NUTRITION AND FOREST HEALTH

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ABSTRACT

Nearly all forest sites in this region are nutrient deficient, usually only nitrogen but sometimes potassium as well. Other elements may be limiting but not as commonly as these two. Forest fertilization can alleviate these deficiencies resulting in trees that should be more resistant to insects and diseases. Recent results suggest that it may be possible to alter tree root chemistry to the detriment of *Armillaria ostoyae* root rot by manipulating tree nutritional status, particularly by using potassium fertilization treatments.

INTRODUCTION

The purpose of this paper is to provide a summary of the empirical and experimental evidence to date demonstrating links between tree nutrition and forest health problems such as *Armillaria* root rot and mountain pine beetle. The evidence for these links comes from Intermountain Forest Tree Nutrition Cooperative (IFTNC) results as well as other research from the Inland Northwest region. The tree species included in these examples are Douglas-fir or ponderosa pine. In keeping with the theme of this symposium, at least some of the study sites were on cedar or hemlock habitat types.

EVIDENCE OF LINKS BETWEEN TREE NUTRITION AND FOREST HEALTH

One important prefacing comment needs to be made, *nitrogen (N) is good.* All trees and sites that we have studied need more N. When we apply N fertilizer, we usually get a large positive response (Mika et al. 1992; Moore et al. 1991; Shafii et al. 1989). However, sometimes when we fertilized with only N, mortality rates increased, producing negative response. At times, this mortality conformed exactly to high nitrogen treatment plot boundaries. This "square death" pattern occurred in both the Douglas-fir and ponderosa pine IFTNC region-wide experiments. Thus, nutrients have an important influence on mortality processes as well as tree growth.

IFTNC members wanted to know why this mortality occurred on some plots but not others. Classifying the study stands based on pre-treatment foliar samples offered some explanation of the mortality patterns (Mika and Moore 1990). Using literature recommendations for optimal potassium (K) and balance with N (K/N), we grouped the stands into three categories representing poor, good, and other K conditions. There was significant difference in response to N fertilization for stands in the "poor" foliar K class prior to treatment (Figure 1). Notice that the 200 lbs. N/ac. was a safe treatment for all 3 K classes, even for the poor K class. However, response to the 400 lbs. N/ac. treatment disappears in the poor K class due to the increased mortality. It appears that small changes in nutrient status can result in large changes in both growth and mortality.

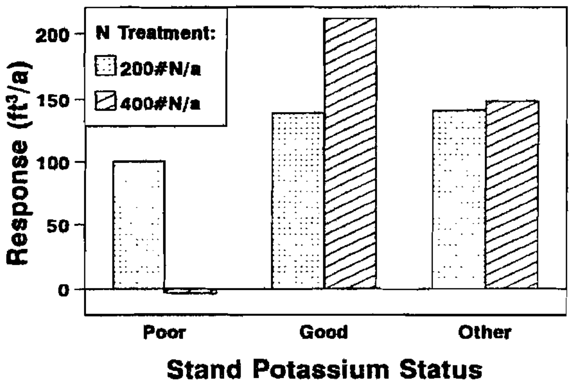

Figure 1.—6-year net volume response by K status and treatment.

What caused the trees to die? Figure 2 shows that most of the mortality associated with the 400 lbs. N treatment in the poor K class was due to *Armillaria* root rot in the Douglas-fir or bark beetles killing some of the ponderosa pine component of these plots. The amount of mortality caused by root rot (almost all *Armillaria*) in the "good" K class was noticeably lower than the other two K classes for all three treatments (Figure 2).

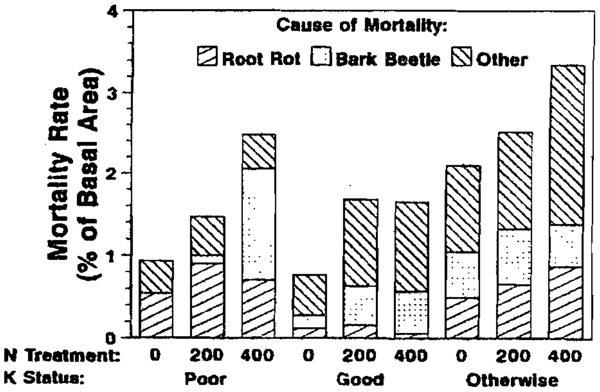

Figure 2.—Mortality rates by cause, treatment, and potassium status.

