THIRD FIVE YEAR STUDY PLAN

for the

INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

A FOREST NUTRITION - FOREST HEALTH EMPHASIS

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INTRODUCTION

Intermountain Forest Tree Nutrition Cooperative members decided that the following were the top two priority areas for the next 5-year phase of the IFTNC:

(1) Forest productivity and ecosystem functioning, particularly forest nutrition and forest health relationships.

(2) Development of operational guidelines and best management practices for forest fertilization.

Quantifying long-term N fertilization effects (Priority 3), was still considered desirable but the Steering Committee (SC) decided that extending the length of future remeasurement cycles should be considered in planning future work.

The SC developed a set of desirable outcomes from future IFTNC activities as follows:

Associated with priority (1);

(A) Improved ability to diagnose nutrient deficiencies and consequent effect on the process of forest longevity, resilience, and productivity.

(B) Improved ability to efficiently conserve and enhance nutrients.

(C) Develop correlations of nutrient levels with forest growth and mortality performance.

(D) Evaluate the effects of silvicultural activities on nutrient levels. (This was considered to be incidental to A, B, and C above).

(E) Develop a prescription recommendation system for nutrient management.

Associated with priority (2);

(A) Develop Best Management Practices for fertilization/nutrient conservation by the IFTNC.

(B) Communicate (transfer) the above information to the profession, the public, and regulatory agencies.

The SC instructed the Technical Committee (TAC) and staff to develop plans and proposals to achieve outcomes 1A through E above for consideration by the SC. Item 2A will be accomplished by the TAC (or a subcommittee) and the staff to be submitted to the SC for consideration at a future date. We propose developing a computer based expert system for distribution to IFTNC members as an efficient way to satisfy the needs specified in 2B.

Further, to keep the IFTNC's goal statement closely in line with the stated outcomes, the SC approved the following goal statement:

> **The goal of the IFTNC is to promote forest longevity, resilience and productivity through understanding of nutrient cycles, conservation of native nutrients through appropriate forest management practices and amelioration of nutrient deficiencies through stand culture or the addition of fertilizers or other amendments.**

THE NEW EXPERIMENT

An Emphasis on Forest Health and Nutrition

Background

Preface: Previous results from IFTNC Douglas-fir and ponderosa pine experiments suggest a link between nutrition, particularly potassium nutrition, and insect and disease pests. Mortality rates in the Douglas-fir trials were significantly higher in stands with poor pre-treatment foliar K status after application of 400 lbs. of N/ Ac. Interestingly, the most common mortality causes in this K status/ treatment category were root rots and bark beetles.
Results from the Montana ponderosa pine experiment showed that N only treated plots experienced higher mortality rates, producing a net loss in volume growth after 4 years. Conversely, N + K treated plots showed less mortality than control plots. The net volume growth effect associated with adding K was highly significant. Mortality on the N only plots was six times as great as control plot mortality; over 80% of it resulting from bark beetle activity N + K plots showed less mortality than control plots with no bark beetle mortality.

Hypothesis: Potassium nutrition affects tree resistance to Armillaria (and perhaps other diseases and insects as well) by influencing the concentrations of phenolics, tannins and sugars in tree roots.

State of Knowledge: Entry et al 1991 found that rates of infection by Armillaria ostoyae were highest in trees that were thinned and fertilized with nitrogen and lowest in trees that were only thinned. Concentrations of sugar, starch, and cellulose in root bark tissue were highest in N fertilized trees and lowest in trees that were thinned but not fertilized. Concentrations of lignin, phenolics, and tannins were highest in root bark from thinned only trees and lowest in root bark from thinned and N fertilized trees. They suggest that fertilized trees may allocate more carbon to sugar and cellulose and less to tree defense compounds, such as lignin, phenolics, and tannins. High amounts of N may shift carbon allocation from the shikimic acid pathways to support increased photosynthetic area, thereby reducing concentrations of phenolics and lignins in root bark tissue. Results of their study are similar to those of others who have analyzed phenolic concentrations in plant tissues. Bryant et al (1987) reported that N fertilization increased tree growth but decreased the concentration of phenolic compounds in leaf tissue of birch. The low sugar concentrations in tree roots growing in thinned only stands may have provided less energy for Armillaria to degrade phenolic compounds and lignin, and, thereby, successfully invade host tissue. Entry et al (1991) also found that the ratio of energy required for phenolic or lignin degradation to the energy available from sugars to Armillaria may provide dependable assays of the physiological response of trees to attack by Armillaria.

