Two Year Basal Area Response to N and S Fertilization for Mixed Conifer in Northeast Oregon and Southeast Washington (Umatilla)

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SUMMARY. Two years after fertilizer treatments were applied, the overall adjusted relative gross basal area response increased 3.1% on those plots receiving 200 lb. nitrogen (N) acre and 17.0% on those plots receiving 200 lb. N acre plus 100 lb. sulphur (S) acre. Nitrogen versus S growth response differs by geographic location with the Pomeroy, Tollgate and Ukiah sites having good N response but little or no S response, while growth response on the Heppner sites were low for N but increased significantly when S was added to the fertilizer treatment. Results from this study also show growth response is different by species, with grand fir expressing higher relative response than western larch or ponderosa pine for both N and N plus S (NS) treatments. Engelmann spruce and lodgepole expressed good relative response while ponderosa pine generally had low or negative response. Response results for Douglas-fir were inconsistent by site and therefore species specific trends could not be concluded.

Methods

Study Area

The study is located in the Blue Mountains of northeast Oregon and southeast Washington. By design, the eight study sites were established on four ranger districts within the Umatilla National Forest. The four ranger districts are Heppner, Pendleton, Pomeroy and Ukiah. Appendix A shows the installation locations in northeast Oregon and southeast Washington.

Design and Treatments

The eight study sites (48 plots) were established in October, 1991 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 three treatments include control (C), nitrogen (N), and nitrogen plus sulphur (NS). Nitrogen was applied in the urea form and sulphur in the ammonium sulfate form at a rate of 200 lb/acre (225 kg/ha.) and 100 lb/acre (113 kg/ha.), respectively for each nutrient by

treatment. The installations were located in mixed species stands. Five stands were regenerated naturally and three were planted. Five of the stands were thinned 6-10 years previously; the remaining stands were unthinned, but were spaced at the time of plantation establishment. 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 Umatilla National Forest in northeast Oregon and southeast Washington.

Site	Elevation	Age	Veg. Series	Parent Material
Pomeroy #1 (313)	5500	26	ABLA	Basalt
Pomeroy #2 (314)	5000	23	ABGR	Basalt
Tollgate #1 (315)	4500	26	ABGR	Basalt
Tollgate #2 (316)	5500	24	ABGR	Basalt
Heppner #1 (317)	4780	10	ABGR	Basalt
Heppner #2 (318)	4800	10	ABGR	Basalt
Heppner #3 (319)	4800	10	ABGR	Basalt
Ukiah (320)	4800	11	ABGR	Basalt

Measurements

Initial measurements were made in the fall of 1991. All live trees larger than 4.5 feet (1.35 m.) in height were tagged and measured for heights, diameters and defect at time of treatment. Every two years diameters will be remeasured on all of the trees and any incidence of damage or mortality along with the probable cause will be noted. Heights will be remeasured every four years after treatment on all trees. Tree volumes were estimated using regional species-specific volume equations (Wykoff et al. 1982). Detailed information on stand characteristics at time of establishment and two years after treatment are given in Appendix B.

One year after treatment, dormant season foliage samples were obtained from the two most dominant species represented within each installation. Two dominant or codominant trees from each 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

Relative gross basal area growth was calculated using this formula:

$$\%Growth = \left[\frac{Growth}{BasalArea_0}\right] X100$$

The experimental design model used for the two-year net and gross volume growth and response took the general form of a covariant model:

$$Growth = F(Installation, Block, Treatment, BA_0)$$

where: Growth - gross basal area (ft^2)

BA - initial basal area as a covariate

General linear contrasts and differences between means by treatment for the 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).

The analysis of variance for relative basal area growth and response for all installations combined, each installation separately and for dominant species within each installation are given in Tables 2, 3 and 4. The contrasts between means are considered average growth responses to the treatments. The combined installation growth responses are smoothed estimates which are adjusted for a common basal area of 60 ft^2/acre. Individual installation growth responses are adjusted by initial basal area for each installation. Since tree mortality was extremely low and did not affect the response results, only gross basal response will be presented for this report. Sulphur response for this study is defined as the difference between the 200 N + 100 S treated plots and the 200 N treated plots.

Results and Discussion

The overall adjusted relative gross basal area response (expressing the growth as a percentage of the initial volume) to the N alone treatment was 3.1% higher than the control plots (Table 2). When S was added to the N fertilizer mix the response over the controls increased significantly ($p \leq 0.10$) to 17.0%. We can see in Figure 1 that the two-year relative basal area response for S is more than five times higher than the N alone response. Although the differences between treatments were not significant, the results show a 13.4% change in the relative growth rate between the N alone and NS contrast (Table 2).

The very large relative growth rates occur on the very young stands that are composed of small trees (Table 1 and 3). This tree size effect will be reduced when height growth response is measured and analyzed after the fourth growing season.

Table 2. Two-year relative gross basal area growth and response for mixed conifer sites in northeastern Oregon and southeastern Washington.

	Growth		Response		
Treatment	% of Initial Density	Contrast	Increase in Relative Growth Rate	*p*	% Change in Relative Growth Rate
Control	80.1				
200 # N	82.6	200N-Control	2.5	(0.73)	3.1
200 # N+100 # S	93.7	200N+100S-Control	13.6	(0.07)	17.0
		200N+100S-200N	11.1	(0.14)	13.4

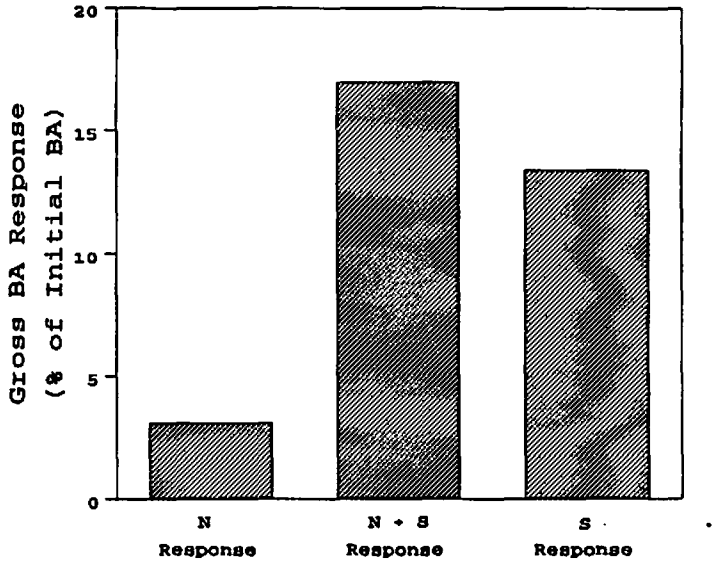


Figure 1. Two-year relative response in gross basal area growth to fertilization for all the mixed conifer sites combined in northeastern Oregon and southeastern Washington.

Although the overall anlaysis did show relative basal area growth response, the effect of fertilization was significantly different between treatments for installations 314, 317 and 320 (Table 3 and Figure 2). Installation 320 expressed the highest N alone relative basal area growth response with a 51.3% increase and installation 313 the highest NS response at 51.0%. In general, relative basal area response was better on the plots receiving the NS treatment than those plots receiving N alone. Adjusted relative basal area growth increases ranged from -12.3 to 24.2 on the N alone treatments and 2.9 to 56.3 on the NS treatments. Interestingly there were no installations that expressed negative response on the NS treatments.

Table 3. Two-year relative gross basal area growth and response by treatment and installation for mixed conifer sites in northeastern Oregon and southeastern Washington.

