Two Year Basal Area Response to N and K Fertilization for Mixed Conifer Stands in North Central Washington

SUMMARY. Two years after fertilization, overall gross basal area response was 31.1% on those plots receiving the 200 lb. nitrogen (N) acre and 33.8% on those plots receiving 200 lb. nitrogen plus 200 lb. potassium (K) acre. Results from this study show that response was different by species, with lodgepole pine expressing higher absolute and relative response than ponderosa pine, western larch or mixed conifer for both treatments. Sites that were predominately ponderosa pine expressed low growth but did show good relative (percent) response to the treatments. Western larch and mixed species sites expressed good absolute response. Gross Basal area response was similar to foliar nutrient and needle weight response. The addition of potassium to the fertilizer mix did not significantly affect two year basal area growth or response.

Methods

Study Area

The study area is located in north central Washington within the Okanogan National Forest. The eight study sites were established on the Chelan, Twisp and Winthrop Ranger Districts. Sites were evenly distributed in two main areas located on either the east or west side of the Okanogan River drainage. Appendix A shows the installation locations in north central Washington.

Design and Treatments

The eight study sites (48 plots) were established in the fall of 1993 and consist of six square 0.1 acre plots. The plots were grouped into two blocks of three plots based on tree and site similarities. The treatments include control (C), nitrogen (N) and nitrogen plus potassium (NK). Nitrogen was applied in

the urea form and potassium in the murate of potash form at the rate of 200 lbs/acre for both nutrients by treatment. Installations were located by design in young (mean DBH 3-11 inches) stands with nearly homogeneous species compositions (basal area/ac. composition > 65% for the dominant species). Ponderosa pine, lodgepole pine and western larch are the dominate species composition types. Site characteristics for the eight conifer study sites are given in Table 1.

Table 1. Site characteristics for eight mixed conifer study sites located on the Okanogan National Forest in north central Washington.

Site	Mean DBH	Elevation	Vegetation Series	Rock Type	Lithology
327	8	3360	PSME	Metamorphic/Plutonic	Gneiss
328	6	5200	ABLA	Metamorphic/Plutonic	Mix/Meta-Diorite
329	4	5500	PSME	Plutonic	Biotite/Granodiorite
330	10	2900	PSME	Plutonic	Light Granite
331	6	5200	ABLA	Volcanic	Mix (Volcanic/Sandstone)
332	4	4950	ABLA	Plutonic	Biotite Granodiorite
333	4	4250	ABLA	Metamorphic/Sedimentary	Mix
334	7	4050	PSME	Plutonic	Light Granodiorite

Measurements

Initial measurements were made in the fall of 1993. At time of establishment all live trees taller than 4.5 feet in height were tallied, tagged, heights and diameters measured and defect determination recorded. Vegetation, soils and parent material information is also collected at time of establishment. Every two years diameters are remeasured on all the trees and any incidence of damage or mortality along with probable cause will be noted. Heights will be remeasured every four years after treatment on all trees, but not after two years. Detailed mensurational and plot characteristics at time of establishment and two years after treatment are given in Appendix B.

One year after treatment, dormant (fall) season foliage samples were obtained for foliar nutrient determination (see Garrison and Moore, 1995). Two dominant or codominant trees from the two most dominant species on each plot were selected for collection. Foliage was collected from the third whorl

from the top of each tree by climbing. Detailed information on foliar nutrient levels one year after treatment are given in Appendix C.

Data Analysis

Growth is be defined as gross basal area (sq.ft./ac.) for a two year period. Response is defined as the difference between the treated plots versus the control plots. Percent relative basal area response for species comparisons was calculated using the following formula:

$$\%BAResponse = \left[\frac{BAResponse}{BAGrowth_{Control}} \right] X100$$

The experimental design model used for absolute and relative two year gross basal area growth took this general form:

Growth = F(Installation, Block, Treatment)

Absolute gross two year basal area growth and relative (control treatment growth) percent basal area response by species type took this general form:

Growth (response) = F(Species, Installation, Block, Treatment)

Species basal area response comparisons were based on species composition by installation. Basal area growth and response by species was determined by pooling installations with composition greater than 65% for a given species.

General linear contrasts and differences between means by treatment for basal area growth 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).

Analysis of variance for gross basal area growth and response for all the installations combined

and each installation separately are given in Tables 2 and 3. Analysis of variance for absolute gross basal area growth and response by species is given in Table 4. The contrasts between means are considered average growth responses to the treatments. Tree mortality was low and did not affect the response results, therefore, only gross basal area response will be presented for this report.

