INTERMOUNTAIN FOREST
TREE NUTRITION COOPERATIVE

Annual Meeting

April 12, 1994

Riverbend Room, Schoenberg Center
Gonzaga University

Spokane, Washington

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INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

GROWTH RESPONSE TO NITROGEN FERTILIZER: RESULTS FROM THE IFTNC REGION-WIDE DOUGLAS-FIR EXPERIMENTS

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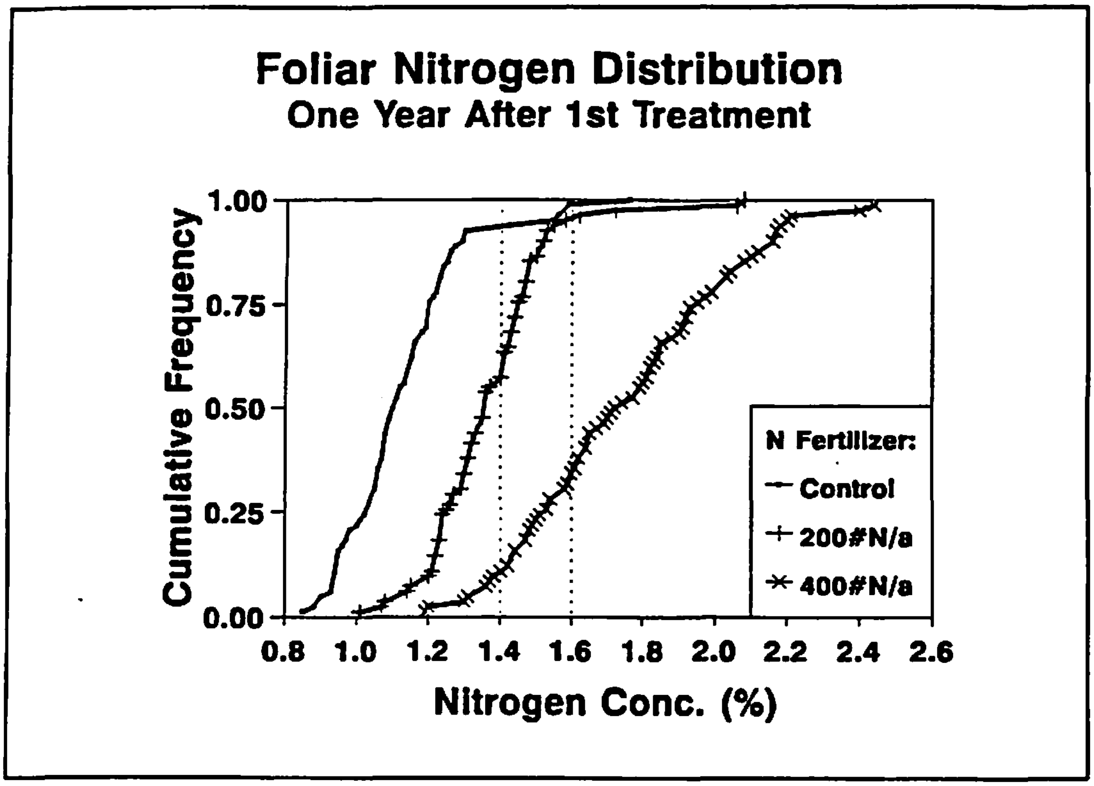
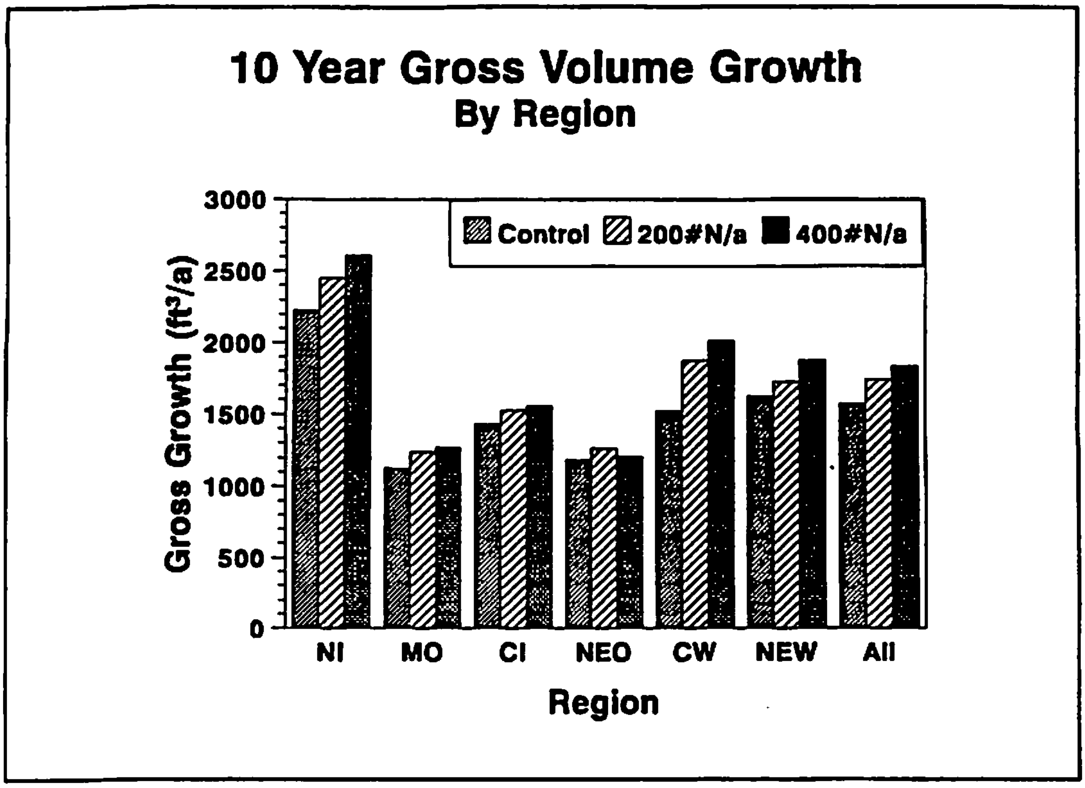
Nearly all Douglas-fir trees sampled on untreated control plots throughout the IFTNC region were below adequate (1.6%) foliar nitrogen concentration. Even after adding 200 # of N per acre, more than 1/2 of the sampled trees still had inadequate (1.4%) foliar N concentration. Only after fertilizing with 400 # of nitrogen did most sample trees show adequate foliar N concentration. These foliar diagnostics suggest that N is limited essentially everywhere in the region and that if N were supplied, growth increases of about 25% would be expected.

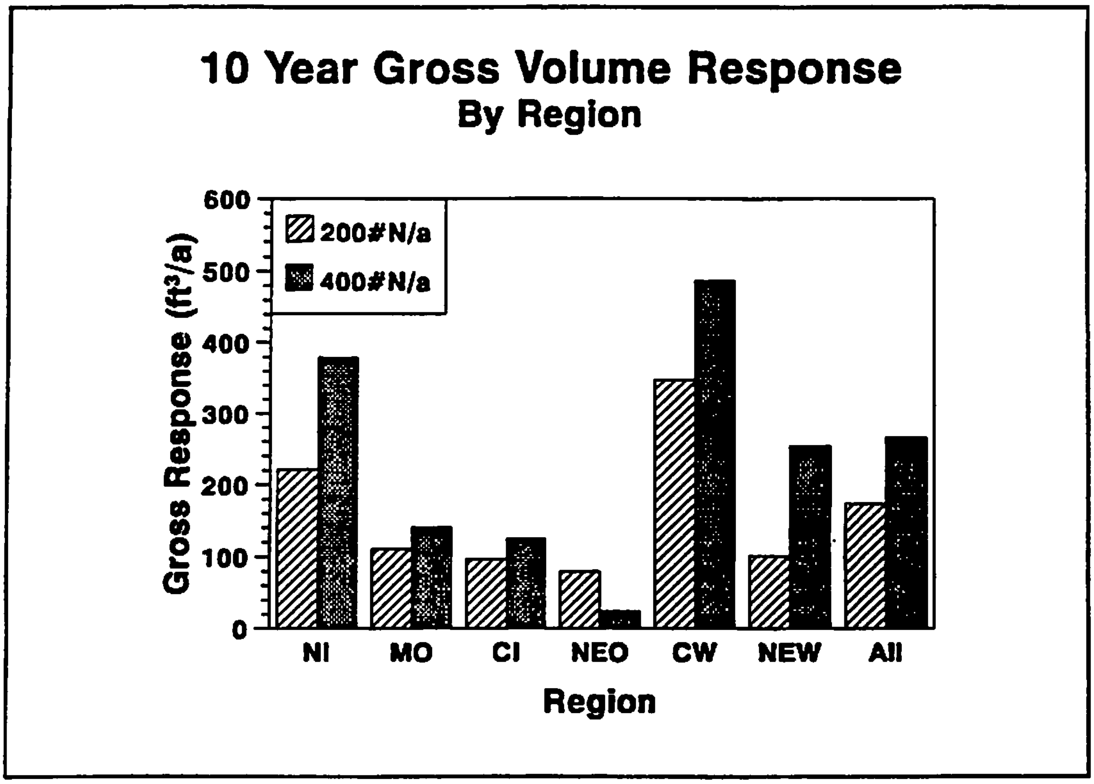


Control plot 10-year average volume growth was highest in northern Idaho and lowest in Montana and northeastern Oregon. Central and northeastern Washington were intermediate and they had about the same growth rates.

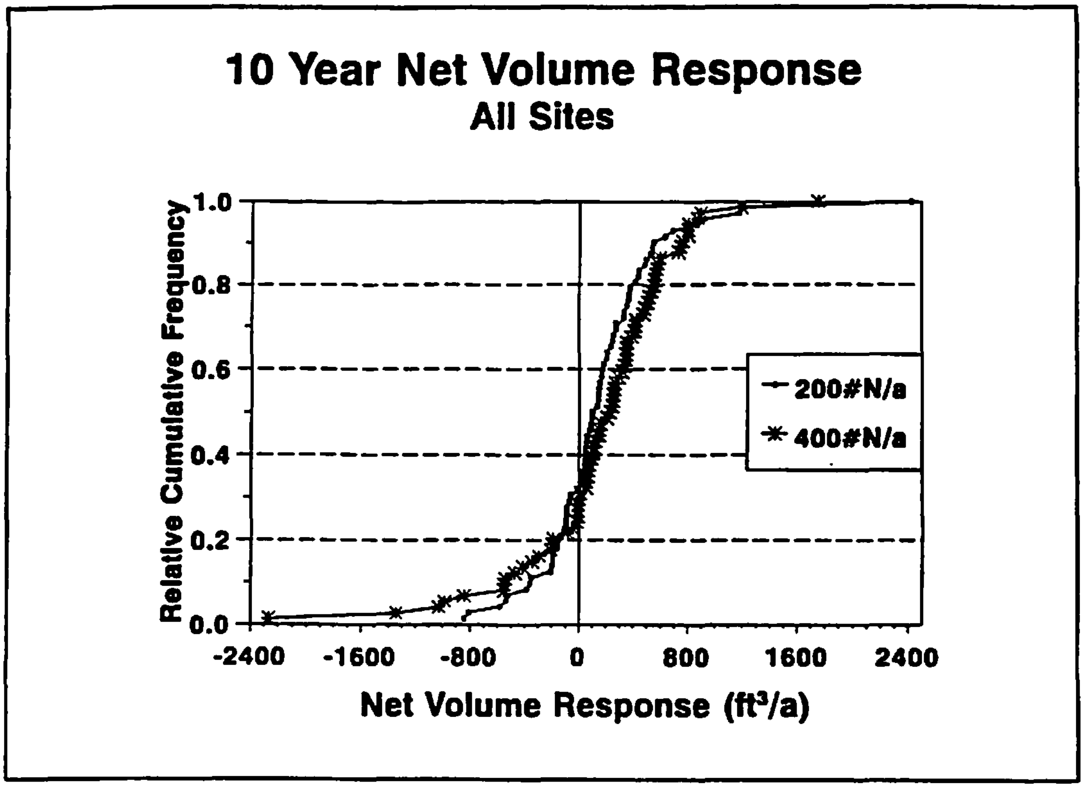
Growth response to the nitrogen fertilization treatments was not necessarily related to the untreated control plots' average growth rate.



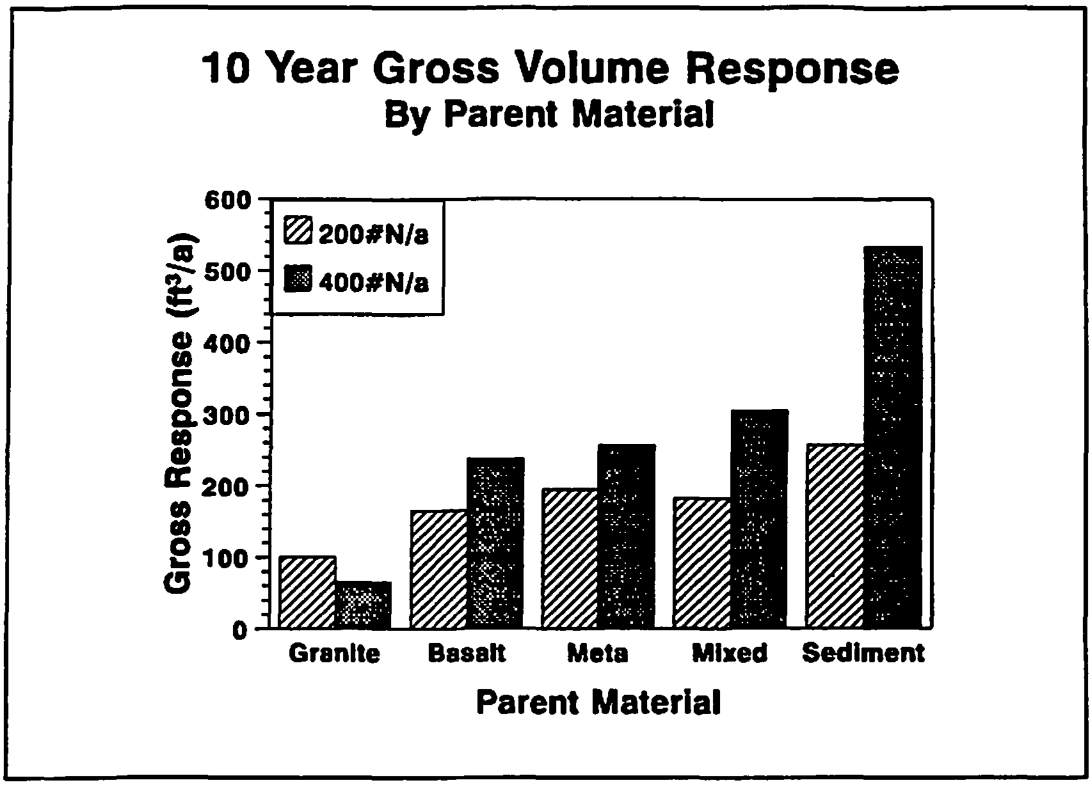
Central Washington showed the largest growth response to both nitrogen treatments (200#N ~ = 360 cu. ft. and 400#N ~ = 500 cu. ft.), and northeastern Oregon produced the lowest average N response. With the exception of northeastern Oregon, the 400 # N response was higher than the 200 # N treatment in all regions, although not significantly so in Montana and central Idaho.



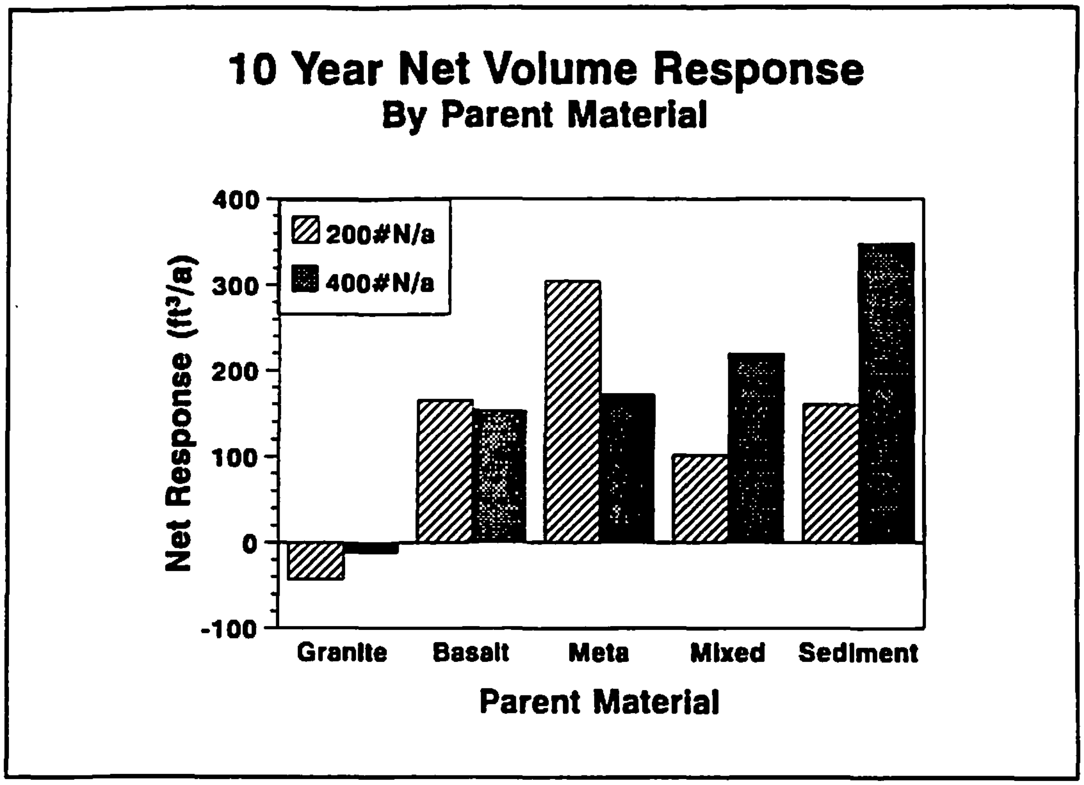
By design the IFTNC selected fertilization test sites that covered a wide range of site and soil conditions, with Douglas-fir site index ranging from 40 to 105 feet at 50 years. We expected a wide range in response to nitrogen fertilization. This figure shows that we achieved a response range from minus 2400 to plus 2500 cu. ft. per acre. The trick is to account for the variation in response to nitrogen fertilization and screen out non-responding acres in an operational fertilization program.



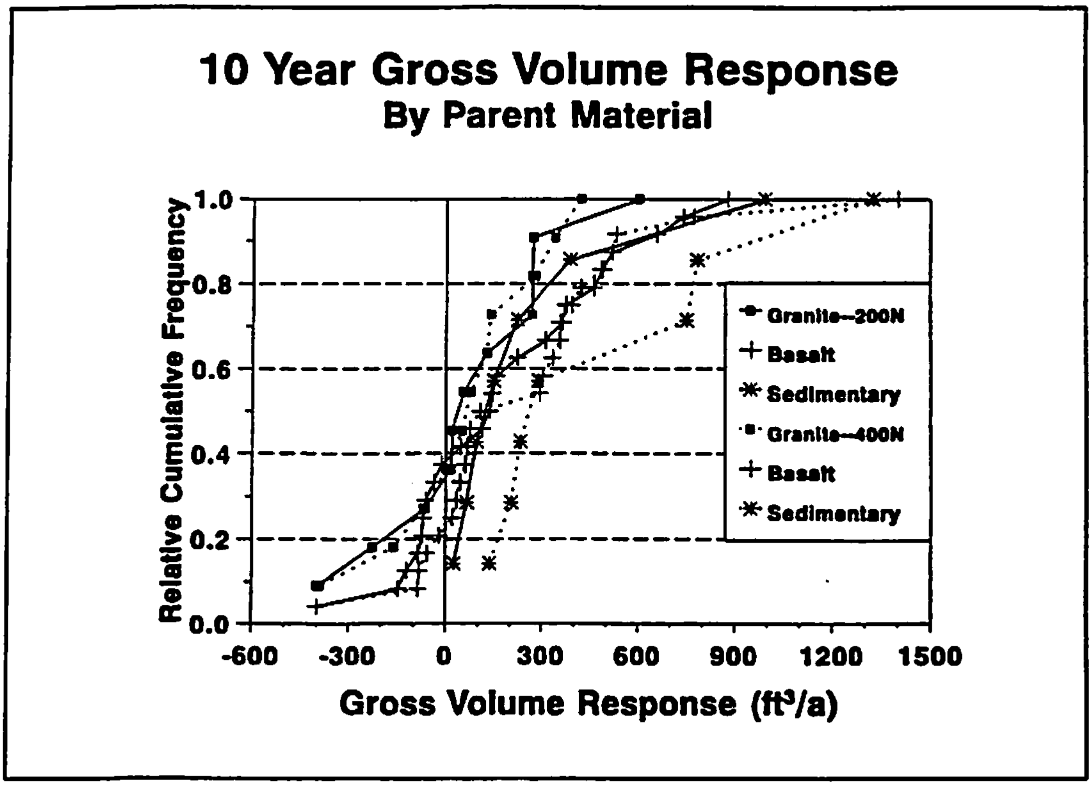
Sedimentary parent materials produced the largest response to both nitrogen treatments (400 # N response averaged > 500 cu. ft.), and the granitics the lowest. The 400 # N response was greater than the 200 # N response for all parent materials except granites.



