Intermountain Forest Tree Nutrition Cooperative

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Foliar Nutrient and Two-Year Basal Area Response on the Round Mountain Multi-Nutrient Fertilization Test Site in Northeast Oregon

SUMMARY

Multi-nutrient fertilization was successful in increasing nitrogen, potassium, sulfur and boron nutrient content in the ponderosa pine foliage. However, only nitrogen and potassium expressed concentrations above reported critical levels, while sulfur and boron foliar levels were deficient. On average, two-year basal area growth was 9.8% higher on the multi-nutrient treatment than on the control.

STUDY AREA

The study area is located in the Blue Mountains of northeast Oregon. The site was established with ponderosa pine stock in the early 1960's and pre-commercially thinned in the 1980's. Site characteristics include grand fir climax vegetation type and shallow silt-loam soils overlaying Columbia River basalt parent material. The stand is starting to experience mortality due to *Armillaria* root rot incidence. There is concern that the root rot may reduce stocking below acceptable levels.

OBJECTIVE

The primary objective of this study is to demonstrate the effects of multiple nutrient fertilizer application on improving plantation health and productivity.

METHODS

Plot Establishment

The study area was established in September, 1996 and consist of six square 0.1 acre plots. The plots are grouped into two areas of three plots based on treatment type, fertilized or unfertilized. Plots were established to be as similar as possible based on tree and site characteristics. Plots were monumented with yellow painted PVC tubing installed at plot corners and plot center. A red forest fertilization study sign is attached to the plot center stake. Plot trees are monumented with a yellow number and paint line at breast height. Trees too small for suitable paint identification were tagged with an aluminum tag at the base of the tree. Forest fertilization study signs are nailed along adjacent road to identify the stand as a study area.

Treatments

The two treatments are a control and a multi-nutrient mix consisting of 100 lbs/ac. nitrogen (N), 100 lbs/ac. potassium (K), 20 lbs/ac. sulfur (S) and 5 lbs/ac. boron (B). Ammonium sulfate, murate of potash and agricultural grade borax were the fertilizer forms. The multi-nutrient fertilizer treatment was commercially applied with hand spreaders (belly bouncers) over approximately 73 acres, excluding the control plot areas.

Measurements

Initial measurements were made in the fall of 1996. All live trees taller than 4.5 feet in height were measured for heights, diameters and defect at the time of treatment. Every two years diameters are remeasured on all of the trees and any incidence of damage or mortality along with probable cause will be noted. Heights will be re-measured every four years after treatment on all trees. Tree volumes are estimated using regional species-specific volume equations (Wykoff et al. 1982). Site characteristics and plot summaries are given in Appendix A.

One year after treatment, dormant season foliage samples were obtained from the most dominant species represented within the installation. Two dominant or codominant trees on each plot were selected for collection. Foliage was collected from the third whorl from the top of each tree by climbing. Foliage was brought in from the field and processed for nutrient chemical analysis. Foliar N concentrations were determined using standard micro-Kjeldahl procedure while all other nutrients were determined by ICP emission. Foliar nutrient contents were calculated for all nutrients present in the fertilizer mix (N, K, S and B) by using this formula: nutrient concentration x weight of thirty needles.

Data Analysis

General linear contrasts and differences between means by treatment for the basal area growth and foliar nutrient responses were determined by using the least-squares routine of the general linear models procedure (PROC GLM) of the Statistical Analysis System (SAS Institute Inc. 1985).

Net and gross basal area growth was calculated using these formulas:

$$\text{Net Basal Area Growth} = BA_2 - BA_0$$

$$\text{Gross Basal Area Growth} = (BA_2 + MBA_2) - BA_0$$

where: BA_0 = Basal Area (initial)
BA_2 = Basal Area (2-year)
MBA_2 = Mortality Basal Area (2-year)

Contrasts between basal area means are considered average growth responses to the treatments. Combined installation growth responses are smoothed estimates which are adjusted to a common basal area of 119 ft^2/acre. Response for this study is defined as the growth difference between the control plots and the multi-nutrient treated plots.

RESULTS AND DISCUSSION

Foliar Response

Needles collected from the upper crown were significantly larger on those trees receiving the multi-nutrient treatment over that of trees receiving no fertilizer treatment (Table 1). On average, needles on trees receiving the multi-nutrient treatment weighed 32% more than those from unfertilized trees (Table 1).

Table 1. Fall/1997 average ponderosa pine needle weights (g/30 needles) by treatment for Round Mtn. multi-nutrient fertilizer test site in northeast Oregon.

