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Intermountain Forest Tree Nutrition Cooperative

Part I

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Ponderosa Pine Response to Nitrogen or Nitrogen Plus Potassium Fertilization

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PONDEROSA PINE RESULTS

Basal Area Growth Response for northeastern Oregon and central Washington:

Ten installations were established in managed ponderosa pine stands during 1985 (5 each located in northeastern Oregon and central Washington). Although they are ponderosa stands, they are situated on either Douglas-fir or grand fir habitat type series. Each installation includes six plots, each plot a minimum of one-tenth acre in size. Nitrogen fertilization treatments were assigned to the plots randomly and applied in the fall. The treatments consisted of: (1) two plots with applications of 200 pounds per acre actual nitrogen, (2) two plots with applications of 400 pounds per acre actual nitrogen, and (3) two control plots. Urea was the nitrogen source. The diameters of all sample trees were measured before treatment and again after two, four and six growing seasons.

Average basal area increment and response to the nitrogen treatments (adjusted to a common initial basal area of 120 ft^2/A) for both gross and net basal area increments are given in Table 1. The six-year gross basal area per acre increments for both the 200 and 400 lb nitrogen treatments were statistically different from the controls for both geographic regions. The gross increments for the 400 lb treatment were not significantly greater than the 200 lb treatment. In contrast to these results, the Douglas-fir trials in central Washington showed a significant increase from the 400 lb N over the 200 lb treatment. For northeastern Oregon, neither the ponderosa pine or Douglas-fir installations showed a significant increase from the 400 lb N treatment over 200 lb treatment after six years. There was no difference between the two regions for gross basal area response to the two treatments.

Gross periodic growth response to both nitrogen treatments was significant for all three

Table 1. Average six-year net and gross basal area growth response to nitrogen fertilization by treatment for ponderosa pine in northeast Oregon and central Washington.[1]

		Net Basal Area			Gross Basal Area		
		Increment	Response		Increment	Response	
Region	Treatment	ft^2/acre	ft^2/acre	percent	ft^2/acre	ft^2/acre	percent
Northeast Oregon	Control	20.7			21.2		
	200 # N	23.7	3.0 NS	14.5	24.7	3.5	16.5
	400 # N	20.5	-0.2 NS	-1.0	25.4	4.2	19.8
	400# vs 200#		-3.2 NS	-15.5		0.7 NS	3.3
Central Washington	Control	21.2			23.3		15.0
	200 # N	24.2	3.0 NS	14.2	26.8	3.5	18.0
	400 # N	20.9	-0.2 NS	-1.0	27.5	4.2	3.0
	400 # vs 200#		-3.2 NS	-15.2		0.7 NS	
Overall	Control	20.9			22.2		
	200 # N	23.9	3.0 NS	14.4	25.7	3.5	15.8
	400 # N	20.7	-0.2 NS	-1.0	26.4	4.2	18.9
	400 # vs 200 #		-3.2 NS	-15.4		0.7 NS	3.1

[1]Averages are adjusted to a common initial basal area of 120 ft^2/A.

NS = Not Significant (α = .1)

growth periods after fertilization (Table 2), and response was essentially the same in each two-year growth period (Figure 1). Therefore, response shows no sign of declining, and remains statistically significant in years 5 and 6 after treatment. The average fertilization response is somewhat less than the Douglas-fir installations in these same geographic regions, although duration of response is, thus far, similar. We don't know if the lower average response is due to species or growing season differences or derives from other causes; in any event, these responses are well within the ranges observed for the Douglas-fir trials in these two geographic regions.

Net basal area response to both treatments was non-significant for all periods, except for the 400 #N treatment in the last period (Table 2). The reason for the different results for gross and net basal area growth response is that fertilized plots had significantly higher mortality rates, particularly during years 3 and 4 than the control plots (Figure 2). This was particularly true for one installation where most of the trees died after the 400 lb treatment was applied, perhaps because of induced nutrient deficiencies. However, by years 5 and 6, the mortality episode experienced in years 3 and 4 seems to have passed. Perhaps the heavy mortality experienced on some installations relieved stresses through a thinning or "nutrient cycling" effect, thus reducing mortality rates in the last two-year period. This pattern of net response is similar to that shown by the Douglas-fir installations six years after treatment. Statistical documentation of these results and individual installation response estimates are provided in the 1992 Technical Report.

