Effects of Fertilization and Herbicide Treatments on Pole and Young Stand Growth in Montana

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Summary

The fertilizer, herbicide, and combination treatments generally had a significant positive effect on tree growth, although response was quite variable between sites. Sometimes the response was very large approaching 70% for some sites. Generally N-P-K fertilizer only treatment was most effective in the larger (pole) sized stands, while the herbicide treatment was not. The results were the opposite for the young stands, the herbicide treatment produced better response than fertilizer only treatment. However, the combined fertilizer and herbicide treatment was sometimes the best treatment for the young stands.

Interestingly, similar to the IFTNC results, foliar K/N ratio (actually the change in the ratio) was a significant predictor of response. If the K/N ratio decreased (usually associated with the fertilizer only treatment) following treatment, then response was negative; however, if the K/N ratio increased (always associated with the combined treatment), then growth response was positive and substantially so.

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Silvicultural treatments, fertilizer (nitrogen, phosphorus, and potassium) and herbicide (pronone), were applied to pole and young stands in May, 1991. A total of 132 plots with 0.1 acre in size were selected from 18 installations. The number of plots in each installation varies from 6 to 10. The treatments includes: control (no treatment), fertilizer, herbicide, and the combination of fertilizer and herbicide. Some installations have all four treatments, some have only the control and herbicide treatments. Measurements were taken before (October, 1990) and after (September, 1992) the application of the treatments. All live plot trees were tagged and measured for total height and diameter at breast-height (DBH). In the young stands, if a tree was less than 4.5 feet tall, the caliper at ground level was measured instead of DBH. Tree volume and crown competition factor were estimated using species-specific equations in the Stand Prognosis Model (Wykoff et al. 1982). Basal areas and total volumes were summed over all trees to obtain plot totals. The averages and ranges of stand characteristics for each treatment were given in Table 1 for the pole stands and in Table 2 for the young stands. The stands are dominated by, in order of basal area percentage, Ponderosa pine, Douglas-fir, Lodgepole pine, Western larch, Grand fir, and other minor species. The detailed information about stand characteristics and species composition

Table 1. Averages and ranges of stand characteristics for the initial and second measurements for pole stands. Values in parentheses represent the ranges.

Stand Attributes	Silvicultural Treatments			
	Control	Fertilizer	Herbicide	Fert + Herb
Initial Measurement				
Number of Plots	15	3	15	9
Trees per acre	183 (60- 380)	163 (60- 270)	165 (70- 320)	181 (60- 350)
Diameter at BH (in)	7.8 (3.0-12.0)	7.7 (4.9-10.5)	8.1 (5.0-11.6)	8.3 (4.3-11.9)
Mean Height (ft)	44 (23- 66)	42 (23- 52)	44 (24- 63)	46 (21- 62)
Basal Area (ft^2 /a)	62 (18- 146)	52 (30- 91)	61 (26- 119)	66 (24- 138)
Volume (ft^3 /a)	1316 (239-3248)	1069 (484-1954)	1300 (375-2722)	1464 (339-3111)
Top Height (ft)	56 (34- 69)	50 (36- 60)	54 (31- 70)	53 (29- 68)
Crown Comp. Factor	59 (20- 137)	48 (31- 81)	57 (28- 105)	60 (26- 122)
Second Measurement				
Number of Plots	15	3	15	9
Trees per acre	180 (60- 370)	160 (60- 270)	160 (70- 320)	176 (60- 350)
Diameter at BH (in)	8.2 (3.7-12.3)	8.3 (5.7-11.1)	8.6 (5.8-12.1)	9.0 (5.4-12.5)
Mean Height (ft)	45 (17- 67)	44 (25- 55)	46 (27- 64)	49 (23- 64)
Basal Area (ft^2 /a)	67 (24- 157)	58 (36- 99)	67 (35- 128)	73 (32- 144)
Volume (ft^3 /a)	1479 (342-3610)	1243 (630-2176)	1466 (549-2977)	1653 (478-3402)
Top Height (ft)	57 (31- 71)	52 (39- 62)	55 (35- 71)	57 (34- 70)
Crown Comp. Factor	63 (27- 146)	53 (34- 87)	62 (36- 111)	65 (33- 127)

Table 2. Averages and ranges of stand characteristics for the initial and second measurements for young stands. Values in parentheses represent the ranges.

Stand Attributes	Silvicultural Treatments			
	Control	Fertilizer	Herbicide	Fert + Herb
Initial Measurement				
Number of Plots	39	3	39	9
Trees per acre	406 (120- 980)	483 (270- 840)	429 (130-1000)	379 (250- 650)
Diameter at BH (in)	1.6 (0.4- 4.6)	2.6 (0.9- 4.8)	1.7 (0.4- 5.1)	2.7 (1.3- 4.5)
Caliper (in)	0.9 (0.3- 1.3)	0.9 (0.8- 0.9)	0.9 (0.5- 1.2)	1.0 (0.5- 1.6)
Mean Height (ft)	7.0 (1.5-17.9)	11.0 (4.2-18.9)	7.0 (1.5-19.7)	11.2 (4.6-17.5)
Basal Area (ft^2 /a)	5.3 (0.0-35.7)	19.5 (1.8-38.6)	5.6 (0.0-39.6)	16.5 (3.0-40.2)
Volume (ft^3 /a)	40.1 (0.0- 312)	141.8 (14.5-352)	42.8 (0.0- 363)	133 (20.7-351)
Top Height (ft)	11.3 (2.7-26.0)	17.1 (8.6-26.6)	11.4 (2.1-27.7)	18.9 (12.7- 25)
Crown Comp. Factor	6.5 (0.0-35.0)	16.8 (2.6-36.9)	6.8 (0.1-37.9)	17.5 (4.1-38.8)
Second Measurement				
Number of Plots	39	3	39	9
Trees per acre	405 (120-1010)	487 (270- 860)	412 (130- 930)	358 (260- 560)
Diameter at BH (in)	2.0 (0.6- 5.2)	3.2 (1.3- 5.4)	2.2 (0.6- 5.8)	3.5 (1.8- 5.2)
Caliper (in)	1.3 (0.7- 2.3)	1.3 (1.2- 1.4)	1.5 (0.6- 2.5)	1.6 (1.2- 1.9)
Mean Height (ft)	9.1 (3.0-19.5)	13.2 (5.9-20.5)	9.3 (3.3-21.5)	14.0 (6.7-19.4)
Basal Area (ft^2 /a)	9.1 (0.0-43.9)	24.9 (6.6-48.4)	10.5 (0.0-51.8)	27.5 (8.6-51.5)
Volume (ft^3 /a)	71.8 (0.4- 408)	217.7 (39.5-469)	81.6 (0.0- 503)	244 (56.5-482)
Top Height (ft)	14.4 (4.3-27.8)	19.7 (11-28.3)	14.4 (4.4-29.1)	21.9 (15.2- 27)
Crown Comp. Factor	10.5 (0.1-42.2)	25.3 (8.4-45.3)	12.6 (0.3-48.2)	28.4 (11-48.4)

for each plot are provided in Appendix A, B, and C.

The objective of the statistical analysis is to investigate the treatment effects on stand volume, basal area, and height growth. The analyses were conducted separately for the pole and young stands by tree species as follows.

I. Statistical Analysis for Ponderosa Pine Pole Stands.

There are 3 installations and 24 plots for the Ponderosa pine pole stands. Two sites had all four treatments (20 plots), while one had only control and herbicide treatments (4 of the 6 plots in the installation). These installations were analyzed as one experiment. The experimental design model took the general form of a covariance model:

GROWTH = F (INSTALLATION, TREATMENT, COVARIATE)

where:

GROWTH - the stand growth including gross volume growth (ft^3/acre), gross basal area growth (ft^2/acre), and mean height growth (ft),

INSTALLATION - installation,

TREATMENT - treatments: 0-control, 1-fertilizer, 2-herbicide, and 3-fertilizer + herbicide,

COVARIATE - covariate variable: initial volume was used as the covariate variable for volume growth analyses; and initial basal area was used as the covariate variable for basal area and height growth analyses.

The analysis of variance for the growth and growth response for this Ponderosa pine experiment are provided in Table 3. The contrasts between treatment means are considered as the average growth responses to the treatments. The growth responses are smoothed estimates which were adjusted for covariate variables (initial volume or basal area) as indicated by the statistical model shown above.

The growth and response estimates for gross volume growth is provided in Table 3(a). Volume responses for all three treatments were about the same (20% to 22%). The herbicide and the combined treatment were marginally statistically significant ($\alpha \approx 0.1$). There was no overall synergistic effect from the combined fertilizer and herbicide effect.

The results were essentially the same for basal area growth response (Table 3(b)), with relative responses ranging from about 20 to 24%. The herbicide treatment was marginally statistically significant ($\alpha \approx 0.1$).

Height growth response to the fertilizer only treatment was about 42% ($\alpha = 0.12$) two years after treatment. The herbicide only and combined treatment effects were positive but not statistically significant. The lack of statistical significance in the response of these pole stands is not surprising since the "power" of the experiment is low and the magnitude of the response is highly variable across the installations.

The Ponderosa pine stands, particularly CAM, showed much higher response than the Lodgepole pine stand (LAK) for all 3

Table 3(a). Gross volume growth and response for Ponderosa pine pole stands.

Install	Treatment	Growth ft^3/a	Contrast	Response ft^3/a	p	%
Overall	Control	186.1				
	Fertilize	227.2	Fertilize-Control	41.1	(0.27)	22.1
	Herbicide	224.0	Herbicide-Control	37.9	(0.10)	20.3
	Fert+Herb	225.8	Fert+Herb-Control	39.7	(0.12)	21.3

Table 3(b). Gross basal area growth and response for Ponderosa pine pole stands.

Install	Treatment	Growth ft^2/a	Contrast	Response ft^2/a	p	%
Overall	Control	5.72				
	Fertilize	7.07	Fertilize-Control	1.35	(0.33)	23.6
	Herbicide	7.02	Herbicide-Control	1.30	(0.13)	22.7
	Fert+Herb	6.87	Fert+Herb-Control	1.15	(0.23)	20.1

Table 3(c). Height growth and response for Ponderosa pine pole stands.

Install	Treatment	Growth ft	Contrast	Response ft	p	%
Overall	Control	1.51				
	Fertilize	2.14	Fertilize-Control	0.63	(0.12)	41.7
	Herbicide	1.76	Herbicide-Control	0.25	(0.31)	16.6
	Fert+Herb	1.77	Fert+Herb-Control	0.26	(0.33)	17.2

response variables: gross volume (Table 4), gross basal area (Table 5), and mean height growth (Table 6). Since there is only one Lodgepole pine pole stand, it is not possible to attribute the lack of response at LAK to species versus installation (site) effects. However, species response differences may be worth pursuing in future study. It is also interesting that the magnitude of the relative fertilization responses is about what would be expected based on the IFTNC Ponderosa pine trials in Montana. Further, most of the treatment response at CAM seems to derive from a herbicide effect.

II. Statistical Analysis for Young Ponderosa Pine Stands.

There are 7 installations and 47 plots for the Ponderosa pine young stands. Three sites had all four treatments. The other 5 young installations had only the control and herbicide treatments. If a plot was dominated by species other than Ponderosa pine, it was not used in the analysis. There are many missing DBH observations for trees less than 4.5 feet tall. The statistical analysis was focused on mean tree height growth. However, tests on mean diameter and caliper growth were also conducted to investigate the treatment effects on the growth of larger and smaller trees in the young stands. The experimental design model is similar to that for the pole stands. The initial diameter was used as a covariate for height and diameter analyses, but not for caliper analysis.

Table 4. Gross volume growth and response for individual pole stands.