Site & Treatment	Growth: % of Initial Density	Contrast	Response: Increase in Relative Growth Rate	*p*	% Change in Relative Growth Rate
313					
Control	19.2	200N-Control	8.0	(0.52)	41.6
200# N	27.2	200N+100S-Control	9.8	(0.41)	51.0
200# N+100 # S	29.0	200N+100S-200N	1.8	(0.82)	6.6
314					
Control	23.4	200N-Control	6.2	(0.06)	26.5
200# N	29.6	200N+100S-Control	11.3	(0.10)	48.3
200# N+100 # S	34.7	200N+100S-200N	5.1	(0.25)	17.2
315					
Control	17.2	200N-Control	3.3	(0.67)	19.2
200# N	20.5	200N+100S-Control	3.3	(0.36)	19.2
200# N+100 # S	20.5	200N+100S-200N	0.0	(0.99)	0.0
316					
Control	20.1	200N-Control	5.6	(0.18)	27.9
200# N	25.7	200N+100S-Control	2.9	(0.25)	14.4
200# N+100 # S	23.0	200N+100S-200N	-2.7	(0.40)	-10.5
317					
Control	172.3	200N-Control	-8.7	(0.10)	-5.0
200# N	163.6	200N+100S-Control	56.3	(0.03)	32.7
200# N+100 # S	228.6	200N+100S-200N	65.0	(0.02)	39.7
318					
Control	163.5	200N-Control	-12.3	(0.74)	-7.5
200# N	151.2	200N+100S-Control	33.4	(0.82)	20.4
200# N+100 # S	196.9	200N+100S-200N	45.7	(0.71)	30.2
319					
Control	155.4	200N-Control	6.7	(0.84)	4.3
200# N	162.1	200N+100S-Control	42.4	(0.44)	27.3
200# N+100 # S	197.8	200N+100S-200N	35.7	(0.41)	22.0
320					
Control	47.2	200N-Control	24.2	(0.03)	51.3
200# N	71.4	200N+100S-Control	3.5	(0.11)	7.4
200# N+100 # S	50.7	200N+100S-200N	-20.7	(0.03)	-29.0

Results from this mixed conifer study show that growth response to fertilization differ by geographic area (Figure 3 and Table 4). We can see in Figure 3 that N response was good for the sites in Pomeroy (313 and 314) and Tollgate (315 and 316) and excellent on the Ukiah (320) site.

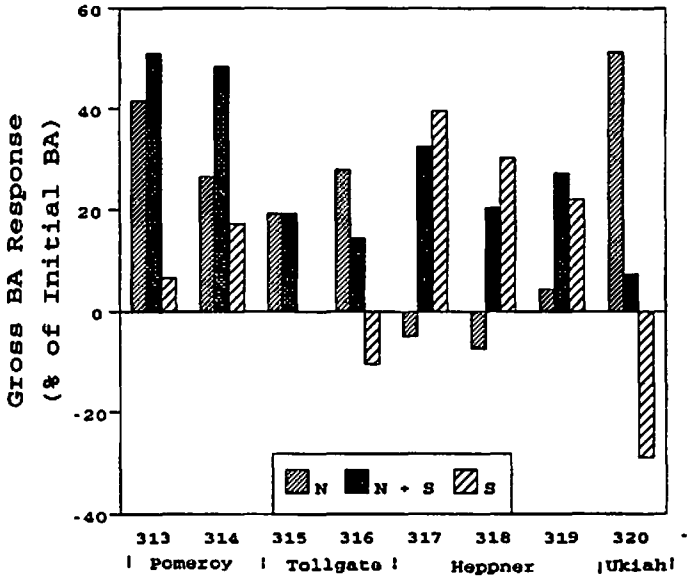


Figure 2. Two-year relative gross basal area growth response by installation for mixed conifer sites in northeastern Oregon and southeastern Washington.

However, S response did differ substantially between these sites with fair response at Pomeroy and negative S response at Tollgate and Ukiah. In contrast, the Heppner sites (317-319) expressed low to negative N response but good to excellent S response (Figure 3). Generally, the results show that if N response was good then S response was poor, but if N response was poor the addition of S to the fertilizer treatment would increased growth response substantially (Figure 3). The sites at Pomeroy, Tollgate and Ukiah significantly ($p \leq 0.05$) increased N response by 31.4%, 33.0% and 51.3% over that of the controls (Table 4). Furthermore, plots on the Heppner sites that were receiving the NS treatment significantly increased growth response by 20.6% over that of the controls and 26.7% over the N alone treatment (Table 4).

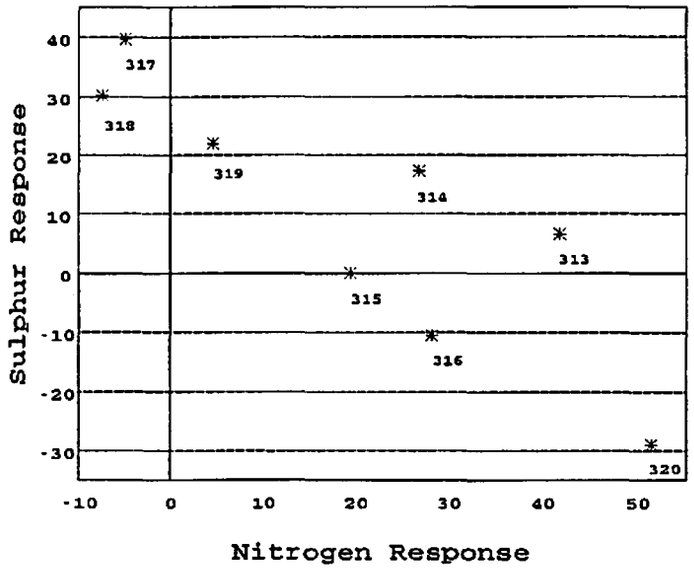


Figure 3. Nitrogen response versus sulphur response for all the installations for mixed conifer sites in northeast Oregon and southeast Washington.

Table 4. Two-year relative gross basal area growth and response by treatment and geographic area for mixed conifer sites in northeastern Oregon and southeastern Washington.

Site & Treatment	Growth: % of Initial Density	Contrast	Response: Increase in Relative Growth Rate	*p*	Response: % Change in Relative Growth Rate
Pomeroy (313 & 314)					
Control	22.3	200N-Control	7.0	(0.03)	31.4
200# N	29.3	200N+100S-Control	7.7	(0.02)	34.5
200# N+100 # S	30.0	200N+100S-200N	0.7	(0.76)	2.4
Tollgate (315 & 316)					
Control	17.9	200N-Control	5.9	(0.02)	33.0
200# N	23.8	200N+100S-Control	3.9	(0.01)	21.8
200# N+100 # S	21.8	200N+100S-200N	2.0	(0.31)	-8.0
Heppner *(317-319)*					
Control	168.0	200N-Control	-8.1	(0.33)	-4.8
200# N	159.9	200N+100S-Control	34.6	(0.01)	20.6
200# N+100 # S	202.6	200N+100S-200N	42.7	(0.01)	26.7
Ukiah (320)					
Control	47.2	200N-Control	24.2	(0.03)	51.3
200# N	71.4	200N+100S-Control	3.5	(0.11)	7.4
200# N+100 # S	50.7	200N+100S-200N	-20.7	(0.03)	-29.0

For this study, relative growth response results are discussed for the two most common species present in each installation (determined by percent species basal area). Gross basal area response by installation and species are presented in Table 5.

Table 5. Gross basal area growth and response by treatment and installation plus % species composition for the two most dominant conifer species in each installation on mixed conifer sites in northeastern Oregon and southeastern Washington.