Four-year Volume Growth Response for Montana

Six additional ponderosa pine installations were established in Montana during 1987. One installation is located on a grand fir habitat type, the rest are on Douglas-fir types. The

Table 2. Average basal area response to nitrogen fertilization for each two-year period for ponderosa pine installations in northeastern Oregon and central Washington.[1]

	Net Response ft²/acre		Gross Response ft²/acre	
Period	200#N	400#N	200#N	400#N
Years 1 & 2	0.6 NS	0.6 NS	0.6	0.7
Years 3 & 4	0.1 NS	-1.6 NS	0.6	0.7
Years 5 & 6	0.8 NS	0.9	0.5	0.6

[1]Averages are adjusted to a common initial basal area of 120 ft^2/A.

NS = Not Significant ($\alpha = .1$)

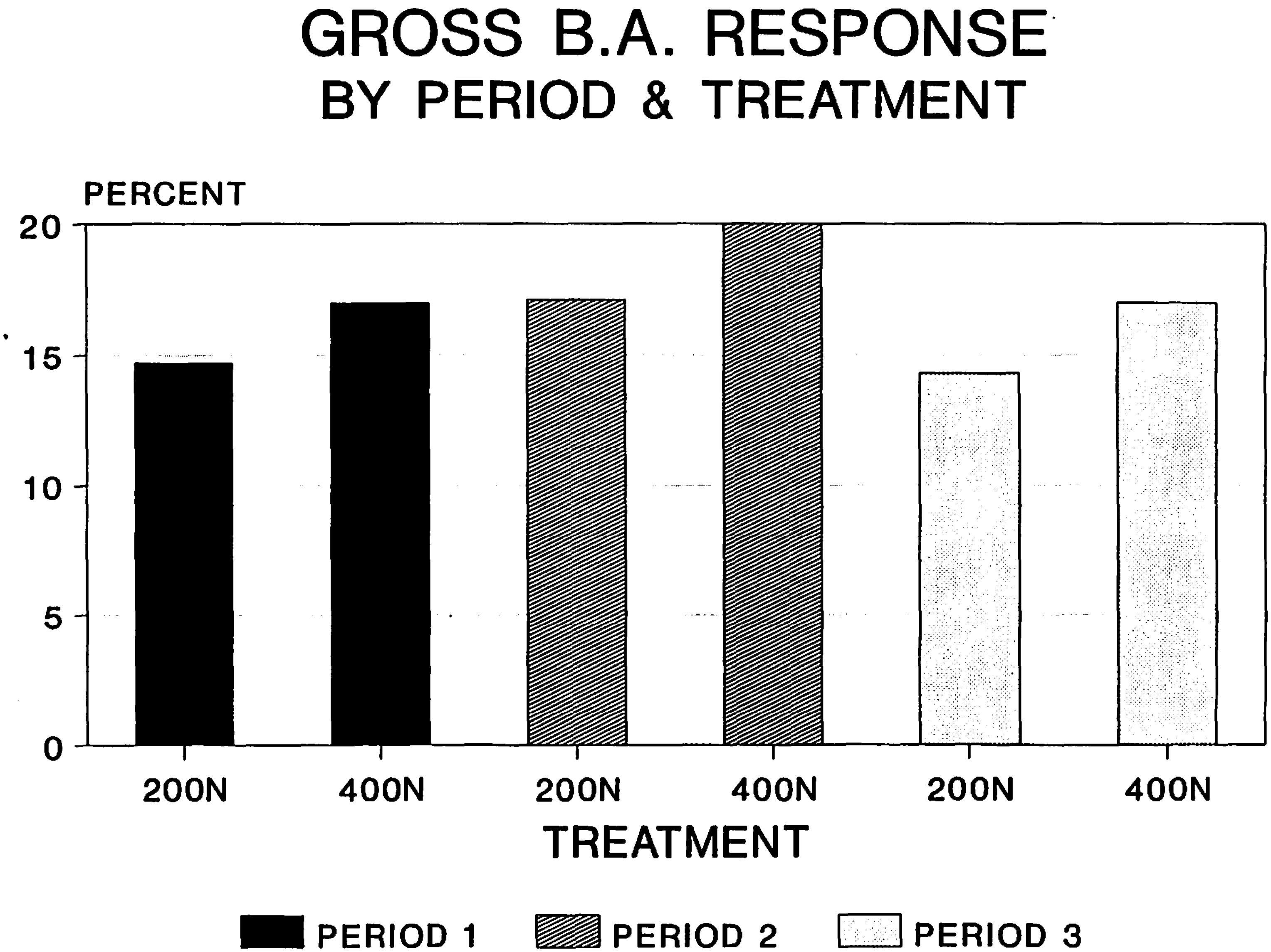

Figure 1. Relative gross basal area response by nitrogen treatment and time period for ponderosa pine installations in northeastern Oregon and central Washington.