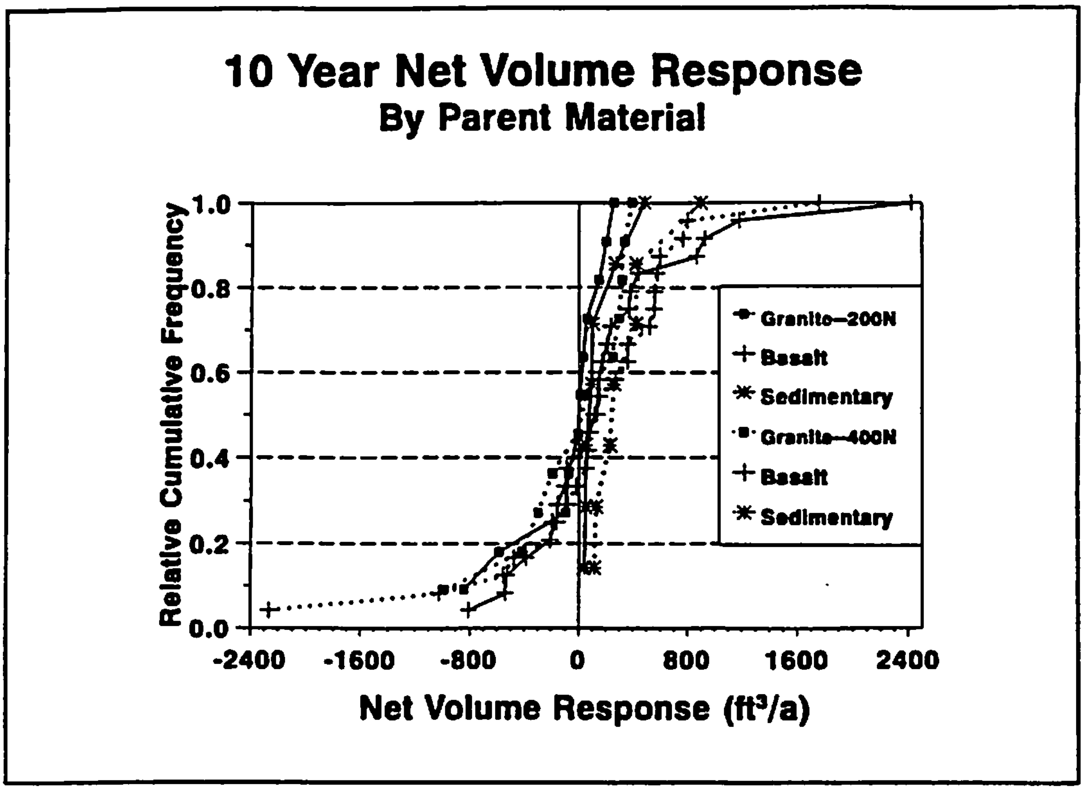
Granite parent materials showed negative net response to both nitrogen fertilization treatments, this resulted from increased treatment related mortality. The 400 # N net response on metamorphic soils was less than the 200 # N treatment , again due to higher mortality rates on the 400 # treatment.



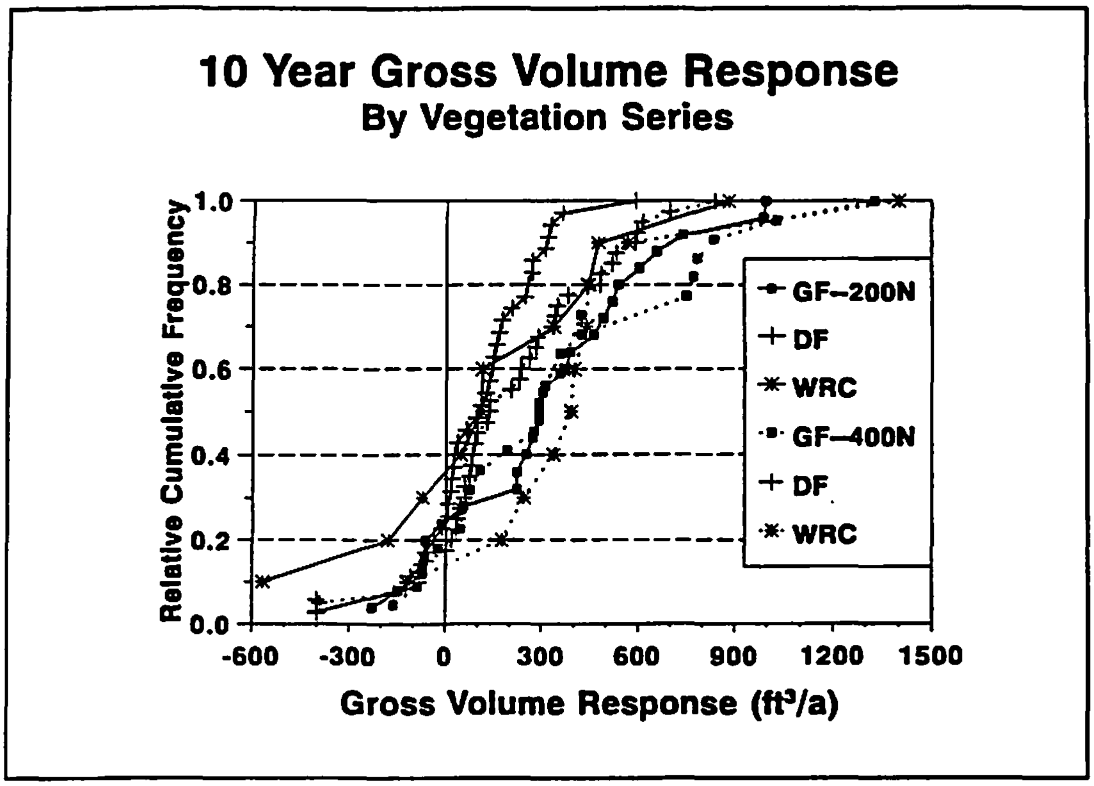
All of the large responders (greater than 500 cu. ft. per ac.) to either N treatment were on basalt and sedimentary soils. No large responders occurred on granitic soils. Soil parent material accounts for some of the wide variation in response to nitrogen fertilization.



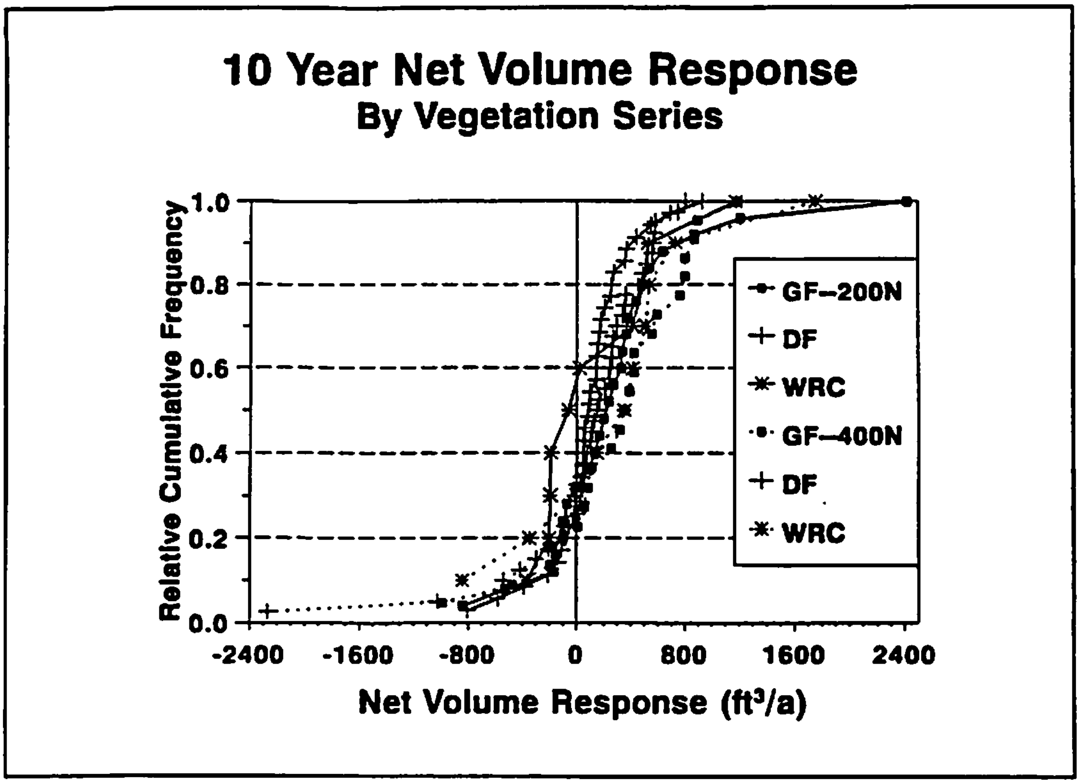
Similar to gross cu. ft. response, no large responders occurred on granitic parent materials. There were two large negative responders to the 400 # N treatment on basalt soils. There were no negative responders on sedimentary soils.



Most of the large responders (greater than 500 cu. ft. per ac.) were located on grand fir and western redcedar habitat series. Two large negative responders on the western redcedar types greatly reduced the average response to the 200 # N treatment. Theoretically, if we could eliminate all sites that respond less than the median (50th %tile) then the new median response would be the current 75th %tile, or about 400 cu. ft. for grand fir and western redcedar types. Habitat type series accounts for some of the wide variation in response to N fertilization.



Similar to gross volume response, the large responders to both nitrogen fertilization rates were on grand fir and western redcedar habitat types rather than on Douglas-fir types. The two largest negative responders resulted from the 400 # N treatment on Douglas-fir types. Fertilizing with 400 # of N on Douglas-fir types is not a good risk since there is a chance of producing large negative response but no chance of large positive response.

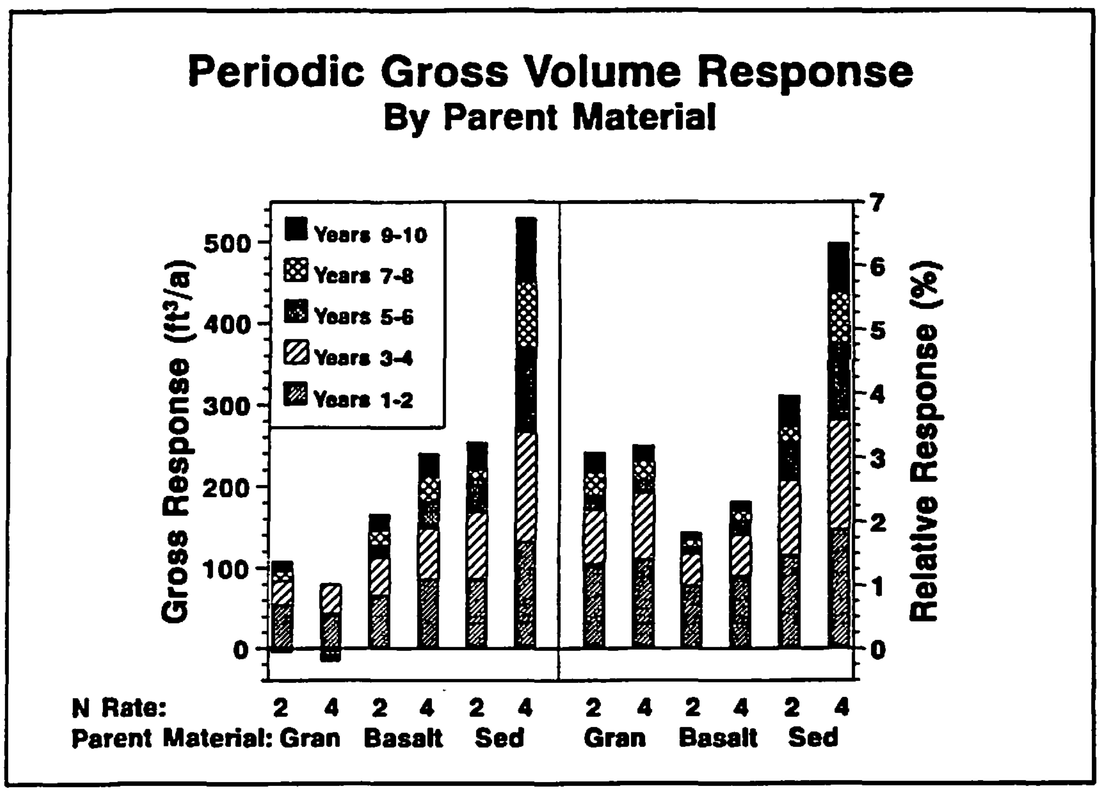


The graph on the left includes both direct and indirect N fertilization responses (ie. the extra wood that could be harvested), the total height of the bar is magnitude of response while the color codes within each bar represents duration of response. Graphs on the right represent direct N effect (this provides useful information on timing of N retreatments).

Granite soils produce weak cu. ft. response of short duration and for the 400# N treatment response is negative during the last two growth periods due to treatment induced mortality. However, on a relative basis, the surviving fertilized trees are growing faster than the control trees even in years 9 and 10 after fertilization.

On the average, basalt soils showed moderate response to N fertilization that continues throughout the ten year period. The 400 # N response was higher than the 200 # N, primarily due to longer response duration. The 400 # N treatment produces as much additional wood in 4 years as the 200 # N does in 8. Either N treatment on basalt produces more additional wood in 4 years than granitic soils do in 10 years.

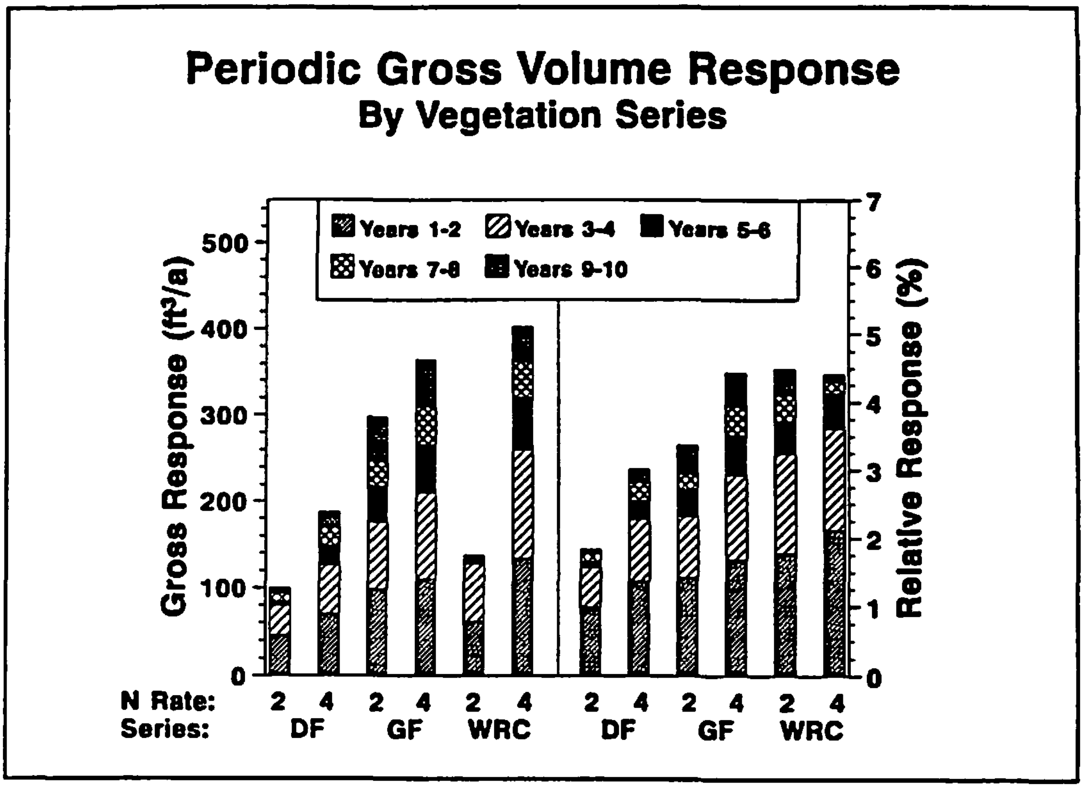
Fertilization on soils derived from sedimentary rocks produced the highest N responses in the region. Their 10-year 200 # N response is the same as the 400 # N response on basalts. The 400 # N response is significantly higher than the 200 # N, with as much extra wood produced in 4 years on 400 # treatments as in 10 years from the 200 # N. The 400 # N response on sedimentary soils remains quite strong in years 9 and 10.



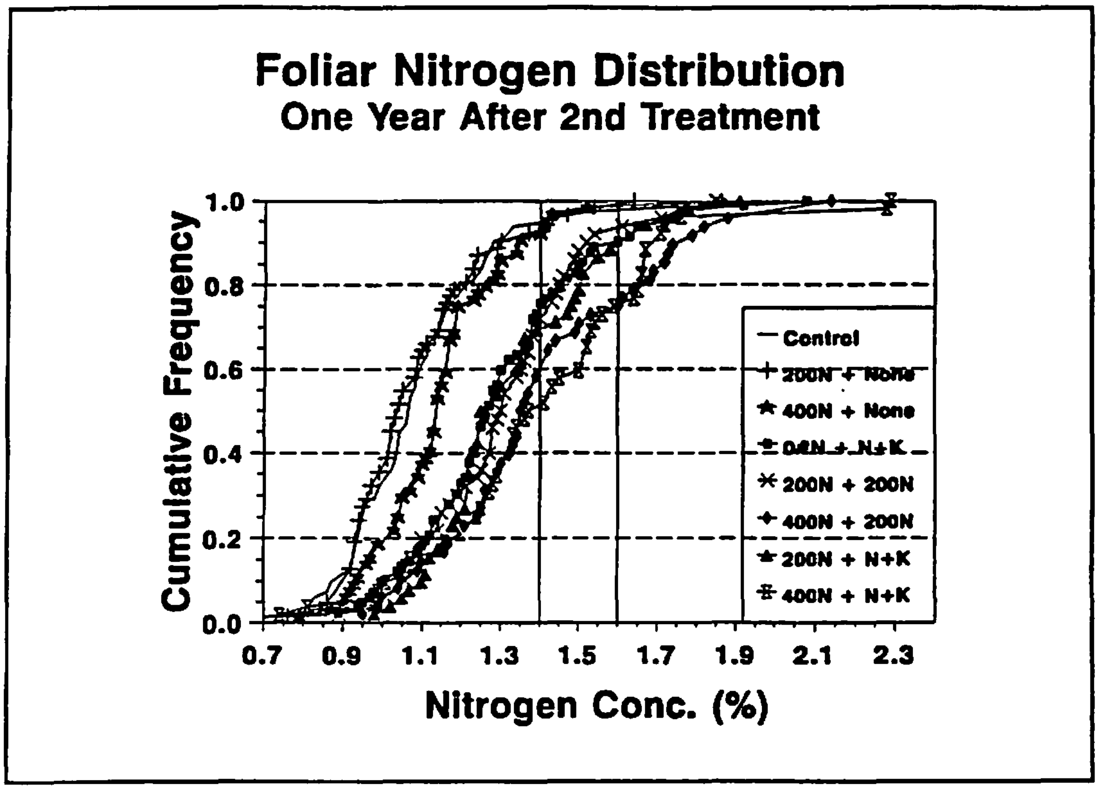
This graph is arranged in a similar fashion as the previous soil parent material graph. The panel on the left represents both direct and indirect N treatment response, and the right panel shows direct N response only.

A "stair-step" pattern is evident for both magnitude and duration of nitrogen cu. ft. growth response proceeding from the 200 # N on Douglas-fir habitat types to the 400 # N treatment on western redcedar types. The only exception to the pattern is the 200 # N treatment on western redcedar habitats. The low response results from mortality on some 200 # N treated plots; however, the surviving fertilized trees still show relatively faster growth (the panel on the right) than the untreated trees in years 9 and 10.

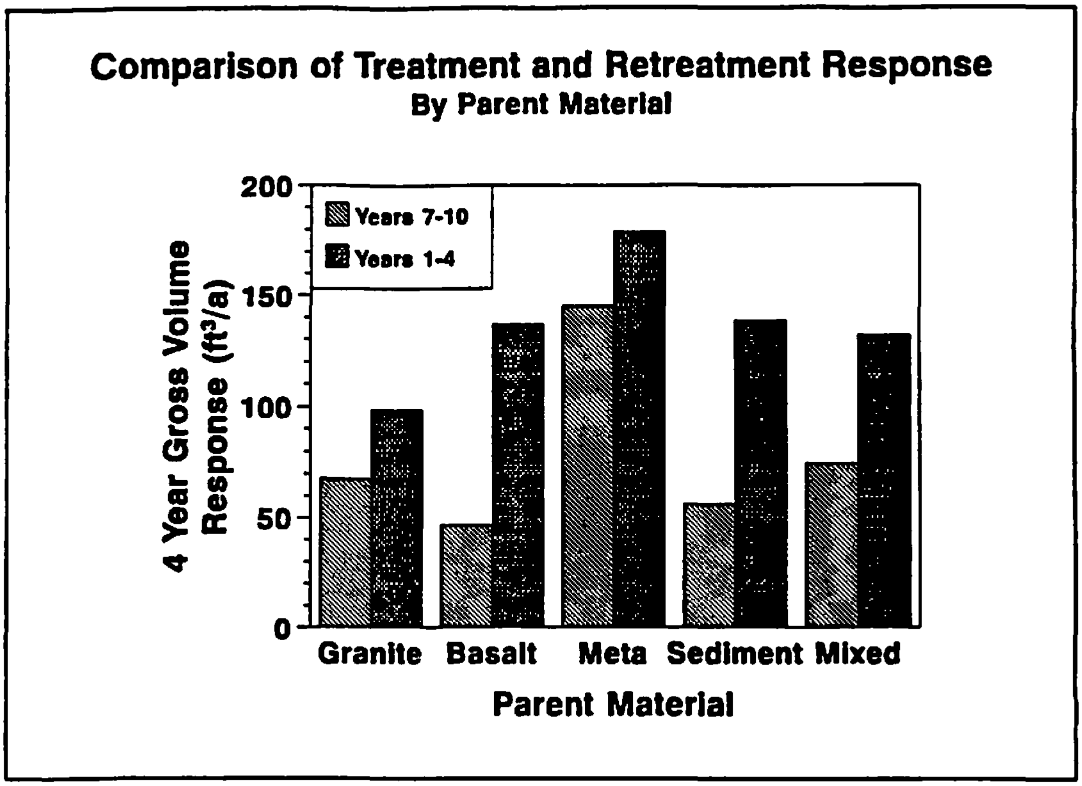
Both N treatments on grand fir habitats and the 400# N on western redcedar produced equal or greater fertilization response in 4 years than Douglas-fir types do in 10 years.