Treatment	**Needle Weight (g/30 needles)**		
	Weight	Difference	% Change
Control	6.26		
Multi-Nutrient	8.25	1.99	*32

Note: Percent change preceded by an asterisk are considered significantly different at the $p \leq 0.10$ level.

Overall, the multi-nutrient fertilization was successful in getting additional nutrients into the trees. Foliar nutrient contents in Table 2, expressed as nutrient concentrations x needle weight, show that the multi-nutrient fertilization treatment increased “target nutrients” (nutrients used in the fertilizer mix) in the ponderosa pine foliage. Nutrient content expresses foliar nutrient levels relative to weight (g./30 needles), therefore eliminating possible growth nutrient dilution. Potassium showed the highest response with a significant 69% increase in those plots receiving the fertilizer treatment over that of the unfertilized plots. Nitrogen also showed high, although only marginally significant ($p = 0.11$), foliar response on the fertilized plots with a 60% increase over that of the unfertilized plots (Table 2). Sulfur response was also significantly higher on the fertilized plots with a 39% increase over that of control plots. Boron fertilization increased foliar content a non-significant 21% over that of the control plots (Table 2).

Table 2. Fall/1997 average ponderosa pine foliar nutrient contents (g/30 needles) by treatment for Round Mtn. multi-nutrient fertilization test site in northeast Oregon.

Nutrient	**Control**	**Multi-Nutrient**	**% Change**
Nitrogen	7.57	12.10	60
Potassium	4.68	7.92	*69
Sulfur	0.44	0.61	*39
Boron	136.4	157.4	21

Note: Percent change preceded by an asterisk are considered significantly different at the $p \leq 0.10$ level.

Foliar nutrient concentrations and foliar nutrient content responses were similar for N and K but not for S and B. Foliar K concentrations were a significant 27% higher on those plots receiving the fertilizer treatment than those plots that did not receive any fertilizer amendment (Table 3). Nitrogen also showed a response, although not significant ($p \leq 0.10$), with concentrations 20% higher on fertilized plots than on the control plots. In contrast to S and B foliar nutrient contents, where both nutrients expressed positive foliar response, multi-nutrient S and B concentrations were either similar or lower than plots receiving no fertilizer treatment (Table 3). This in part may have been due to large needle expansion and the dilution of S and B concentrations in the foliage. Furthermore, S to N ratios were 17% lower on the fertilized plots than the unfertilized plots (Table 3), which may indicate that the S fertilization rates (@ 20 lb/ac., prescribed is 90 lb/ac.) were too low and especially so with N fertilization. According to Ingestad (1979) S to N ratios for optimal growth should be 0.09 (N to S = 0.15, Blake 1990). Sulfur to N ratios on the fertilized plots were 0.05 and 0.06 on the control plots (Table 3), indicating S to N imbalances. The K to N ratio on the fertilized plots was 0.70 (above Ingestad's 0.65 optimal recommendation for K) and 8% higher than those plots receiving no fertilizer (Table 3).

Table 3. Fall/1997 average ponderosa pine foliar nutrient concentrations by treatment for Round Mtn. multi-nutrient fertilization test site in northeast Oregon.

Nutrient	**Control**	**Multi-Nutrient**	**% Change**
Nitrogen (%)	1.18	1.41	20
Phosphorus (%)	0.19	0.22	*16
Potassium (%)	0.75	0.95	*27
Sulfur (%)	0.07	0.07	0
Molybdenum (ppm)	0.58	0.62	7
Boron (ppm)	21.8	18.9	-13
Copper (ppm)	3.04	3.76	*24
Zinc (ppm)	43.2	51.7	20
K/N Ratio	0.65	0.70	8
S/N Ratio	0.06	0.05	-17

Note: Percent change preceded by an asterisk are considered significantly different at the $p \leq 0.10$ level.