Install	Treatment	Growth ft^3/a	Contrast	Response ft^3/a	p	%
CAM (PP)	Control	154.3				
	Fertilize	166.2	Fertilize-Control	11.9	(0.84)	7.7
	Herbicide	226.8	Herbicide-Control	72.5	(0.09)	47.0
	Fert+Herb	210.1	Fert+Herb-Control	55.8	(0.17)	36.2
DUN (PP)	Control	177.8				
	Fertilize	230.9	Fertilize-Control	53.1	(0.39)	29.9
	Herbicide	222.4	Herbicide-Control	44.6	(0.31)	25.1
	Fert+Herb	228.8	Fert+Herb-Control	51.0	(0.26)	28.7
LAK (LP)	Control	198.3				
	Fertilize	212.7	Fertilize-Control	14.4	(0.83)	7.3
	Herbicide	181.5	Herbicide-Control	-16.8	(0.73)	-8.5
	Fert+Herb	249.9	Fert+Herb-Control	51.6	(0.34)	26.0
CLA (MIX)	Control	134.9				
	Herbicide	133.6	Herbicide-Control	-1.3	(0.95)	-0.9
TEA (MIX)	Control	206.7				
	Herbicide	210.6	Herbicide-Control	3.9	(0.84)	1.9

Table 5. Gross basal area growth and response for individual pole stands.

Install	Treatment	Growth ft^2/a	Contrast	Response ft^2/a	p	%
CAM	Control	4.14				
(PP)	Fertilize	4.58	Fertilize-Control	0.44	(0.83)	10.6
	Herbicide	6.43	Herbicide-Control	2.28	(0.14)	55.1
	Fert+Herb	6.38	Fert+Herb-Control	2.24	(0.15)	54.1
DUN	Control	5.47				
(PP)	Fertilize	7.83	Fertilize-Control	2.36	(0.19)	43.1
	Herbicide	7.86	Herbicide-Control	2.39	(0.08)	43.7
	Fert+Herb	6.79	Fert+Herb-Control	1.32	(0.28)	24.1
LAK	Control	9.22				
(LP)	Fertilize	10.57	Fertilize-Control	1.35	(0.61)	14.6
	Herbicide	10.14	Herbicide-Control	0.92	(0.62)	10.0
	Fert+Herb	12.17	Fert+Herb-Control	2.95	(0.16)	32.0
CLA	Control	5.18				
(MIX)	Herbicide	5.56	Herbicide-Control	0.38	(0.68)	7.3
TEA	Control	7.15				
(MIX)	Herbicide	6.82	Herbicide-Control	-0.33	(0.51)	-4.6

Table 6. Height growth and response for individual pole stands.

Install	Treatment	Growth ft	Contrast	Response ft	p	%
CAM	Control	1.79				
(PP)	Fertilize	2.84	Fertilize-Control	1.05	(0.19)	58.7
	Herbicide	2.29	Herbicide-Control	0.50	(0.33)	27.9
	Fert+Herb	1.97	Fert+Herb-Control	0.18	(0.71)	10.1
DUN	Control	1.31				
(PP)	Fertilize	1.23	Fertilize-Control	-0.08	(0.78)	-6.1
	Herbicide	1.42	Herbicide-Control	0.11	(0.60)	8.4
	Fert+Herb	1.76	Fert+Herb-Control	0.45	(0.07)	34.4
LAK	Control	3.60				
(LP)	Fertilize	3.28	Fertilize-Control	-0.32	(0.89)	-8.9
	Herbicide	3.34	Herbicide-Control	-0.26	(0.87)	-7.2
	Fert+Herb	5.06	Fert+Herb-Control	1.46	(0.39)	40.6
CLA	Control	2.84				
(MIX)	Herbicide	2.39	Herbicide-Control	-0.45	(0.60)	-15.8
TEA	Control	1.27				
(MIX)	Herbicide	1.73	Herbicide-Control	0.46	(0.25)	36.2

GROWTH = F (INSTALLATION, TREATMENT, COVARIATE)

where:

GROWTH - the growth including mean height growth (ft), mean diameter growth (in), and mean caliper growth (in),

INSTALLATION - installation,

TREATMENT - treatments: 0-control, 1-fertilizer, 2-herbicide, and 3-fertilizer + herbicide,

COVARIATE - covariate variable (initial diameter).

Overall height growth response for these Ponderosa pine installations is provided for each treatment in Table 7(a). Fertilizer only treatment had a negative non-significant effect on the average, while herbicide treatment produced a significant positive response. The combined fertilizer and herbicide treatment produced the largest height growth response. The same results were true for diameter growth response of these young Ponderosa pine stands (Table 7(b)). The caliper growth of the smallest trees (less than 4.5 feet tall) in these stands was significantly effected only by the herbicide treatments (Table 7(c)). Herbicide is the most responsive treatment in these young ponderosa stands, although there is some evidence for a synergistic effect from the combined fertilizer and herbicide treatment.

In ten young stands, pronone herbicide was the only treatment tested. Five of the stands were Ponderosa pine and their height growth response ranged from 4.4 to 27.5% (Table 8), while diameter growth response was larger, ranging from 5.8 to

Table 7(a). Two-year height growth and response for Ponderosa pine young stands.

Install	Treatment	Growth ft	Contrast	Response ft	p	%
Overall	Control	2.57				
	Fertilize	2.28	Fertilize-Control	-0.29	(0.18)	-11.3
	Herbicide	2.76	Herbicide-Control	0.19	(0.06)	7.4
	Fert+Herb	2.90	Fert+Herb-Control	0.33	(0.05)	12.8

Table 7(b). Diameter growth and response for Ponderosa pine young stands.

Install	Treatment	Growth in	Contrast	Response in	p	%
Overall	Control	0.91				
	Fertilize	1.02	Fertilize-Control	0.11	(0.32)	12.1
	Herbicide	1.07	Herbicide-Control	0.16	(0.01)	17.6
	Fert+Herb	1.19	Fert+Herb-Control	0.28	(0.01)	30.8

Table 7(c). Caliper growth and response for Ponderosa pine young stands.

Install	Treatment	Growth in	Contrast	Response in	p	%
Overall	Control	0.50				
	Fertilize	0.35	Fertilize-Control	-0.15	(0.41)	-30.0
	Herbicide	0.75	Herbicide-Control	0.25	(0.01)	50.0
	Fert+Herb	0.50	Fert+Herb-Control	0.00	(0.99)	0.0

Table 8. Two-year height growth and response for individual young stands.

Install	Treatment	Growth ft	Contrast	Response ft	p	%
BOI	Control	1.90				
(MIX)	Fertilize	1.68	Fertilize-Control	-0.22	(0.60)	-11.6
	Herbicide	1.93	Herbicide-Control	0.03	(0.91)	1.6
	Fert+Herb	2.10	Fert+Herb-Control	0.20	(0.41)	10.5
BUL	Control	3.93				
(PP)	Fertilize	3.63	Fertilize-Control	-0.30	(0.43)	-7.6
	Herbicide	3.80	Herbicide-Control	-0.13	(0.58)	-3.3
	Fert+Herb	3.96	Fert+Herb-Control	0.03	(0.93)	0.8
JOH	Control	1.61				
(PP)	Fertilize	1.72	Fertilize-Control	0.11	(0.57)	6.8
	Herbicide	2.04	Herbicide-Control	0.43	(0.02)	26.7
	Fert+Herb	2.00	Fert+Herb-Control	0.39	(0.02)	24.2
CYR	Control	1.60				
(PP)	Herbicide	1.67	Herbicide-Control	0.07	(0.64)	4.4
DAI	Control	2.84				
(LP)	Herbicide	3.12	Herbicide-Control	0.28	(0.46)	35.2
DEE	Control	1.50				
(DF)	Herbicide	1.66	Herbicide-Control	0.16	(0.44)	10.7
FAI	Control	2.58				
(PP)	Herbicide	2.75	Herbicide-Control	0.17	(0.49)	6.6
HOR	Control	2.26				
(MIX)	Herbicide	2.21	Herbicide-Control	-0.05	(0.87)	-2.2
IND	Control	2.22				
(PP)	Herbicide	2.58	Herbicide-Control	0.36	(0.28)	16.2
MOL	Control	1.99				
(PP)	Herbicide	2.08	Herbicide-Control	0.09	(0.31)	4.5
NBR	Control	2.35				
(MIX)	Herbicide	1.78	Herbicide-Control	-0.57	(0.10)	-24.3
OBR	Control	2.73				
(MIX)	Herbicide	2.90	Herbicide-Control	0.17	(0.66)	6.2
RIV	Control	1.67				
(PP)	Herbicide	2.13	Herbicide-Control	0.46	(0.11)	27.5

47.1% (Table 9). For the smallest trees (less than 4.5 feet tall), basal caliper growth was analyzed and the herbicide treatment produced the largest relative growth increase after two years (up to about 70%, Table 10) for these baby trees. We also analyzed a variable that is proportional to volume response for these little trees (Table 11). There was a nice (approximate 38% growth increase) synergistic effect for the combined fertilizer and herbicide treatment for the JOH installation.

III. Treatment Effects on Foliar Nutrients

The treatments all had a positive effect on foliar N, P, and K (Table 12). The largest effect was on foliar N, both the fertilizer and the combination treatments produced about a 17% increase in foliar N. Even the herbicide only treatment increased foliar N about 9%. Phosphorus and potassium concentrations were significantly increased only by the combination treatment (15% and 12%, respectively). The foliar K/N ratio was significantly reduced by the fertilizer treatment (Table 12), while the herbicide and the combination treatments did not have a significant effect on the K/N ratio.

The three treatments had different effects on foliar N and K concentrations (Figures 1 through 3). The herbicide only treatment generally increased both foliar N and K concentrations (except on installations BUL and IND where both nutrients decreased). Thus, the K/N ratio was little changed (Figure 3).

Table 9. Two-year diameter growth and response for young stands.

Install	Treatment	Growth in	Contrast	Response in	p	%
BOI	Control	0.73				
(MIX)	Fertilize	0.82	Fertilize-Control	0.09	(0.39)	12.3
	Herbicide	0.83	Herbicide-Control	0.10	(0.10)	13.7
	Fert+Herb	1.03	Fert+Herb-Control	0.30	(0.01)	41.1
BUL	Control	1.05				
(PP)	Fertilize	1.29	Fertilize-Control	0.24	(0.12)	22.9
	Herbicide	1.04	Herbicide-Control	-0.01	(0.92)	-0.1
	Fert+Herb	1.45	Fert+Herb-Control	0.40	(0.01)	38.1
JOH	Control	0.62				
(PP)	Fertilize	0.62	Fertilize-Control	0.00	(0.97)	0.0
	Herbicide	0.75	Herbicide-Control	0.13	(0.20)	21.0
	Fert+Herb	0.72	Fert+Herb-Control	0.10	(0.23)	16.1
CYR	no data available					
DAI	Control	0.92				
(LP)	Herbicide	1.01	Herbicide-Control	0.09	(0.47)	9.8
DEE	Control	0.57				
(DF)	Herbicide	0.70	Herbicide-Control	0.13	(0.04)	22.8
FAI	Control	1.04				
(PP)	Herbicide	1.10	Herbicide-Control	0.06	(0.73)	5.8
HOR	Control	0.73				
(MIX)	Herbicide	0.44	Herbicide-Control	-0.29	(0.28)	-39.7
IND	Control	0.85				
(PP)	Herbicide	1.09	Herbicide-Control	0.24	(0.08)	28.2
MOL	Control	0.84				
(PP)	Herbicide	1.16	Herbicide-Control	0.32	(0.01)	38.1
NBR	Control	0.83				
(MIX)	Herbicide	0.97	Herbicide-Control	0.14	(0.29)	16.9
OBR	Control	0.90				
(MIX)	Herbicide	0.97	Herbicide-Control	0.07	(0.81)	7.8
RIV	Control	0.70				
(PP)	Herbicide	1.03	Herbicide-Control	0.33	(0.05)	47.1

Table 10. Two-year caliper growth and response for individual young stands.