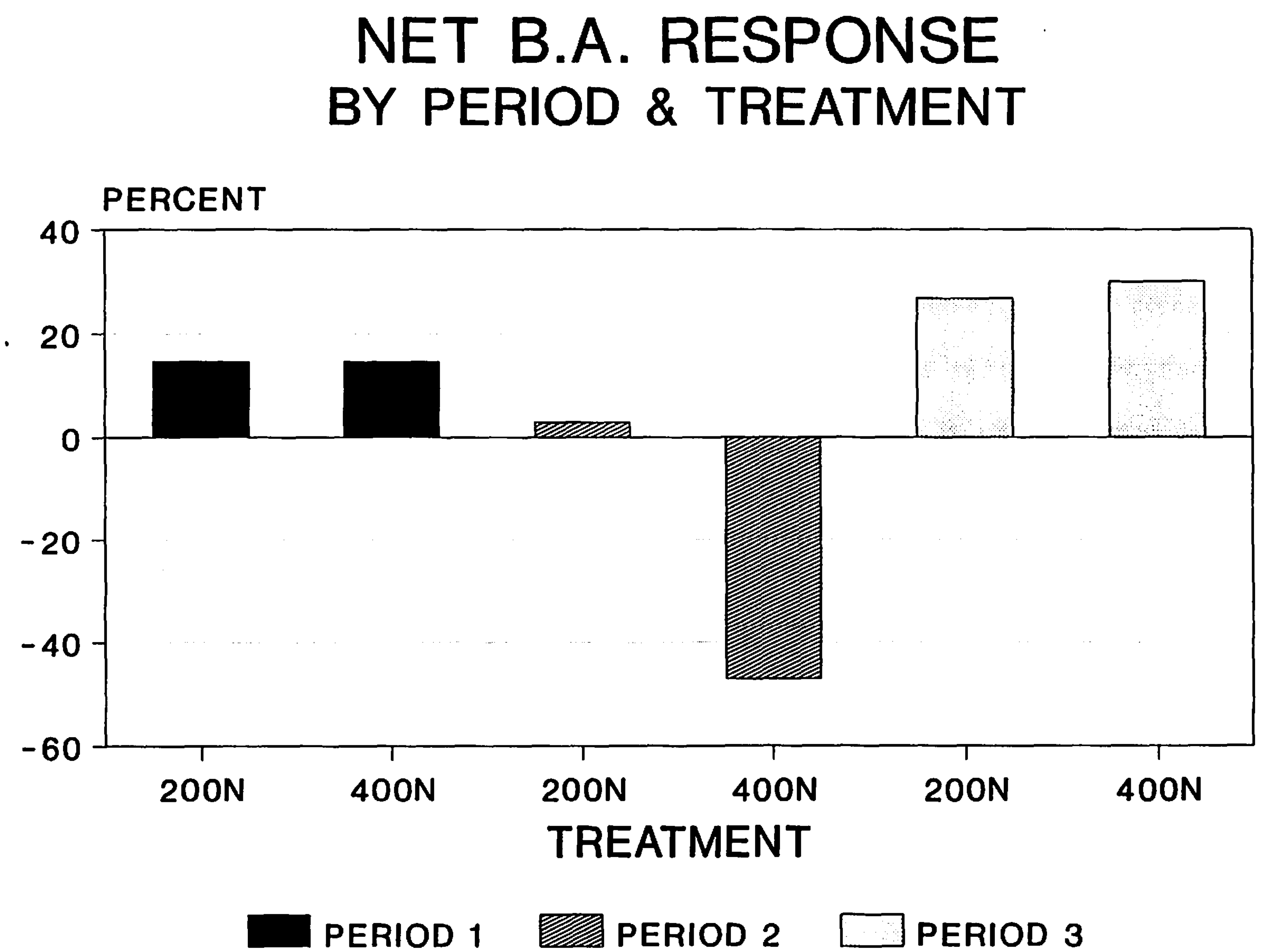

Figure 2. Relative net basal area response by nitrogen treatment and time period for ponderosa pine installations in northeastern Oregon and central Washington.

treatments were different than the other ponderosa pine trials in that by the time these sites were established we had empirically observed the influence of foliar potassium status on Douglas-fir response to nitrogen fertilization. Although the IFTNC had previously decided to retreat the Douglas-fir experiment with nitrogen and nitrogen plus potassium, this Montana ponderosa pine experiment was the first opportunity to test the effect of a nitrogen plus potassium treatment from the start of the experiment. Thus the 400 pounds per acre nitrogen treatment was replaced with a treatment of 200 pounds per acre of nitrogen plus 200 pounds per acre of potassium. The rest of the experiment was identical to other IFTNC Douglas-fir and ponderosa pine trials. Murate of potash was the potassium source.

Total height was measured for all sample trees at the start of the experiment and after the fourth growing season. Height was measured for a subsample of trees after the second growing season. Mortality was recorded by cause at each measurement period. The following analyses are based on volume growth for four years after treatment for the Montana sites. Volume equations used are from the Prognosis model for individual tree total cubic foot volume.

The average gross volume per acre response to the 200 lb nitrogen treatment was statistically significant and the 200 lb nitrogen plus 200 lb potassium treatment also produced a significant average gross volume response (Table 3). However, there was not a statistical difference between the two treatments.

Neither of the two fertilizer treatments produced a significant four-year net volume response. Despite the fact that the average net volume response to nitrogen alone was negative (-6.2%) while the nitrogen plus potassium response was positive (18.9%). However, there was a significant potassium effect (25.9%). The cumulative distributions of four-year net volume response for the two treatments is perhaps the best way to illustrate the potassium effect (Figure

Table 3. Average four-year net and gross cubic foot volume growth response to nitrogen and nitrogen plus potassium fertilization by treatment for ponderosa pine in Montana.[1]

		Net Volume			Gross Volume		
		Increment	Response		Increment	Response	
Region	Treatment	ft^3/acre	ft^3/acre	percent	ft^3/acre	ft^3/acre	percent
Montana	Control	592			603		
	200 # N	556	-37 NS	- 6.2	672	69	11.4
	200N + 200 K	705	112 NS	18.9	711	108	17.9
	K effect		149	25.2		39 NS	6.5

[1]Averages are adjusted to a common initial basal area of 120 ft^2/A.

NS = Not Significant (α = .1)

3). The N + K treatment did not produce negative responders as the nitrogen treatment did.