	Growth			Response					
Site & Treatment	% of Initial Density		Contrast	Increase in Relative Growth Rate		% Change in Relative Growth Rate		% Species Composition	
313	WL	ES		WL	ES	WL	ES	WL	ES
Control	14.1	28.6	200N-Control	-3.4	11.6	-24.1	40.6	29	22
200#N	10.7	40.2	200N+100S-Control	3.4	12.4	24.1	43.4		
200#N+100#S	17.5	41.0	200N+100S-200N	6.8	0.8	63.6	2.0		
314	WL	GF		WL	GF	WL	GF	WL	GF
Control	19.8	25.0	200N-Control	6.2**	2.6	31.3	10.4	33	32
200#N	26.0	27.6	200N+100S-Control	10.3	15.8	52.0	63.2		
200#N+100#S	30.1	40.8	200N+100S-200N	4.1	13.2	15.8	47.8		
315	GF	PP		GF	PP	GF	PP	GF	PP
Control	17.6	20.7	200N-Control	12.0	-7.9	68.2	-38.2	17	59
200#N	29.6	12.8	200N+100S-Control	8.0	-1.7	45.5	-8.2		
200#N+100#S	25.6	19.0	200N+100S-200N	-4.0	6.2	-13.5	48.4		
316	WL	GF		WL	GF	WL	GF	WL	GF
Control	22.7	19.3	200N-Control	3.4	17.1	15.0	88.6	20	21
200#N	26.1	36.4	200N+100S-Control	-1.7	16.3	-7.5	84.5		
200#N+100#S	21.0	35.6	200N+100S-200N	-5.1	-0.8	-19.5	-2.2		
317	DF	LP		DF	LP	DF	LP	DF	LP
Control	166.9	240.5	200N-Control	-4.1	-3.8	-2.5	-1.6	75	18
200#N	162.8	236.7	200N+100S-Control	-18.8	67.3	-11.3	28.0		
200#N+100#S	148.1	307.8	200N+100S-200N	-14.7	71.1	-9.0	30.0		
318	WL	PP		WL	PP	WL	PP	WL	PP
Control	156.9	169.0	200N-Control	-12.2	-19.3	-7.8	-11.4	12	82
200#N	144.7	149.7	200N+100S-Control	235.3	-12.1	150.0	-7.2		
200#N+100#S	392.2	156.9	200N+100S-200N	247.5	7.2	171.0	4.8		
319	PP	DF		PP	DF	PP	DF	PP	DF
Control	211.8	145.4	200N-Control	-51.7	26.9	-24.4	18.5	37	60
200#N	160.1	172.3	200N+100S-Control	-46.9	63.9	-22.1	43.9		
200#N+100#S	164.9	209.3	200N+100S-200N	4.8	37.0	3.0	21.5		
320	WL	PP		WL	PP	WL	PP	WL	PP
Control	47.5	19.0	200N-Control	10.2	123.7*	21.5	651.0	45	41
200#N	57.7	142.7	200N+100S-Control	-1.5	24.5*	-3.2	128.9		
200#N+100#S	46.0	43.5	200N+100S-200N	-11.7	-99.2*	-20.3	-69.9		

* denotes significant contrast ($p \leq 0.05$)
** denotes significant contrast ($p \leq 0.10$)

Results for western larch response were inconsistent between the two Pomeroy installations with installation 313 expressing a significant ($p \leq 0.10$) negative relative basal area response to the N treatment, but installation 314 showed positive N response. Grand fir and Engelmann spruce responded well to the fertilizer treatments but showed different patterns by installation with grand fir expressing higher response to S (low N response) on installation 314 while Engelmann spruce expressed low S response (high N response) on installation 313. Both grand fir and Engelmann spruce showed higher NS treatment response than western larch (Figure 4).

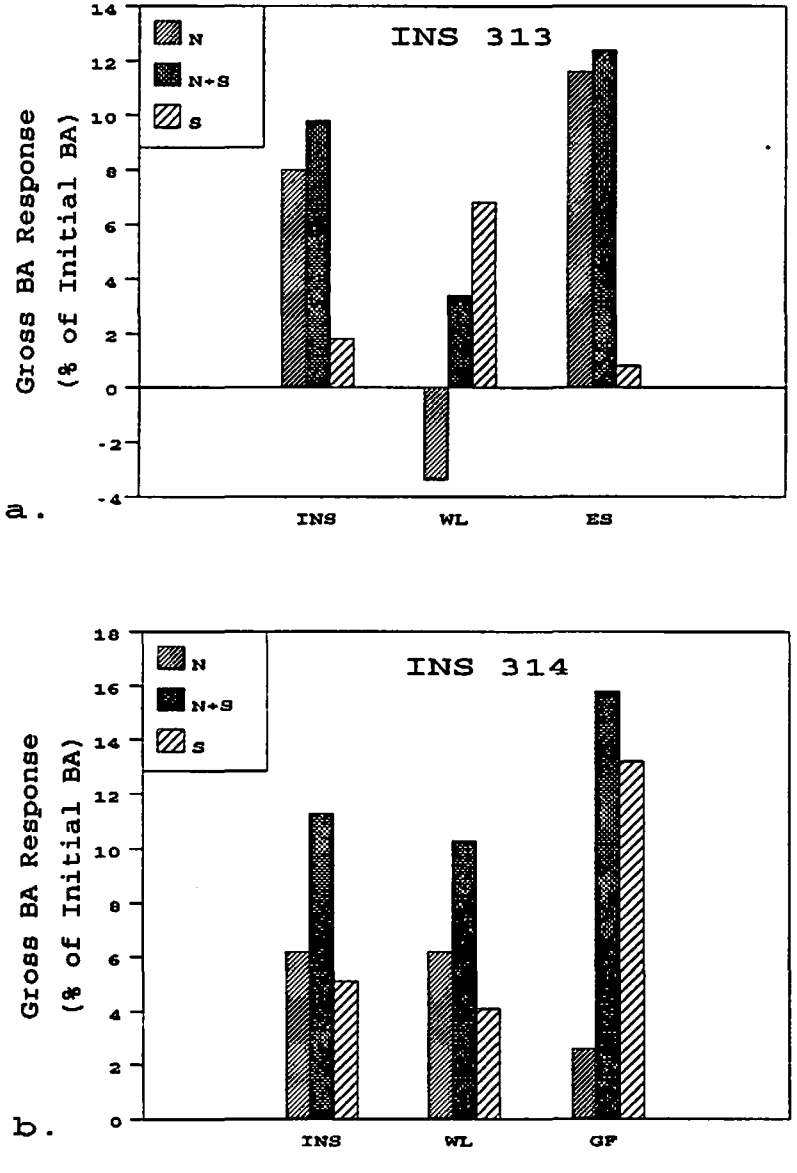


Figure 4. Two-year relative gross basal area response on the Pomeroy sites (313 and 314) for each installation and for the two most common conifer species present within each site.

The fertilized plots on the Tollgate sites (315 and 316) grew at a higher rate than controls, however, response was lower than on the Pomeroy sites. Grand fir response was consistent between the two sites, with excellent N alone response (combined average 14.6%) and poor S response (combined average -2.4%) (Figure 5). This is in contrast with grand fir response in Pomeroy where grand fir response was better for S than N. Installation 316 western larch N response was low at 3.4% and negative at -5.1% when S was added to the fertilizer mix. Ponderosa pine response on installation 315 was poor with negative responses resulting from both treatments. The results show that grand fir was the highest responder on the Tollgate sites (Figure 5).

Two-year relative gross basal area growth for the Heppner sites (317, 318 and 319) was greatly improved by the fertilizer amendments (Table 4 and Figure 6). Most of the response was due to the addition of S to the fertilizer mix. All three sites had similar increased NS response, increased S response and low to negative N response (Figures 6a, 6b and 6c). Western larch and lodgepole pine had similar response trends with high NS and S response but low to negative N response. In contrast, ponderosa pine expressed negative NS and S response and low but positive N response. Notably this was the same response trend that ponderosa pine expressed on the Tollgate sites (315 and 316). Douglas-fir response was inconsistent between sites with installation 317 (Figure 6a) expressing negative response for N, NS and S while installation 319 (Figure 6b) showed positive response for all three treatment contrasts.

Response results from the Ukiah (320) installation were significant ($p \leq 0.05$) between treatments (Table 4). Overall N response was significant ($p \leq 0.05$) but NS or S response either was low or responded negatively (Figure 7). Growth N response was similar for western larch and ponderosa pine which were positive at 10.2% and 123.7% ($p \leq 0.05$) greater than the controls, respectively.