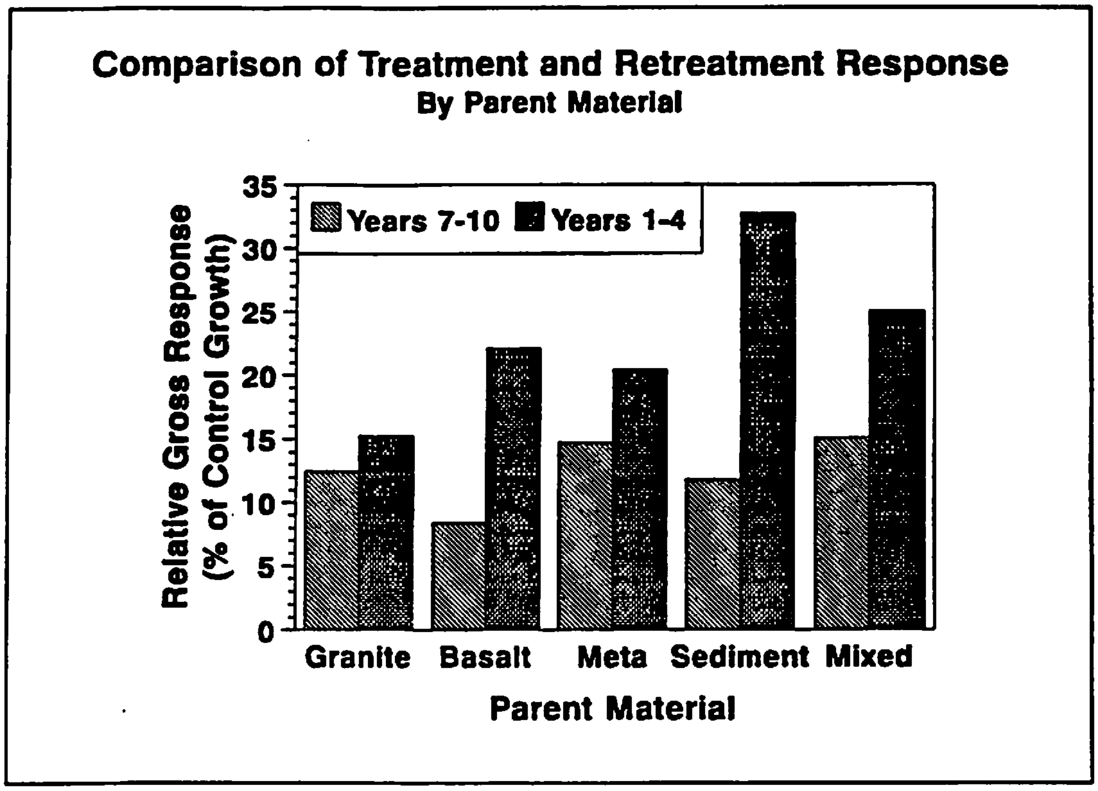
The original 400 # N fertilization still shows foliar N concentrations that are elevated over the control plots six years after the original treatments were applied. The increase in foliar N concentrations from the 200 # N retreatments (regardless of whether combined with K) was about the same as for the original 200 # N treatments. Nitrogen uptake is very consistent across a wide variety of sites even given different years and associated variation in growing conditions. Based only on these foliar diagnostics, we would expect about the same growth response to the retreatments as occurred after the original treatments (except for the original 400 # N treatments).



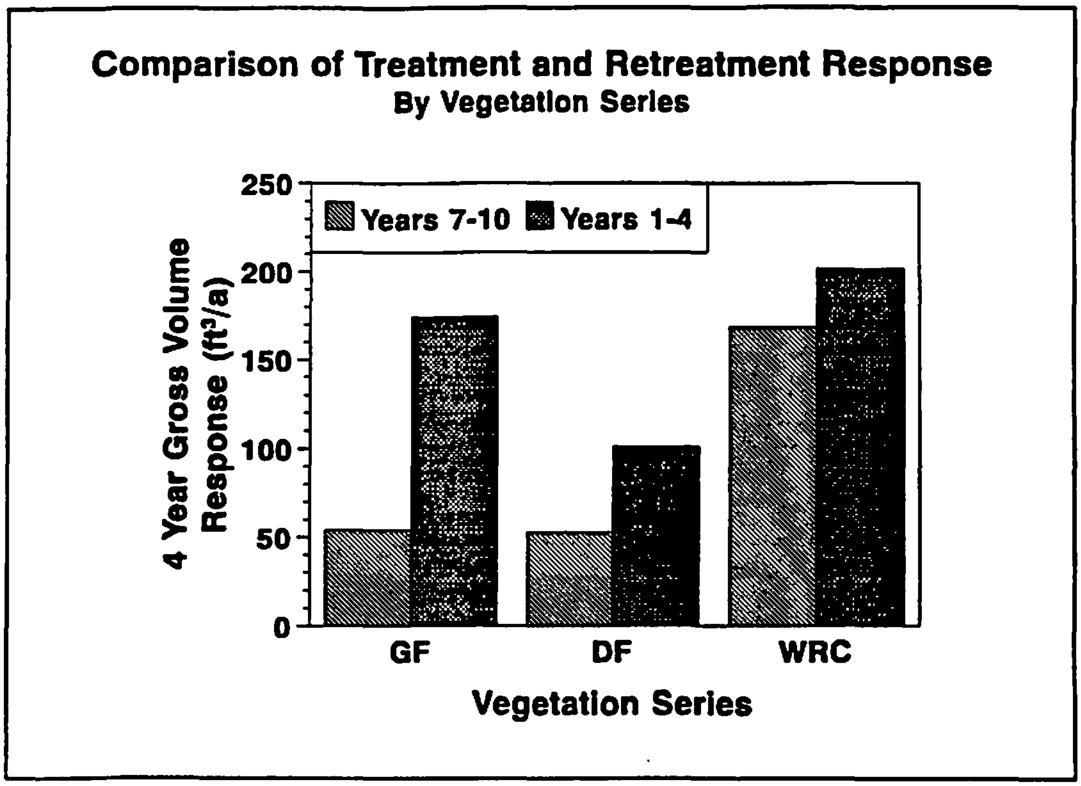
The absolute cu. ft. response (both direct and indirect effects) to the 200 # N retreatments (years 7-10) was less than for the original 200 # N treatments response (years 1-4) for all soil parent materials.



Just as for absolute response, the relative (growth on fertilized plots/growth on control plots) response to the 200 # N retreatments was also less than the original treatment response for all parent materials. Retreatment response was particularly less on those soils that produced the largest response to the original N treatments. This suggests that the original fertilization effects have not "worn off" and that six years is too soon to retreat with N to obtain the same growth response per pound of N applied.



Similar to the retreatment comparisons for soil parent material, all habitat types showed less growth response to the N retreatments than to the original 200 # N treatment. The retreatment response on redcedar habitat series was almost the same as for the original response.



INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

TEN YEAR WITHIN-STAND DISTRIBUTION OF GROWTH RESPONSE TO NITROGEN FERTILIZATION

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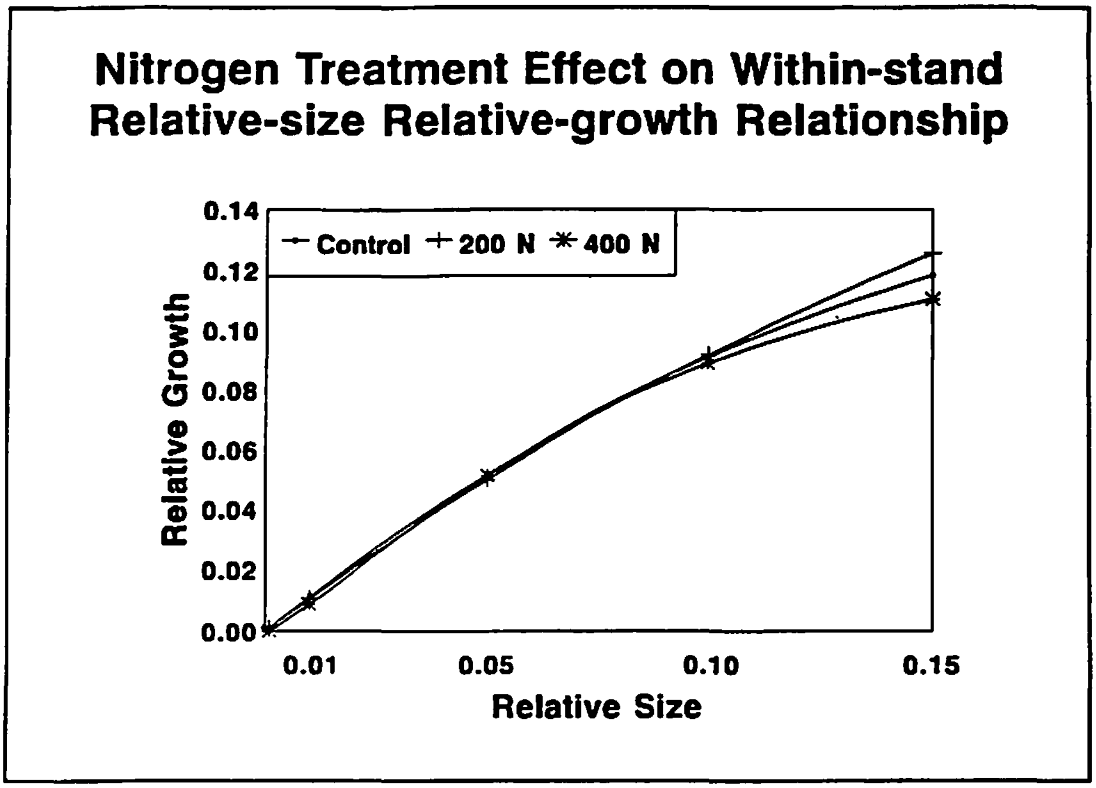
The nitrogen fertilization treatments had little effect on the characteristic within-stand relationship between individual tree relative growth and relative size. On a relative basis, trees that were growing well before nitrogen fertilization responded well to the treatments.

There is a slight trend for large trees to grow relatively less after nitrogen fertilization.



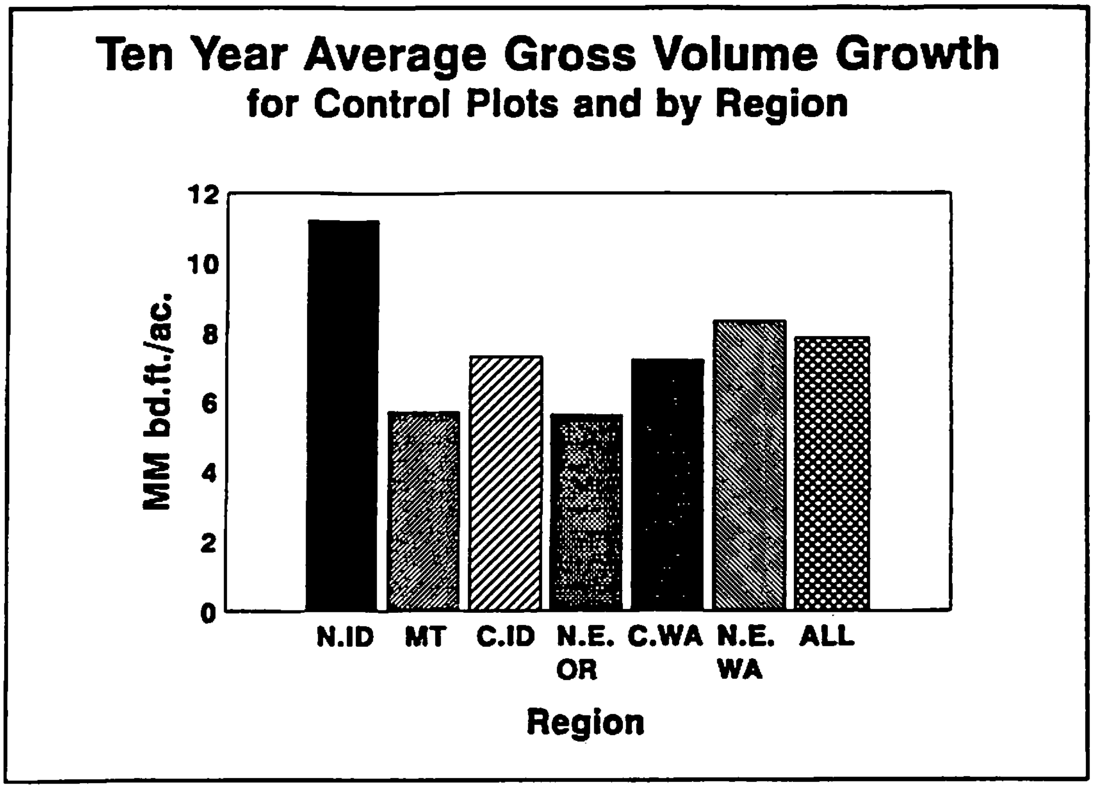
INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

TEN YEAR BOARD FOOT RESPONSE TO NITROGEN FERTILIZATION FOR DOUGLAS-FIR

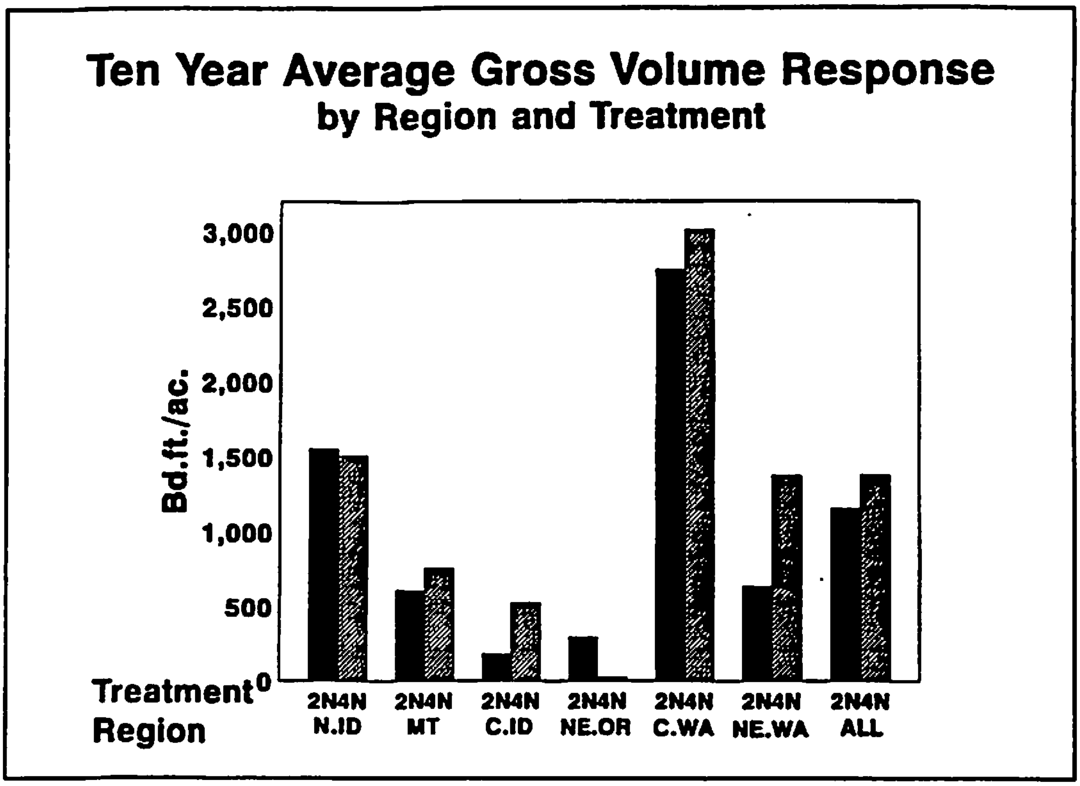
JIM MOORE

UNIVERSITY OF IDAHO
MOSCOW, IDAHO

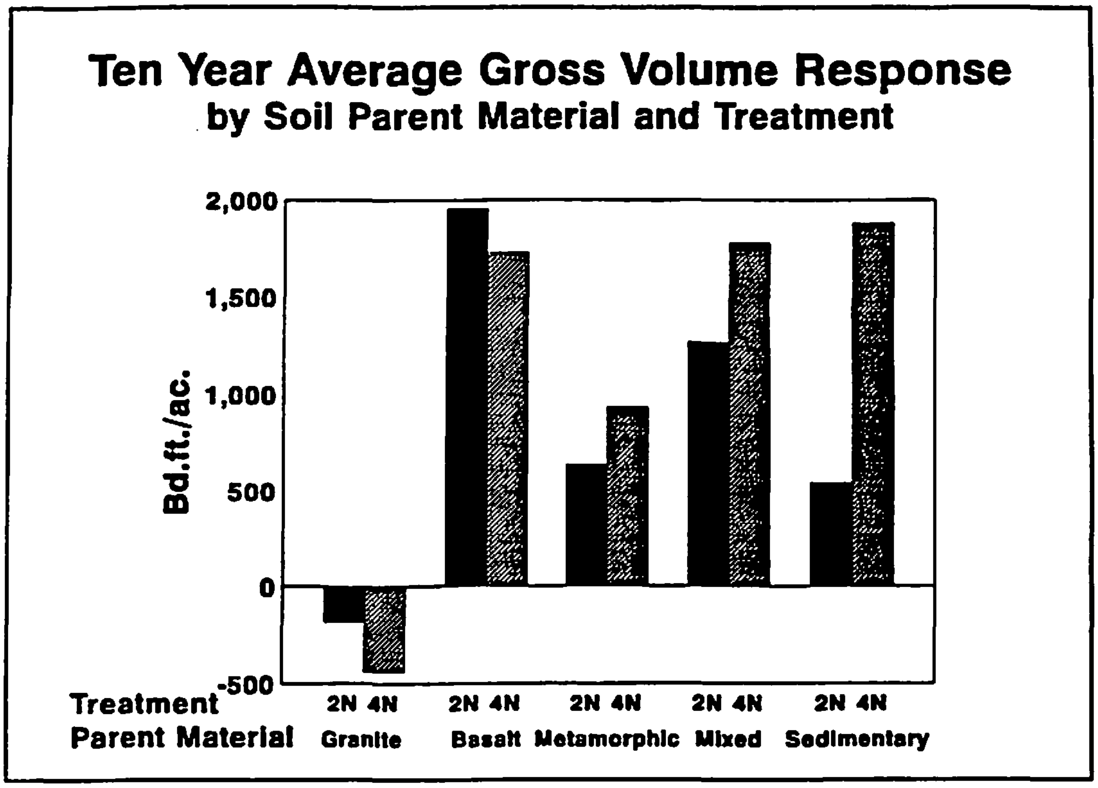
The northern Idaho region shows the highest periodic growth rates for the untreated control plots. The other regions are all about the same.



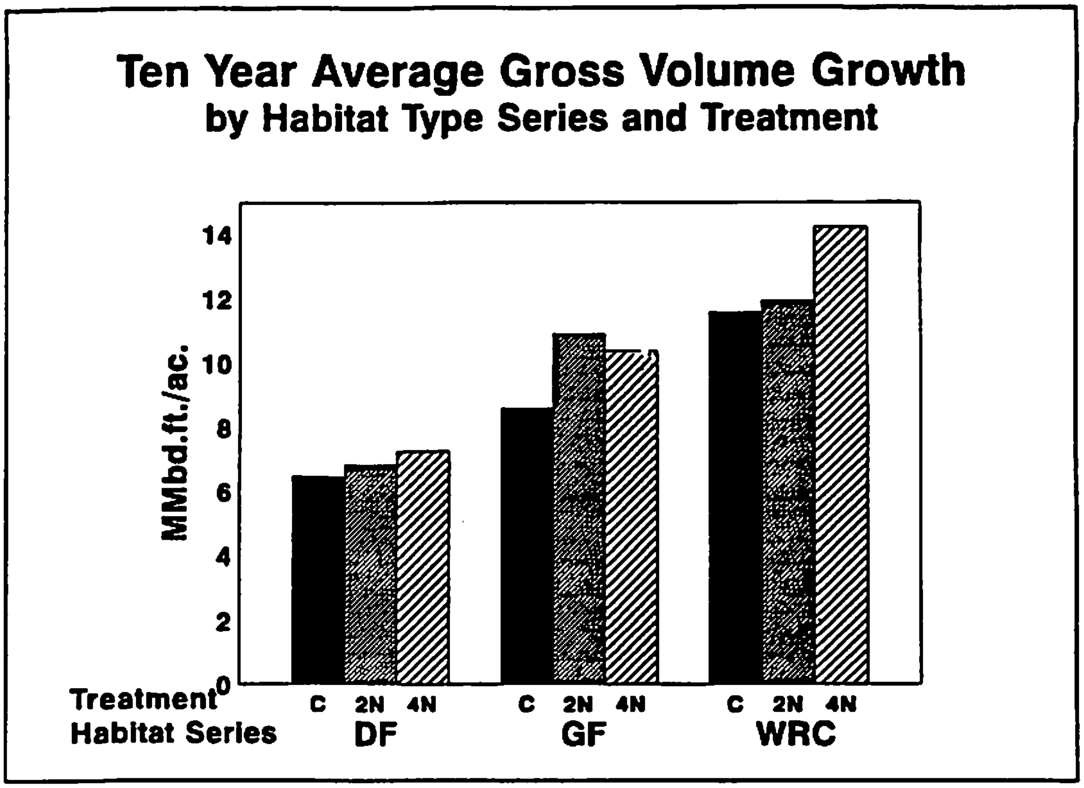
Central Washington averaged about 2700 and 3000 bd. ft. per acre response to the 200 and 400 # N treatments respectively. Central Idaho and northeastern Oregon showed low average response to N fertilization.

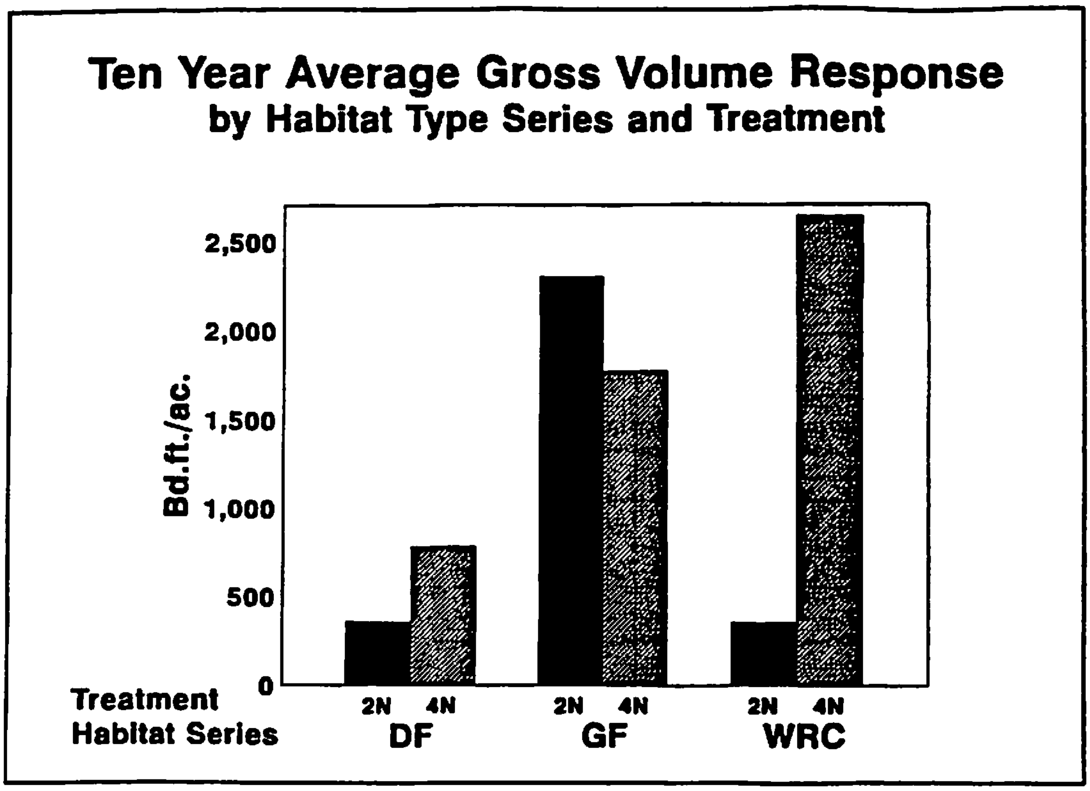


Granite soils showed negative average response to both nitrogen treatments. Basalt soils produced large average nitrogen growth response but no significant difference between the 200 and 400 # N treatments. The 400 # N treatment response was significantly greater than the 200 # N treatment on those soils derived form sedimentary rocks.