In a separate study, Entry et al (1992) found that tree species that are more susceptible to infection by Armillaria produce lower concentrations of phenolics and more sugar in root bark, thereby increasing the energy available to the fungus to degrade the phenolics and invade the host trees. This result is consistent with previous greenhouse and field studies. Wargo (1984) proposed that pathogenic species of Armillaria infect hosts because the energy available to the fungus through sugars, nitrogen, and ethanol in root bark is great enough to overcome host defense compounds such as tannins and phenolics. Entry et al's (1992) study and previous studies support this hypothesis. Wargo suggests that high concentrations of phenolic compounds inhibit growth of Armillaria. Increased glucose concentration enables Armillaria to grow in the presence of inhibitory concentrations of phenolics.

The textbook " Potassium in Agriculture (1985)" contains an entire chapter titled " Potassium Interactions with Plant Disease". There are more than 100 references documenting K nutrition / disease interactions (some regarding trees). Following are some excerpts from the book:
" The intricate relationship of K nutrition to metabolic functions and growth, as well as its interrelationship with the various other nutrients within the plant and soil, provide ample opportunity for K to modify disease resistance or susceptibility. As a mobile regulator of enzyme activity, K is involved in essentially all cellular functions that influence disease severity.---------- Potassium probably exerts its greatest effect on disease through specific metabolic functions that alter compatibility relationships of the host-parasite environment. --------- The accumulation of inhibitory amino acids, phytoalexins, phenols, and auxins around infection sites of resistant plants is dependent on the level of K and other minerals present."

There seems to be ample evidence from our data and the literature summarized above that the stated hypothesis is a reasonable one for the IFTNC to test in future work. Such an effort should lead to a better understanding of forest nutrition and health in the region and perhaps development of bioassays of tree nutrition and tree resistance to pests.

Literature Cited

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Munson, R.D. (ed.) 1985. Potassium in Agriculture. American Society of Agronomy, Madison, WI. 1223p.

Wargo, P.M. 1984. How stress predisposes trees to attack by Armillaria mellea: - a hypothesis. pgs. 115-121 in: Proceedings of the Sixth International Conference on Root and Butt Rots of Forest Trees. G.A. Kile, ed. CSIRO, Melbourne, Australia.

The Experiment:

The overall purpose of this proposed experiment is to obtain a better understanding of the relationship between forest nutrient status and forest growth and mortality processes in the Inland West.

To accomplish this we propose to establish trials in an agreed upon matrix covering typical forest habitat types and soils found in the region (Figure 1). There will be a core experiment conducted in all the strata shown in Figure 1. In addition, there will be strata specific prescriptions (treatments) tested (Table 1).

Nitrogen Rate Experiment:

The basic experiment involves a factorial design of N and K fertilization, each at 2 rates, for a total of 4 plots. One rate will be 0; the other will be represent an amount likely to yield optimal response; 300 #/a for N and 200 #/a of K will be tested.

This basic experiment will be replicated on 3 sites in each of 12 categories, the latter based on combinations of parent material (granite, basalt, metasediment, and mixed glacial) and vegetation series (DF, GF, and WRC), yielding a total of 36 sites (see Figure 1). Stands selected will be mixed conifer (primarily composed of grand fir, Douglas-fir, and ponderosa pine but including other species as well) between 15 and 80 years old that have had some sort of stocking control conducted at least 5 years previous to plot establishment.

Each plot will be 1/2 acre in size with a buffer strip. Mortality would be monitored over the entire plot and growth measurements would be taken on an interior 1/10 acre plot. For the 2 most common species on each site, foliage, bole, and root samples will be collected from 10 trees within each 1/2 acre plot.

Armillaria resistance/susceptibility will be assayed by inoculating roots and monitoring infection incidence and by analyzing the organic chemistry of selected individual tree root samples. Bark beetle resistance will be quantified by measuring production of secondary resins and acetone-soluble compounds in wounds inoculated with a mountain pine beetle fungal symbiont (Europhium clavigerum).

On four sites, mountain pine beetle attractant will be used to attract beetles to plots; beetle population parameters will be measured to judge tree resistance. As such treatment is likely to kill most of the plot trees and prevent further meaningful plot monitoring, these sites (an additional 4 plots) will be somewhat removed from the rest of the plots (Figure 1).

Vegetation Control experiment:

On sites with a substantial understory component, a vegetation control factor will be added to the basic experiment. This will require an additional 4 plots treated with herbicide. Any site with greater that 30 percent shrub and grass cover would include this additional treatment. If beetle attractants are to be used on such a site, an additional 8 plots (one replication) will be needed.

Response Surface Designs:

A basic N and K response surface (RS) design using a central composite design will be accomplished using 14 plots at each installation in 8 of 12 habitat type / soil strata (Figure 1). These 14 plots, when combined with the nitrogen rate experiment, would give us responses for a total of 5 different rates of both N and K fertilization.