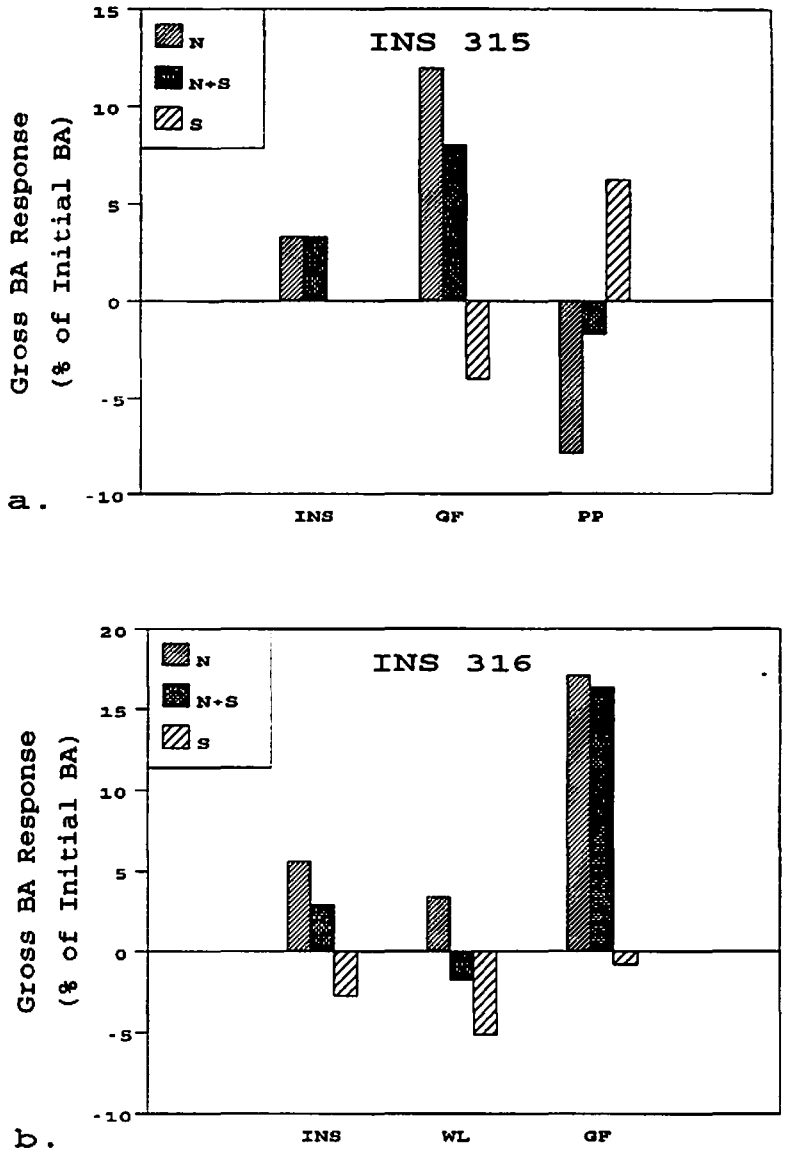


Figure 5. Two-year relative gross basal area response for the Tollgate sites (315 and 316) by installation and for the two most common conifer species present within each site.

In addition, NS or S response for the two species was either small or negative. In contrast with the other installations, ponderosa pine on the Ukiah installation expressed good response for N, poor for NS and negative for S (Figure 7).

Nitrogen versus S response differences by species were the same as were observed by geographic area. Figures 8a and 8b show grand fir and ponderosa pine N versus S response. The results show that grand fir had poor N response and good sulphur response on installation 314

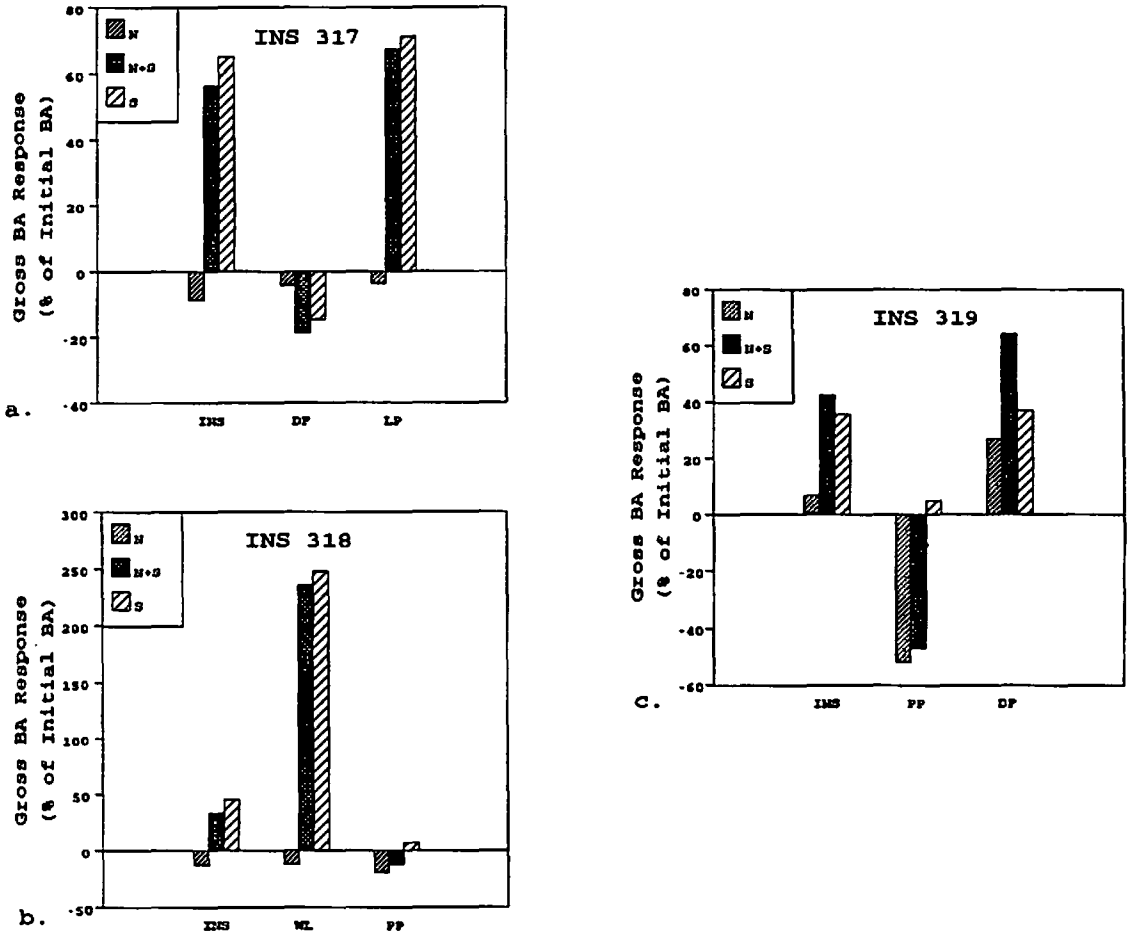


Figure 6. Two-year relative gross basal area response for the Heppner sites (317, 318 and 319) by installation and for the two most common conifer species present within each site.

(Pomeroy) but good N response and poor sulphur response on installation 315 and 316 (Tollgate). It seems that grand fir responds better on the Pomeroy sites when S is added to the fertilizer mix, however additional S does not seem to improve grand fir growth response on the Tollgate sites as much as N did. Ponderosa pine expressed low S response and negative N response on the Tollgate and Heppner sites but extremely high N response along with extremely negative S response on the Ukiah site. Both species seem to follow growth response trends unique to their geographic location suggesting that the species respond similarly to N or S nutrient limitations.