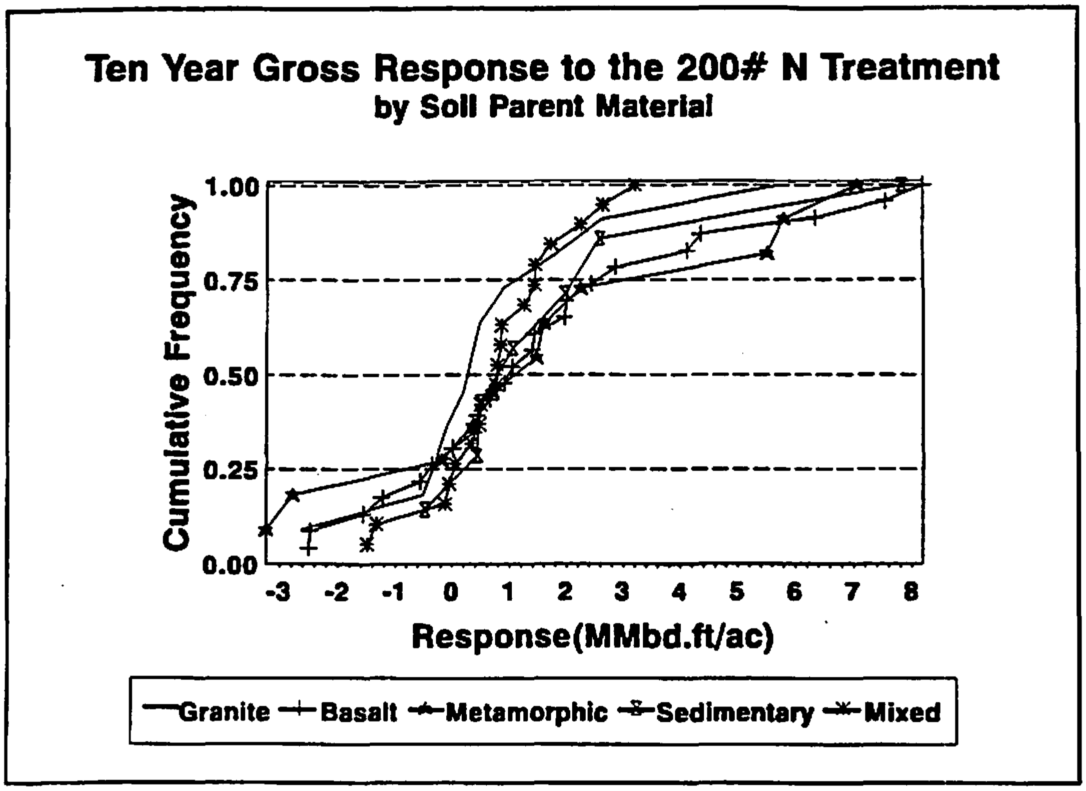


Western red cedar habitats grew faster than grand fir types which in turn grew faster Douglas-fir habitat series.

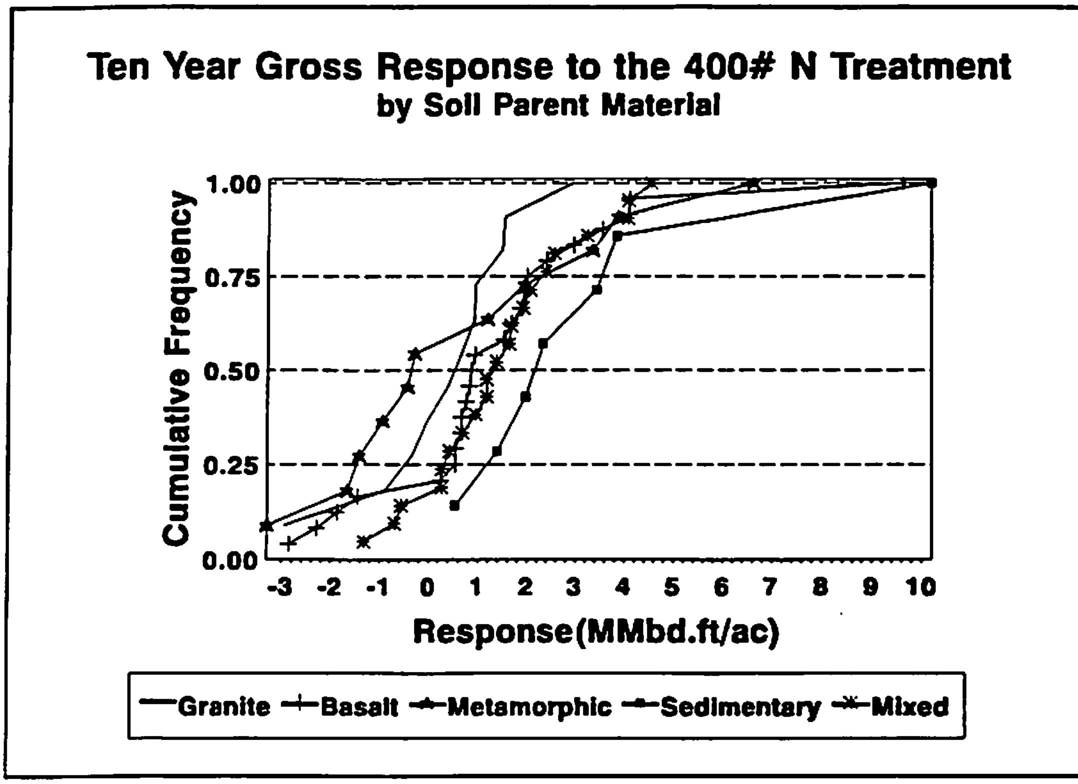



Ten Year Average Gross Volume Response
by Habitat Type Series and Treatment
2,500
2,000
1,500
1,000
500
0
Bd.ft./ac.
Treatment
Habitat Series
2N 4N
DF
2N 4N
GF
2N 4N
WRC

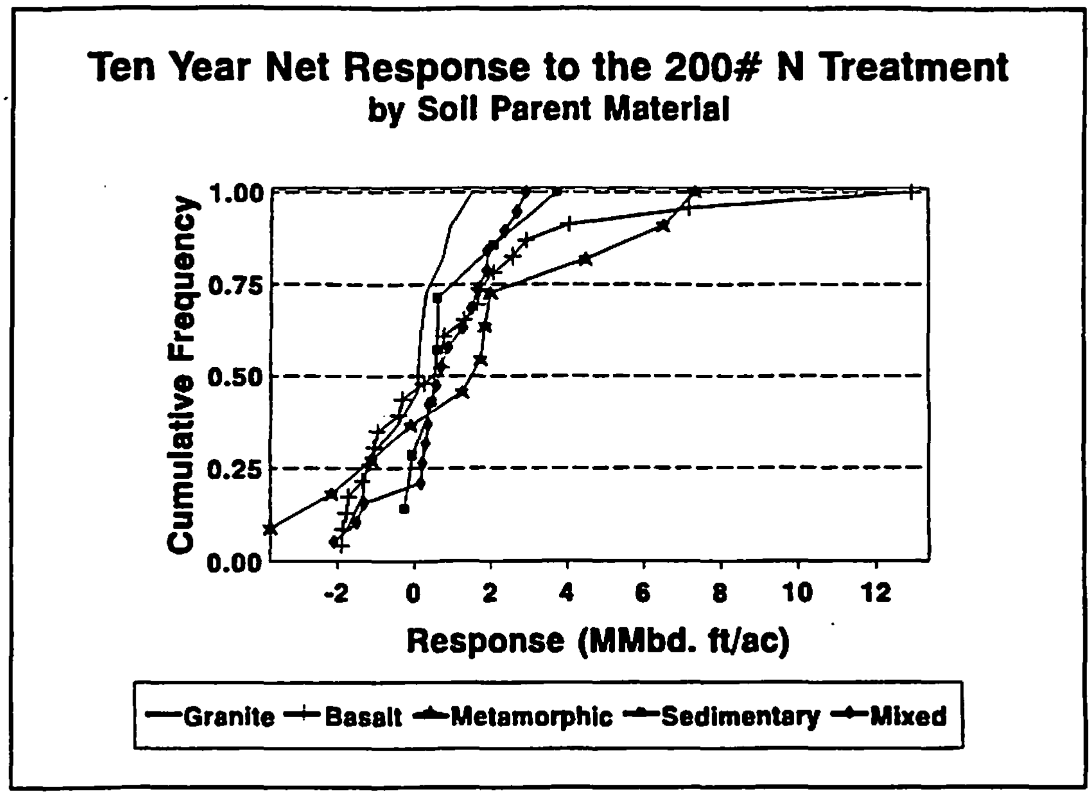
Twenty-five percent of the sites on basalt, metamorphic, and sedimentary soils showed response to the 200 # N treatment greater than ~ 2000 bd. ft. per acre.

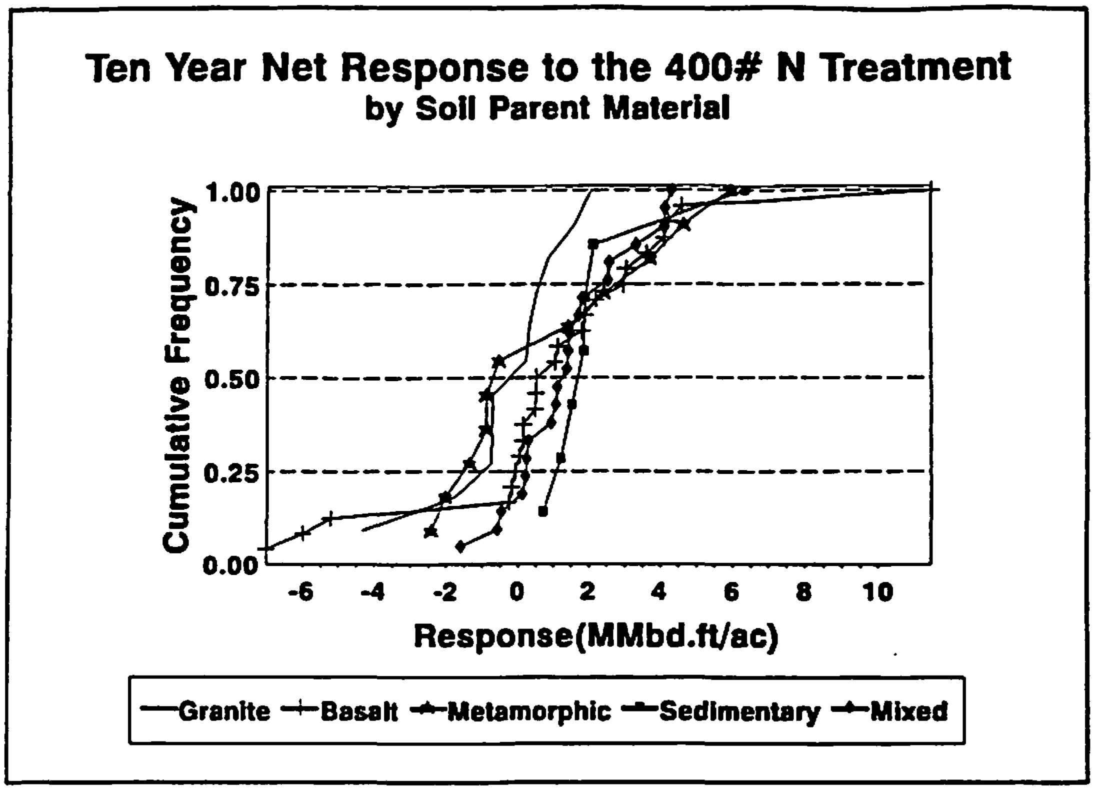


One-half of the sites on sedimentary rocks produced growth increases of more than 2000 bd. ft. per acre after the 400 # N treatment was applied. More than 1/2 of the metamorphic test sites showed negative growth response.



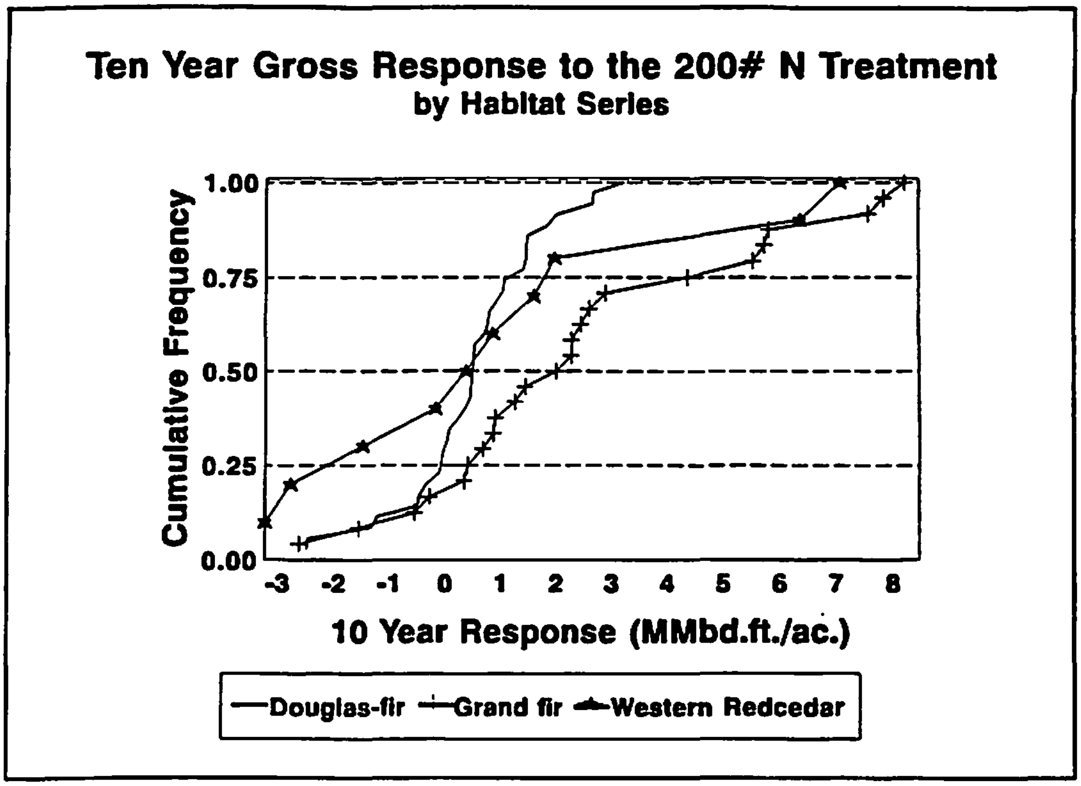
Some sites on basalt soils showed very high response to the 200 # N fertilization; however, no granite soils produced high growth response. Metamorphic soils were highly variable in their fertilization response, while sedimentary soils were much less variable.

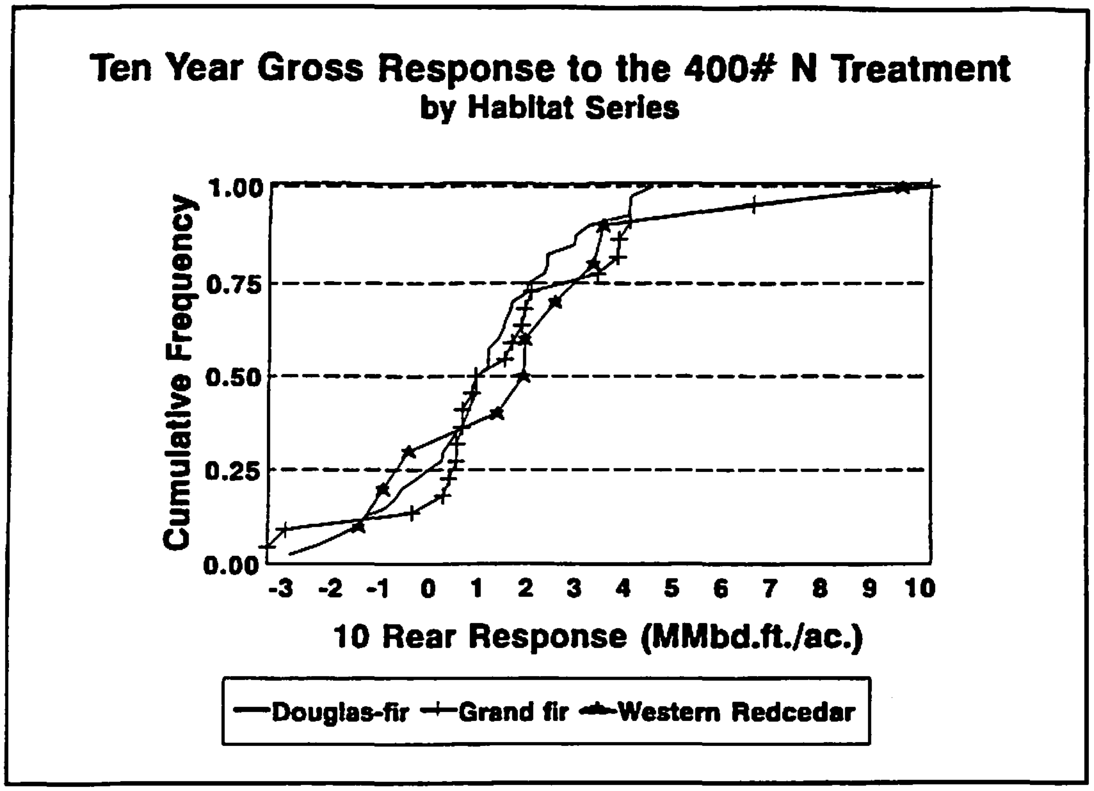




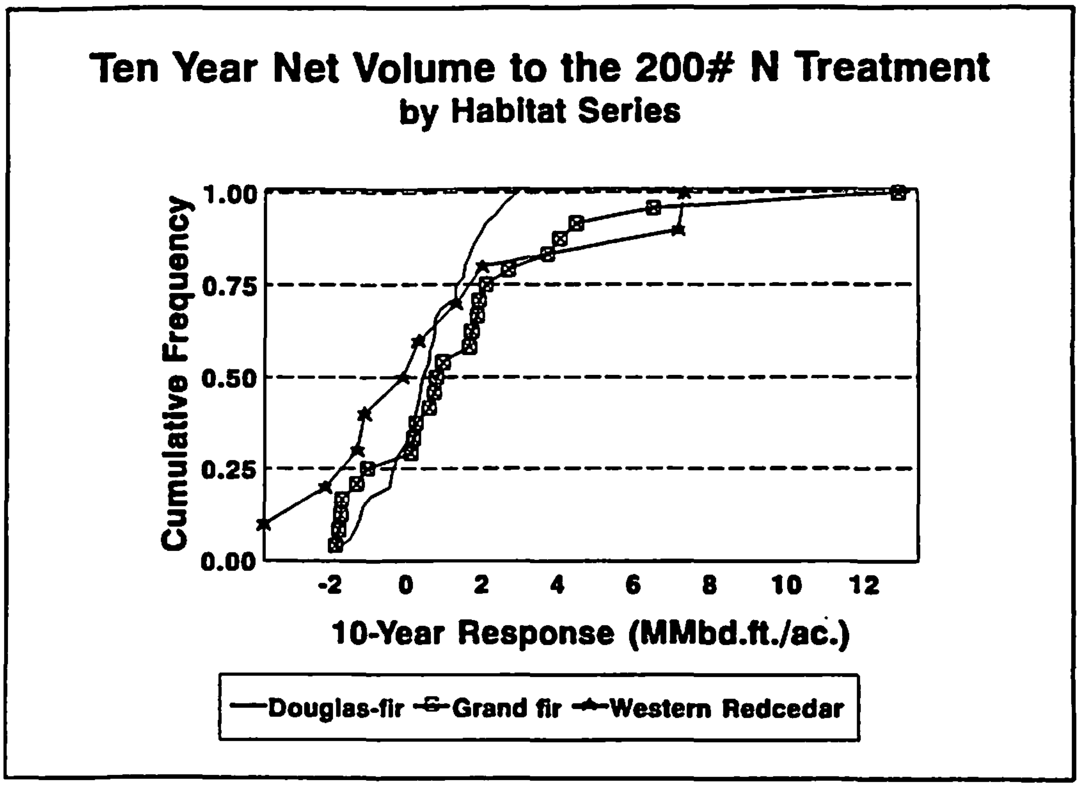
Ten Year Net Response to the 400# N Treatment
by Soil Parent Material
Cumulative Frequency
1.00
0.75
0.50
0.25
0.00
-6
-4
-2
0
2
4
6
8
10
Response(MMbd.ft/ac)
Granite
Basalt
Metamorphic
Sedimentary
Mixed

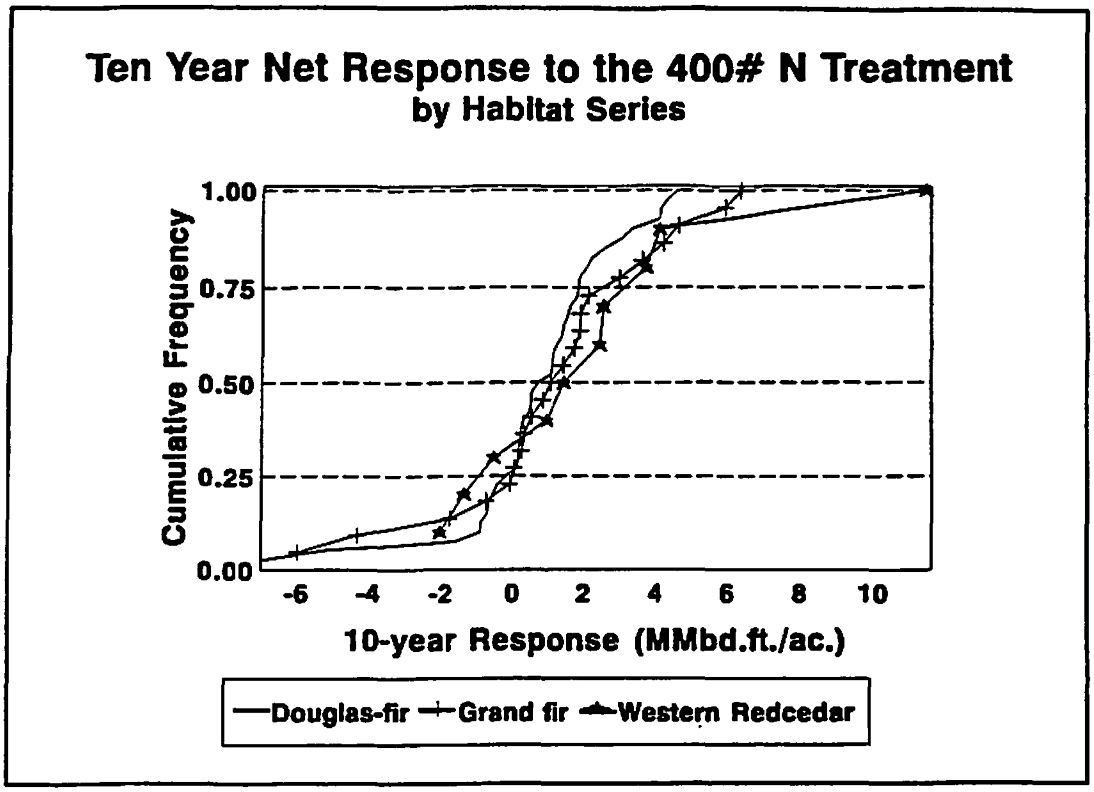
There were no large responders to the 200 # N treatment on Douglas-fir habitat series. Western red cedar types are highly variable in their growth response.