Including K, along with N seems to act as an "insurance policy" for fertilization since all of the installations showed positive net response to the N + K treatment, but one-half of the sites produced negative response to the N alone treatment (Figure 3). The reason for the response differences between the two treatments is the increased mortality rates on the N alone treatment. Mortality rates by cause for each installation is provided in Table 4. Mortality rates were ten times higher on the N alone treated plots than on the untreated controls. Nearly all of the mortality was due to the mountain pine beetle. In striking contrast, there were no bark beetle killed trees on the N + K plots. The beetles seem to have preferentially selected trees on the N alone plots adjacent to the control and N + K plots. Perhaps the beetles were responding to some physiological or chemical differences in the trees that were fertilized with only N.

These results support the hypothesis that inadequate K limits response to N fertilization, and demonstrates the link between nutrition, particularly K nutrition, and forest health. This experiment also shows that K nutrient status does not directly affect growth but rather influences processes related to tree mortality. This can make studying K effects difficult at the stand or forest level. However, as McDonald et al (1991) clearly show, at the tree level, N and P nutrition determine leaf area and thus growth, while K nutrition does not influence leaf area. Potassium influences many plant processes (such as water relations, production of phenolic compounds, carbohydrate transport) other than photosynthesis. McDonald et al also show that "response to limiting K supply does not involve any large shift in dry-matter allocation between shoots and roots." They further conclude that N, P, and K nutrient limitations behave "differently" ie. in trees that are K-limited, N and P can be taken-up in excess of growth