Install	Treatment	Growth in	Contrast	Response in	p	%
BOI	Control	0.30				
(MIX)	Fertilize	0.40	Fertilize-Control	0.10	(0.55)	33.3
	Herbicide	0.47	Herbicide-Control	0.17	(0.19)	56.7
	Fert+Herb	0.57	Fert+Herb-Control	0.27	(0.06)	90.0
BUL	no data available					
JOH	no data available					
CYR	Control	0.57				
(PP)	Herbicide	0.83	Herbicide-Control	0.26	(0.05)	45.6
DAI	Control	0.75				
(LP)	Herbicide	0.87	Herbicide-Control	0.12	(0.58)	16.0
DEE	Control	0.25				
(DF)	Herbicide	0.30	Herbicide-Control	0.05	(0.67)	20.0
FAI	Control	0.30				
(PP)	Herbicide	0.50	Herbicide-Control	0.20	(0.01)	67.7
HOR	Control	0.37				
(MIX)	Herbicide	0.57	Herbicide-Control	0.20	(0.01)	54.1
IND	Control	0.43				
(PP)	Herbicide	0.45	Herbicide-Control	0.02	(0.79)	4.7
MOL	Control	0.65				
(PP)	Herbicide	1.10	Herbicide-Control	0.45	(0.03)	69.2
NBR	Control	0.40				
(MIX)	Herbicide	0.57	Herbicide-Control	0.17	(0.19)	42.5
OBR	Control	0.63				
(MIX)	Herbicide	0.90	Herbicide-Control	0.27	(0.02)	42.9
RIV	Control	0.40				
(PP)	Herbicide	0.67	Herbicide-Control	0.27	(0.02)	67.5

Note: some plots did not have caliper measurements.

Table 11. Biomass growth and response for three young stands.

Install	Treatment	Growth	Contrast	Response	p	%
JOH	Control	42703				
(PP)	Fertilize	46210	Fertilize-Control	3507	(0.61)	8.2
	Herbicide	51211	Herbicide-Control	8508	(0.09)	19.9
	Fert+Herb	58773	Fert+Herb-Control	16070	(0.01)	37.6
CYR	Control	2644				
(PP)	Herbicide	3331	Herbicide-Control	687	(0.22)	26.0
HOR	Control	4364				
(MIX)	Herbicide	5850	Herbicide-Control	1486	(0.25)	34.1

Note:

Biomass = DBH^2 * HT for Installation JOH

Biomass = $Caliper^2$ * HT for Installation CYR and HOR

Table 12. Foliage nutrients for Ponderosa pine stands (including pole and young stands) one year after treatment.

Nutrient	Treatment	Concentration	Contrast	Change in Concentration	p	%
N	Control	13103				
	Fertilize	15280	Fertilize-Control	2177	(0.04)	16.6
	Herbicide	14259	Herbicide-Control	1156	(0.10)	8.8
	Fert+Herb	15235	Fert+Herb-Control	2132	(0.05)	16.3
P	Control	1684				
	Fertilize	1825	Fertilize-Control	141	(0.23)	8.4
	Herbicide	1734	Herbicide-Control	50	(0.53)	3.0
	Fert+Herb	1944	Fert+Herb-Control	260	(0.03)	15.4
K	Control	7396				
	Fertilize	7473	Fertilize-Control	77	(0.86)	1.0
	Herbicide	7539	Herbicide-Control	143	(0.63)	1.9
	Fert+Herb	8289	Fert+Herb-Control	893	(0.05)	12.1
K/N	Control	0.57				
	Fertilize	0.50	Fertilize-Control	-0.07	(0.06)	-12.3
	Herbicide	0.54	Herbicide-Control	-0.03	(0.24)	-5.3
	Fert+Herb	0.56	Fert+Herb-Control	-0.01	(0.79)	-1.8

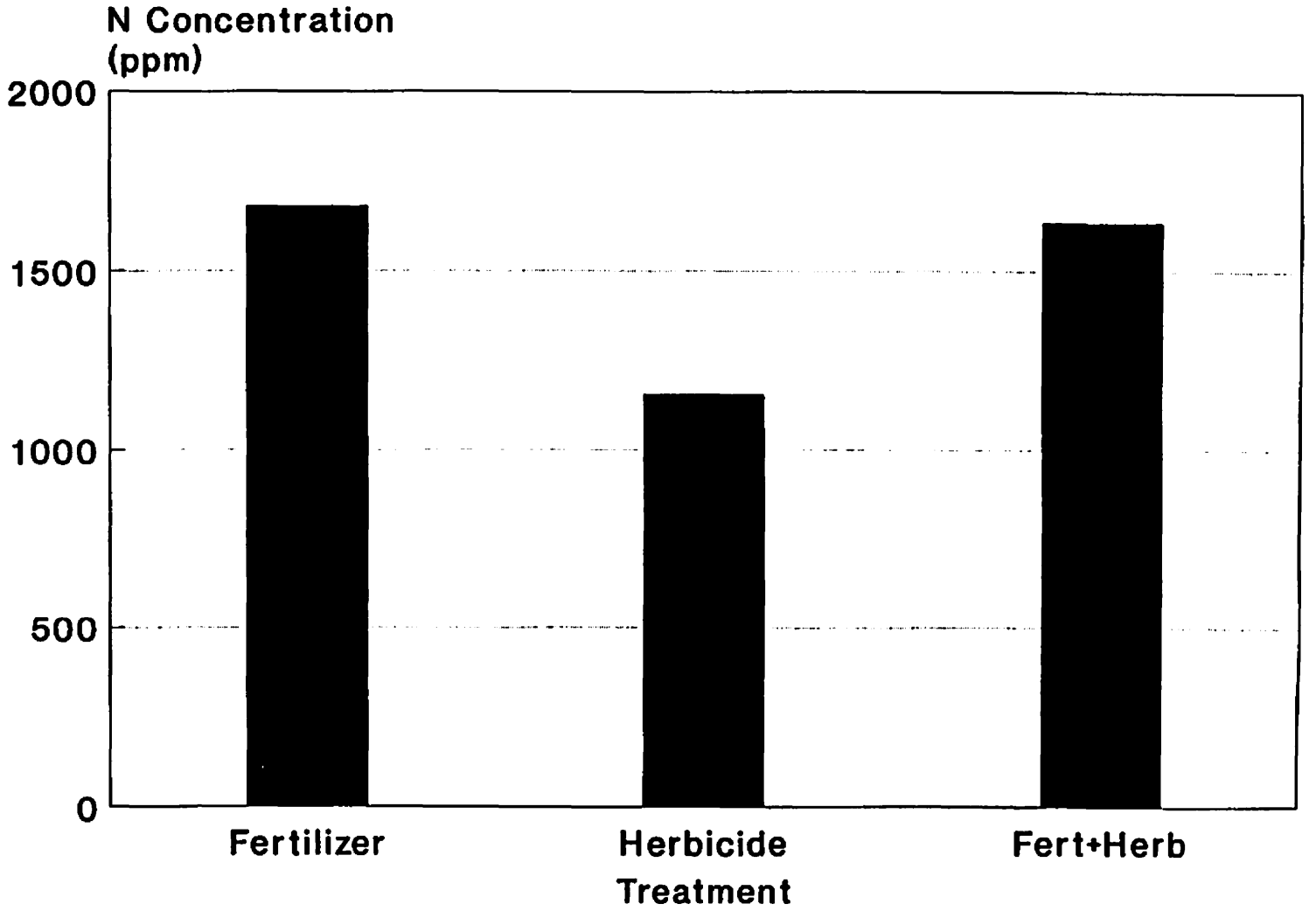

Figure 1. One-year change in foliar nitrogen concentration after fertilizer, herbicide, or combined fertilizer and herbicide treatments.

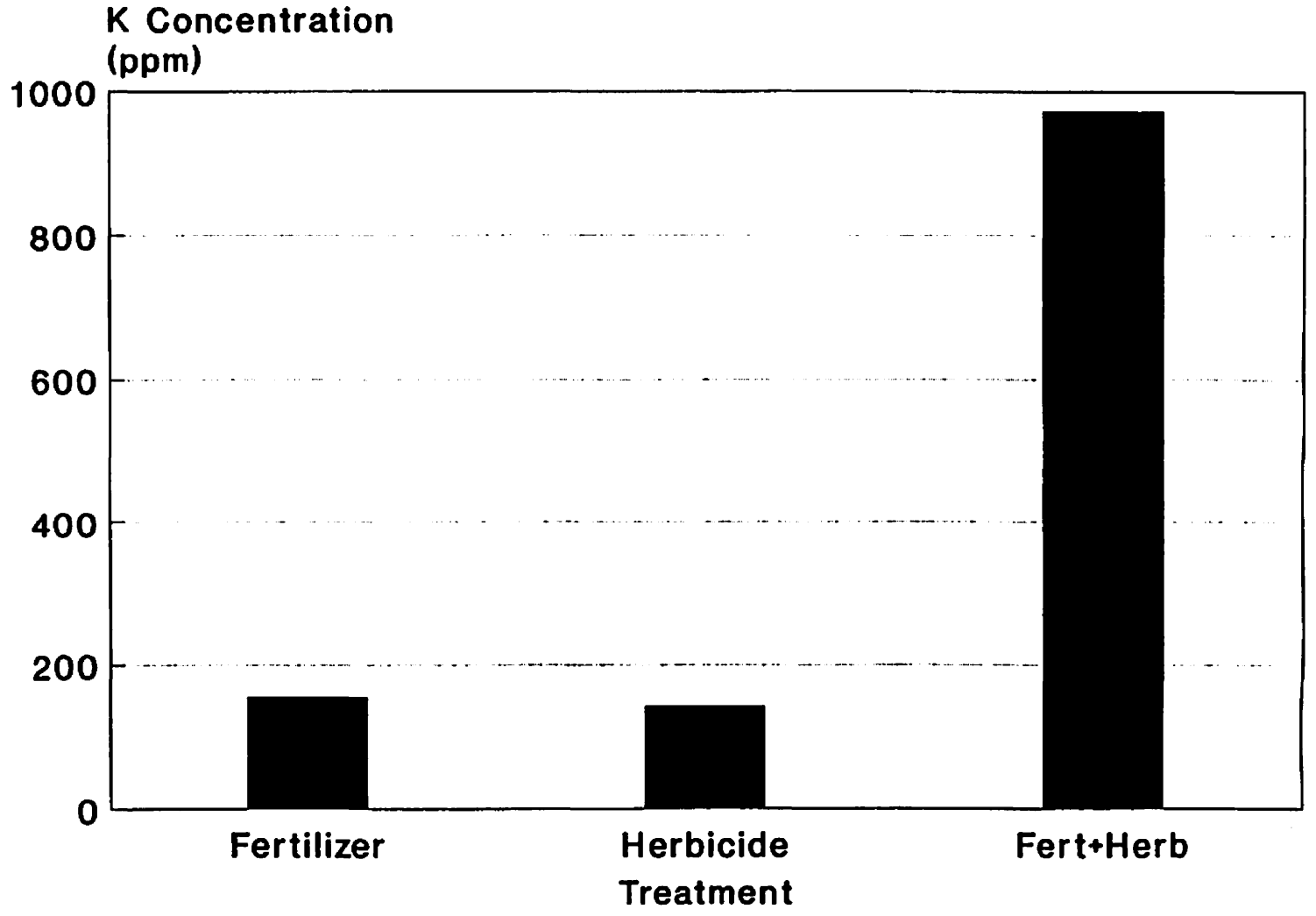

Figure 2. One-year change in foliar potassium concentration after fertilizer, herbicide, or combined fertilizer and herbicide treatments.

