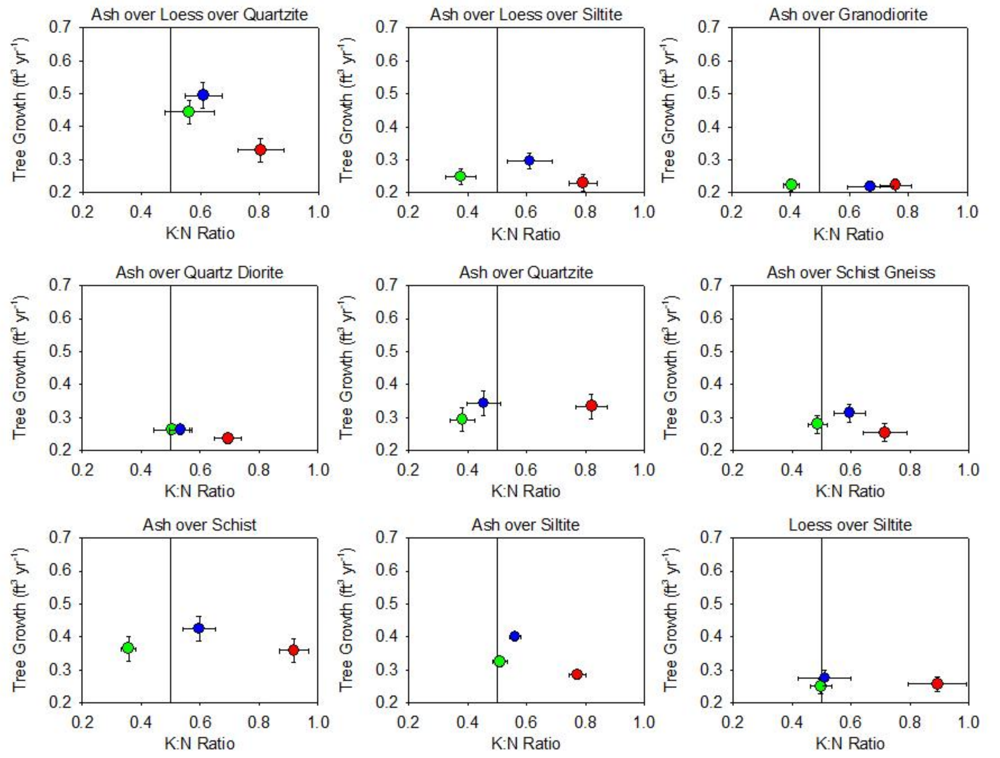


Figure 4 Tree growth against the K:N ratios of the soil parent material x fertilizer treatments. Circles are colored by fertilizer, control (red), N-only (green) and NKSB (blue). Vertical lines represent the critical values, and error bars represent standard error.

Conclusion: Soil parent material influences the growth response to N-only and NKSB fertilizers and the foliar nutrient balance of Douglas-fir. Soil parent material can facilitate decisions regarding the management of forest nutrients.

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