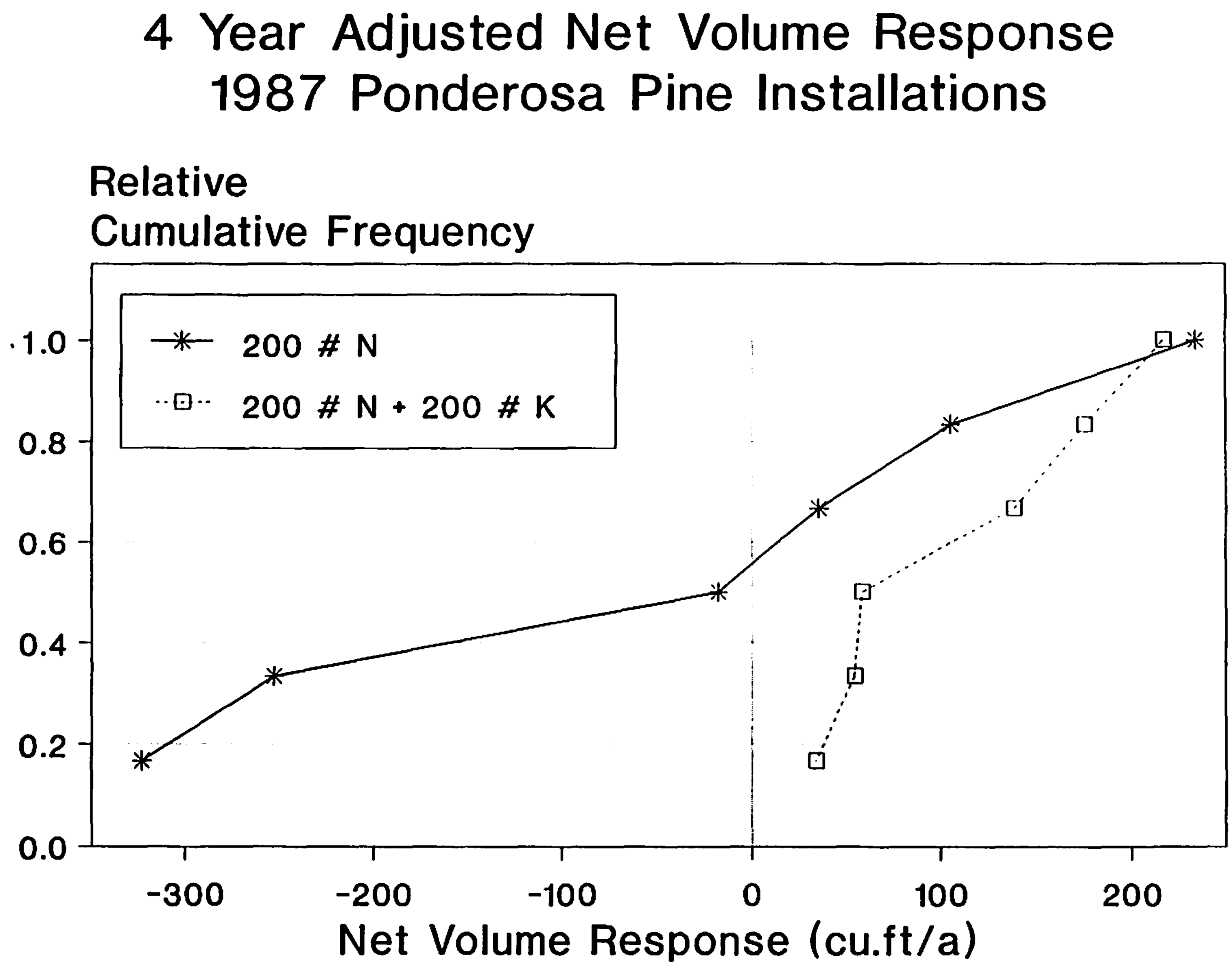

Figure 3 - Cummulative distribution of four year net volume response to nitrogen or nitrogen plus potassium fertilization for ponderosa pine installations in Montana.

Table 4. Four year mortality rate by cause and treatment for ponderosa pine installations in Montana. All mortality is in ponderosa pine.

Installation	Cause of Mortality	Mortality (trees/acre) Treatment Control	200 # N	200 # N + 200 # K
301	Bark Beetle	0	0	0
	Other	0	0	0
302	Bark Beetle	0	15	0
	Other	5	0	5
303	Bark Beetle	0	0	0
	Other	0	0	0
304	Bark Beetle	5	0	0
	Other	0	0	0
305	Bark Beetle	0	15	0
	Other	0	10	0
306	Bark Beetle	0	20	0
	Other	0	0	0
Average	Bark Beetle	0.83	8.33	0
	Other	0.83	1.67	0.83

requirements while in plants with limited N and P supplies, K uptake is closely linked to growth requirements. Their findings may explain the foliage concentration results provided in Table 5. On the average foliar K concentrations one year after the treatments increased over the controls after fertilizing with N plus K, furthermore, concentrations decreased after fertilizing with N alone. However, there was substantial variation in treatment effects on K concentrations between individual stands (Table 5). Despite the variability in foliar K