Ten Year Gross Response to the 400# N Treatment
by Habitat Series
Cumulative Frequency
1.00
0.75
0.50
0.25
0.00
-3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
10 Rear Response (MMbd.ft./ac.)
Douglas-fir
Grand fir
Western Redcedar

None of the big responders to 200 # N treatments are on Douglas-fir habitat series, and about one-half of the Douglas-fir types showed negative net response.





Ten Year Net Response to the 400# N Treatment
by Habitat Series
Cumulative Frequency
1.00
0.75
0.50
0.25
0.00
-6
-4
-2
0
2
4
6
8
10
10-year Response (MMbd.ft./ac.)
Douglas-fir
Grand fir
Western Redcedar

INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

TEN YEAR GROWTH RESPONSE TO NITROGEN FERTILIZATION VERSUS PRE-TREATMENT FOLIAR POTASSIUM STATUS FOR DOUGLAS-FIR

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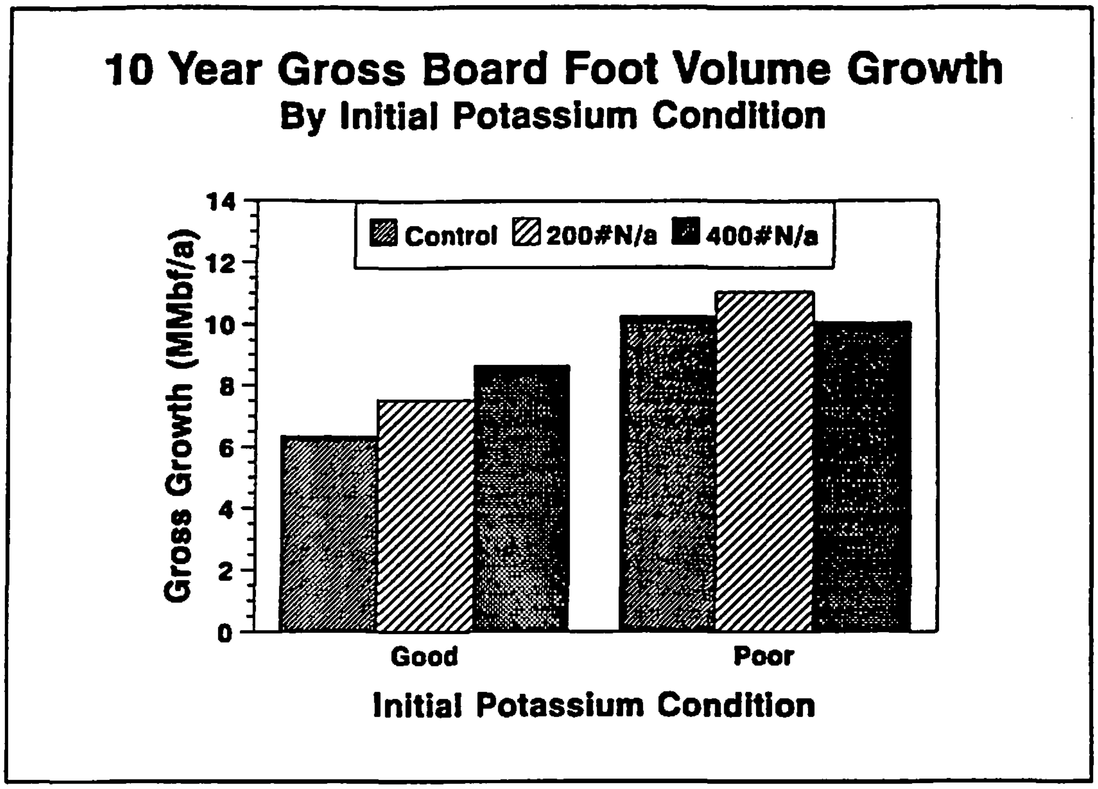
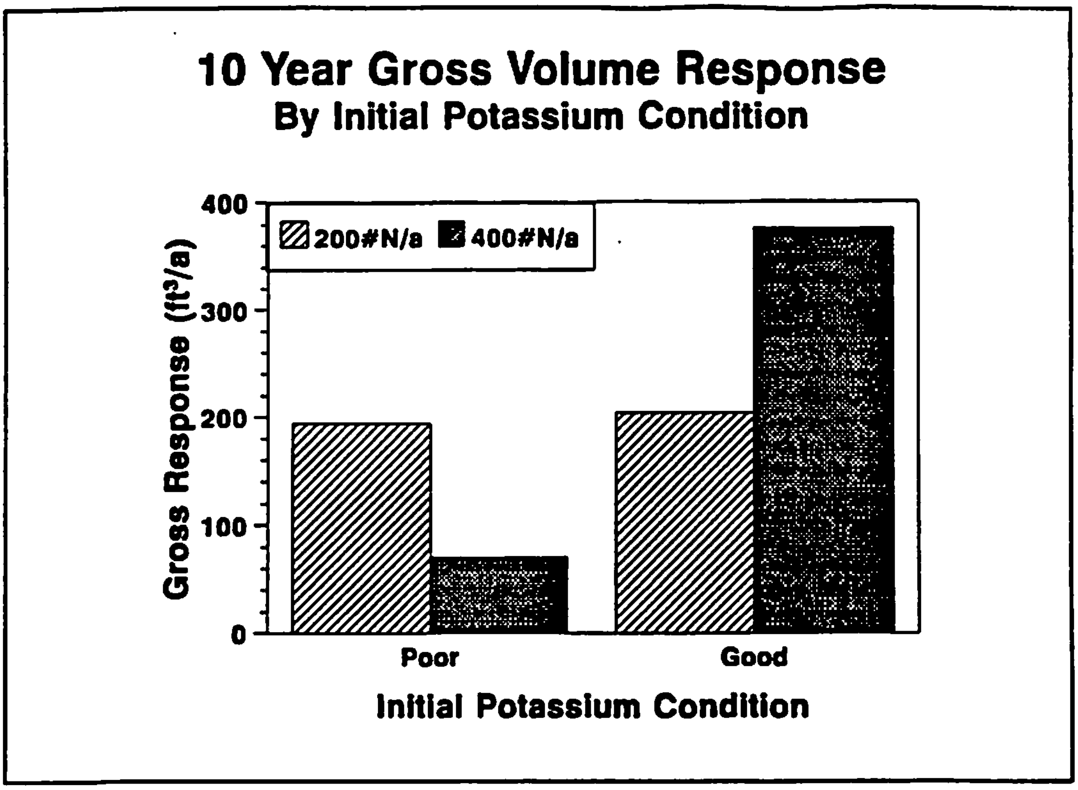
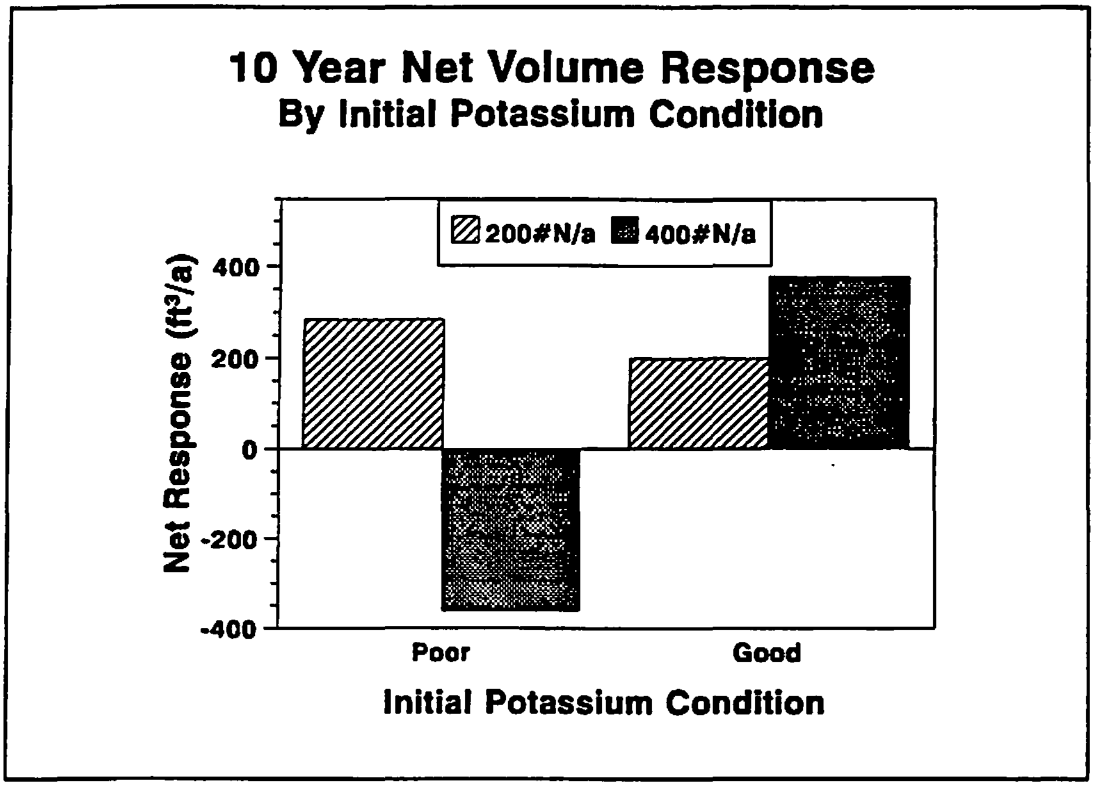
The untreated control plots on the good K-status plots averaged about 620 bd. ft. / ac. / year. While the control plots on the poor K-status sites grew almost twice as fast averaging over 1000 bd. ft. / ac. / year. Another illustration of the possibility that the soils were unable to supply sufficient K to support rapid growth rates on the poor K sites.

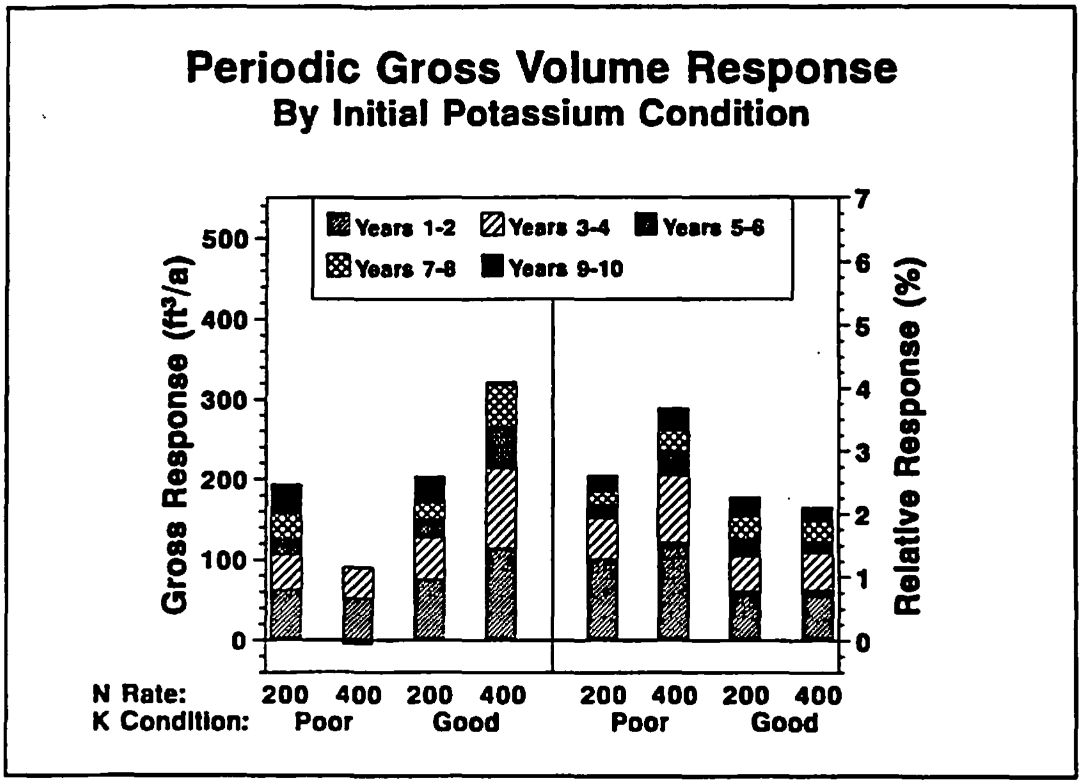



10 Year Gross Volume Response
By Initial Potassium Condition
200#N/a
400#N/a
Gross Response (ft³/a)
400
300
200
100
0
Poor
Good
Initial Potassium Condition

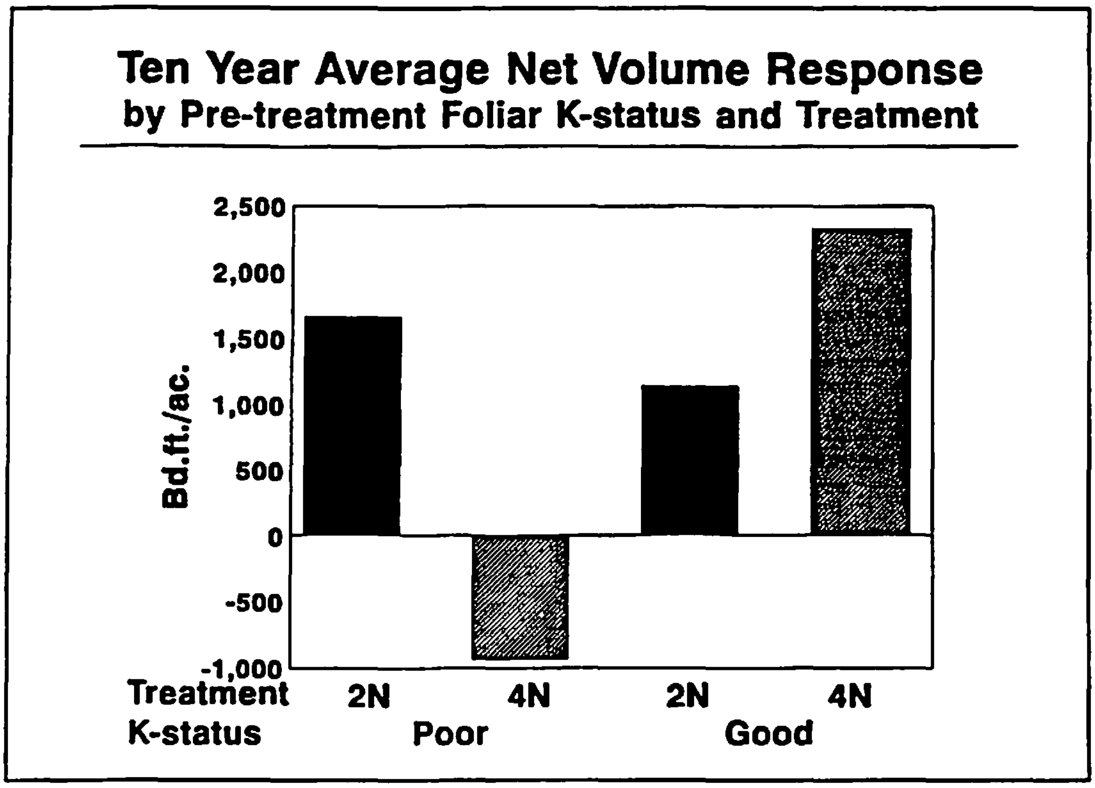
Some years after fertilizing with nitrogen only, trees began dying on the poor K-status sites that received the 400 # N treatments within the confines of the plot boundaries. In contrast, on the good K-status sites the 400 # fertilization rate produced significantly more growth response than the 200 # N treatment just as would be expected if nitrogen were the primary limiting element. Nutrition is important for tree life (growth) and death. Small changes in nutrition can have a large impact on forest health.



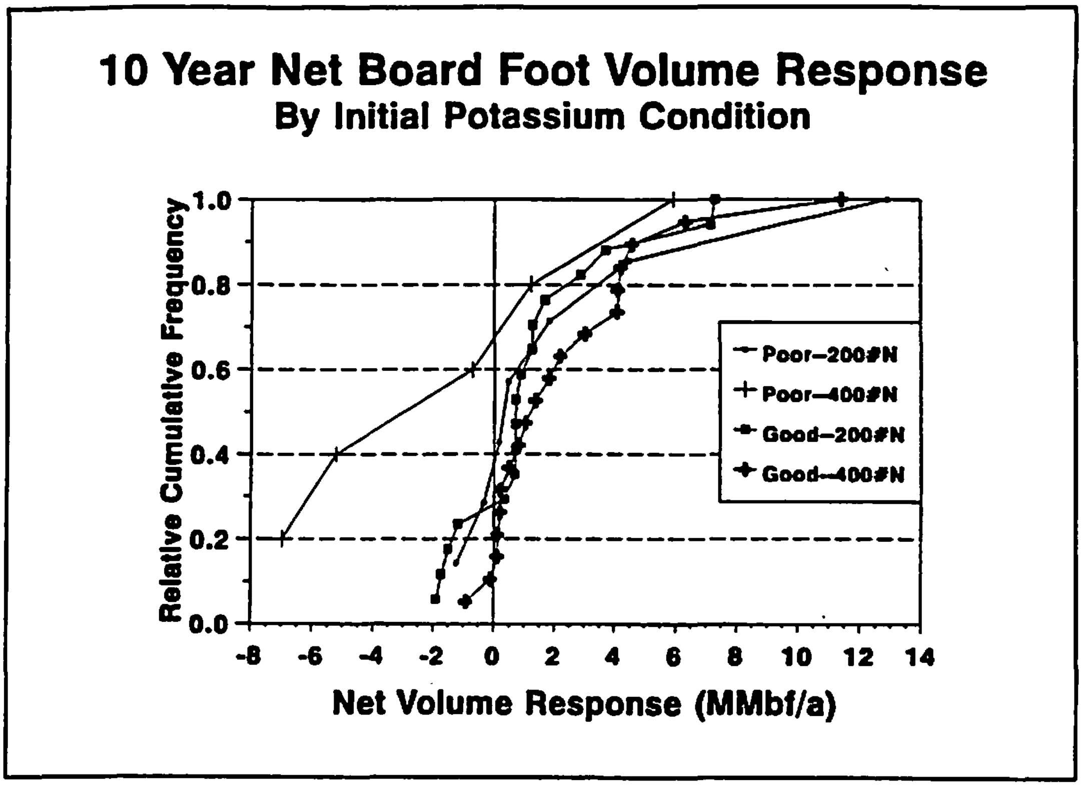
The left panel includes both direct and indirect N fertilization response (ie. the extra wood that could be harvested), the right panel represents direct N effect (which is useful for determining N retreatment timing). The 400 # N treatment cu. ft. response on the poor K-status sites (the left panel) was positive, although somewhat weak, for the first 4 years after treatment. The growth response is negative for the last six years due to treatment induced mortality which began in years 5 and 6 after N fertilization. However, on a relative basis (the right panel), the surviving trees on the poor K-status sites are still responding better than those on the good K sites. Perhaps another indication that the soil was unable to supply sufficient K to support higher growth rates on the poor K sites.



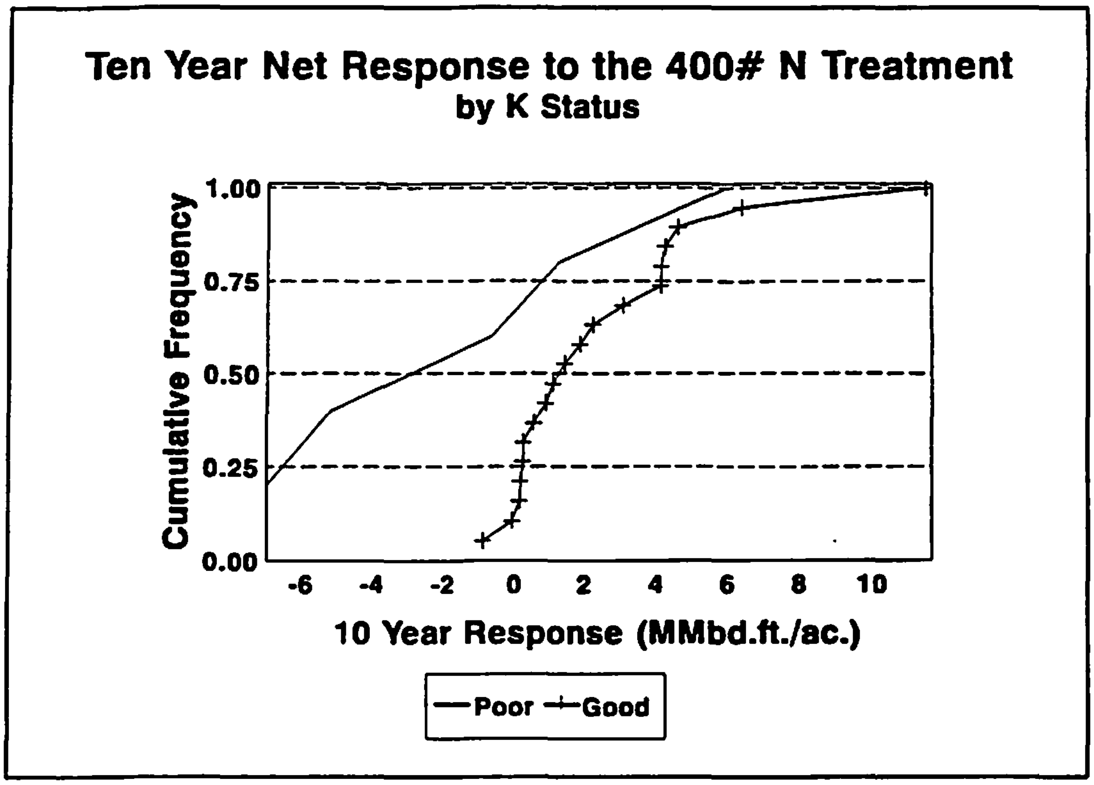
The good pre-treatment K-status sites showed good net response to the 200 # N treatment and a significant further response increase from the 400 # N treatment. This is exactly the response pattern expected in a strongly N limited forest system. However, while the poor K-status sites produced good growth response to the 200 # N treatment, the average response to the 400 # fertilization was negative for the poor K category. There was significant treatment induced tree mortality from the 400 # N treatment.