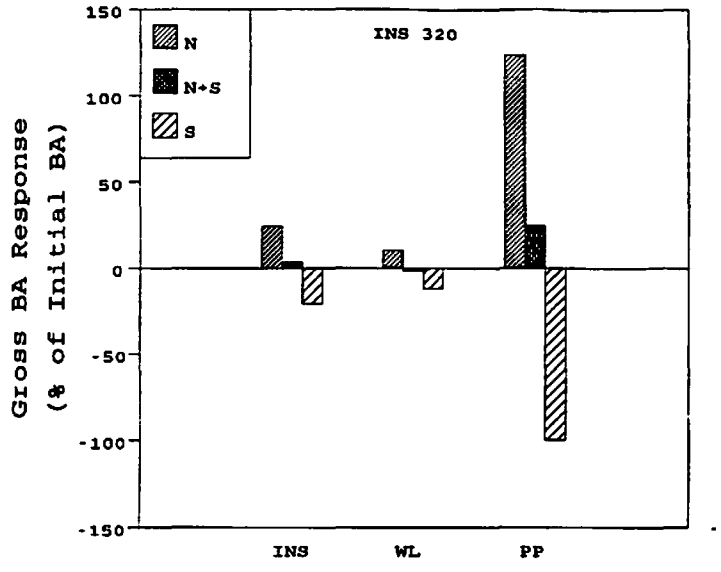
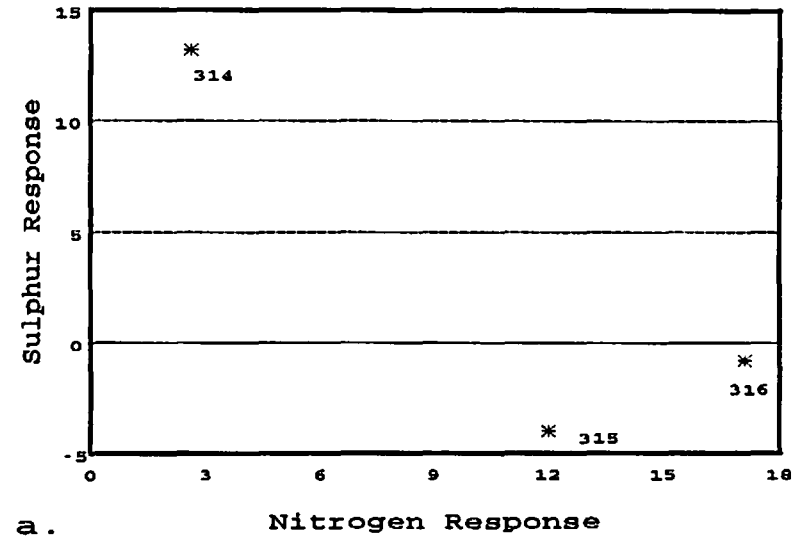


Figure 7. Two-year relative gross basal area response on the Ukiah site 320 for the installation and the two most common conifer species present on the site.

Although site characteristics such as parent material and vegetation types were generally the same between the sites there are striking growth response differences to N and S fertilization by geographic location. No explanation for these differences was apparent in our detailed information collected on foliar and soil chemical levels. Perhaps an explanation can be found in further analysis of different forms of soil sulphur for each site.



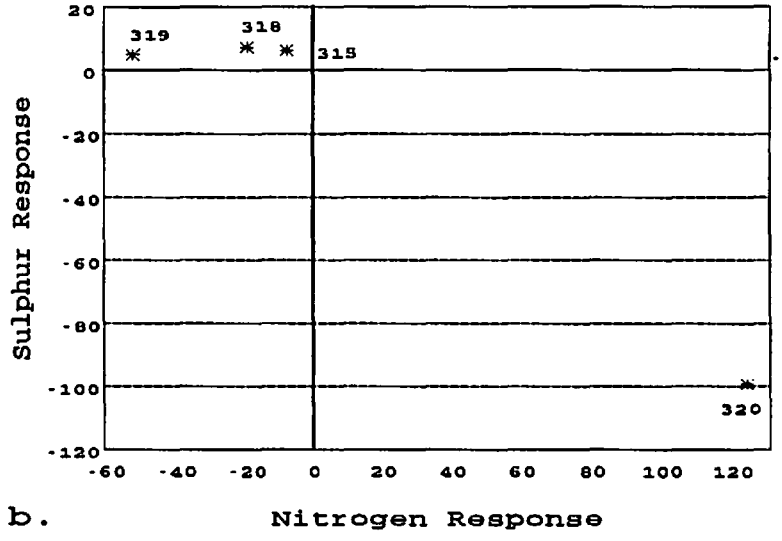
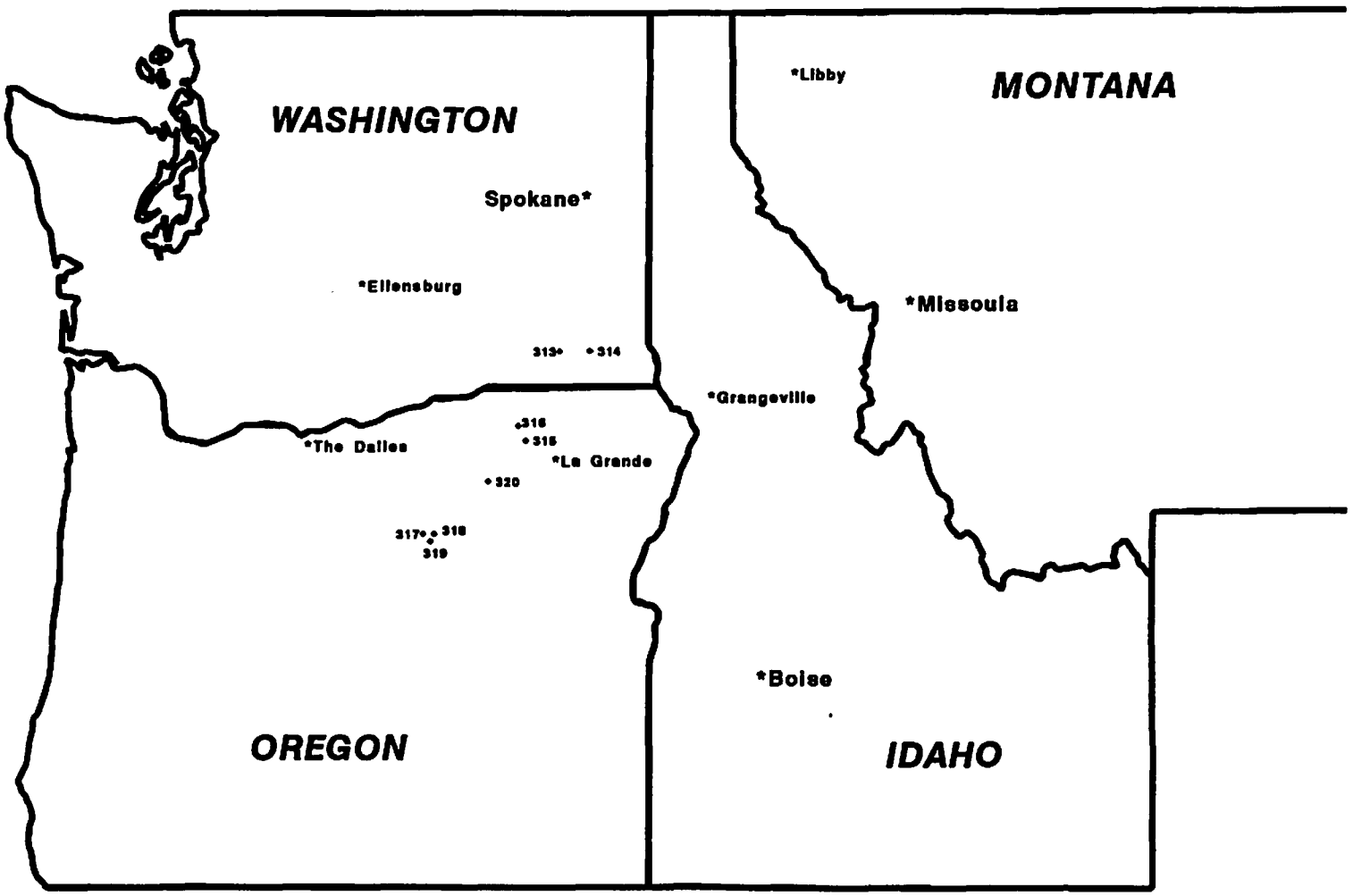


Figure 8. Scatter plots of nitrogen growth response versus sulphur growth response for grand fir (a) and ponderosa pine (b).

Even though there are no obvious reasons for the geographic trend across sites, we can conclude that N and S fertilization was significantly successful in increasing growth on the Umatilla National Forest. Future operational fertilization programs on the Umatilla National Forest should reflect the geographic response differences.