For N, we want to try rates higher than 400 #/a since we have already demonstrated significant increases from 400 over 200 #/a rates for certain regions, vegetation types, etc. Thus, we propose a design using a 600 #/a maximum treatment. For K, the choice is less obvious since we have little information on which to base a decision. If we expect maximum response at 200 #K/a, then we should use a maximum rate of 400 #K/a.

Recommendations by Vegetation Series:

Western Red Cedar Type: Mortality rates in this type for the DF experiment showed no trends with K treatments, although there were some weak trends of growth response improvement with K amendments. But this type does show significant differences in growth response between 200 and 400 #N treatments. Thus, a straightforward N rate trial would be most suitable for these sites; using rates of 100, 200, 300, and 600 #/a. Bark beetle mortality is very low on this type, so experiments with attractants are not recommended here.

Since not too many plots are needed on this type, we will replicate the rate trial plots to allow for repeated fertilizer applications at four installations. Based on the Belfair Washington DNR results we might expect to get maximum growth response if we retreated every 3 or 4 years, while our own DF experiment tells us that first treatment direct effects last at least 8 years on our better sites; retreatment at years 4 and 8 will be tested on our new sites. A factorial design with 5 rates (0, 100, 200, 300 and 600) and 2 retreatment frequencies (once and twice per 8 years) would require 7 addition plots. However, this requires a long term commitment to these plots-- monitoring for 12 or more years.

Grand Fir Type: Potassium seems to have its greatest effect on this type in the Douglas-fir species experiment, so we will test various K rates here. Even though this type did not produce great differences between 200 and 400 #N responses to the original treatments, addition of K may change this story. RS designs will be used here (Figure 1). Both bark beetles and root rots are important mortality factors, so both sorts of inoculations will be conducted on all parent materials on this habitat type.

The N and K response surface design requires 14 plots (18 when herbicide use is included in the basic factorial), so little room is left for expanding the experiment in other ways.

Douglas-Fir Type: Previous results for this type are similar to those for the WRC type; we have no evidence of K effects on this type, but do show significant increases in gross growth response to 400 #N/a versus 200 #/a. Thus, experiments looking at N rate-related response are in order. Bark beetle mortality is very important on this type, so beetle attractant experiments will be conducted on four installations on DF habitat types. Installations with bark beetle attractants require an additional four plots spatially separated from the rest of the installation.

All establishment, treatment application, tree measurement, soil, foliage, root, and bark sampling and analysis will follow the existing procedures of the IFTNC study plan (or as ammended).

Figure 1.

IFTNC SITE SELECTION DESIGNS BY PARENT MATERIAL AND SERIES			
	DOUGLAS-FIR	GRAND FIR	WESTERN RED CEDAR
GRANITE	B, V, K	V, K	V, K
BASALT	B, V, R, N	V, K	V, R, N
METASEDIMENT	B, V, K	V, K	V, K
GLACIAL	B, V, N	V, K	V, N

B - Bark Beetle Attractant
V - Vegetation Control
R - Repeated Nitrogen Application
N - Nitrogen Rate Experiment
K - Potassium Rate Experiment

(N) Nitrogen rate experiment: 12 sites (3 each in DF-Basalt, DF-Glacial, WRC-Basalt, and WRC-Glacial types)

	N rate	K rate
7 plots:	0 lbs/a	0 lbs/a
	300	0
	0	200
	300	200
	100	0
	200	0
	600	0

(R) Repeated nitrogen applications add-on: added to the N rate study at 4 sites (2 each in DF-Basalt and WRC-Basalt)

	N rate	K rate	Interval
7 plots:	100 lbs/a	0 lbs/a	8 years
	200	0	8
	300	0	8
	600	0	8
	100	0	4
	200	0	4
	300	0	4

(K) Nitrogen-potassium response surface: 24 sites (3 each on GF vegetation types or Granite or Metasedimentary parent materials)

	N rate	K rate
14 plots:	0 lbs/a	0 lbs/a
	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
	300	200
	300	200
	300	200
	300	200

(V) Vegetation control add-on: added to the experiment on an estimated 18 sites

	N rate	K rate	Herbicide
4 plots	0 lbs/a	0 lbs/a	Yes
	300	0	Yes
	0	200	Yes
	300	200	Yes

(B) Bark beetle attractant experiment: 4 separate sites all on DF vegetation types

	N rate	K rate	BB attractant
4 plots	0 lbs/a	0 lbs/a	Yes
	300	0	Yes
	0	200	Yes
	300	200	Yes