Two of the 400 # N treatments on the poor K-status sites showed negative N treatment response of about 5000 and 7000 bd. ft. per ac. These were very definitely plots that exhibited the "square death syndrome".



About 75% of the sites in the poor K-status showed negative net response to the 400# N treatment, while only about 5% of the good category were negative responders. Twenty-five percent of the good potassium sites responded greater than 4000 bd. ft. per acre in ten years.



INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

FOUR-YEAR GROWTH RESPONSE TO POTASSIUM FERTILIZATION VERSUS PRE-TREATMENT FOLIAR POTASSIUM STATUS FOR DOUGLAS-FIR

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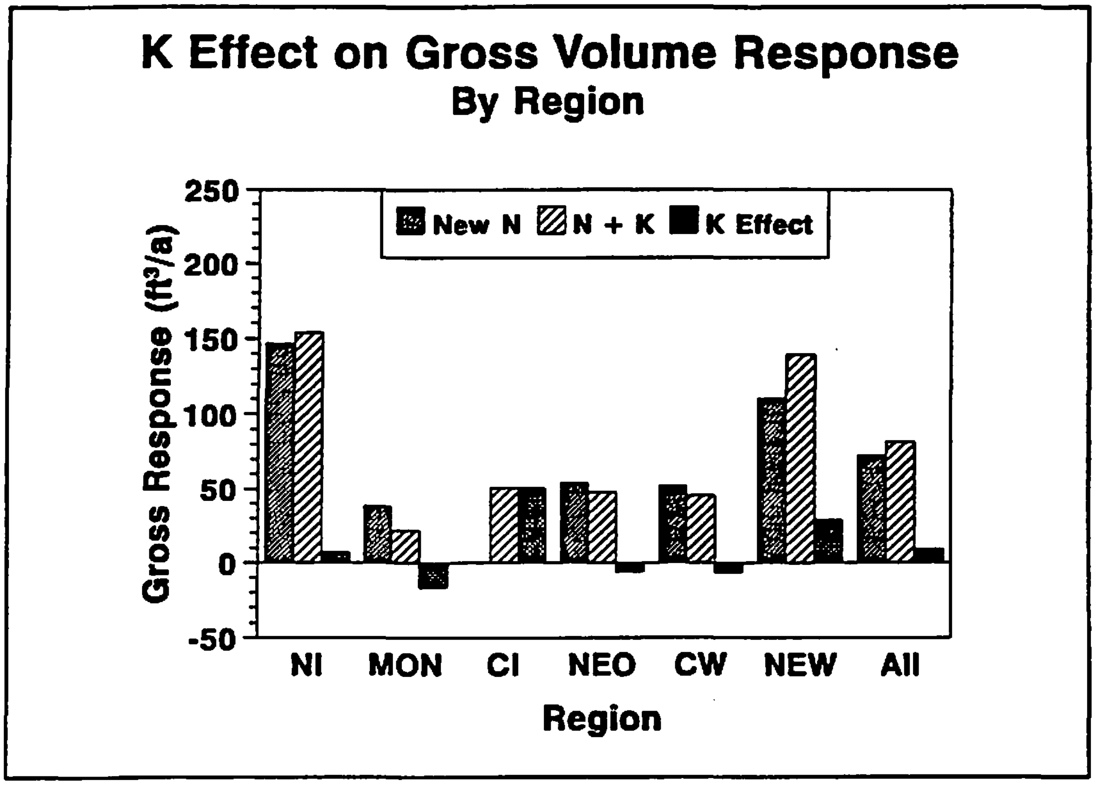
At the time when the Douglas-fir installations were retreated with 200 lbs/a of N, some of the plots were fertilized with a mixture of 200 lbs/a N and 200 lbs/a K. This figure and the seven that follow show the influence of the addition of K on volume growth response 4 years after fertilization. Each figure shows the response to the new N treatment, the response to the N+K treatment, and the K effect (the difference between the 2 responses).

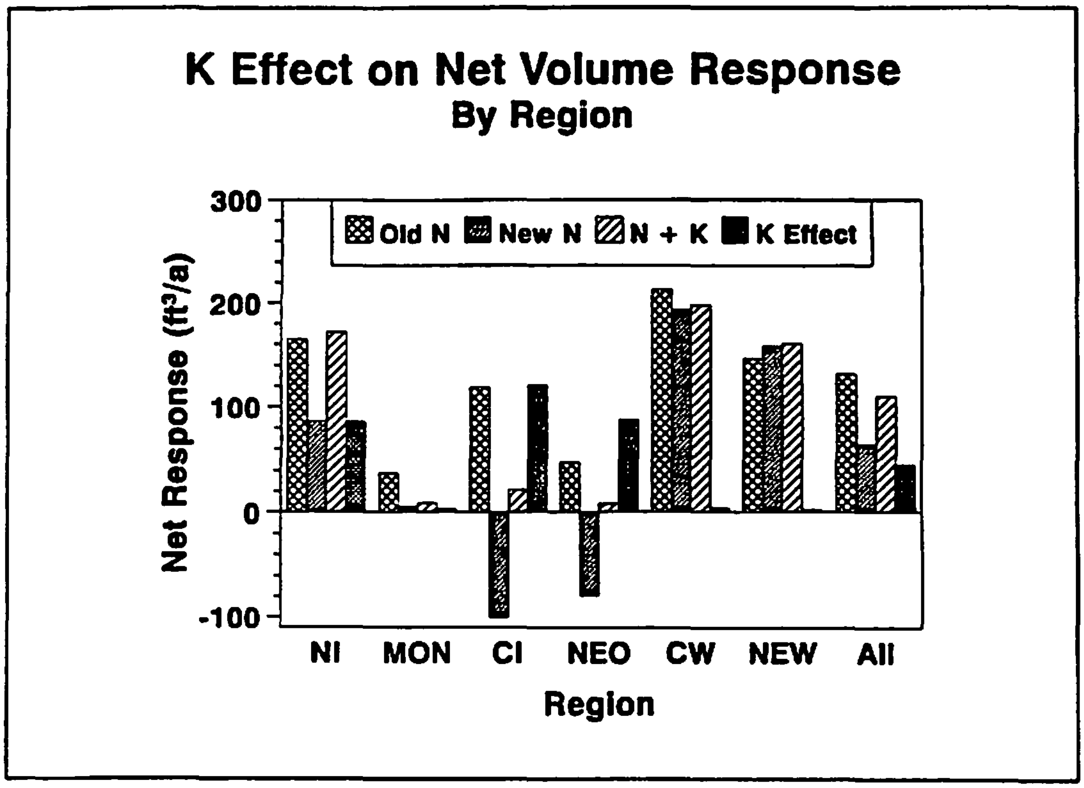
There was no overall K effect on gross volume response, nor did any region show significant K effects. Central Idaho did have a K effect of 51 ft^3/a due to the lack of any response to the N retreatment.



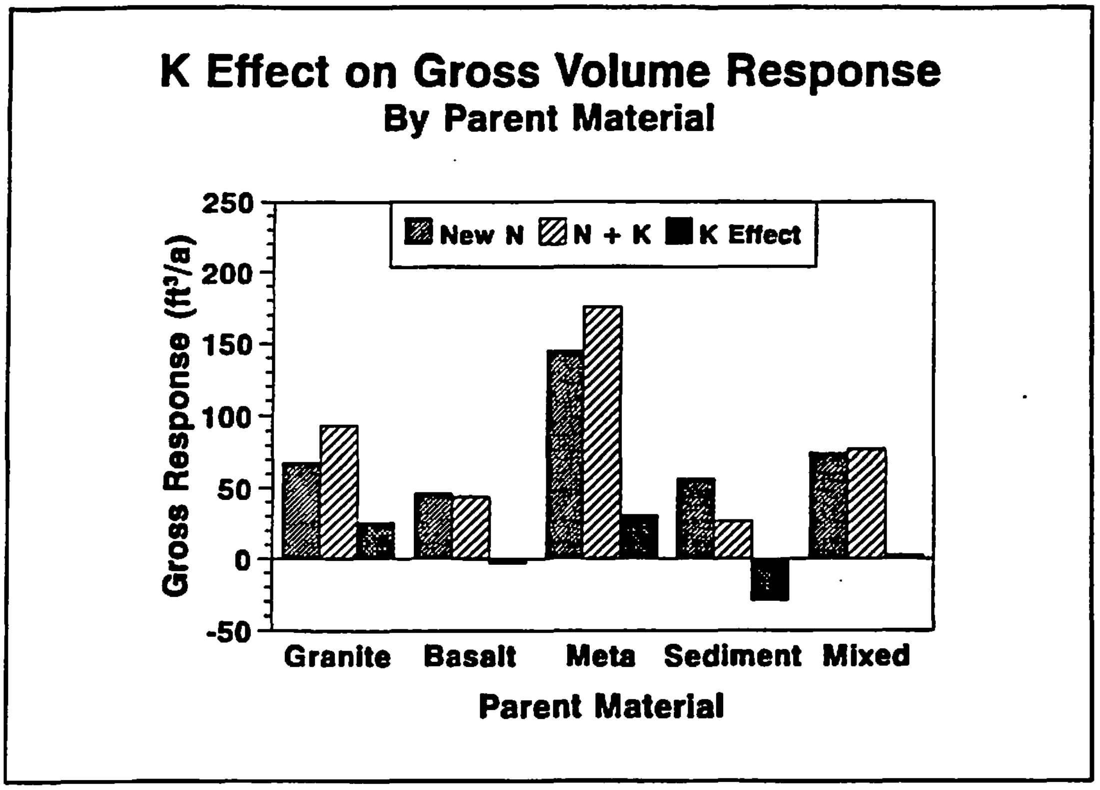
Means for net volume response indicate that K additions produce a positive effect in many regions. North Idaho, central Idaho, and northeast Oregon showed K effects of 86, 122, and 88 ft^3/a, respectively.

In addition to the 4 year response to retreatment, this figure also shows the 4 year response to the original N treatment. The regions with large K effects all experienced substantial declines in response to N from the first to the second treatment, with central Idaho and northeast Oregon actually showing negative responses. Without a K supplement, addition of N increased mortality rates beyond those occurring on non-retreated plots, but the K addition apparently prevented this.

In regions where N treatment did not lead to reduced response (central and northeast Washington), K additions had no effect.

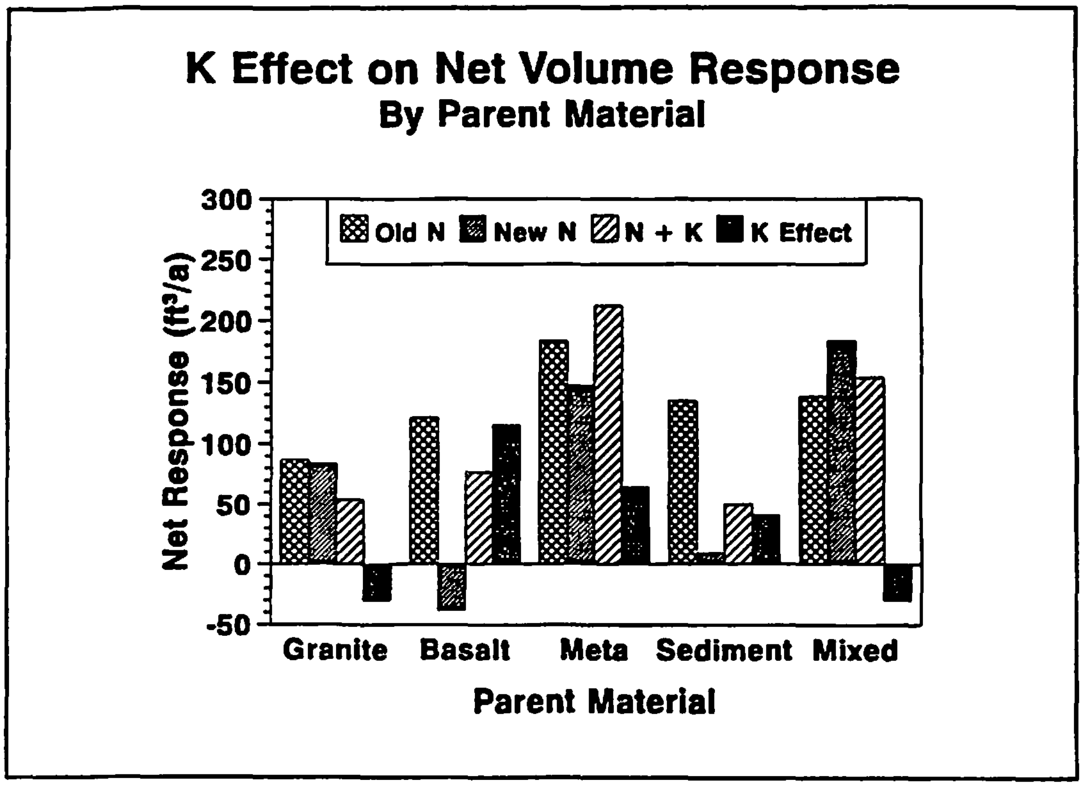


When sites are grouped according to parent material, no trends for differential gross volume response to K are apparent. If K supplements does influence gross volume response on certain sites, the distinguishing characteristics of those sites are not related to the underlying rock type.



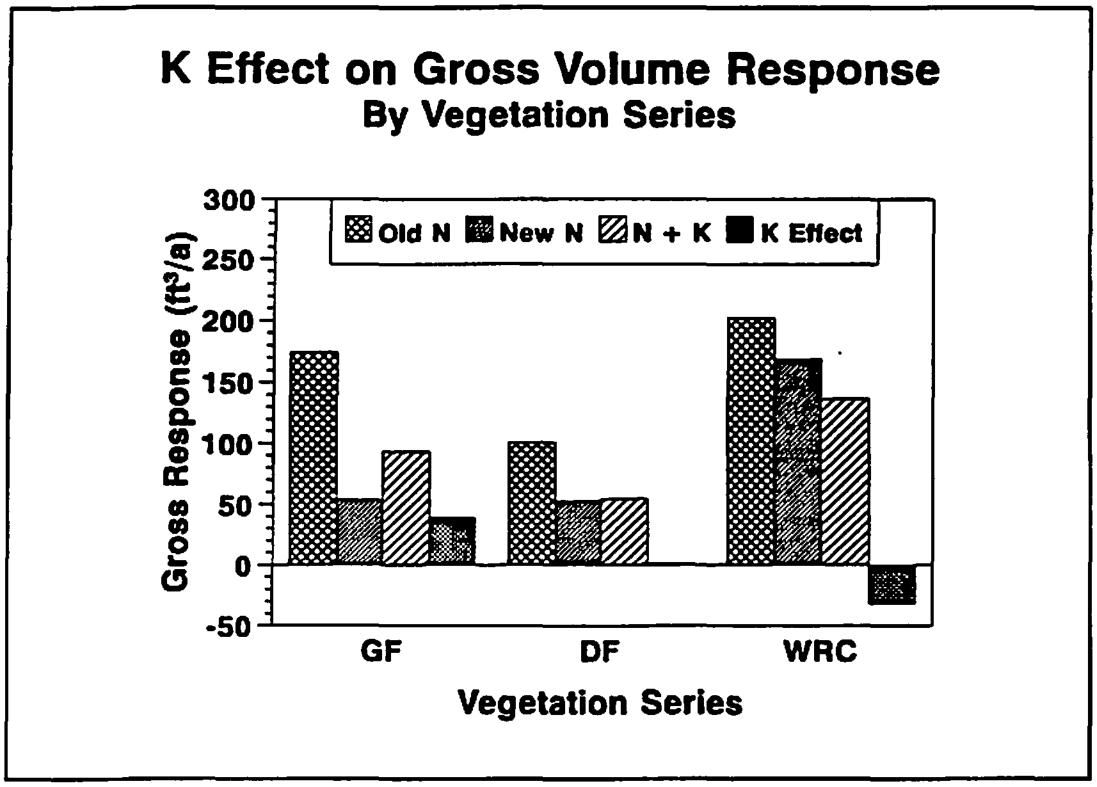
Installations growing on granite and mixed (glacial till) parent materials showed no reduction in response to N retreatment from the original response levels. These installations also failed to show any response to the K supplement.

Installations on basalt showed a large reduction in response to N (from 121 to -39 ft^3/a) and a large K effect (115 ft^3/a). K and N nutrition may play a large role in mortality processes on these sites.

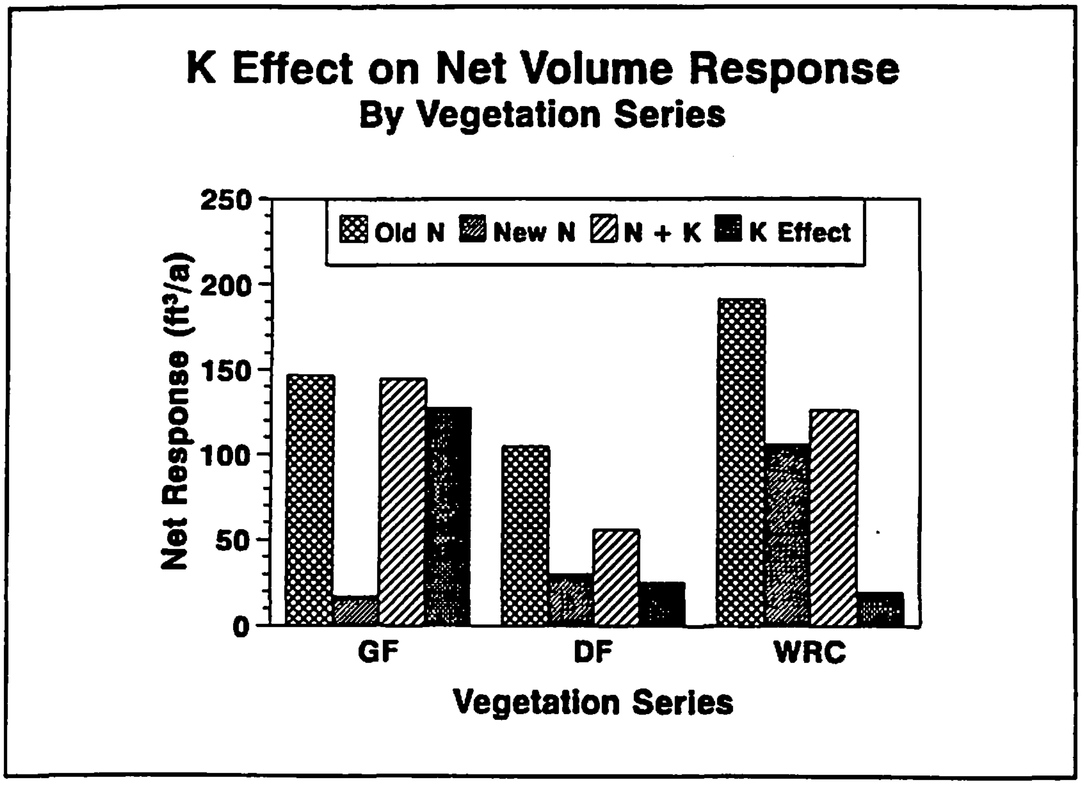


Grand fir sites showed substantial declines in gross volume response to N (from 175 to 54 ft^3/a) and also showed significant improvement (40 ft^3/a) when K was added. Douglas-fir sites also declined in N response but failed to respond to K supplements. Installations on western redcedar sites showed little decline in N response and no K effect.

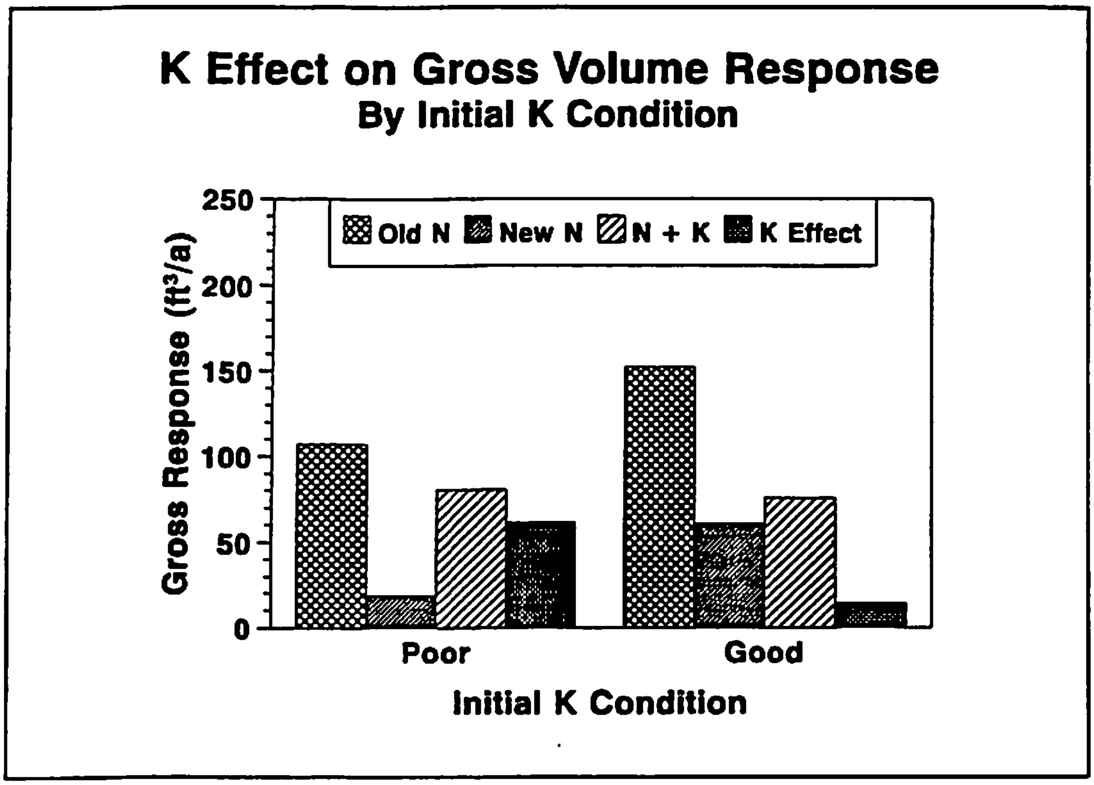
Differences in species nutritional requirements may be affecting these outcomes. Grand fir often makes up a considerable amount of the total basal area in our GF and WRC sites: the difference in response behavior of GF and DF sites may reflect a tree species difference in response to K fertilization.