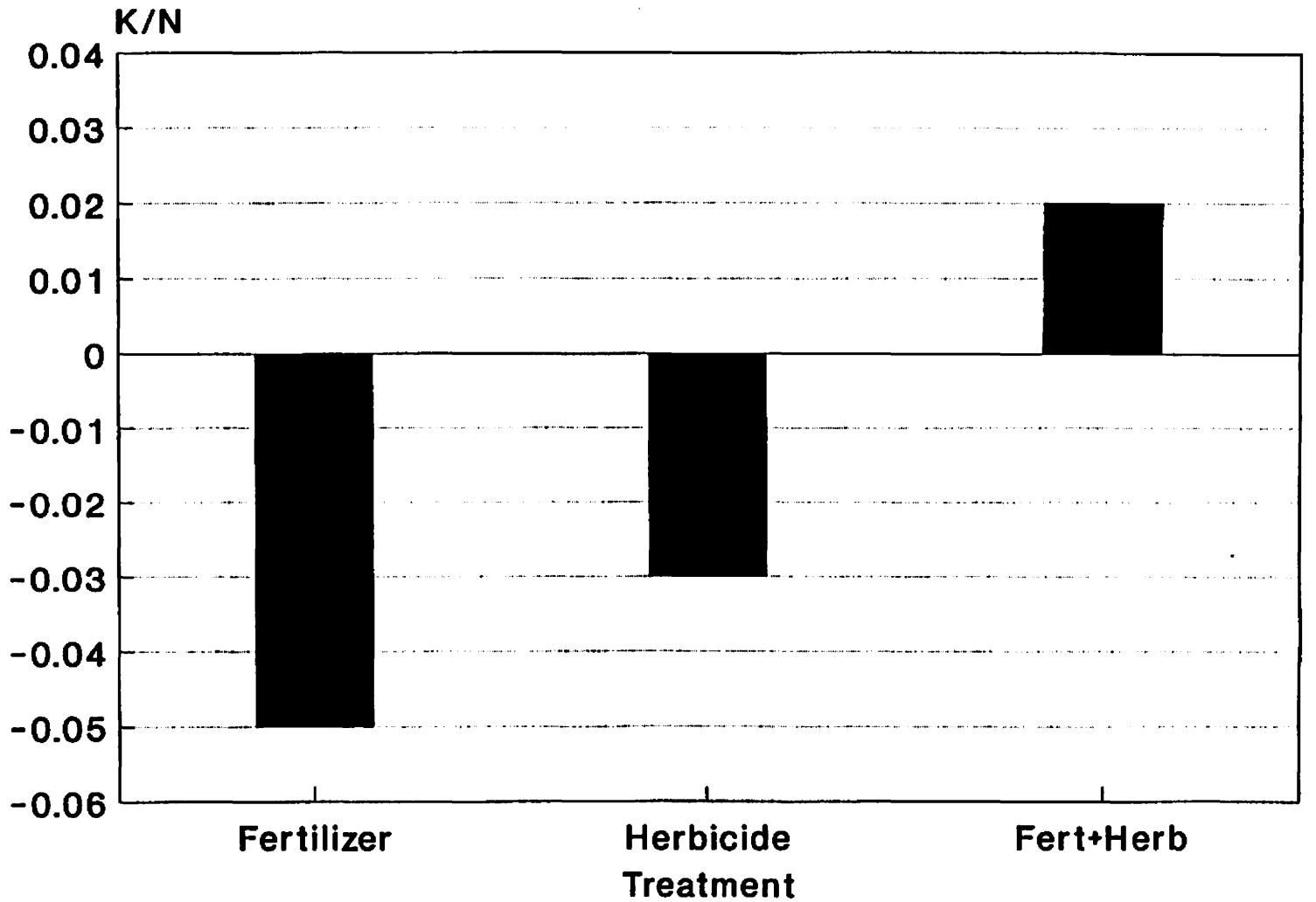

Figure 3. One-year change in foliar K/N ratio after fertilizer, herbicide, or combined fertilizer and herbicide treatments.

The fertilizer only treatment usually increased both N and K concentrations (except for the BUL site), but there was a relatively greater increase in N resulting in an average decrease in the foliar K/N ratio. The combined fertilizer and herbicide treatment showed a greater proportionate increase in K than N, thus the K/N ratio increased after treatment. These results suggest that the understory plants may have some competitive advantage over the trees in taking up the additional K supplied by the fertilizer (Figure 2). However, the understory did not seem to have a similar effect on foliar N (Figure 1).

IV. Relationships Between Foliar Nutrients and Treatment Growth Response

Regression analyses were conducted to investigate the relationships between foliar nutrient estimates and two-year relative growth response for the Ponderosa pine sites. The results showed that the change in N (Tables 1 and 2; Figures 1 and 2, Appendix D) was not a significant predictor of response. However, similar to previous IFTNC results, the change in foliar K/N ratio was a significant predictor of Ponderosa pine response (Table 13 and Figure 4). If the K/N ratio decreased following treatment, then growth response was negative; if the K/N ratio increased, then growth response also increased. Interestingly, a decreasing K/N ratio was usually associated with the fertilizer only treatment while increasing foliar K/N ratios resulted from the combined treatment.

Table 13. Analysis of variance of relative two-year Ponderosa pine response verses foliar K/N ratio for the fertilizer and combined treatments.

Dependent Variable: RESP

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	3365.07177607	2.33	0.2161
Error	4	1927.39841684		
Corrected Total	7	5292.47019291		

R-Square	C.V.	RESP Mean
0.635823	461.7394	4.75399556

Source	DF	Type I SS	F Value	Pr > F
TREAT	1	1250.42061521	2.60	0.1825
K_N	1	947.64048886	1.97	0.2334
K_N*TREAT	1	1167.01067199	2.42	0.1946

Source	DF	Type III SS	F Value	Pr > F
TREAT	1	495.11081723	1.03	0.3681
K_N	1	2104.21440353	4.37	0.1049
K_N*TREAT	1	1167.01067199	2.42	0.1946

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		14.549893 B	1.27	0.2731	11.4616689
TREAT	1	33.420704 B	1.01	0.3681	32.9700902
	3	0.000000 B	.	.	.
K_N		178.731262 B	0.82	0.4586	218.1229874
K_N*TREAT	1	1042.808110 B	1.56	0.1946	670.0739580
	3	0.000000 B	.	.	.

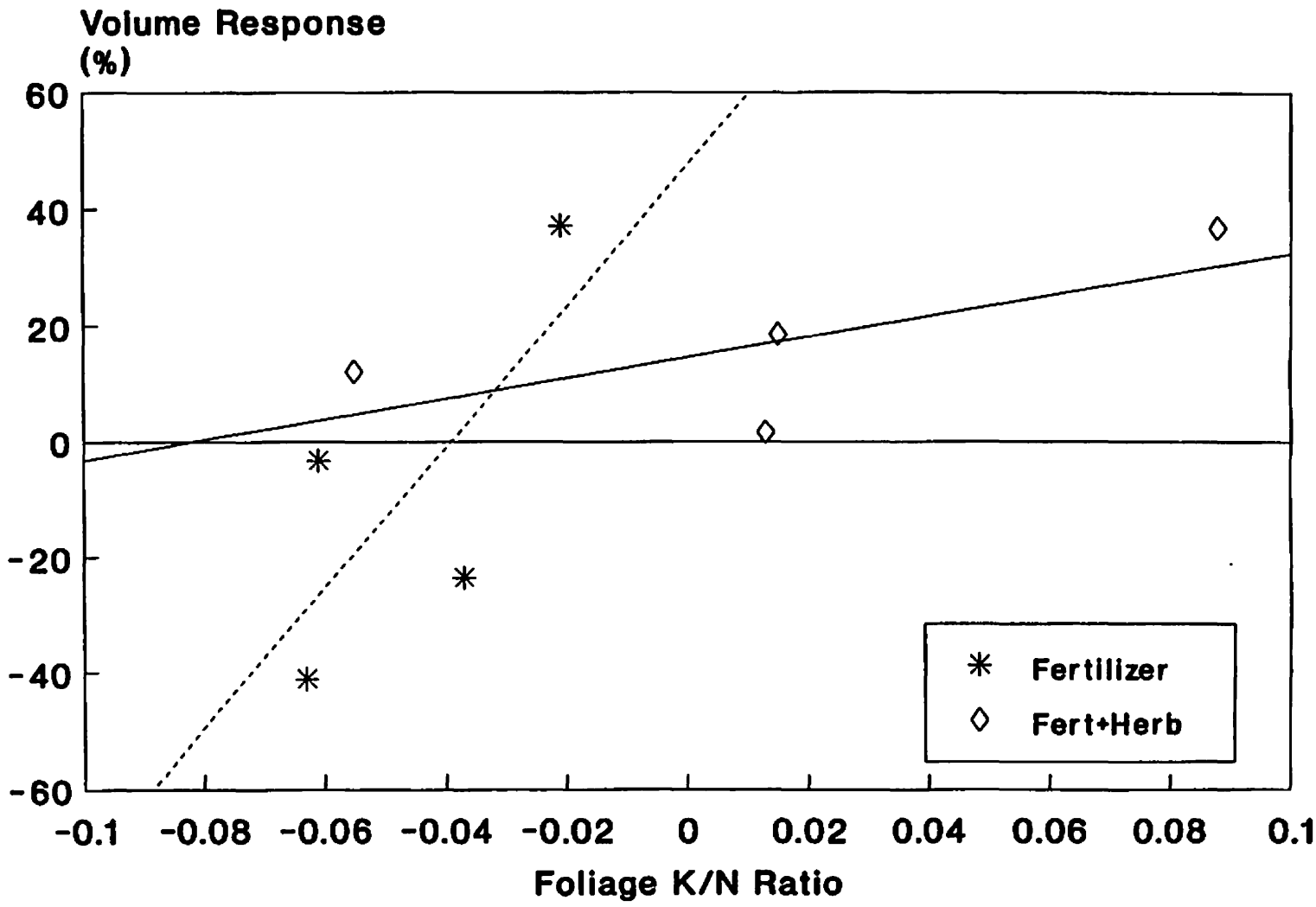

Figure 4. The relationship between two-year relative Ponderosa pine volume response and change in foliar K/N ratio after fertilizer, or combined fertilizer and herbicide treatments.