Results and Discussion

Nitrogen basal area response differed significantly between the fertilizer treatments and the control treatment. Overall gross basal area response on N alone treated plots was 31.1% higher than control plots. When K was added to the N fertilizer mix overall response was 33.8% higher over that of the control plots. Basal area response was not significantly different between plots receiving N alone and plots receiving the NK treatment (Table 2).

Table 2. Overall absolute two year gross basal area growth and response for conifer sites in north central Washington.

	Growth		Response		
Treatment	sq.ft/ac.	Contrast	sq.ft/ac.	*p*	%
Control	6.1				
200 # N	8.0	200N-Control	1.9	(0.0001)	31.1
200 # N+K	8.1	200N+K-Control	2.0	(0.0001)	33.8
		200N+K-200N	0.1	(0.5858)	1.3

The effects of fertilization on the increase of two year basal area growth was significantly ($p \leq 0.10$) different between treatments for all installations except installations 327 and 330. Two year absolute basal area growth response ranged from 0.4 to 4.0 sq. ft./ac. on the plots receiving N alone and 0.6 to 4.1 sq. ft./ac. on the plots receiving the NK treatment (Table 3). Addition of K to the fertilizer mix did not significantly ($p \leq 0.10$) increase growth response over that of the N alone treatment for any installation. Although potassium has an indirect effect on plant growth, existing literature and previous IFTNC results show that K primarily effects tree mortality rather than tree growth. Therefore, growth effects from K fertilization would not likely be seen within

the first couple of years after treatment. The nitrogen plus potassium treatment on Installation 328 had the highest basal area response on the NK treatment with a 87% increase over that of the control plots. Installation 330 did not show a significant absolute growth response, however, relative basal area response to the N alone treatment was higher (65%) than for any other installation (Table 3). High percent response but low growth increase for installation 330 is an example of good fertilization response on a slow growing site.

Table 3. Two year absolute gross basal area growth and response by treatment and installation in north central Washington.

	Growth		Response		
Installation/ Treatment	sq.ft/ac.	Contrast	sq.ft/ac.	*p*	%
327					
Control	2.8				
200 # N	3.2	200N-Control	0.4	(0.6413)	14.3
200 # N+K	3.4	200N+K-Control	0.6	(0.4737)	21.4
		200N+K-200N	0.2	(0.7991)	6.3
328					
Control	4.7				
200 # N	7.5	200N-Control	2.8	(0.0055)	59.6
200 # N+K	8.8	200N+K-Control	4.1	(0.0002)	87.2
		200N+K-200N	1.3	(0.1420)	17.3
329					
Control	11.5				
200 # N	13.2	200N-Control	1.7	(0.0850)	14.8
200 # N+K	13.3	200N+K-Control	1.8	(0.0630)	15.7
		200N+K-200N	0.1	(0.8734)	0.8
330					
Control	2.0				
200 # N	3.3	200N-Control	1.3	(0.1805)	65.0
200 # N+K	3.4	200N+K-Control	1.4	(0.1327)	70.0
		200N+K-200N	0.1	(0.8562)	3.0
331					
Control	3.6				
200 # N	4.6	200N-Control	1.0	(0.2378)	27.8
200 # N+K	5.2	200N+K-Control	1.6	(0.0863)	44.4
		200N+K-200N	0.6	(0.5560)	13.0
332					
Control	7.4				

200 # N	11.4	200N-Control	4.0	(0.0003)	54.1
200 # N+K	11.2	200N+K-Control	3.8	(0.0005)	51.4
		200N+K-200N	-0.2	(0.8129)	-1.8
333					
Control	12.5				
200 # N	14.7	200N-Control	2.2	(0.0226)	17.6
200 # N+K	13.5	200N+K-Control	1.0	(0.2556)	8.0
		200N+K-200N	-1.2	(0.1980)	-8.7
334					
Control	4.7				
200 # N	5.9	200N-Control	1.2	(0.1884)	25.5
200 # N+K	6.3	200N+K-Control	1.6	(0.0941)	34.0
		200N+K-200N	0.4	(0.6902)	6.8

Table 4. Absolute two year gross basal area growth and response by species stand types for conifer sites in central Washington.