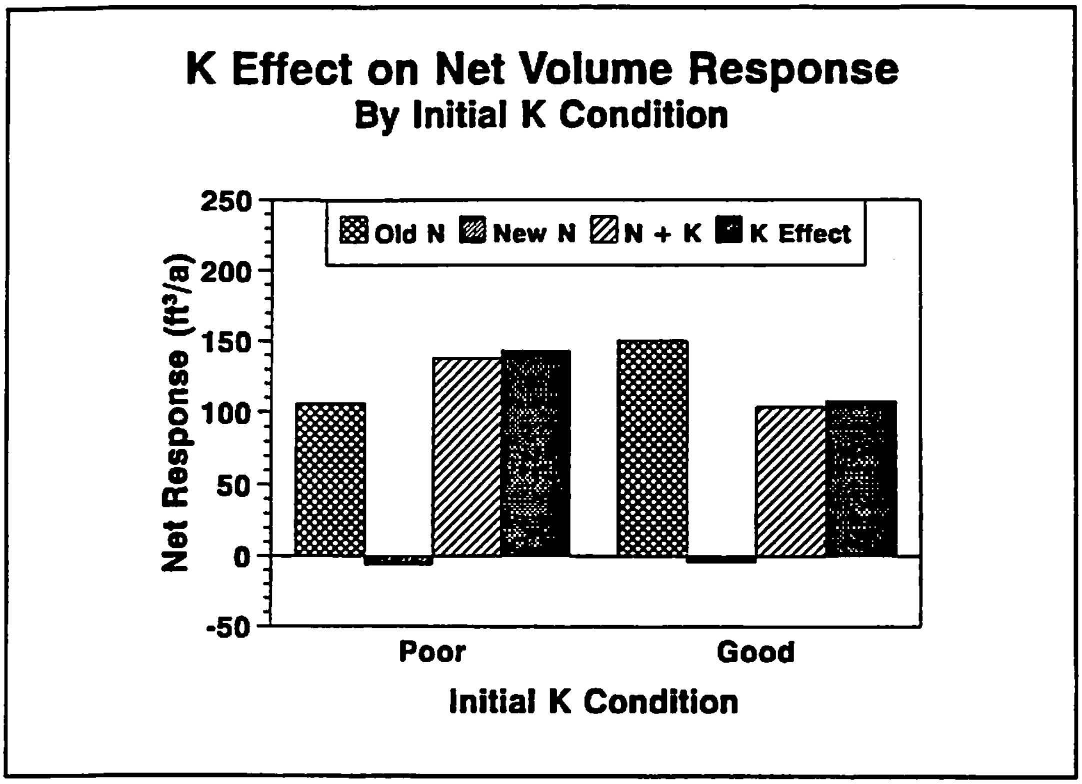
While the net response to N retreatment was greatly reduced from original response rates on all vegetation series, only on grand fir types was the K effect substantial (127 ft^3/a). If a schedule of repeated N fertilizations are being considered for stands on grand fir sites, addition of K to the fertilizer mix may be well justified.



Sites exhibiting poor initial K conditions showed improved gross volume response to N retreatment when K was also included (K effect = 62 ft^3/a). Perhaps improved osmotic regulation could account for this: when provided with sufficient K, tree water use efficiency could improve and growing season length could be prolonged, thereby actually increasing individual tree growth.



Both good and poor K sites showed large reductions in net response to N treatment from previous N treatment response rates. And both types of sites also responded positively to K supplements (143 ft^3/a on poor K sites, 108 ft^3/a on good K sites). For both site types, N retreatment increased mortality rates, while N+K improved tree growth and minimized mortality.



INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

EVIDENCE OF LINKS BETWEEN NUTRITION AND FOREST HEALTH

JIM MOORE

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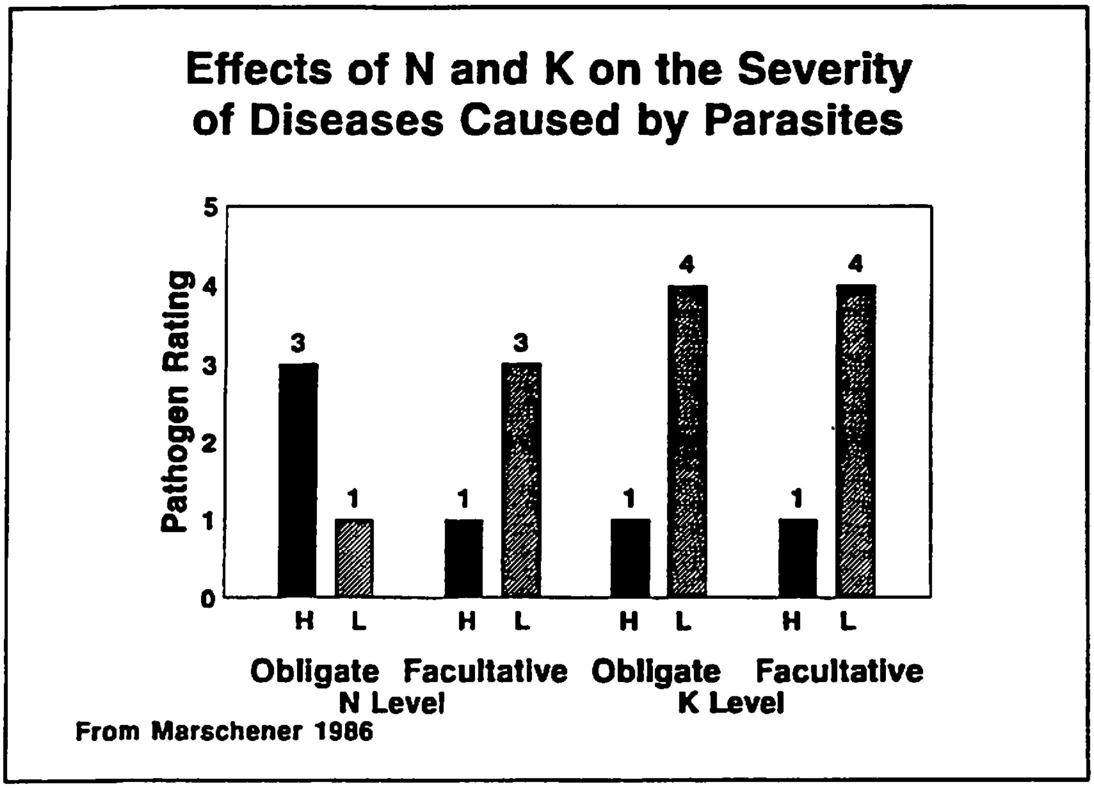
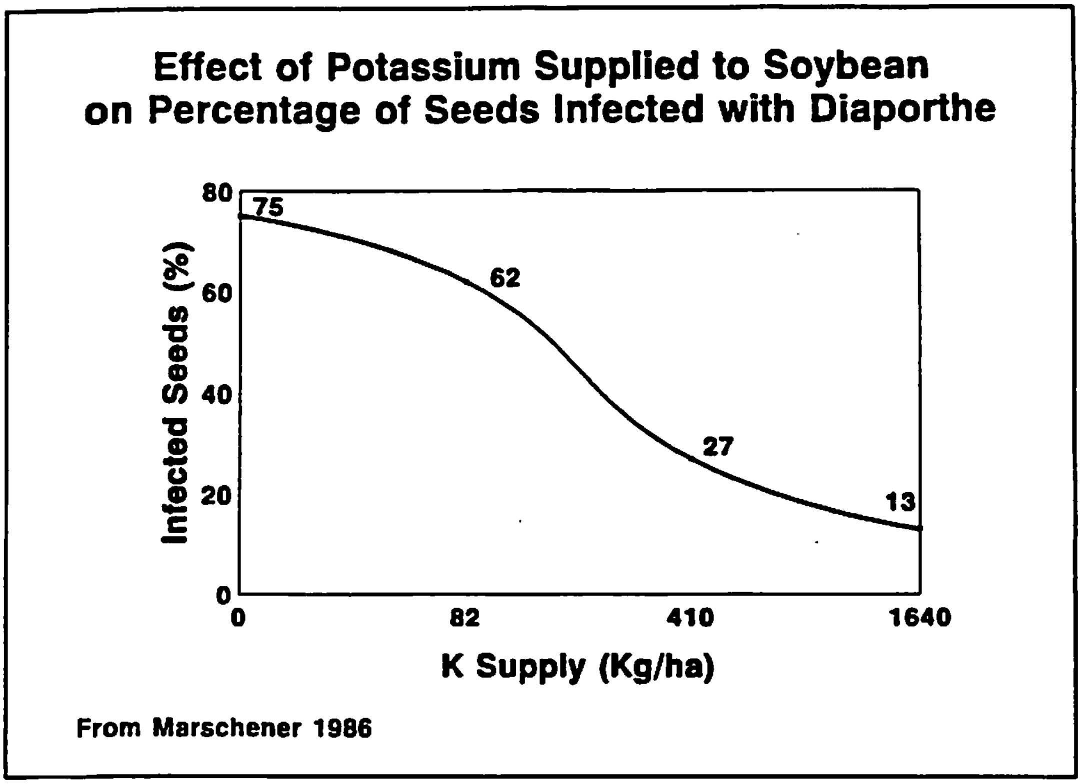
Obligate pathogens are those that require living tissue, while facultative can infect dead or dying tissue. Potassium nutrition has the same effect on both types of pathogens. High potassium levels result in low pathogen success. However, high nitrogen benefits facultative and reduces obligate pathogen success.

Potassium nutrition effects disease severity more than does nitrogen nutrition.



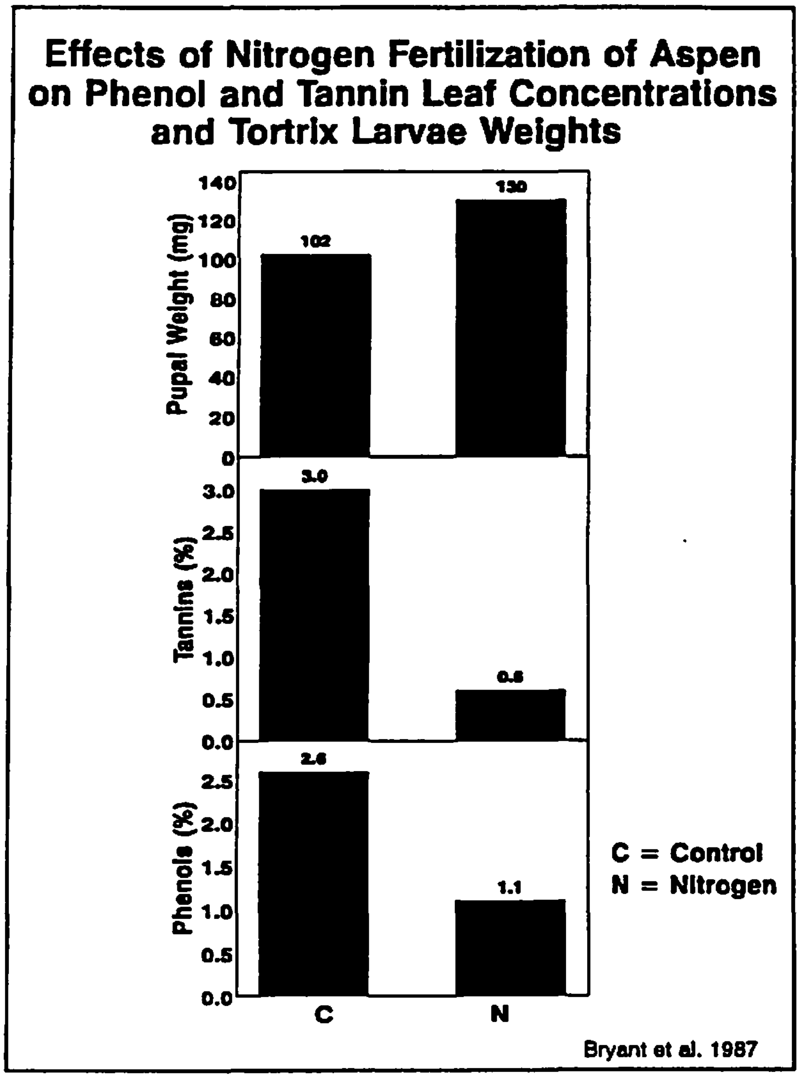
As potassium supply increases, the percent of soybean seeds infected with pod blight decreases significantly.

These kind of effects have been known and used in agriculture for many years.



Fertilization with high nitrogen doses reduced leaf phenol and tannin concentrations which consequently produced higher average larvae weights for an aspen defoliator.

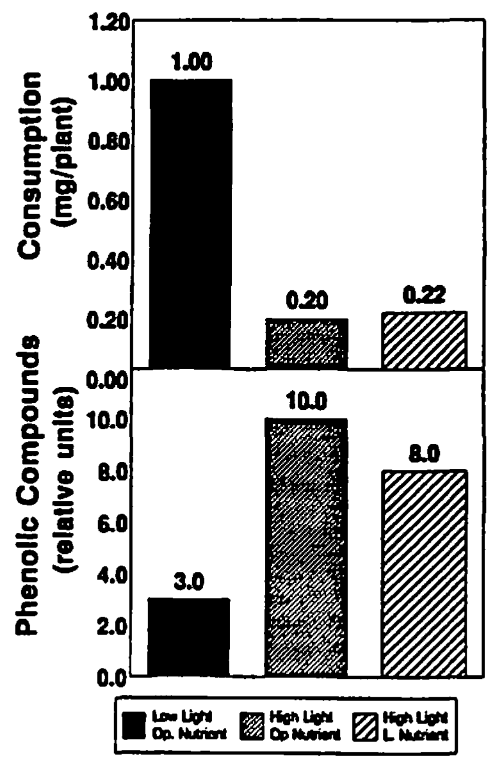
Phenols and tannins are plant defense chemicals.



Effects of Nitrogen Fertilization of Aspen on Phenol and Tannin Leaf Concentrations and Tortrix Larvae Weights

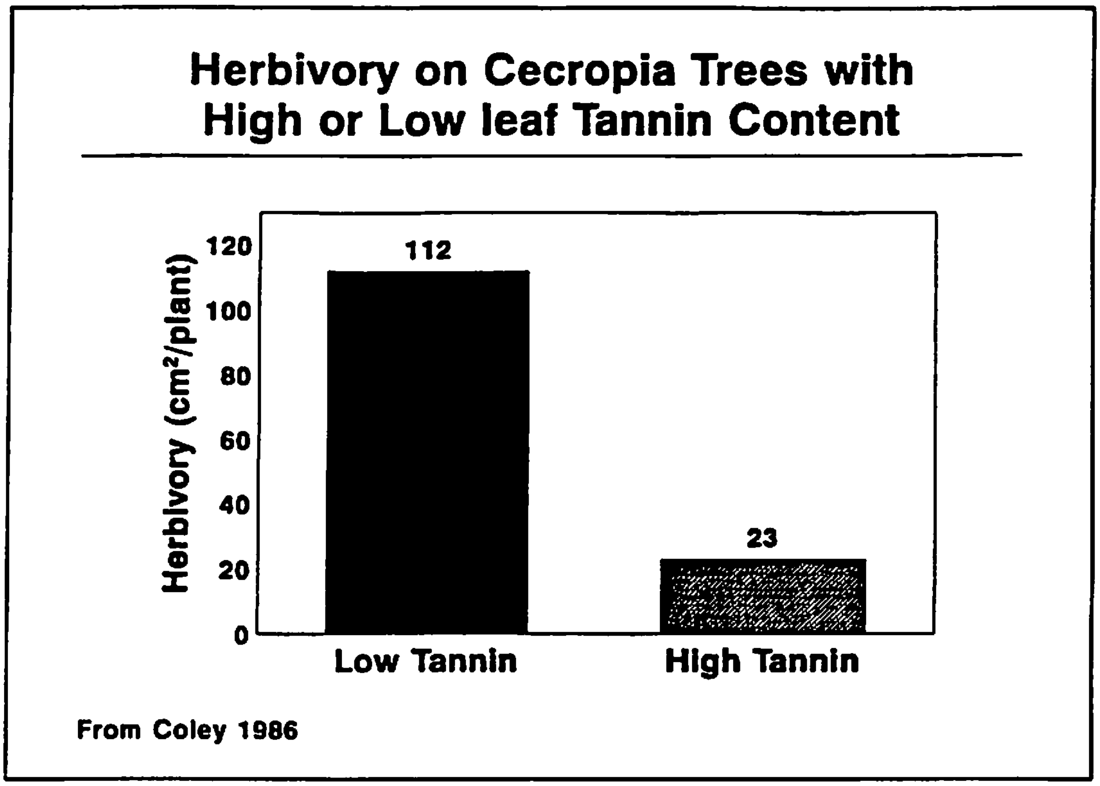
High leaf phenolic concentrations result in low levels of leaf consumption by insects. Leaf phenolic concentrations are significantly effected by changes in the trees' (Salix sp.) light and nutrient environment.

Leaf Consumption by Beetles and Leaf Concentrations of Phenolic Compounds



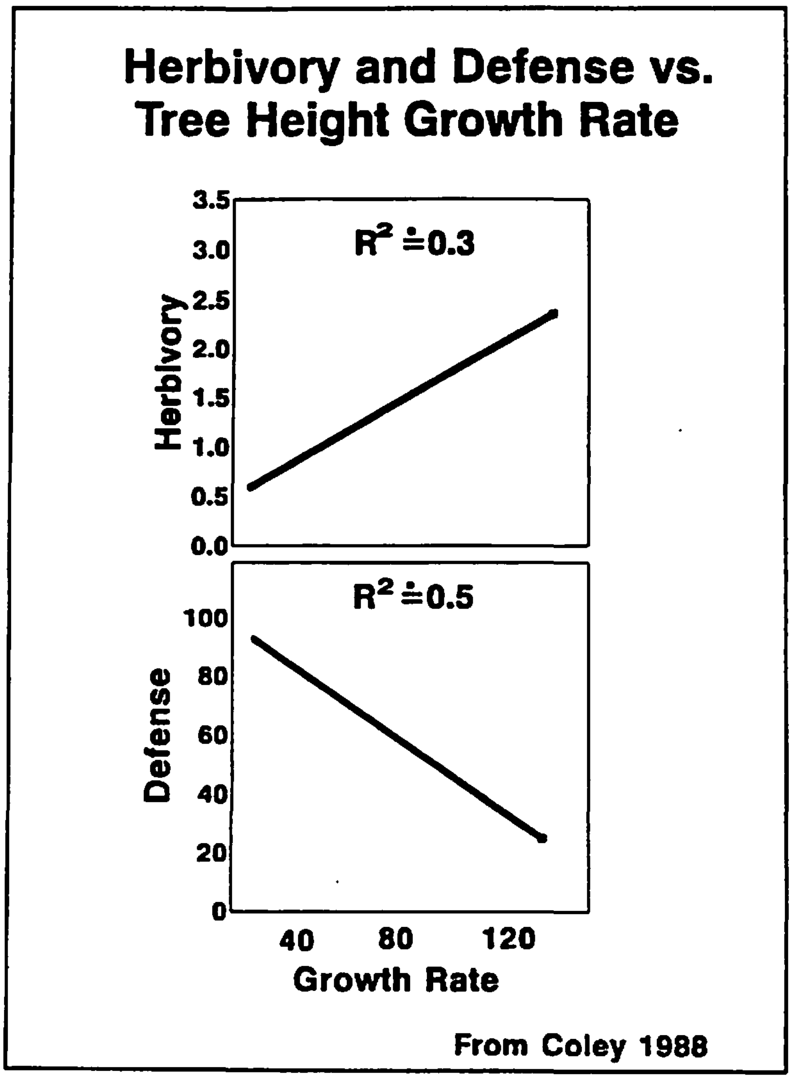
From Larsson et al 1986

High leaf tannin concentration inhibits insect feeding on Cecropia (a tropical tree) leaves.

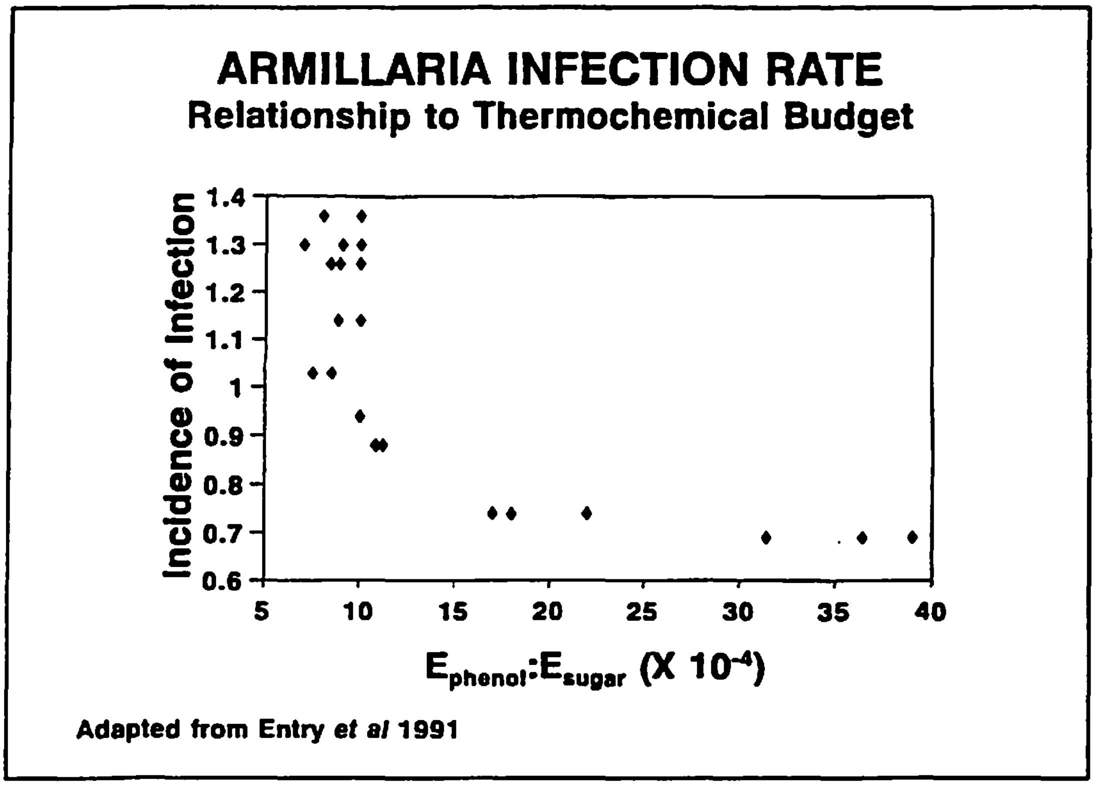


Based on averages from 41 tropical tree species, as growth rate increases plant defense chemicals decrease, and as a consequence insect herbivory increases.