APPENDIX A.

INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE



Mixed Species Umatilla Study Site

APPENDIX B.

PLOT SUMMARY REPORT

INSTALLATION 313 U. PATAHA

REGION: S.E. WASHINGTON OWNERSHIP: UMATILLA NF

LEGAL DESCRIPTION: T09N R42E SECTION 32 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	200#N	0#N	N+S	0#N	200#N	N+S
SITE CHARACTERISTICS:						
SLOPE (%)	27	17	21	21	11	26
ASPECT (DEGREES)	18	59	19	357	50	69
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE = 26					
LIVE TREES PER ACRE	480	410	450	470	390	430
LIVE BASAL AREA (SQ.FT/A)	52.8	69.6	49.3	63.9	56.8	66.8
LIVE TOTAL VOLUME (CU.FT/A)	608	836	610	816	735	850
CROWN COMPETITION FACTOR	61	72	58	73	62	79
RELATIVE DENSITY INDEX	24.9	29.5	23.3	28.6	25.0	28.9
MEAN DIAMETER (IN)	4.5	5.6	4.5	5.0	5.2	5.3
SITE HEIGHT (FEET)	34.1	35.5	35.4	39.6	35.0	39.2
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	3.1	7.6	0.0	3.5	4.9	6.6
GRAND FIR	12.8	5.5	24.3	2.1	9.2	17.8
SUBALPINE FIR	10.3	6.7	10.3	39.4	1.0	11.3
WESTERN LARCH	24.4	30.8	41.9	25.0	35.9	17.0
LODGEPOLE PINE	15.9	13.6	6.2	7.9	27.4	20.3
PONDEROSA PINE	6.5	0.0	0.9	0.0	15.5	4.3
ENGELMANN SPRUCE	26.9	35.9	16.4	22.1	6.0	22.7
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	480	410	450	460	390	430
LIVE BASAL AREA (SQ.FT/A)	70.5	83.6	64.3	72.6	68.8	85.2
CROWN COMPETITION FACTOR	80	85	74	81	74	99
RELATIVE DENSITY INDEX	30.0	33.6	27.4	30.4	28.3	33.4
MEAN DIAMETER (IN)	5.5	6.2	5.5	5.7	5.9	6.5
DEAD TREES PER ACRE	0	0	0	10	0	0
DEAD BASAL AREA (SQ.FT/A)	0.0	0.0	0.0	3.0	0.0	0.0

PLOT SUMMARY REPORT

INSTALLATION 314 UNFRIED
REGION: S.E. WASHINGTON OWNERSHIP: UMATILLA NF
LEGAL DESCRIPTION: T09N R42E SECTION 27 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	0#N	200#N	N+S	N+S	200#N	0#N
SITE CHARACTERISTICS:						
SLOPE (%)	41	35	30	38	36	41
ASPECT (DEGREES)	41	35	37	37	22	38
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE = 23					
LIVE TREES PER ACRE	450	390	400	380	400	440
LIVE BASAL AREA (SQ.FT/A)	43.0	45.2	50.4	45.7	42.2	45.7
LIVE TOTAL VOLUME (CU.FT/A)	486	557	644	630	498	631
CROWN COMPETITION FACTOR	62	59	65	63	50	56
RELATIVE DENSITY INDEX	21.0	21.1	23.0	21.1	20.1	21.9
MEAN DIAMETER (IN)	4.2	4.6	4.8	4.7	4.4	4.4
SITE HEIGHT (FEET)	31.9	38.3	38.8	43.1	34.2	41.4
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	28.2	18.2	3.5	7.5	2.4	7.5
GRAND FIR	32.7	24.0	36.8	45.8	26.6	23.9
WESTERN LARCH	16.3	32.9	41.6	27.9	36.5	42.3
LODGEPOLE PINE	5.5	15.5	8.6	17.0	0.0	8.1
PONDEROSA PINE	10.5	6.5	7.3	0.0	0.6	0.0
ENGELMANN SPRUCE	6.8	2.9	2.3	1.8	33.9	18.3
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	450	390	400	380	400	440
LIVE BASAL AREA (SQ.FT/A)	54.1	59.5	64.9	60.7	55.9	56.7
CROWN COMPETITION FACTOR	76	75	83	81	64	69
RELATIVE DENSITY INDEX	22.9	24.4	26.1	24.2	24.0	24.5
MEAN DIAMETER (IN)	5.6	5.9	6.2	6.3	5.4	5.4
DEAD TREES PER ACRE	0	0	0	0	0	0
DEAD BASAL AREA (SQ.FT/A)	0.0	0.0	0.0	0.0	0.0	0.0

PLOT SUMMARY REPORT

INSTALLATION 315 TOLLGATE #1

REGION: N.E. OREGON OWNERSHIP: UMATILLA NF

LEGAL DESCRIPTION: T04N R39E SECTION 34 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	N+S	200#N	N+S	200#N	0#N	0#N
SITE CHARACTERISTICS:						
SLOPE (%)	7	9	8	10	12	32
ASPECT (DEGREES)	125	96	92	102	62	22
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE = 26					
LIVE TREES PER ACRE	250	240	250	220	200	280
LIVE BASAL AREA (SQ.FT/A)	93.3	100.8	83.4	103.2	83.1	83.2
LIVE TOTAL VOLUME (CU.FT/A)	1321	1378	1107	1392	1145	1089
CROWN COMPETITION FACTOR	95	91	89	101	86	95
RELATIVE DENSITY INDEX	32.4	34.0	29.8	33.9	28.1	30.6
MEAN DIAMETER (IN)	8.3	8.8	7.8	9.3	8.7	7.4
SITE HEIGHT (FEET)	38.1	38.0	37.6	34.2	36.6	36.2
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	20.4	2.1	0.0	1.9	9.1	5.2
GRAND FIR	8.4	4.8	24.0	15.5	19.9	27.1
SUBALPINE FIR	0.0	0.0	1.6	0.0	0.0	0.0
WESTERN LARCH	16.5	7.8	11.7	4.3	8.4	23.4
LODGEPOLE PINE	0.0	0.0	3.9	6.5	0.0	0.0
PONDEROSA PINE	54.7	79.0	50.1	71.2	59.8	41.6
ENGELMANN SPRUCE	0.0	6.4	8.7	0.6	2.9	2.8
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	250	240	250	220	200	280
LIVE BASAL AREA (SQ.FT/A)	112.3	122.0	101.0	122.6	97.5	98.2
CROWN COMPETITION FACTOR	114	108	107	118	100	110
RELATIVE DENSITY INDEX	37.1	40.5	33.9	38.9	31.5	33.7
MEAN DIAMETER (IN)	9.2	9.1	8.9	9.9	9.6	8.5
DEAD TREES PER ACRE	0	0	0	0	0	0
DEAD BASAL AREA (SQ.FT/A)	0.0	0.0	0.0	0.0	0.0	0.0