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In Montana, the IFTNC established an experiment testing the effect of N and N plus K fertilizers on growth and mortality of ponderosa pine. This experiment provided the first chance for the IFTNC to test a combined N plus K treatment at the start of an experiment. After four years there were large mortality differences (net volume) among treatments (Figure 3). The N only (200 lbs. N/ac.) fertilization had significantly more mortality than the N plus K (200 lbs. N and 200 lbs. K/ac.) treatment. Mountain pine beetles killed a significant number of trees on the N only plots, while on the adjacent N plus K plots not a single tree was killed by beetles in the 4-year period (Figure 4). Potassium added to the fertilizer mix seemed somehow to "protect" the ponderosa from the beetles.

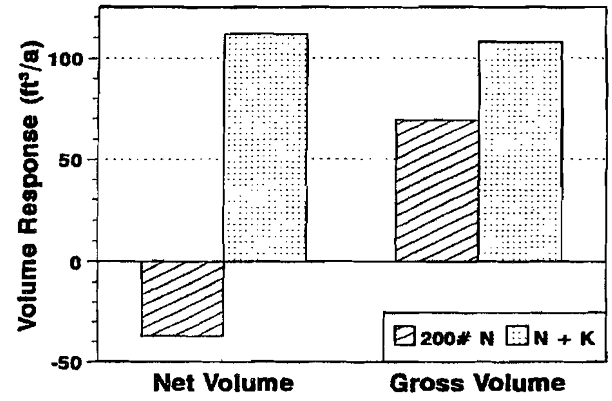


Figure 3.—4-year volume response, 1987 ponderosa pine.

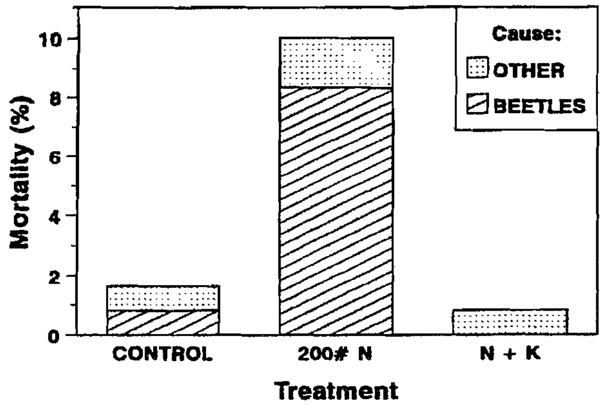


Figure 4.—4-year mortality rates, 1987 ponderosa pine.

Ponderosa Pine mortality was related to pretreatment foliar K status. Mortality occurred (the large negative responders) when N alone was added to those sites that had poor K/N balance prior to treatment (Figure 5). However, if both N and K were in the fertilizer, then the tree mortality did not occur, even on those sites with low pre-treatment K/N ratios.

Recent results from Entry et al. (1991) may explain the physiological basis for the IFTNC results. They went back to some previously existing fertilizer trials (Scanlin and Loewenstein 1981) located in Douglas-fir stands on cedar habitat types in northern Idaho and inoculated tree roots with *Armillaria* root rot. Comparison of inoculated roots from thinned plots versus thinned and fertilized (with 200 lbs. N/ac.) plots showed that incidence of infection was significantly higher on the thinned and fertilized treatment than on the thinned only plots. They found that *Armillaria* incidence was related to root chemistry. Tree roots from thinned stands contained high concentrations of phenols and low sugar concentrations, while thinned and fertilized tree roots had lower phenols and higher sugar concentrations. The ratio of phenols to sugars was strongly correlated to incidence of infection (Figure 6): only trees with ratios less than 15 seem susceptible to *Armillaria*. Phenolics are plant defense chemicals while sugar is "good food" for *Armillaria* (Wargo et al. 1980).