APPENDIX

Appendix A. The initial stand characteristics for each plot

OBS	INSTALL	PLOT	DIS	TRT	TPA0	TOPH0	BA0	VOL0	HT0	DBH0	CAL0
1	BOI	1E	C1	2	490	12.8	3.7	25.7	5.8	1.3	0.7
2	BOI	1W	C1	0	370	12.1	2.6	17.5	5.8	1.2	0.8
3	BOI	2E	C1	1	840	8.6	1.8	14.5	4.2	0.9	0.8
4	BOI	2S	C1	3	460	13.6	3.2	22.8	5.7	1.3	0.9
5	BOI	3S	C1	2	610	10.0	1.9	15.4	4.5	0.9	0.8
6	BOI	3W	C1	3	650	12.9	3.0	20.7	4.6	1.3	0.8
7	BOI	4N	C1	0	530	13.2	4.1	25.3	5.9	1.4	0.9
8	BOI	4S	C1	2	500	15.8	4.8	37.2	5.9	1.5	0.9
9	BOI	5N	C1	3	370	12.7	3.2	21.5	6.6	1.4	1.0
10	BOI	5S	C1	0	510	12.5	4.0	26.9	5.8	1.4	0.9
11	BUL	1E	C1	0	340	18.7	14.0	97.9	11.9	2.4	.
12	BUL	1W	C1	2	310	18.6	17.1	117.3	13.6	3.0	.
13	BUL	2E	C1	1	340	16.1	8.9	58.4	10.0	2.2	0.9
14	BUL	2W	C1	3	330	19.8	13.4	108.5	10.9	2.4	1.2
15	BUL	3N	C1	2	280	18.9	12.1	84.8	11.8	2.6	1.2
16	BUL	3W	C1	0	230	18.9	12.9	93.9	13.6	3.0	.
17	BUL	4E	C1	2	400	15.6	14.0	83.9	11.4	2.4	.
18	BUL	4W	C1	3	270	17.9	11.9	97.7	13.4	2.8	1.6
19	BUL	5E	C1	3	420	20.1	12.1	93.1	8.2	2.3	0.5
20	BUL	5W	C1	0	280	18.2	11.9	77.9	11.6	2.5	.
21	CAM	1N	C2	0	70	61.5	52.8	1318.0	59.1	11.7	.
22	CAM	1S	C2	3	100	67.5	72.5	1960.1	62.4	11.4	.
23	CAM	2N	C2	2	110	59.5	58.9	1334.7	55.0	9.8	.
24	CAM	2S	C2	3	60	64.8	46.9	1220.1	61.7	11.9	.
25	CAM	3N	C2	2	100	69.8	76.4	2101.3	62.7	11.6	.
26	CAM	3S	C2	0	80	69.0	63.5	1790.4	65.9	12.0	.
27	CAM	4N	C2	0	60	63.0	44.4	1127.8	59.5	11.6	.
28	CAM	4S	C2	2	70	55.8	48.5	1078.2	53.1	11.2	.
29	CAM	5N	C2	1	60	53.0	36.3	770.5	51.7	10.5	.
30	CAM	5S	C2	3	90	58.5	60.6	1374.0	52.4	11.0	.
31	CLA	1N	C2	2	150	47.5	37.8	624.3	35.0	6.4	.
32	CLA	1S	C2	2	150	56.8	48.9	970.6	43.3	7.5	.
33	CLA	2E	C2	0	130	53.8	35.4	651.9	40.0	6.7	.
34	CLA	2S	C2	0	160	53.6	46.4	805.5	42.9	7.0	.
35	CLA	3N	C2	2	130	61.3	49.6	1126.7	48.6	7.8	.
36	CLA	3S	C2	0	110	55.3	47.3	932.4	44.3	8.5	.
37	CYR	1N	C1	0	600	2.7	0.0	0.0	1.5	.	0.5
38	CYR	1W	C1	2	420	2.1	0.0	0.0	1.5	.	0.5
39	CYR	2N	C1	2	390	2.4	0.0	0.0	1.7	.	0.5
40	CYR	2W	C1	0	230	4.2	0.0	0.3	2.3	0.6	0.8
41	CYR	3N	C1	0	900	3.9	0.0	0.0	2.2	.	0.7
42	CYR	3S	C1	2	220	5.2	0.4	1.8	2.7	1.9	0.8

Appendix A. continue...

OBS	INSTALL	PLOT	DIS	TRT	TPA0	TOPH0	BA0	VOL0	HT0	DBH0	CAL0
43	DAI	1E	C1	0	590	10.1	1.6	8.0	5.3	0.9	1.3
44	DAI	1W	C1	2	620	10.4	2.5	13.0	5.5	0.9	1.2
45	DAI	2E	C1	0	390	7.2	0.4	1.7	3.9	0.8	1.1
46	DAI	2W	C1	2	460	9.5	1.4	6.7	5.2	0.9	1.1
47	DAI	3E	C1	0	260	8.9	1.4	5.7	6.5	0.9	0.8
48	DAI	3N	C1	2	250	8.0	0.7	2.6	5.7	0.7	1.0
49	DEE	1N	C1	0	260	15.7	3.6	31.2	8.5	1.8	0.5
50	DEE	1S	C1	2	750	14.1	2.0	17.9	3.8	1.3	0.5
51	DEE	2N	C1	2	220	19.3	5.0	47.0	12.4	1.8	.
52	DEE	2S	C1	0	330	17.4	3.3	31.3	7.0	1.4	0.4
53	DEE	3N	C1	2	170	17.6	3.9	34.7	13.3	1.9	.
54	DEE	3S	C1	0	160	17.6	4.0	36.2	12.7	2.0	.
55	DUN	1N	C2	2	230	62.3	89.5	2016.9	53.6	8.3	.
56	DUN	1S	C2	3	180	61.3	74.4	1700.2	53.6	8.5	.
57	DUN	2N	C2	2	320	62.4	118.7	2722.3	54.0	8.1	.
58	DUN	2S	C2	0	370	64.0	123.1	2800.7	53.5	7.6	.
59	DUN	3E	C2	2	260	55.0	95.8	1863.0	46.1	8.1	.
60	DUN	3W	C2	0	180	54.5	67.0	1309.9	45.8	8.1	.
61	DUN	4N	C2	3	350	63.8	137.7	3111.1	53.5	8.3	.
62	DUN	4S	C2	3	220	61.5	91.8	2055.8	54.5	8.7	.
63	DUN	5E	C2	1	270	60.0	90.6	1953.9	51.9	7.8	.
64	DUN	5N	C2	0	210	62.5	95.9	2168.5	51.4	8.8	.
65	FAI	1N	C1	0	120	11.8	4.1	22.1	10.4	2.4	.
66	FAI	1W	C1	2	130	14.9	6.2	37.9	12.1	2.8	.
67	FAI	2N	C1	0	120	14.3	6.0	35.7	11.8	2.9	.
68	FAI	2S	C1	2	160	13.7	7.9	44.7	11.9	3.0	.
69	FAI	3N	C1	0	180	17.6	8.9	69.0	10.3	2.9	1.0
70	FAI	3S	C1	2	170	14.1	5.6	33.0	9.8	2.5	1.1
71	HOR	1E	C1	0	360	5.9	0.1	0.7	2.9	0.7	0.7
72	HOR	1W	C1	2	630	5.0	0.1	0.2	3.0	0.6	0.8
73	HOR	2E	C1	0	380	5.3	0.3	1.3	3.1	1.1	0.7
74	HOR	2W	C1	2	790	6.2	0.3	1.4	3.1	0.8	0.7
75	HOR	3E	C1	2	1000	5.6	0.3	0.8	3.0	0.7	0.8
76	HOR	3W	C1	0	980	4.8	0.3	0.7	2.9	1.1	0.7
77	IND	1N	C1	0	320	17.8	12.8	88.7	10.9	2.6	1.0
78	IND	1S	C1	2	280	16.3	11.8	76.1	11.0	2.5	.
79	IND	2S	C1	0	220	11.9	2.8	16.8	5.6	1.8	1.3
80	IND	2W	C1	2	350	11.6	2.9	17.6	4.9	1.5	0.9
81	IND	3N	C1	0	230	12.4	4.0	21.7	6.7	2.2	1.2
82	IND	3S	C1	2	210	10.8	1.6	10.8	4.4	1.9	1.0

Appendix A. continue...

OBS	INSTALL	PLOT	DIS	TRT	TPA0	TOPH0	BA0	VOL0	HT0	DBH0	CAL0
83	JOH	1E	C1	2	240	25.6	28.3	242.9	17.3	4.4	.
84	JOH	1W	C1	0	270	26.0	35.7	312.1	17.9	4.6	.
85	JOH	2E	C1	0	280	22.7	30.2	240.1	17.2	4.3	.
86	JOH	2W	C1	2	260	23.4	31.5	255.3	17.2	4.5	.
87	JOH	3E	C1	0	270	22.7	26.9	212.3	16.1	4.0	.
88	JOH	3W	C1	1	270	26.6	38.6	352.4	18.9	4.8	.
89	JOH	4E	C1	2	260	27.7	39.6	362.7	19.7	5.1	.
90	JOH	4W	C1	3	310	25.4	40.2	350.5	17.5	4.5	.
91	JOH	5E	C1	3	350	24.3	33.4	268.7	16.5	4.0	.
92	JOH	5W	C1	3	250	23.1	27.8	216.1	17.1	4.3	.
93	LAK	1N	C2	0	200	51.4	17.5	239.0	22.7	3.0	.
94	LAK	1W	C2	3	160	28.8	24.3	339.1	20.6	4.5	.
95	LAK	2N	C2	1	160	35.8	29.6	483.9	23.1	4.9	.
96	LAK	2W	C2	2	150	34.3	26.1	375.0	23.5	5.0	0.4
97	LAK	3N	C2	3	240	33.3	34.4	515.7	21.5	4.3	.
98	LAK	3W	C2	2	170	30.6	27.3	380.6	23.9	5.1	.
99	LAK	4E	C2	3	230	39.0	51.9	895.8	33.8	6.4	.
100	LAK	4W	C2	2	200	34.8	43.7	650.9	27.5	6.1	.
101	LAK	5N	C2	0	200	34.0	35.6	533.7	24.9	5.2	.
102	LAK	5W	C2	0	210	36.0	37.6	552.7	25.2	5.4	.
103	MOL	1E	C1	0	360	8.3	1.5	13.5	5.9	0.9	1.3
104	MOL	1W	C1	2	450	8.4	2.3	18.1	6.1	1.0	1.0
105	MOL	2E	C1	2	330	11.3	4.8	27.3	7.7	1.6	0.9
106	MOL	2W	C1	0	340	10.1	2.9	19.9	7.2	1.2	0.3
107	MOL	3N	C1	2	320	8.8	1.9	12.3	5.8	1.2	0.9
108	MOL	3W	C1	0	230	10.8	3.6	20.5	8.0	1.6	.
109	NBR	1E	C1	0	760	8.4	1.9	14.4	4.9	0.8	0.8
110	NBR	1W	C1	2	840	8.2	1.9	13.6	4.4	0.8	0.8
111	NBR	2E	C1	0	810	8.0	0.3	3.2	3.3	0.5	0.8
112	NBR	2W	C1	2	520	7.9	0.6	5.3	3.7	0.8	0.9
113	NBR	3E	C1	0	660	8.4	1.2	9.1	4.3	0.8	0.9
114	NBR	3W	C1	0	790	7.3	0.7	8.7	4.1	0.6	0.9
115	OBR	1N	C1	0	530	5.5	0.0	0.1	2.9	0.4	1.2
116	OBR	1S	C1	2	570	5.7	0.1	0.3	2.5	0.7	0.8
117	OBR	2N	C1	0	430	4.3	0.0	0.3	2.4	0.6	0.9
118	OBR	2S	C1	2	560	6.6	0.1	0.2	3.3	0.4	0.8
119	OBR	3N	C1	0	650	5.1	0.2	0.6	2.9	0.8	0.8
120	OBR	3S	C1	2	770	5.7	0.3	1.2	3.0	0.7	0.7

Appendix A. continue...

OBS	INSTALL	PLOT	DIS	TRT	TPA0	TOPH0	BA0	VOL0	HT0	DBH0	CAL0
121	RIV	1E	C1	0	380	4.9	0.0	1.0	2.9	0.4	0.8
122	RIV	1N	C1	2	290	5.8	0.2	3.2	3.5	0.6	0.7
123	RIV	2E	C1	0	350	7.0	0.6	4.4	3.6	0.9	0.7
124	RIV	2W	C1	0	500	5.8	0.3	3.2	3.3	0.7	0.8
125	RIV	3N	C1	2	410	7.9	0.6	3.7	3.8	0.8	0.8
126	RIV	3S	C1	2	450	5.6	0.3	3.1	3.6	0.6	1.0
127	TEA	1N	C2	2	130	58.2	76.0	1615.4	50.2	10.0	.
128	TEA	1S	C2	0	140	59.5	59.3	1258.2	48.6	8.4	.
129	TEA	2N	C2	2	130	55.8	51.6	1086.3	41.5	7.7	.
130	TEA	2S	C2	0	240	55.8	52.2	1005.1	28.3	5.2	.
131	TEA	3N	C2	0	380	59.3	146.0	3248.3	42.2	7.4	.
132	TEA	3S	C2	2	170	59.0	71.7	1549.3	43.6	8.0	.