levels, there was a significant (α = .10) relationship between foliar K/N ratios prior to treatment and the K effect after fertilization (Figure 4). The relationship actually fit was: K effect = -490 + 38180 * (N/K). Perhaps foliar K/N balance has some diagnostic value before deciding to fertilize ponderosa pine stands with nitrogen.

Literature Cited

McDonald, A.J.S., T. Ericsson, and T. Ingestad. 1991. Growth and nutrition of tree seedlings. In A.S. Raghavendra. (ed.) Physiology of Trees. Chap. 9. Wiley Interscience. New York. 509 p.

Table 5. Foliar nutrient concentrations one year after treatment for ponderosa pine installations in Montana.

Installation	Treatment	Nitrogen (µg/g)	Potassium (µg/g)	K/N (%)
301	Control	9860	6572	66.82
	200 # N	12459	7414	60.17
	N + K	15567	6480	41.36
302	Control	10841	10389	94.36
	200 # N	14247	6937	51.71
	N + K	13252	8331	63.31
303	Control	13395	7810	60.26
	200 # N	15650	7851	52.65
	N + K	14090	9089	65.35
304	Control	11072	7018	64.52
	200 # N	14197	7042	49.67
	N + K	14874	9576	63.65
305	Control	13657	7353	53.20
	200 # N	15387	6685	43.75
	N + K	16007	7137	44.35
306	Control	15407	6116	42.00
	200 # N	15462	7422	49.83
	N + K	15172	7348	49.01
Average	Control	12372	7543	63.53
	200 # N	14567	7225	51.30
	N + K	14827	7994	54.51