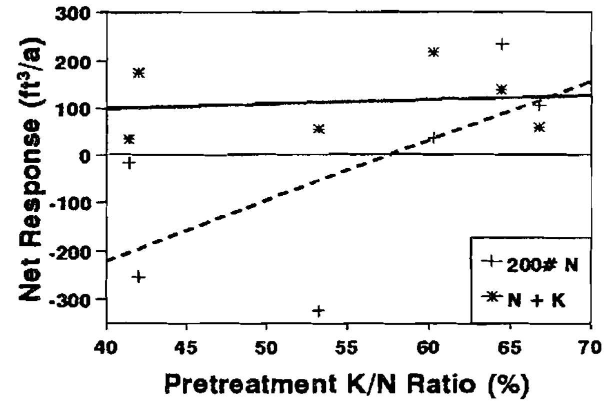
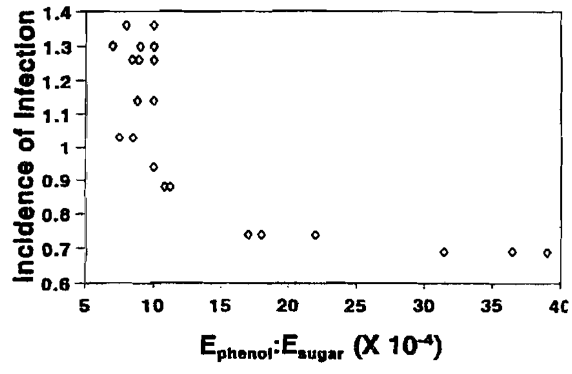


Figure 5.—Net volume response, 1987 ponderosa pine.



Adapted from Entry *et al* 1991

Figure 6.—Armillaria infection rate, relationship to thermochemical budget.

Several IFTNC cooperators established a nutrition experiment in a Douglas-fir stand with an active *Armillaria* infestation. The study is located near the town of Grangemont in northern Idaho. The five treatments were: unfertilized controls; 200 lbs. N/ac. only (urea); 200 lbs. N + 200 lbs. K/ac. (urea & KCL); 200 lbs. K/ac. only (KCL); 200 lbs. K/ac. only (K_2SO4). Four years after treatment, growth responses indicate that no treatment-related mortality effects have shown up as of yet (Figure 7). The N response of + ~ 20% is just about typical of Douglas-fir response in the region-wide IFTNC experiment. The N + K basal area growth response of + ~ 25% is not significantly greater than the N alone treatment. Further, there is no significant growth effect from the K only treatments; however, based on existing literature, K would effect tree mortality rather than growth.

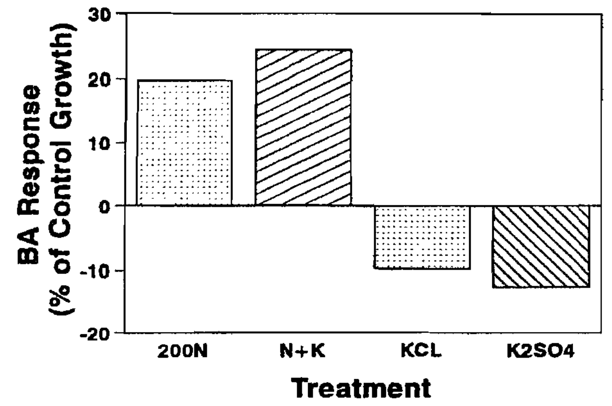


Figure 7.— 4-year gross basal area response, Grangemont Root Rot Study.

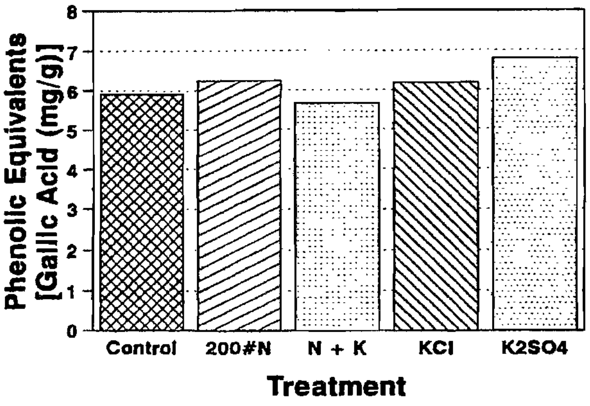


Figure 8.—Root tissue phenolics concentration , Grangemont Root Rot Study.

Four years after the fertilization treatments were applied root samples were collected using methods similar to Entry et al. (1991). We sampled pairs of healthy as well as infected trees on each plot, and to date have completed chemical analysis of the healthy trees. Root tissue phenolic concentration by fertilizer treatment is shown in Figure 8. There were no significant differences among the treatments, although there is a tendency for the K treatments to have higher phenolic concentrations. However, there was a significant reduction in root sugar concentrations resulting from all the fertilizer treatments, particularly from the K only treatments, which caused a reduction in root sugar to about one-half that of the controls (Figure 9). The root phenolic:sugar ratios by treatment are provided in Figure 10, these ratios are proportional to Entry et al.'s values shown in Figure 6. A stronger statistical relationship exists for the phenolic:sugar ratio than for sugar concentration alone, although treatment effects on sugar concentrations clearly dominates the ratio results. Potassium treatments significantly increased the root phenolic/sugar ratio. Given that a high ratio is bad for the fungus and good for the trees, this experiment demonstrates that it may be possible to change tree root chemistry to the detriment of *Armillaria* by manipulating tree nutritional status by fertilization.