Note:

(1) Treatment codes (TRT):

0 - control
1 - fertilizer
2 - herbicide
3 - fertilizer + herbicide

(2) Stand attributes:

INSTALL - installation
PLOT - plot
DIS - district (C1-young stands; C2-pole stands)
TPA - trees per acre
TOPH - stand top height (ft)
BA - basal area (ft^2/acre)
VOL - total volume (ft^3/acre)
HT - mean tree height (ft)
DBH - mean diameter at breast-height (in)
CAL - mean caliper (in)

Appendix B. The second meansurements of stand characteristics for each plot

OBS	INSTALL	PLOT	DIS	TRT	TPA2	TOPH2	BA2	VOL2	HT2	DBH2	CAL2
1	BOI	1E	C1	2	450	15.6	9.6	62.5	8.3	1.9	1.2
2	BOI	1W	C1	0	370	14.9	6.4	42.1	7.8	1.7	1.2
3	BOI	2E	C1	1	860	11.0	6.6	39.5	5.9	1.3	1.2
4	BOI	2S	C1	3	400	15.8	8.7	56.5	8.2	1.9	1.6
5	BOI	3S	C1	2	530	12.9	6.0	38.0	6.7	1.5	1.5
6	BOI	3W	C1	3	560	15.2	8.6	61.4	6.7	1.8	1.4
7	BOI	4N	C1	0	550	14.6	7.0	46.3	7.2	1.6	1.2
8	BOI	4S	C1	2	400	18.3	9.4	75.9	8.3	2.0	1.2
9	BOI	5N	C1	3	350	15.9	8.9	62.1	8.9	2.1	1.4
10	BOI	5S	C1	0	490	15.1	8.7	59.1	7.6	1.9	1.0
11	BUL	1E	C1	0	320	23.4	20.9	181.3	14.7	3.0	.
12	BUL	1W	C1	2	330	23.8	31.1	257.4	17.2	4.0	0.9
13	BUL	2E	C1	1	330	19.7	19.8	145.2	13.2	2.9	1.4
14	BUL	2W	C1	3	330	25.4	30.4	284.3	14.9	3.5	1.8
15	BUL	3N	C1	2	290	23.5	22.6	189.5	15.4	3.4	1.7
16	BUL	3W	C1	0	240	23.8	23.9	208.0	17.2	4.2	1.1
17	BUL	4E	C1	2	390	19.1	25.3	175.5	14.6	3.3	.
18	BUL	4W	C1	3	270	22.7	27.0	272.1	17.5	4.0	1.9
19	BUL	5E	C1	3	390	24.2	27.3	235.8	12.3	3.1	1.2
20	BUL	5W	C1	0	280	23.1	22.2	181.1	15.9	3.6	.
21	CAM	1N	C2	0	70	64.0	57.0	1486.6	61.6	12.1	.
22	CAM	1S	C2	3	80	69.8	62.6	1757.7	63.9	12.5	.
23	CAM	2N	C2	2	110	62.0	66.8	1608.7	57.7	10.5	.
24	CAM	2S	C2	3	60	66.5	51.9	1389.4	62.8	12.5	.
25	CAM	3N	C2	2	100	71.0	82.9	2342.3	64.3	12.1	.
26	CAM	3S	C2	0	80	71.0	66.9	1930.1	67.1	12.3	.
27	CAM	4N	C2	0	60	64.3	49.1	1282.6	60.8	12.2	.
28	CAM	4S	C2	2	70	57.8	53.6	1250.0	55.4	11.8	.
29	CAM	5N	C2	1	60	55.4	40.6	922.9	54.8	11.1	.
30	CAM	5S	C2	3	90	59.0	69.2	1629.0	54.4	11.8	.
31	CLA	1N	C2	2	150	49.0	43.3	742.6	36.9	6.9	.
32	CLA	1S	C2	2	110	53.4	41.4	846.7	44.0	8.0	.
33	CLA	2E	C2	0	130	62.5	40.1	768.5	44.3	7.2	.
34	CLA	2S	C2	0	150	56.5	48.8	894.4	45.1	7.5	.
35	CLA	3N	C2	2	120	62.5	54.8	1285.0	48.5	8.7	.
36	CLA	3S	C2	0	110	57.3	51.9	1065.2	46.4	8.9	.
37	CYR	1N	C1	0	590	4.3	0.0	0.4	3.0	0.9	1.0
38	CYR	1W	C1	2	400	4.5	0.0	0.0	3.3	.	1.2
39	CYR	2N	C1	2	390	4.4	0.0	0.0	3.4	.	1.4
40	CYR	2W	C1	0	220	6.7	0.3	2.3	4.1	1.0	1.5
41	CYR	3N	C1	0	900	5.9	0.1	1.5	3.7	0.8	1.2
42	CYR	3S	C1	2	220	6.5	0.1	0.7	4.2	1.3	1.8

Appendix B. continue...

OBS	INSTALL	PLOT	DIS	TRT	TPA2	TOPH2	BA2	VOL2	HT2	DBH2	CAL2
43	DAI	1E	C1	0	580	14.8	8.8	53.6	8.5	1.6	2.1
44	DAI	1W	C1	2	610	14.6	10.3	64.5	9.1	1.6	1.9
45	DAI	2E	C1	0	390	10.9	2.2	12.5	6.2	1.2	1.7
46	DAI	2W	C1	2	450	13.8	6.4	39.0	8.1	1.5	1.8
47	DAI	3E	C1	0	230	11.9	3.6	20.2	9.7	1.6	.
48	DAI	3N	C1	2	250	11.3	3.5	18.0	8.5	1.5	2.1
49	DEE	1N	C1	0	260	17.7	5.6	48.4	9.5	2.3	0.7
50	DEE	1S	C1	2	710	16.6	4.5	38.1	5.0	2.0	0.8
51	DEE	2N	C1	2	220	21.2	8.5	80.5	14.4	2.5	.
52	DEE	2S	C1	0	330	19.9	5.6	53.2	8.5	2.1	0.7
53	DEE	3N	C1	2	160	18.9	6.2	57.3	14.8	2.5	.
54	DEE	3S	C1	0	160	19.5	6.6	59.6	14.4	2.6	.
55	DUN	1N	C2	2	230	62.8	98.1	2261.2	54.9	8.7	.
56	DUN	1S	C2	3	180	62.0	82.9	1957.9	55.3	9.0	.
57	DUN	2N	C2	2	320	63.3	127.5	2977.3	54.8	8.4	.
58	DUN	2S	C2	0	360	65.3	126.2	2925.0	54.1	7.8	.
59	DUN	3E	C2	2	240	55.4	96.1	1931.6	47.6	8.4	.
60	DUN	3W	C2	0	180	57.0	72.3	1449.5	46.4	8.4	.
61	DUN	4N	C2	3	350	64.8	143.8	3401.5	55.5	8.5	.
62	DUN	4S	C2	3	220	60.5	97.5	2209.3	55.0	8.9	.
63	DUN	5E	C2	1	270	61.8	98.5	2175.5	53.0	8.1	.
64	DUN	5N	C2	0	210	64.5	101.6	2376.0	52.7	9.1	.
65	FAI	1N	C1	0	120	14.5	7.6	45.1	12.7	3.3	.
66	FAI	1W	C1	2	130	18.1	12.0	84.2	15.1	4.0	.
67	FAI	2N	C1	0	120	17.8	12.1	81.5	14.7	4.2	.
68	FAI	2S	C1	2	160	16.7	13.7	88.6	14.7	3.9	.
69	FAI	3N	C1	0	180	20.9	14.4	121.6	12.8	3.4	1.3
70	FAI	3S	C1	2	170	17.8	11.3	76.3	12.4	3.2	1.6
71	HOR	1E	C1	0	350	8.2	0.3	2.6	4.8	0.6	1.1
72	HOR	1W	C1	2	660	8.5	1.6	10.4	5.1	0.8	1.4
73	HOR	2E	C1	0	400	8.9	0.7	3.9	5.3	0.6	1.2
74	HOR	2W	C1	2	720	8.5	1.0	6.6	4.9	0.6	1.2
75	HOR	3E	C1	2	930	8.9	1.9	14.1	5.3	0.7	1.4
76	HOR	3W	C1	0	1010	9.0	1.5	10.1	5.4	0.6	1.1
77	IND	1N	C1	0	360	22.0	21.9	176.5	12.8	3.1	1.2
78	IND	1S	C1	2	300	20.7	22.9	172.4	13.6	3.4	0.6
79	IND	2S	C1	0	230	15.1	5.2	36.5	7.3	1.7	1.6
80	IND	2W	C1	2	350	15.3	6.8	44.6	6.9	1.7	1.3
81	IND	3N	C1	0	230	15.1	8.0	47.8	8.6	2.5	1.7
82	IND	3S	C1	2	210	14.3	3.6	26.8	6.3	1.8	1.5

Appendix B. continue...

OBS	INSTALL	PLOT	DIS	TRT	TPA2	TOPH2	BA2	VOL2	HT2	DBH2	CAL2
83	JOH	1E	C1	2	240	27.6	37.2	345.2	19.4	5.1	.
84	JOH	1W	C1	0	270	27.8	43.9	408.0	19.5	5.2	.
85	JOH	2E	C1	0	280	24.0	38.8	327.8	18.8	4.9	.
86	JOH	2W	C1	2	270	25.3	41.2	359.4	18.8	5.1	.
87	JOH	3E	C1	0	290	24.2	35.6	298.8	17.3	4.4	.
88	JOH	3W	C1	1	270	28.3	48.4	468.5	20.5	5.4	.
89	JOH	4E	C1	2	260	29.1	51.8	503.3	21.5	5.8	.
90	JOH	4W	C1	3	310	27.2	51.5	482.1	19.4	5.2	.
91	JOH	5E	C1	3	350	26.5	46.9	409.8	18.7	4.8	.
92	JOH	5W	C1	3	260	24.6	38.6	330.5	19.1	5.1	.
93	LAK	1N	C2	0	200	31.3	24.1	342.2	17.4	3.7	1.2
94	LAK	1W	C2	3	150	34.0	31.7	478.2	23.1	5.4	.
95	LAK	2N	C2	1	150	38.8	36.2	630.2	25.4	5.7	.
96	LAK	2W	C2	2	150	38.5	34.7	548.8	26.7	5.8	.
97	LAK	3N	C2	3	230	52.6	50.4	820.1	30.2	5.5	.
98	LAK	3W	C2	2	170	34.5	37.3	578.7	27.5	6.0	0.7
99	LAK	4E	C2	3	220	42.8	64.6	1237.2	37.8	7.3	.
100	LAK	4W	C2	2	200	37.3	55.3	799.5	30.7	6.9	.
101	LAK	5N	C2	0	200	38.0	45.5	755.3	28.7	5.9	.
102	LAK	5W	C2	0	200	40.8	44.2	719.4	29.2	6.1	.
103	MOL	1E	C1	0	360	10.5	4.3	24.3	7.5	1.6	2.3
104	MOL	1W	C1	2	430	10.5	8.1	40.5	7.8	2.0	2.5
105	MOL	2E	C1	2	330	14.2	16.3	90.5	10.3	3.0	2.0
106	MOL	2W	C1	0	340	12.8	7.9	42.5	9.0	2.0	2.3
107	MOL	3N	C1	2	320	11.1	6.7	34.0	7.7	2.2	2.1
108	MOL	3W	C1	0	220	13.7	8.9	48.2	10.6	2.6	.
109	NBR	1E	C1	0	750	12.7	8.0	48.0	7.4	1.3	1.3
110	NBR	1W	C1	2	830	12.0	9.8	53.0	6.5	1.5	1.2
111	NBR	2E	C1	0	770	11.4	1.6	13.6	4.7	0.7	1.1
112	NBR	2W	C1	2	520	10.5	3.1	19.3	5.5	1.0	1.5
113	NBR	3E	C1	2	650	11.7	5.4	32.3	6.6	1.1	1.6
114	NBR	3W	C1	0	790	10.8	4.2	27.5	6.2	1.0	1.3
115	OBR	1N	C1	0	530	9.8	2.4	16.7	5.9	1.0	1.8
116	OBR	1S	C1	2	540	8.6	1.3	9.1	4.7	0.8	1.6
117	OBR	2N	C1	0	430	8.5	1.3	10.5	4.9	0.9	1.5
118	OBR	2S	C1	2	460	10.7	2.7	14.9	6.5	1.1	1.9
119	OBR	3N	C1	0	650	8.9	2.0	11.3	5.5	0.9	1.3
120	OBR	3S	C1	2	720	10.3	3.6	19.6	6.1	1.0	1.6

Appendix B. continue...