Figures 1a-1d show ponderosa pine foliar nutrient concentrations and critical levels (Turner and Lambert 1978, Powers 1983, Powers et al. 1985, Blake et al. 1990) for the four "target nutrients" used in the fertilizer treatment. Foliar ponderosa pine nutrient concentration levels below these critical values are considered deficient for adequate growth. Figures 1a and 1b show N and K concentrations on both the control and multi-nutrient treatments are above the recommended critical level. However, foliar S

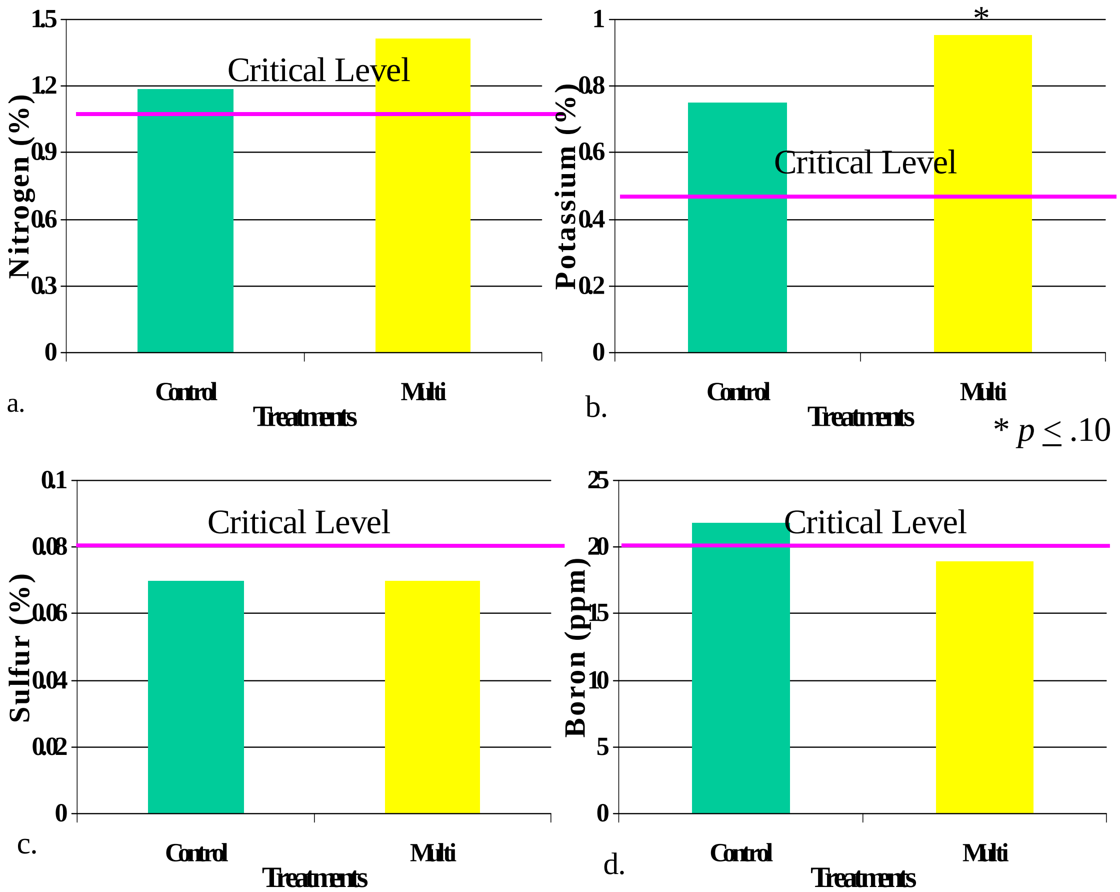

Figure 1. Foliar nitrogen (a.), potassium (b.), sulfur (c.) and boron (d.) concentrations with critical levels by treatment for Round Mtn. multi-nutrient fertilization test site in northeast Oregon.

concentrations shown in Figure 1c are below the 0.08% critical level for both the control and multi-fertilizer treatments. Moreover, even though nutrient contents did show S response (Table 2), these results show that the S fertilizer amendment was not sufficient enough to successfully increase foliar S above recommended critical values (Figure 1c). The same conclusions can be made about B foliar concentration shown in figure 1d. Boron concentrations were slightly above the critical value on the control but below the critical value on the multi-nutrient treatment. Apparently, boron concentrations on the multi-nutrient treatment experienced growth dilution effects. Phosphorus and copper showed significantly higher concentrations on plots receiving the fertilizer treatment than those plots receiving no fertilizer treatment (Table 3). Foliar nutrient concentrations, other than the “target nutrients” in the fertilizer mix, are not considered deficient for either the control or fertilized plots.