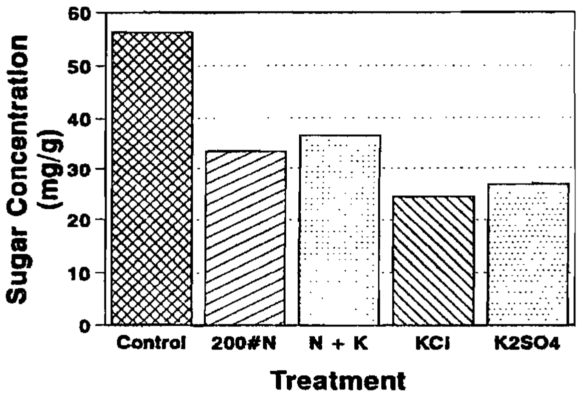


Figure 9.—Root tissue sugar concentration, Grangemont Root Rot Study.

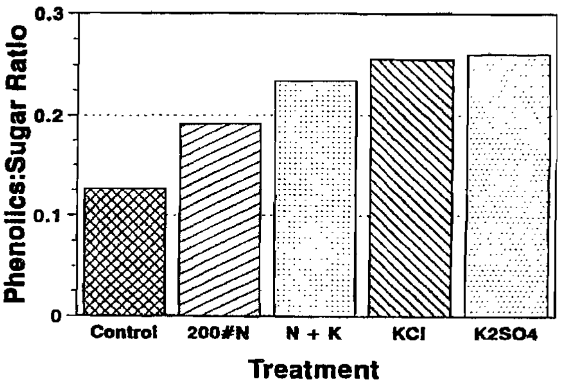


Figure 10.—Root Phenolics:Sugar Ratios, Grangemont Root Rot Study.

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QUESTIONS AND ANSWERS

Question: Would you expect the same fertilization response from the applications of N/K tablets at the time of planting as you saw with the older stands? Would you recommend this practice?

Answer: We are not aware of any large scale trials of this fertilization technique in our region, thus our answer is speculation. The application at the time of planting would probably not be as effective as applying the treatment later in the for two primary reasons: 1) trees can be shipped from the nursery with a high nutrient "load", particularly potassium. This may be more efficient than putting fertilizer in the planting hole; and 2) nutrient demands on a site are greatest sometime after crown closure. For these reasons we would not recommend fertilization at the time of planting without substantial field testing.

Question: Any speculation on the mechanism whereby K works it's magic on sugar/phenol ratio? Going into sap production rather than available for *Armillaria*? I thought K was an important component of phenols?

Answer: The textbook "Potassium in Agriculture" suggests that K is a mobile regulator of enzyme activity, and is involved in essentially all cellular functions that influence disease severity and probably exerts its greatest effect on disease through specific metabolic functions such as the shikimic pathway. Potassium is believed to effect carbon allocation from the production of simple carbon compounds to more complex ones such as phenolics.

Question: In looking at Jim Entry's work on incidence of root rot infection, data also shows somewhat lower infection rate in thinned only trees compared to control. Is this significant? Could competition and vigor and growing space influence phenolic production?

Answer: I think the speculation in your question is probably correct; however, our guess is that root sugar concentrations are more effected than phenolics. High sugar concentrations in the roots or bole probably indicates some physiological problem with the trees. The thinned trees were probably allocating carbon to better "stuff" than sugar such as lignin and cellulose.

Question: In light of your results, can you speculate on the possible effects of fire suppression on the nutritional status of sites, and thus on the trees growing on those sites and their susceptibility to infection by *Armillaria.*

Answer: Fire exclusion has had a major effect on the forest nutritional environment. Trees growing in nutrient conditions much different than they were prior to fire exclusion. Since potassium is volatilized only at very high temperatures compared to other elements, frequent fires probably had the effect of increasing K availability. Thus, fire exclusion may play an important role in the K deficiencies that we currently observe around the Inland Northwest.