OBS	INSTALL	PLOT	DIS	TRT	TPA2	TOPH2	BA2	VOL2	HT2	DBH2	CAL2
121	RIV	1E	C1	0	380	7.6	0.6	6.8	4.5	0.7	1.3
122	RIV	1N	C1	2	270	8.7	1.7	10.6	5.4	1.2	1.5
123	RIV	2E	C1	0	350	10.5	1.8	12.6	5.4	1.0	1.1
124	RIV	2W	C1	0	480	8.3	1.0	9.0	4.8	0.7	1.1
125	RIV	3N	C1	2	360	9.2	1.7	11.5	5.5	1.0	1.4
126	RIV	3S	C1	2	450	9.4	2.3	16.4	6.0	1.0	1.7
127	TEA	1N	C2	2	130	59.8	82.7	1807.8	51.8	10.4	.
128	TEA	1S	C2	0	140	61.3	65.5	1422.0	49.6	8.9	.
129	TEA	2N	C2	2	130	57.5	56.3	1235.0	42.8	8.0	.
130	TEA	2S	C2	0	240	58.5	57.8	1159.7	29.5	5.5	.
131	TEA	3N	C2	0	370	61.5	157.4	3609.5	43.9	7.9	.
132	TEA	3S	C2	2	170	61.2	78.9	1779.0	45.4	8.4	.

Note:

(1) Treatment codes (TRT):

0 - control
1 - fertilizer
2 - herbicide
3 - fertilizer + herbicide

(2) Stand attributes:

INSTALL - installation
PLOT - plot
DIS - district (C1-young stands; C2-pole stands)
TPA - trees per acre
TOPH - stand top height (ft)
BA - basal area (ft^2/acre)
VOL - total volume (ft^3/acre)
HT - mean tree height (ft)
DBH - mean diameter at breast-height (in)
CAL - mean caliper (in)

Appendix C. Species composition (percent basal area) for each plot

OBS	INSTALL	PLOT	DIS	TRT	DF %	GF %	WL %	LP %	PP %
1	BOI	1E	C1	2	0.0	0	0.0	34.6	65.4
2	BOI	1W	C1	0	0.0	0	1.1	40.7	58.2
3	BOI	2E	C1	1	0.0	0	0.1	24.1	75.8
4	BOI	2S	C1	3	0.0	0	0.1	63.5	36.4
5	BOI	3S	C1	2	0.0	0	0.0	42.8	57.2
6	BOI	3W	C1	3	0.0	0	2.6	79.6	17.8
7	BOI	4N	C1	0	0.0	0	16.5	46.1	37.3
8	BOI	4S	C1	2	0.0	0	0.0	87.8	12.2
9	BOI	5N	C1	3	0.0	0	0.7	75.3	24.0
10	BOI	5S	C1	0	0.0	0	0.0	59.1	40.9
11	BUL	1E	C1	0	0.4	0	0.0	24.2	75.5
12	BUL	1W	C1	2	0.0	0	0.0	7.3	92.7
13	BUL	2E	C1	1	1.0	0	0.0	33.1	65.9
14	BUL	2W	C1	3	0.3	0	0.0	37.7	62.0
15	BUL	3N	C1	2	0.0	0	0.0	16.9	83.1
16	BUL	3W	C1	0	0.0	0	0.0	33.2	66.8
17	BUL	4E	C1	2	0.5	0	0.0	3.4	96.1
18	BUL	4W	C1	3	0.0	0	0.0	87.5	12.5
19	BUL	5E	C1	3	0.0	0	0.0	18.1	79.1
20	BUL	5W	C1	0	0.7	0	0.0	16.7	82.6
21	CAM	1N	C2	0	0.0	0	0.0	0.0	100.0
22	CAM	1S	C2	3	0.0	0	0.0	0.0	100.0
23	CAM	2N	C2	2	0.0	0	0.0	0.0	100.0
24	CAM	2S	C2	3	0.0	0	0.0	0.0	100.0
25	CAM	3N	C2	2	0.0	0	0.0	0.0	100.0
26	CAM	3S	C2	0	0.0	0	0.0	0.0	100.0
27	CAM	4N	C2	0	0.0	0	0.0	0.0	100.0
28	CAM	4S	C2	2	0.0	0	0.0	0.0	100.0
29	CAM	5N	C2	1	0.0	0	0.0	0.0	100.0
30	CAM	5S	C2	3	0.0	0	0.0	0.0	100.0
31	CLA	1N	C2	2	31.8	0	9.5	13.0	45.7
32	CLA	1S	C2	2	5.0	0	0.0	0.0	95.0
33	CLA	2E	C2	0	70.1	0	13.9	0.0	16.0
34	CLA	2S	C2	0	18.7	0	37.1	0.0	44.3
35	CLA	3N	C2	2	32.8	0	5.0	27.7	34.5
36	CLA	3S	C2	0	60.2	0	0.0	0.0	39.8
37	CYR	1N	C1	0	.	.	.	.	.
38	CYR	1W	C1	2	.	.	.	.	.
39	CYR	2N	C1	2	.	.	.	.	.
40	CYR	2W	C1	0	0.0	0	0.0	0.0	100.0
41	CYR	3N	C1	0	.	.	.	.	.
42	CYR	3S	C1	2	100.0	0	0.0	0.0	0.0

Appendix C. continue...

OBS	INSTALL	PLOT	DIS	TRT	DF %	GF %	WL %	LP %	PP %
43	DAI	1E	C1	0	0.0	0	0.0	86.6	13.4
44	DAI	1W	C1	2	0.0	0	0.0	90.8	9.2
45	DAI	2E	C1	0	0.0	0	0.0	90.1	9.9
46	DAI	2W	C1	2	0.0	0	0.0	100.0	0.0
47	DAI	3E	C1	0	0.0	0	0.0	100.0	0.0
48	DAI	3N	C1	2	0.0	0	0.0	100.0	0.0
49	DEE	1N	C1	0	100.0	0	0.0	0.0	0.0
50	DEE	1S	C1	2	95.5	0	0.0	0.0	4.5
51	DEE	2N	C1	2	100.0	0	0.0	0.0	0.0
52	DEE	2S	C1	0	100.0	0	0.0	0.0	0.0
53	DEE	3N	C1	2	87.8	0	12.2	0.0	0.0
54	DEE	3S	C1	0	95.6	0	0.0	0.0	4.4
55	DUN	1N	C2	2	0.0	0	0.0	0.0	100.0
56	DUN	1S	C2	3	0.0	0	0.0	0.0	100.0
57	DUN	2N	C2	2	0.0	0.0	0.0	0.0	100.0
58	DUN	2S	C2	0	0.0	0.0	0.0	0.0	100.0
59	DUN	3E	C2	2	3.8	0.0	0.0	0.0	96.2
60	DUN	3W	C2	0	0.0	0.0	0.0	0.0	100.0
61	DUN	4N	C2	3	0.0	0.0	0.0	0.0	100.0
62	DUN	4S	C2	3	0.0	0.0	0.0	0.0	100.0
63	DUN	5E	C2	1	0.0	0.0	0.0	0.0	100.0
64	DUN	5N	C2	0	0.0	0.0	0.0	0.0	100.0
65	FAI	1N	C1	0	0.0	0.0	0.0	0.0	100.0
66	FAI	1W	C1	2	0.0	0.0	0.0	14.8	85.2
67	FAI	2N	C1	0	0.0	0.0	0.0	0.0	100.0
68	FAI	2S	C1	2	0.0	0.0	0.0	0.0	100.0
69	FAI	3N	C1	0	0.0	0.0	0.0	27.4	72.6
70	FAI	3S	C1	2	0.0	0.0	0.0	1.0	99.0
71	HOR	1E	C1	0	49.0	0.0	51.0	0.0	0.0
72	HOR	1W	C1	2	0.0	0.0	0.0	100.0	0.0
73	HOR	2E	C1	0	0.0	0.0	1.5	37.1	61.4
74	HOR	2W	C1	2	31.7	0.0	10.9	51.1	6.3
75	HOR	3E	C1	2	0.0	0.0	3.3	96.7	0.0
76	HOR	3W	C1	0	0.0	0.0	1.7	98.3	0.0
77	IND	1N	C1	0	0.0	0.0	0.0	24.6	75.4
78	IND	1S	C1	2	0.0	0.0	1.8	18.4	79.7
79	IND	2S	C1	0	0.0	0.0	0.1	21.0	78.9
80	IND	2W	C1	2	0.0	0.0	0.2	0.0	99.8
81	IND	3N	C1	0	0.0	0.0	0.0	6.7	93.3
82	IND	3S	C1	2	0.0	0.0	0.0	78.6	21.4

Appendix C. continue...

OBS	INSTALL	PLOT	DIS	TRT	DF %	GF %	WL %	LP %	PP %
83	JOH	1E	C1	2	0.0	0.0	0.0	0.0	100.0
84	JOH	1W	C1	0	1.4	0.0	0.0	0.0	98.6
85	JOH	2E	C1	0	0.0	0.0	0.0	0.0	100.0
86	JOH	2W	C1	2	0.0	0.0	0.0	0.0	100.0
87	JOH	3E	C1	0	0.0	0.0	0.0	0.0	100.0
88	JOH	3W	C1	1	0.0	0.0	0.0	0.0	100.0
89	JOH	4E	C1	2	0.0	0.0	0.0	0.0	100.0
90	JOH	4W	C1	3	0.0	0.0	0.0	0.0	100.0
91	JOH	5E	C1	3	0.0	0.0	0.0	0.0	100.0
92	JOH	5W	C1	3	6.8	0.0	0.0	0.0	93.2
93	LAK	1N	C2	0	0.1	2.8	0.0	96.1	1.0
94	LAK	1W	C2	3	1.3	1.0	0.0	97.7	0.0
95	LAK	2N	C2	1	0.0	0.7	0.0	99.3	0.0
96	LAK	2W	C2	2	0.0	4.1	0.0	80.0	5.9
97	LAK	3N	C2	3	1.2	0.0	0.0	98.7	0.0
98	LAK	3W	C2	2	0.0	0.0	0.0	98.6	1.4
99	LAK	4E	C2	3	0.0	0.0	0.0	100.0	0.0
100	LAK	4W	C2	2	0.0	0.0	0.0	99.6	0.4
101	LAK	5N	C2	0	0.0	0.0	0.0	100.0	0.0
102	LAK	5W	C2	0	0.0	0.0	0.0	94.9	5.1
103	MOL	1E	C1	0	0.0	0.0	0.0	0.0	100.0
104	MOL	1W	C1	2	0.0	0.0	0.0	0.0	100.0
105	MOL	2E	C1	2	0.0	0.0	0.0	0.0	100.0
106	MOL	2W	C1	0	0.0	0.0	0.0	0.0	100.0
107	MOL	3N	C1	2	0.0	0.0	0.0	0.0	100.0
108	MOL	3W	C1	0	0.0	0.0	0.0	0.0	100.0
109	NBR	1E	C1	0	10.9	0.0	0.0	5.8	83.3
110	NBR	1W	C1	2	5.2	0.0	0.0	5.0	89.8
111	NBR	2E	C1	0	62.1	1.7	0.0	12.4	23.7
112	NBR	2W	C1	2	46.0	0.0	0.0	6.9	47.1
113	NBR	3E	C1	2	9.0	0.0	0.0	4.7	86.3
114	NBR	3W	C1	0	9.4	0.0	0.0	13.2	77.4
115	OBR	1N	C1	0	0.0	0.0	41.9	58.1	0.0
116	OBR	1S	C1	2	0.0	7.4	0.0	7.4	0.0
117	OBR	2N	C1	0	0.0	0.0	0.0	0.0	100.0
118	OBR	2S	C1	2	0.0	0.0	62.7	37.3	0.0
119	OBR	3N	C1	0	0.0	24.1	0.0	75.9	0.0
120	OBR	3S	C1	2	0.0	0.0	0.0	91.1	8.9

Appendix C. continue...