Basal Area Growth Response

Adjusted 2-year basal area response was not significant for either net or gross basal area. Due to mortality on the unfertilized plots, net basal area response (1.2 sq. ft./ac.) was slightly higher than gross basal area response (1.1 sq. ft./ac.). Net basal area response was 9.8% higher on the multi-nutrient treatment than that of the controls (Table 4). In comparison to N and S fertilization test sites established in northeastern Oregon in 1991 (Shaw and Moore 1995), where basal area response was 17%, response for this site was some what low at 9.8%. However, the test sites established in 1991 had 200#/ac. N fertilization rates or twice the amount applied for this study. IFTNC response data shows a nearly linear relationship with N application rates and growth response. Additional N probably would have increased growth response. In addition, N and/or S response on the 1991 sites were variable by region. Some 1991 sites did not respond as well as other with the addition of sulfur to the fertilizer mix. In addition, the 1991 N and S fertilization sites had species compositions that were only partially ponderosa pine which showed low response to the fertilizer treatment.

Table 4. Average ponderosa pine two-year net and gross basal area growth response to multi-nutrient fertilization by treatment for Round Mtn. fertilization test site in northeastern Oregon.

			RESPONSE	
	Treatment	**Increment**	**Difference**	**% of Control**
2-year Net Basal Area (sq. ft./ac.)	Control	12.2		
	Multi-Nutrient	13.4	1.2NS	9.8
2-year Gross Basal Area (sq. ft./ac.)				
	Control	12.3		
	Multi-Nutrient	13.4	1.1NS	8.9

Note: all increments have been adjusted to a common initial basal area of 119 sq. ft/a.
NS = Not significant ($p \leq 0.10$)

CONCLUSIONS

Foliar nutrient response to the multi-nutrient treatment was good for all the nutrients applied in the fertilizer mix. However, multi-nutrient S and B concentration levels were below standard deficiency levels reported for ponderosa pine. This result was due to initially low S and B nutrient levels and large needle expansion (growth) caused by N fertilization. Higher S application rate could have increased S foliar concentration to acceptable levels.

Although it is difficult to draw strong conclusions from one site, results from this study are similar and reasonable when compared to other fertilization study sites in this region.

References

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Appendix A

INSTALLATION ROUND MTN.
Region: N.E. Oregon Ownership: USFS (Walla Walla R.D.) Meridian: Willamette
Legal Description: T2N R37E Sections 21&28 Veg. Series: GF Parent Material: Basalt

AVE. INITIAL CHARATERISTICS: **(Columbia R.)**

Age (years)	35	CCF	104
Trees per Acre	350	Relative Density Index	42.1
Basal Area (sq. ft/a)	119	Average Crown Length (ft.)	26.4
Total Volume (cu. ft./a)	2247	Average Crown Ratio (%)	54.0
Species Composition (% of total BA)		Mean Diameter (in.)	8.0
Ponderosa pine	88	Site Height	48.8
Lodgepole pine	7		
Western Larch	4		
Douglas-fir	<1		
Grand fir	<1		
Engelmann spruce	<1		
Subalpine fir	<1		

PLOT SUMMARY CHARACTERISTICS

	PLOT NUMBER					
	1	2	3	4	5	6
TREATMENT:	Control	Control	Control	Multi	Multi	Multi
Mensurational Characteristics **At Time of Treatment (1996)**:						
Live Trees per Acre	490	350	320	310	270	360
Live Basal Area (sq. ft/a)	112.3	133.9	126.7	118.0	120.2	103.0
Live Total Volume (cu. ft/a)	1891	2592	2435	2224	2334	2003
Crown Competition Factor	100	117	110	105	103	91
Relative Density	44.1	46.3	43.4	40.8	40.0	38.3
Site Height	47.7	51.0	47.8	45.8	51.7	49.1
Mean Diameter	6.5	8.4	8.5	8.4	9.0	7.2
Ave. Crown Ratio	44	57	58	52	51	60
Ave. Crown Length	21	29	28	24	26	29
Species Composition (% of BA)						
Ponderosa pine	80.1	87.5	92.6	84.2	97.8	83.3
Lodgepole pine		12.2	4.0	14.8		14.2
Western larch	19.6		3.0	0.4	2.1	
Douglas-fir	0.2	0.3	0.2			
Grand fir	0.1		0.1	0.6	0.1	2.5
Engelmann spruce			present		present	present
Subalpine fir						present
2 Years After Treatment:						
Live Trees per Acre	470	350	310	310	270	360
Live Basal Area (sq. ft/a)	123.4	146.5	138.5	132.2	130.9	119.4
Crown Competition Factor	109	126	120	116	110	104
Relative Density	48.4	51.4	47.8	45.9	44.5	44.2
Mean Diameter	6.5	8.1	8.4	8.3	8.7	7.3
Dead Trees per Acre	20	0	10	0	0	0
Dead Basal Area (sq. ft/a)	0.03	0	0.35	0	0	0