PLOT SUMMARY REPORT

INSTALLATION 316 TOLLGATE #2

REGION: N.E. OREGON OWNERSHIP: UMATILLA NF

LEGAL DESCRIPTION: T04N R39E SECTION 18 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	0#N	N+S	0#N	200#N	N+S	200#N
SITE CHARACTERISTICS:						
SLOPE (%)	14	10	5	0	10	5
ASPECT (DEGREES)	200	126	144	134	112	182
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE = 24					
LIVE TREES PER ACRE	280	280	330	220	260	280
LIVE BASAL AREA (SQ.FT/A)	72.2	53.7	69.4	86.9	79.9	79.2
LIVE TOTAL VOLUME (CU.FT/A)	805	568	794	1127	1032	939
CROWN COMPETITION FACTOR	75	68	82	83	83	85
RELATIVE DENSITY INDEX	27.5	22.0	27.9	29.8	29.1	29.5
MEAN DIAMETER (IN)	6.9	5.9	6.2	8.5	7.5	7.2
SITE HEIGHT (FEET)	30.9	25.5	31.2	35.8	36.1	30.8
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	0.0	0.0	0.0	0.0	4.6	23.7
GRAND FIR	16.8	38.5	28.1	10.9	17.5	11.4
SUBALPINE FIR	0.0	2.0	0.0	0.0	0.0	0.0
WESTERN LARCH	11.7	23.1	45.9	10.3	14.6	16.6
LODGEPOLE PINE	0.0	7.0	17.5	0.0	0.0	0.0
PONDEROSA PINE	68.4	29.0	0.0	71.8	63.3	45.6
ENGELMANN SPRUCE	3.2	0.3	8.4	7.0	0.0	2.7
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	280	280	330	220	260	280
LIVE BASAL AREA (SQ.FT/A)	87.5	69.9	84.1	104.4	96.6	98.4
CROWN COMPETITION FACTOR	89	88	96	98	101	106
RELATIVE DENSITY INDEX	31.6	25.4	31.1	34.8	33.3	34.1
MEAN DIAMETER (IN)	7.7	7.6	7.3	9.0	8.4	8.3
DEAD TREES PER ACRE	0	0	0	0	0	0
DEAD BASAL AREA (SQ.FT/A)	0.0	0.0	0.0	0.0	0.0	0.0

PLOT SUMMARY REPORT

INSTALLATION 317 NOTCH #1

REGION: N.E. OREGON OWNERSHIP: UMATILLA NF

LEGAL DESCRIPTION: T07S R23E SECTION 12 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	N+S	200#N	N+S	0#N	200#N	0#N
SITE CHARACTERISTICS:						
SLOPE (%)	16	13	18	20	29	28
ASPECT (DEGREES)	13	4	14	8	342	332
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE =		10			
LIVE TREES PER ACRE	410	440	500	470	430	480
LIVE BASAL AREA (SQ.FT/A)	1.6	4.1	2.4	2.1	1.7	4.0
LIVE TOTAL VOLUME (CU.FT/A)	12	32	19	17	15	33
CROWN COMPETITION FACTOR	4	10	7	6	5	10
RELATIVE DENSITY INDEX	1.7	3.6	2.5	2.2	1.8	3.6
MEAN DIAMETER (IN)	0.8	1.3	0.9	0.9	0.9	1.2
SITE HEIGHT (FEET)	9.0	12.4	10.4	11.4	12.6	13.0
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	52.6	73.1	77.4	77.5	90.8	75.2
WESTERN LARCH	11.3	2.7	5.6	1.0	0.8	5.2
LODGEPOLE PINE	27.1	21.5	10.2	21.5	8.4	19.6
PONDEROSA PINE	8.9	2.7	6.8	0.0	0.0	0.0
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	410	440	490	470	430	470
LIVE BASAL AREA (SQ.FT/A)	5.6	9.6	7.9	6.1	4.8	9.6
CROWN COMPETITION FACTOR	10	19	17	13	11	20
RELATIVE DENSITY INDEX	3.8	5.7	5.0	4.0	3.3	5.8
MEAN DIAMETER (IN)	2.1	2.8	2.5	2.3	2.2	2.8
DEAD TREES PER ACRE	0	0	10	0	0	10
DEAD BASAL AREA (SQ.FT/A)	0.0	0.0	0.1	0.0	0.0	0.2

PLOT SUMMARY REPORT

INSTALLATION 318 NOTCH #2
REGION: N.E. OREGON OWNERSHIP: UMATILLA NF
LEGAL DESCRIPTION: T07S R23E SECTION 11 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	200#N	0#N	200#N	N+S	N+S	0#N
SITE CHARACTERISTICS:						
SLOPE (%)	9	12	8	10	15	16
ASPECT (DEGREES)	27	27	28	15	352	332
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE =	10				
LIVE TREES PER ACRE	290	320	380	420	420	350
LIVE BASAL AREA (SQ.FT/A)	3.2	2.2	2.2	5.3	4.6	2.2
LIVE TOTAL VOLUME (CU.FT/A)	19	13	14	29	27	14
CROWN COMPETITION FACTOR	4	3	3	7	7	3
RELATIVE DENSITY INDEX	2.7	2.1	2.2	4.3	3.9	2.1
MEAN DIAMETER (IN)	1.4	1.1	1.0	1.5	1.4	1.1
SITE HEIGHT (FEET)	10.6	9.5	9.7	11.1	10.5	9.3
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	7.8	1.7	1.4	7.3	14.2	5.3
GRAND FIR	0.0	1.3	0.0	0.1	0.0	0.0
WESTERN LARCH	11.9	10.7	16.3	13.6	8.7	7.5
PONDEROSA PINE	80.3	86.4	82.3	79.0	77.1	87.2
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	280	320	370	420	410	350
LIVE BASAL AREA (SQ.FT/A)	8.0	6.5	6.2	13.9	11.2	6.4
CROWN COMPETITION FACTOR	10	8	8	17	15	8
RELATIVE DENSITY INDEX	5.0	4.4	4.5	8.5	7.0	4.4
MEAN DIAMETER (IN)	2.6	2.1	1.9	2.7	2.6	2.1
DEAD TREES PER ACRE	10	0	10	0	10	0
DEAD BASAL AREA (SQ.FT/A)	0.1	0.0	0.0	0.0	0.1	0.0

PLOT SUMMARY REPORT

INSTALLATION 319 NOTCH #3

REGION: N.E. OREGON OWNERSHIP: UMATILLA NF

LEGAL DESCRIPTION: T07S R23E SECTION 12 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	N+S	0#N	N+S	200#N	200#N	0#N
SITE CHARACTERISTICS:						
SLOPE (%)	23	14	20	20	11	15
ASPECT (DEGREES)	161	162	162	162	162	162
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE =		10			
LIVE TREES PER ACRE	280	340	300	280	360	380
LIVE BASAL AREA (SQ.FT/A)	2.4	3.6	1.4	3.7	1.1	2.2
LIVE TOTAL VOLUME (CU.FT/A)	18	24	11	26	9	18
CROWN COMPETITION FACTOR	5	7	3	7	3	6
RELATIVE DENSITY INDEX	2.2	3.0	1.4	3.0	1.2	2.2
MEAN DIAMETER (IN)	1.3	1.4	0.9	1.6	0.7	1.0
SITE HEIGHT (FEET)	12.7	10.8	8.9	12.0	8.7	10.6
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	61.1	45.0	60.3	47.2	74.6	71.9
GRAND FIR	0.0	11.0	0.0	0.8	0.0	0.0
WESTERN LARCH	0.0	8.6	0.9	0.0	0.0	0.0
PONDEROSA PINE	38.9	35.5	38.8	52.1	25.5	28.1
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	260	340	300	280	350	370
LIVE BASAL AREA (SQ.FT/A)	6.3	8.3	4.7	8.3	3.2	6.0
CROWN COMPETITION FACTOR	11	14	10	13	7	12
RELATIVE DENSITY INDEX	3.7	5.0	3.0	4.8	2.3	3.9
MEAN DIAMETER (IN)	2.8	2.8	2.4	3.0	2.0	2.4
DEAD TREES PER ACRE	20	0	0	0	10	10
DEAD BASAL AREA (SQ.FT/A)	0.1	0.0	0.0	0.0	0.0	0.0