OBS	INSTALL	PLOT	DIS	TRT	DF %	GF %	WL %	LP %	PP %
121	RIV	1E	C1	0	6.6	0.0	0.0	0.0	93.4
122	RIV	1N	C1	2	0.0	0.0	2.4	0.0	97.6
123	RIV	2E	C1	0	43.4	0.0	0.0	0.0	56.6
124	RIV	2W	C1	0	29.3	0.0	0.7	0.0	70.0
125	RIV	3N	C1	2	11.6	0.0	20.4	0.0	68.0
126	RIV	3S	C1	2	22.2	0.0	0.0	0.0	77.8
127	TEA	1N	C2	2	66.0	0.0	0.0	0.0	34.0
128	TEA	1S	C2	0	69.4	0.0	0.0	0.0	30.6
129	TEA	2N	C2	2	14.6	0.0	0.0	0.0	85.4
130	TEA	2S	C2	0	22.4	0.0	0.0	0.0	77.6
131	TEA	3N	C2	0	19.0	0.0	0.0	0.0	81.0
132	TEA	3S	C2	2	30.5	0.0	0.0	0.0	69.5

Appendix D.

Table 1. Analysis of variance of relative two-year Ponderosa pine response verses foliar nutrient concentration for the herbicide treatment.

Dependent Variable: RESP

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	463.23113213	0.32	0.7380
Error	7	5108.36685981		
Corrected Total	9	5571.59799195		

R-Square	C.V.	RESP Mean
0.083142	315.1725	8.57123989

Source	DF	Type I SS	F Value	Pr > F
N	1	332.97902973	0.46	0.5210
K_N	1	130.25210241	0.18	0.6854

Source	DF	Type III SS	F Value	Pr > F
N	1	455.39911895	0.62	0.4555
K_N	1	130.25210241	0.18	0.6854

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	11.30419151	1.18	0.2753	9.5529611
N	-0.00377368	-0.79	0.4555	0.0047771
K_N	-56.96959856	-0.42	0.6854	134.8474715

Appendix D.

Table 2. Analysis of variance of relative two-year Ponderosa pine response verses foliar nutrient concentration for the fertilizer and combined treatments.

Dependent Variable: RESP

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	1845.89390083	0.71	0.5928
Error	4	3446.57629208		
Corrected Total	7	5292.47019291		

R-Square	C.V.	RESP Mean
0.348777	617.4548	4.75399556

Source	DF	Type I SS	F Value	Pr > F
TREAT	1	1250.42061521	1.45	0.2947
N	1	197.01294029	0.23	0.6575
N*TREAT	1	398.46034533	0.46	0.5338

Source	DF	Type III SS	F Value	Pr > F
TREAT	1	1469.16332800	1.71	0.2617
N	1	30.45297439	0.04	0.8600
N*TREAT	1	398.46034533	0.46	0.5338

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		27.12179336 B	1.40	0.2349	19.41144172
TREAT	1	-40.61785568 B	-1.31	0.2617	31.10612443
	3	0.00000000 B	.	.	.
N		-0.00603591 B	-0.78	0.4808	0.00777244
N*TREAT	1	0.00945731 B	0.68	0.5338	0.01390718
	3	0.00000000 B	.	.	.

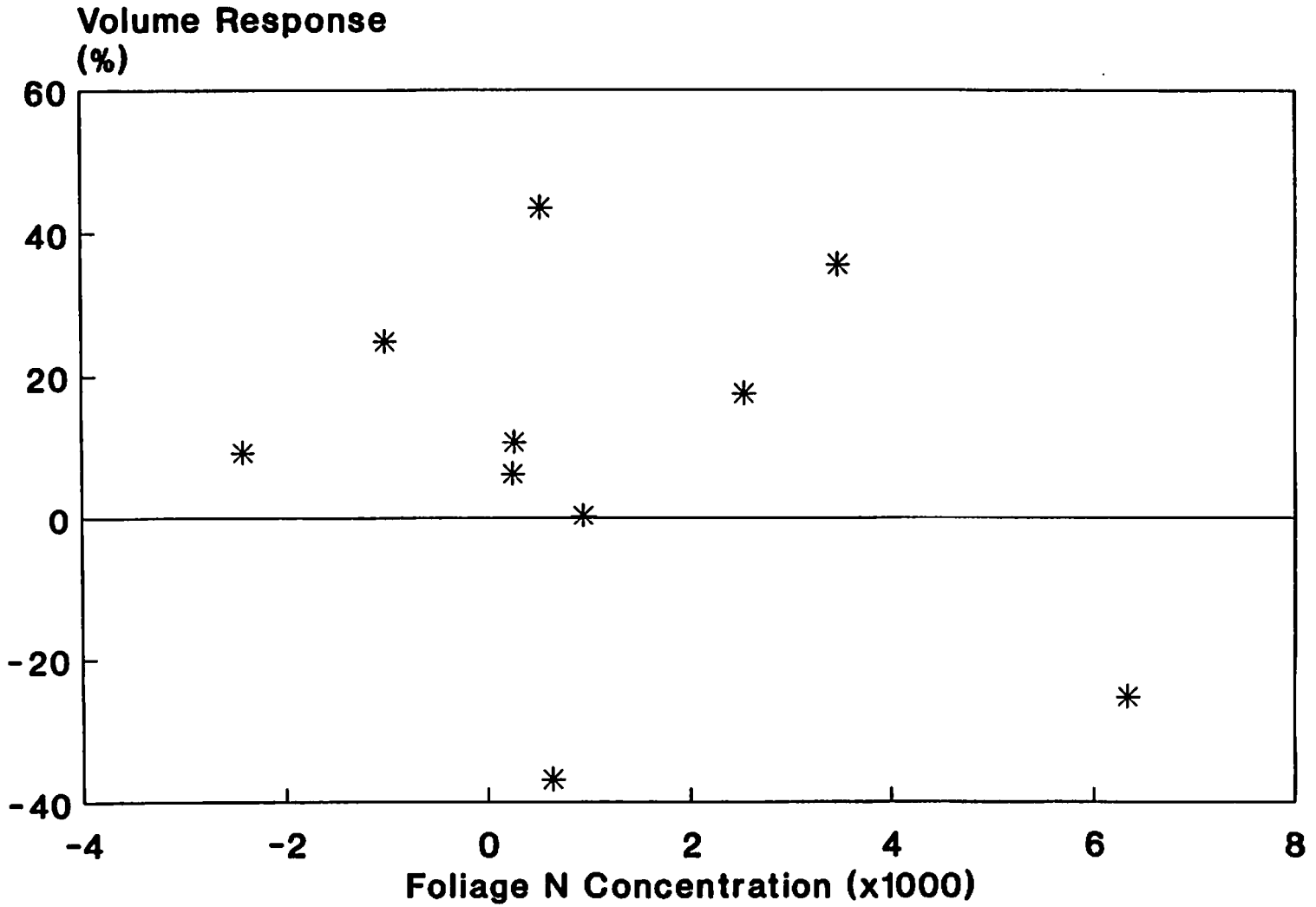

Figure 1. Two-year relative Ponderosa pine volume response verses change in foliar nitrogen concentration one year after herbicide treatment.

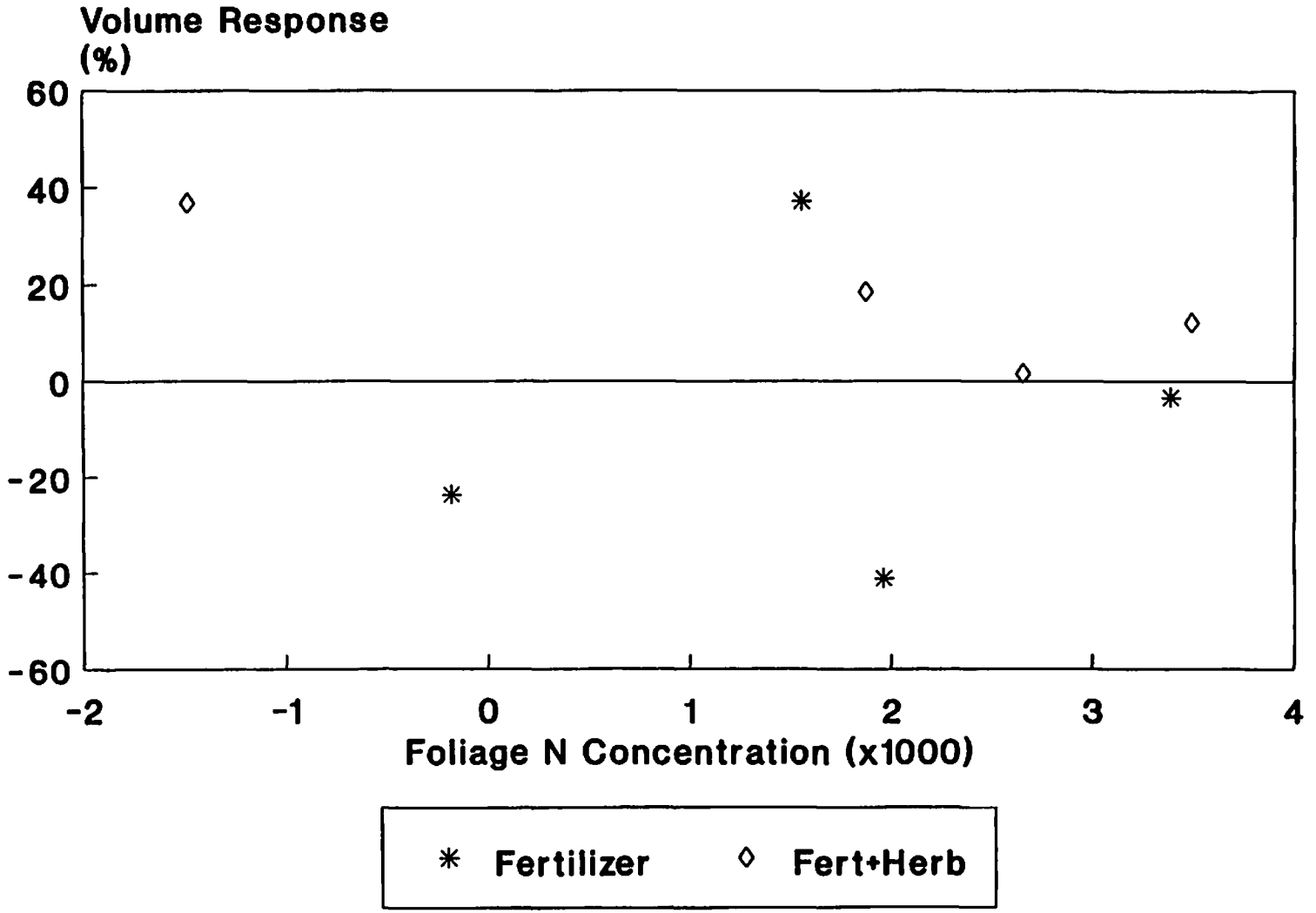

Figure 2. Two-year relative Ponderosa pine volume response verses change in foliar nitrogen concentration one year after fertilizer or combined fertilizer and herbicide treatments.