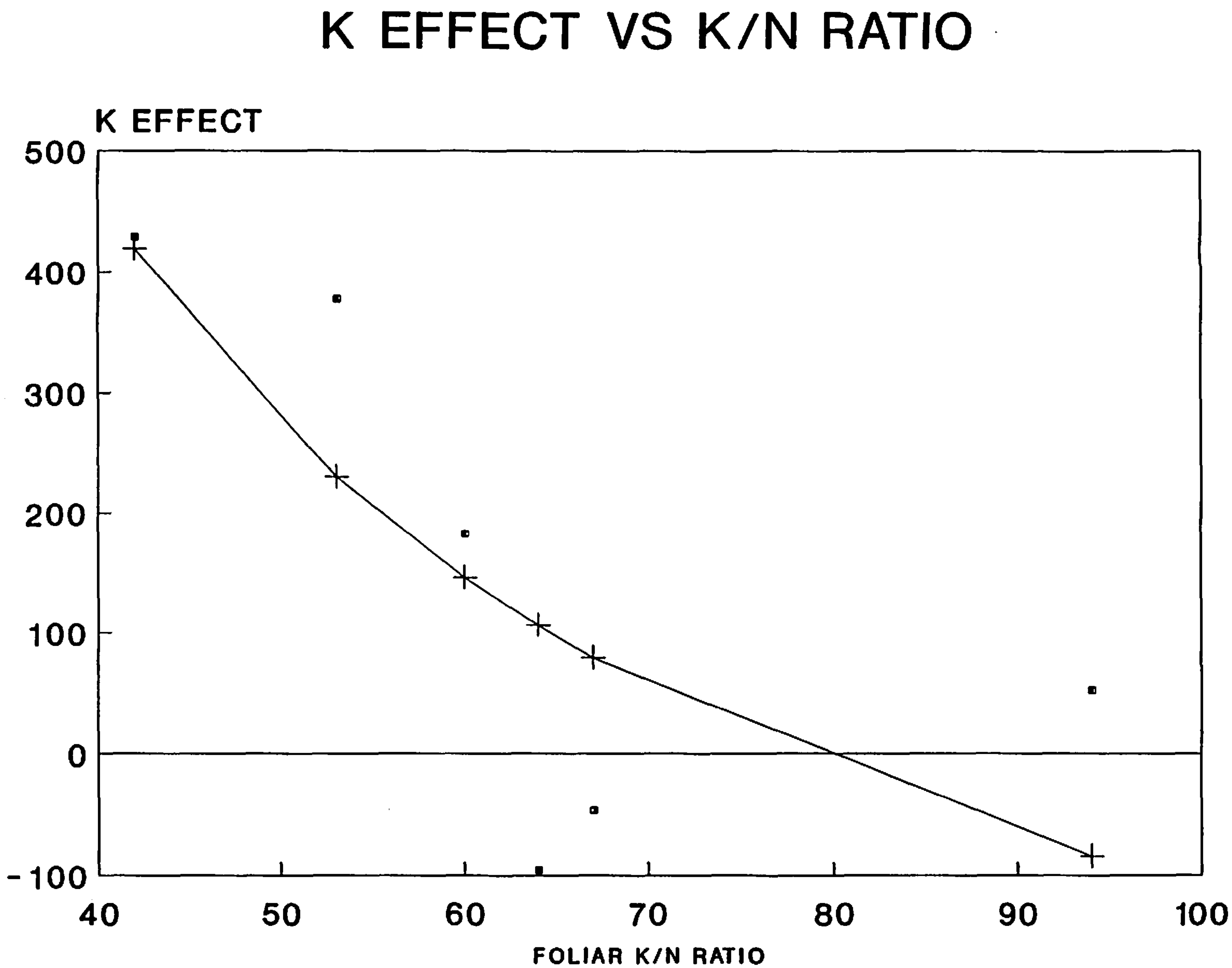

Figure 4. The relationship between potassium effect (response to N + K treatment minus response to the N alone treatment) and the pre-treatment foliar concentration K/N ratios.