	Growth	Response			
Species & Treatment	sq.ft/ac.	Contrast	sq.ft/ac.	*p*	%
PP					
Control	2.4				
200 # N	3.2	200N-Control	0.8	(0.2168)	33.3
200 # N+K	3.4	200N+K-Control	1.0	(0.1300)	41.7
		200N+K-200N	0.2	(0.7670)	6.3
LP					
Control	5.2				
200 # N	7.8	200N-Control	2.6	(0.0001)	50.0
200 # N+K	8.4	200N+K-Control	3.2	(0.0001)	62.0
		200N+K-200N	0.6	(0.3032)	7.7
WL					
Control	8.6				
200 # N	10.3	200N-Control	1.7	(0.0145)	20.0
200 # N+K	9.9	200N+K-Control	1.3	(0.0568)	15.0
		200N+K-200N	-0.4	(0.5321)	-3.9
MIX					

Control	11.5				
200 # N	13.1	200N-Control	1.6	(0.0918)	13.9
200 # N+K	13.3	200N+K-Control	1.8	(0.0680)	15.6
		200N+K-200N	0.2	(0.8782)	1.5

Species specific absolute basal area growth and response comparisons were made between ponderosa pine, lodgepole pine, western larch and mixed conifer types (Table 4). Two year absolute gross basal area growth for all treatments was highest for the mixed conifer installation (#333) and sites with species composition predominately western larch (basal area > 65%) (Table 4). Two year gross basal area response for each species type follow this order: LP > MIX > WL > PP. Large growth rates occur on the mixed conifer installation (#329) which is a young stand comprised of small trees (Table 1). The large basal area growth differences between installations may explain response differences and therefore species comparisons. Further analysis will be required after the fourth growing season when height growth will be measured.

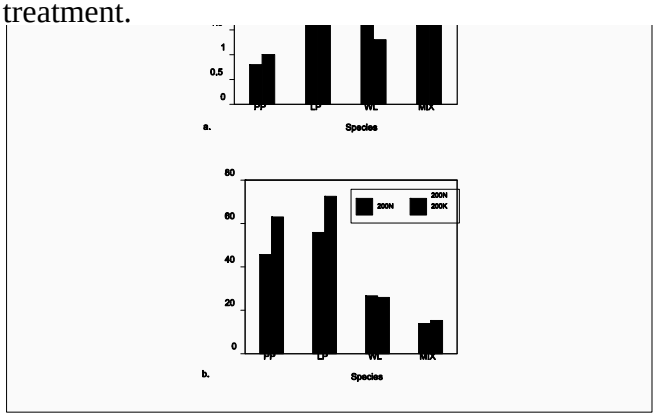
All four species types show a positive response to the fertilization treatments. Response results are illustrated graphically on an individual installation basis in Figure 1 and on a species composition basis in Figure 2. Figure 1a shows that both ponderosa pine installations (327 and 330) produced a low absolute growth response (wood production) but #330 had a percent response (70%) relative to the controls. Lodgepole pine (Figure 1b) nitrogen fertilization response over the controls was very high on installations 328 and 332 and high on installation 331. Western larch (Figure 1c) and mixed conifer installations (Figure 1d) produced low growth response but installation #334 showed high percent response.

Analysis by combined species type (Table 4 and Figure 2a) shows that absolute basal area response to nitrogen fertilization was highest for those sites with species composition dominated by lodgepole pine. Lodgepole pine fertilization response was significantly higher on fertilized plots (N alone ($p \leq 0.0001$) 2.6 sq. ft/ac. (50%) and NK 3.2 sq. ft/ac. (62%) (Table 4). Nitrogen alone and NK treatment plots were significantly ($p \leq 0.10$) higher than the control for both the western larch and mixed species composition types. Ponderosa pine had the lowest growth response for both fertilizer treatments

but did show good percent response by treatment. Relative response by species type is shown in Figure 2b. Response relative to control plot relative growth for both fertilizer treatments by species type followed this order: LP > PP > WL > MIX. Relative percent response is consistant with absolute percent response to the fertilizer treatments (Table 4 and Figure 2a).

Figure 1. Two year absolute gross basal area growth and percent response by installation and by species

composition for conifer sites in north central Washington. Ponderosa pine installations 327 and 330 (a), lodgepole pine installations 328, 331 and 332 (b), western larch installations 333 and 334 (c), and mixed conifer species installation 329 (d). Note: percentages on bars are percent response relative to the control treatment.



Basal Area
(%of Control Plots)

Figure 2. Absolute (a) and % relative (control treatment growth) (b) two year gross basal area growth and response by speicies types for conifer sites in north central Washington.

Lodgepole pine and ponderosa pine two year basal area results for these installations are consistent with foliar nutrient and needle weight responses reported by Garrison and Moore (1995). Results from the current report on basal area response and from Garrison and Moore (1995) on foliar nutrition and needle weights show that lodgepole pine had the highest basal area response, the most efficient nutrient uptake and the only significant increase in needle weight after treatment, when compared to the other species in the study. Ponderosa pine followed lodgepole pine in foliar and needle weight response. In addition, in a similar IFTNC mixed conifer study located on the Umatilla National Forest, lodgepole pine expressed high two year relative basal area response with ponderosa pine showing low or negative response.

Literature Cited

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