PLOT SUMMARY REPORT

INSTALLATION 320 UKIAH

REGION: N.E. OREGON OWNERSHIP: UMATILLA NF

LEGAL DESCRIPTION: T04S R30E SECTION 21 MERIDIAN: WILLAMETTE

PLOT NUMBER	1	2	3	4	5	6
TREATMENT	N+S	N+S	200#N	0#N	0#N	200#N
SITE CHARACTERISTICS:						
SLOPE (%)	7	9	10	9	8	7
ASPECT (DEGREES)	32	18	46	31	55	365
MENSURATIONAL CHARACTERISTICS:						
AT TIME OF TREATMENT (1991)	STAND AGE = 11					
LIVE TREES PER ACRE	410	500	490	420	560	540
LIVE BASAL AREA (SQ.FT/A)	15.9	26.7	16.8	17.8	31.2	10.9
LIVE TOTAL VOLUME (CU.FT/A)	104	189	115	111	230	59
CROWN COMPETITION FACTOR	19	29	20	22	33	13
RELATIVE DENSITY INDEX	9.7	15.1	10.6	10.7	17.4	7.9
MEAN DIAMETER (IN)	2.7	3.1	2.5	2.8	3.2	1.9
SITE HEIGHT (FEET)	22.2	19.3	21.2	17.1	19.7	17.6
SPECIES COMPOSITION (% OF BA)						
DOUGLAS-FIR	8.3	3.9	5.1	1.9	2.1	0.5
GRAND FIR	2.0	0.0	0.1	20.3	0.3	0.0
WESTERN LARCH	64.8	39.4	39.0	29.9	13.8	85.2
LODGEPOLE PINE	3.6	8.6	11.9	2.7	9.2	0.0
PONDEROSA PINE	21.3	48.2	43.9	45.3	74.5	14.3
2 YEARS AFTER TREATMENT (1993)						
LIVE TREES PER ACRE	410	500	490	420	560	540
LIVE BASAL AREA (SQ.FT/A)	24.7	39.3	27.4	27.3	45.3	19.0
CROWN COMPETITION FACTOR	28	42	31	32	46	21
RELATIVE DENSITY INDEX	13.1	19.8	14.8	14.1	23.0	11.6
MEAN DIAMETER (IN)	3.5	3.9	3.4	3.7	3.9	2.7
DEAD TREES PER ACRE	0	0	0	0	0	0
DEAD BASAL AREA (SQ.FT/A)	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX C.

Site & Treatment	Nitrogen Concentration						Species[a] Contrasts	
		Change			Change		Difference	
		%	*P*		%	*P*	%	*P*
313	GF			LP				
C	1.07			1.28			-16	(0.34)
N	1.41	31	(0.13)	1.43	12	(0.47)	-01	(0.91)
NS	1.79	67	(0.00)	1.36	06	(0.71)	24	(0.05)
314	DF			GF				
C	1.17			1.03			12	(0.40)
N	1.81	55	(0.00)	1.72	67	(0.00)	05	(0.56)
NS	1.42	21	(0.13)	1.38	34	(0.04)	03	(0.83)
315 & 316	GF			PP				
C	1.14			1.41			-19	(0.02)
N	1.51	32	(0.00)	1.60	13	(0.11)	-06	(0.42)
NS	1.43	25	(0.01)	1.53	08	(0.32)	-07	(0.42)
317	DF			LP				
C	1.36			1.06			22	(0.05)
N	2.85	110	(0.00)	1.78	68	(0.00)	38	(0.00)
NS	1.47	08	(0.44)	1.19	12	(0.38)	19	(0.07)
318	DF			PP				
C	1.40			1.20			14	(0.28)
N	1.95	39	(0.01)	1.71	43	(0.01)	12	(0.20)
NS	1.54	10	(0.46)	1.33	11	(0.48)	14	(0.27)
319	DF			PP				
C	1.22			1.19			03	(0.88)
N	1.96	61	(0.00)	1.84	55	(0.00)	06	(0.53)
NS	1.46	20	(0.23)	1.34	13	(0.44)	08	(0.54)
320	DF			PP				
C	1.18			1.26			-06	(0.55)
N	1.74	32	(0.00)	1.56	24	(0.05)	10	(0.20)
NS	1.33	13	(0.64)	1.63	29	(0.01)	-18	(0.04)

Note: Means in rows are species nutrient level contrasts and % **difference**; within each site means in columns are nutrient level contrasts and % **change** for the following treatment contrasts: C vs. N and C vs. NS.

[a]The Species Contrasts column represents the percent difference and significance between two species within each row and by treatment, with the first species as basis for relative comparison.

Site & Treatment	Sulphur Concentration						Species[a] Contrasts	
		Change			Change		Difference	
		%	*P*		%	*P*	%	*P*
313	GF			LP				
C	0.08			0.06			25	(0.15)
N	0.06	-25	(0.20)	0.07	17	(0.58)	-14	(0.71)
NS	0.08	00	(1.00)	0.05	-17	(0.71)	38	(0.05)
314	DF			GF				
C	0.09			0.06			33	(0.09)
N	0.06	-34	(0.12)	0.08	33	(0.34)	-25	(0.42)
NS	0.08	-11	(0.52)	0.10	67	(0.03)	-20	(0.27)
315 & 316	GF			PP				
C	0.08			0.08			00	(0.93)
N	0.10	25	(0.04)	0.07	-13	(0.13)	30	(0.00)
NS	0.10	25	(0.04)	0.07	-13	(0.16)	30	(0.00)
317	DF			LP				
C	0.07			0.06			14	(0.40)
N	0.05	-29	(0.33)	0.05	-17	(0.90)	00	(1.00)
NS	0.10	43	(0.15)	0.07	17	(0.47)	30	(0.12)
318	DF			PP				
C	0.06			0.05			17	(0.80)
N	0.07	17	(0.15)	0.05	00	(1.00)	29	(0.05)
NS	0.08	34	(0.01)	0.07	40	(0.22)	13	(0.10)
319	DF			PP				
C	0.04			0.03			25	(0.27)
N	0.05	25	(0.58)	0.05	67	(0.10)	00	(1.00)
NS	0.05	25	(0.40)	0.04	34	(0.58)	20	(0.17)
320	DF			PP				
C	0.07			0.06			14	(0.72)
N	0.07	00	(1.00)	0.05	-17	(0.47)	29	(0.29)
NS	0.05	-29	(0.16)	0.04	-34	(0.22)	20	(0.86)

Note: Means in rows are species nutrient level contrasts and % difference; within each site means in columns are nutrient level contrasts and % change for the following treatment contrasts: C vs. N and C vs. NS.

[a]The Species Contrasts column represents the percent difference and significance between two species within each row and by treatment, with the first species as basis for relative comparison.

Site & Treatment	Potassium Concentration						Species Contrasts	
		Change			Change		Difference	
		%	*P*		%	*P*	%	*P*
313	GF			LP				
C	0.99			0.58			41	(0.00)
N	0.94	-05	(0.69)	0.52	-10	(0.62)	45	(0.00)
NS	1.15	16	(0.16)	0.68	17	(0.36)	41	(0.00)
314	DF			GF				
C	0.89			1.01			-12	(0.29)
N	0.67	-25	(0.05)	0.99	-02	(0.87)	-32	(0.01)
NS	0.84	-06	(0.66)	0.96	-05	(0.61)	-13	(0.33)
315 & 316	GF			PP				
C	1.18			1.02			14	(0.48)
N	1.71	45	(0.02)	0.80	-22	(0.34)	53	(0.00)
NS	1.43	21	(0.27)	0.87	-15	(0.52)	39	(0.02)
317	DF			LP				
C	0.79			0.68			14	(0.67)
N	0.65	-18	(0.59)	0.35	-48	(0.19)	46	(0.23)
NS	1.21	53	(0.10)	0.48	-29	(0.42)	60	(0.01)
318	DF			PP				
C	0.81			0.67			17	(0.17)
N	0.64	-21	(0.10)	0.51	-24	(0.15)	20	(0.25)
NS	1.14	41	(0.01)	0.85	27	(0.09)	25	(0.01)
319	DF			PP				
C	0.99			0.70			29	(0.01)
N	0.97	-02	(0.80)	0.68	-03	(0.82)	30	(0.01)
NS	0.98	-01	(0.94)	0.67	-04	(0.76)	32	(0.01)
320	DF			PP				
C	1.08			0.86			20	(0.11)
N	0.78	-28	(0.03)	0.84	-02	(0.87)	-07	(0.64)
NS	0.89	-18	(0.15)	0.82	-05	(0.75)	08	(0.62)

Note: Means in rows are species nutrient level contrasts and % difference; within each site means in columns are nutrient level contrasts and % change for the following treatment contrasts: C vs. N and C vs. NS.

[a]The Species Contrasts column represents the percent difference and significance between two species within each row and by treatment, with the first species as basis for relative comparison.