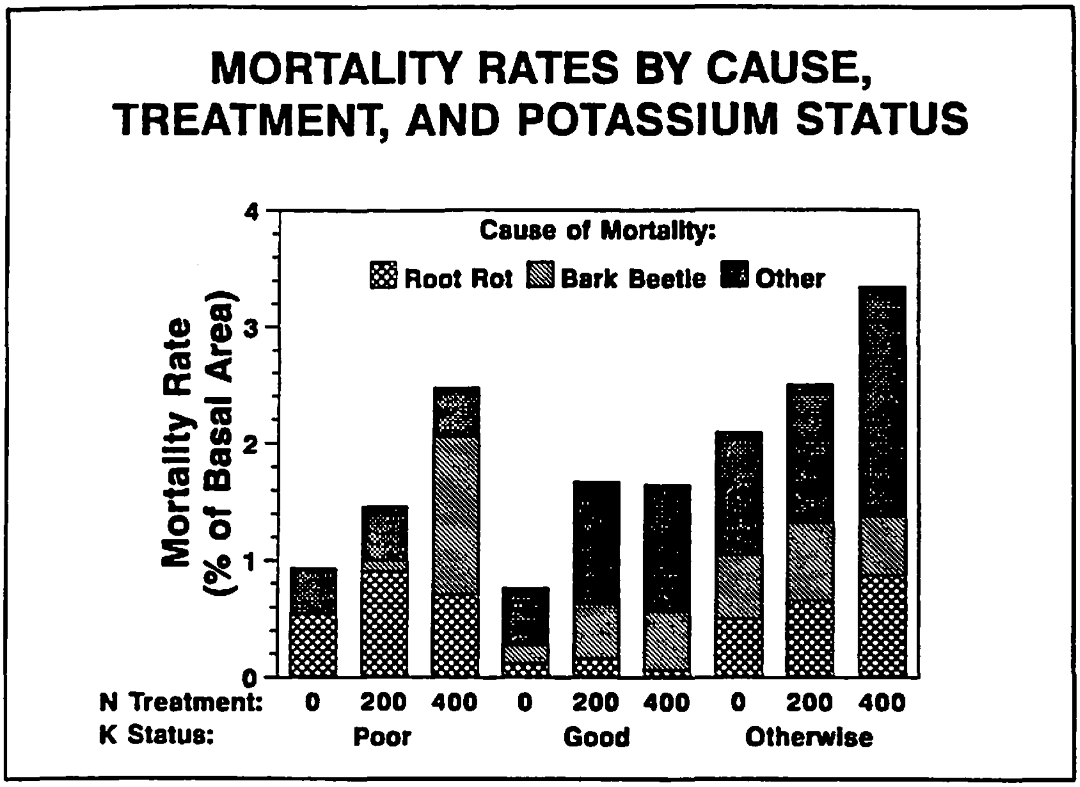
There is also evidence from other work that the same relationships hold for fast growing individuals within a species.



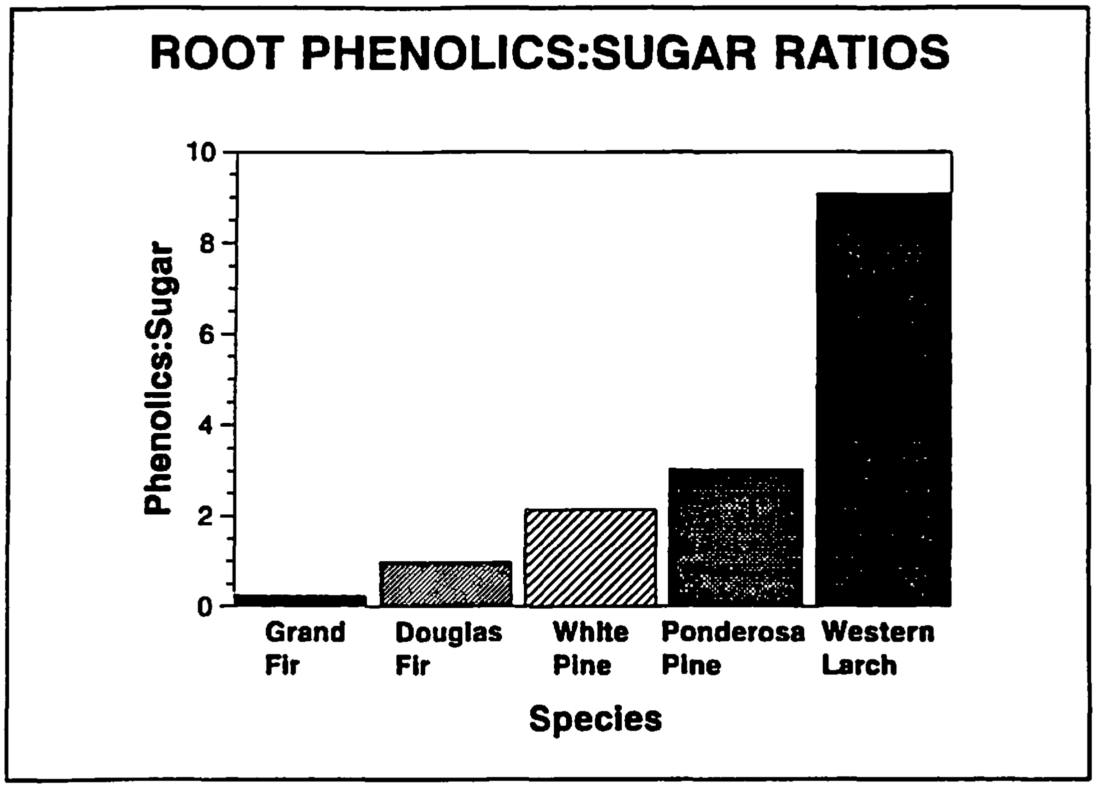
This study was conducted on Douglas-fir in north Idaho. The X-axis is root concentration of phenolics (the energy to break down the molecules) divided by root sugar concentration (the energy supplied to the fungus by the sugar). Root phenolic/sugar ratios less than ~ 15 are good for the Armillaria and bad for the trees.



Armillaria caused mortality is higher in the poor pre-treatment foliar K-status compared to the good K-status. (The same is also true when comparing the otherwise and good categories.)



This work is from Entry et al. 1992 on common north Idaho conifers. The species are very different in their root chemistry characteristics, western larch has by far the highest phenolic/sugar ratio (bad for Armillaria success) while grand fir has very low phenolic/sugar ratio (good for Armillaria success). It is likely not a coincidence that the species ranking for resistance to Armillaria closely follows the ranking for root phenol/sugar ratio.



INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

THE EFFECTS OF NUTRITION ON DOUGLAS-FIR ROOT CHEMISTRY FROM A GREENHOUSE EXPERIMENT

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Nutrient Treatments
(% of Optimal)

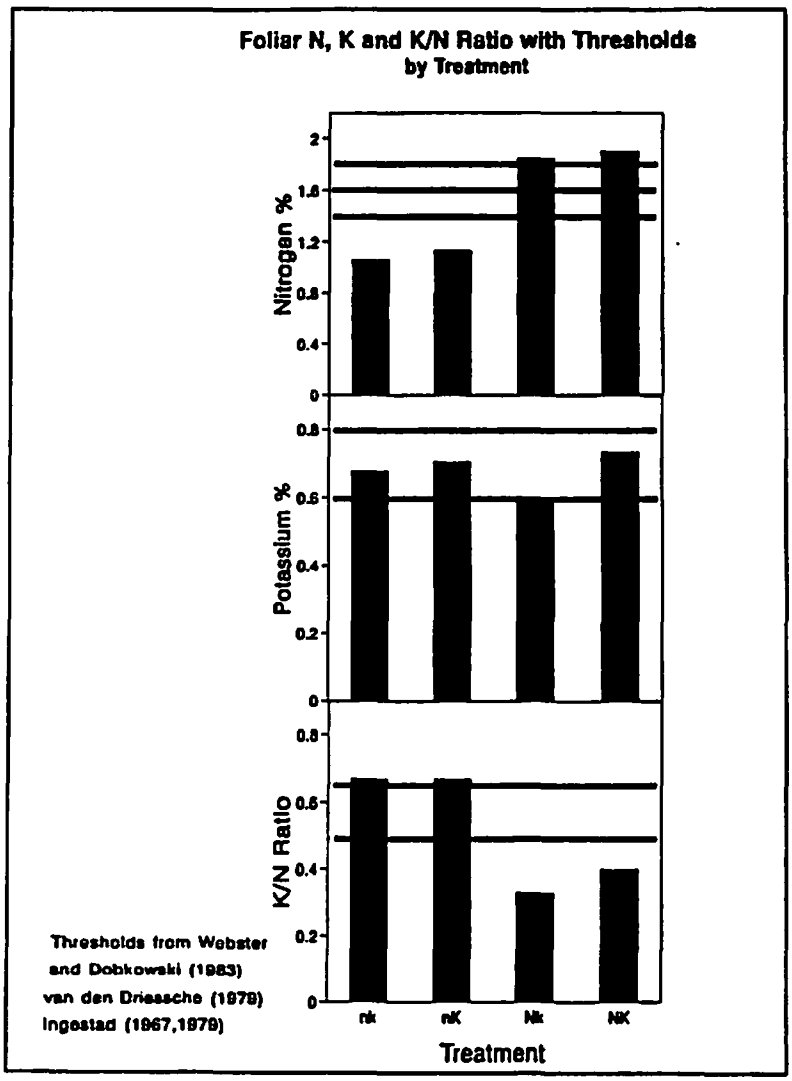
- Treatment 1 (nk) - 10% Nitrogen & 10% Potassium
- Treatment 2 (nK) - 10% Nitrogen & 100% Potassium
- Treatment 3 (Nk) - 100% Nitrogen & 10% Potassium
- Treatment 4 (NK) - 100% Nitrogen & 100% Potassium

All nutrients other than N and K are optimal
Ingestad (1979)

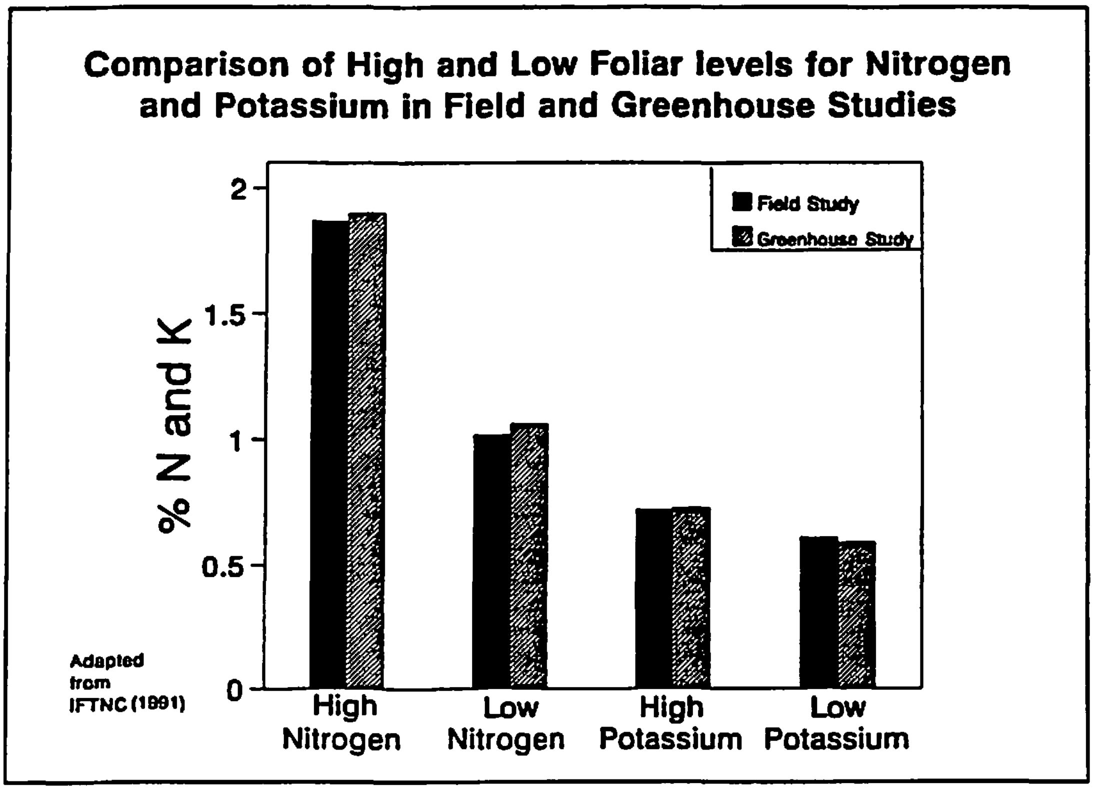
Nutritional thresholds reported for optimal growth on N, K and K/N ratio:
Nitrogen - Inadequate < 1.4%, Marginal 1.4-1.6%, Adequate 1.6-1.8%, Excessive > 1.8%
Potassium - Inadequate < 0.60%, Marginal 0.60-0.80%
K/N Ratio - Acceptable region - 0.50-0.65

The objective was to induce N and K deficiency while maintaining levels similar to field observations.

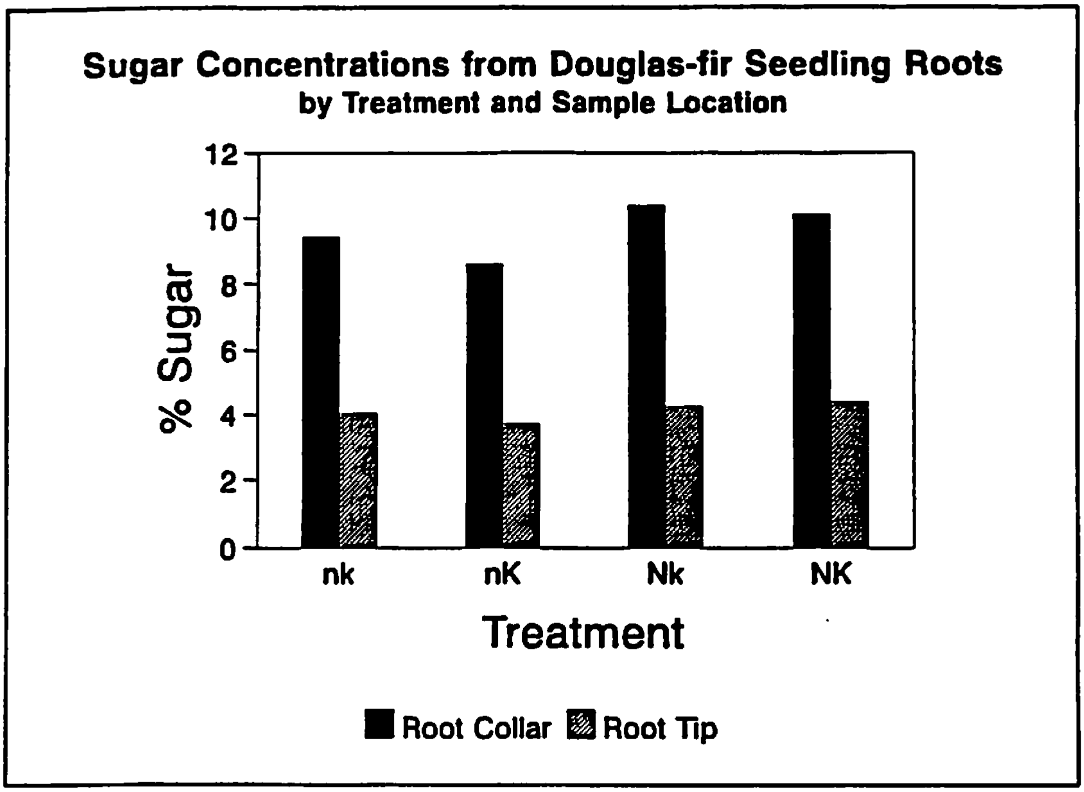
Treatment effects for N were successful. The high N treatments resulted in concentrations above the recommended adequate level, while the low N treatments were substantially below the inadequate level. Treatment effects for K were not as pronounced as in nitrogen. All treatments were in the marginal threshold except the Nk treatment which fell below the inadequate level. K/N ratios followed the same trends as the N treatments. High nitrogen treatments had low K/N ratios.



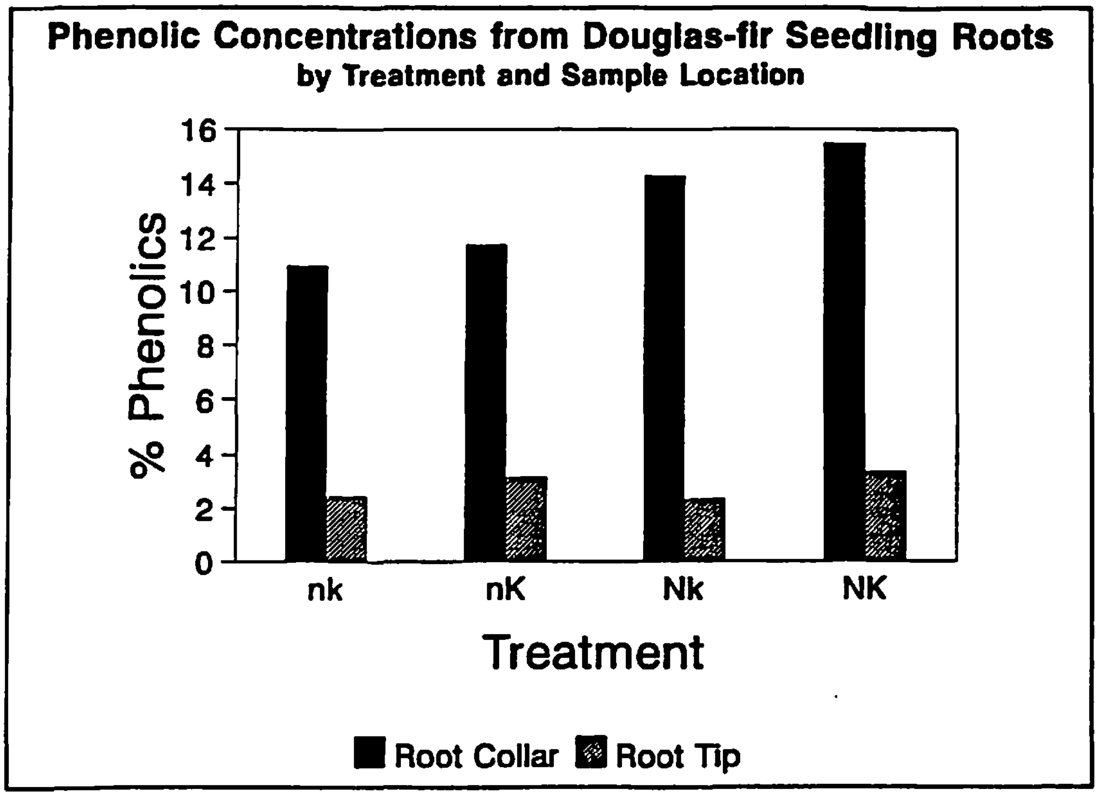
A comparison between high and low nitrogen and potassium concentration for IFTNC Douglas-fir and this greenhouse study show striking similarities. Based on these similarities, inferences may be made regarding N and K nutrition and biochemical production of Douglas-fir growing in the forest.



Even though root collar sugar concentrations are 2 to 3 times higher than the root tips, the trends between the treatments and the two sample locations are similar.

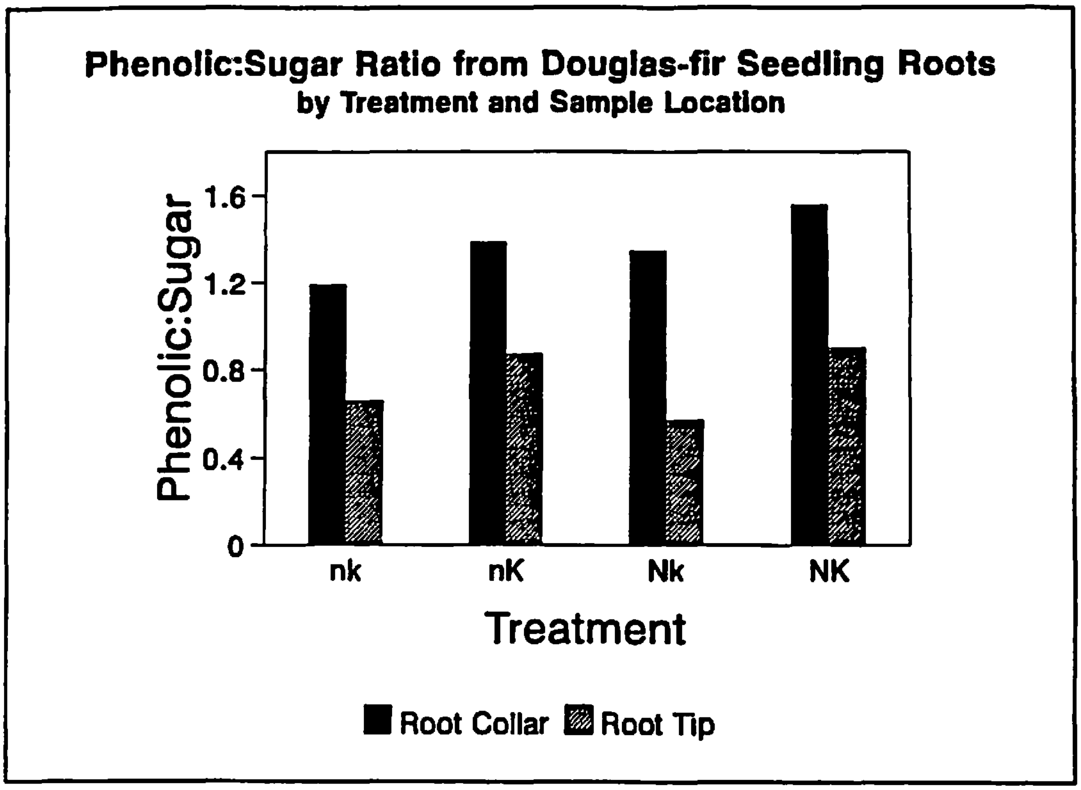


Phenolic levels were up to six times higher in the root collar area than in the root tip area.

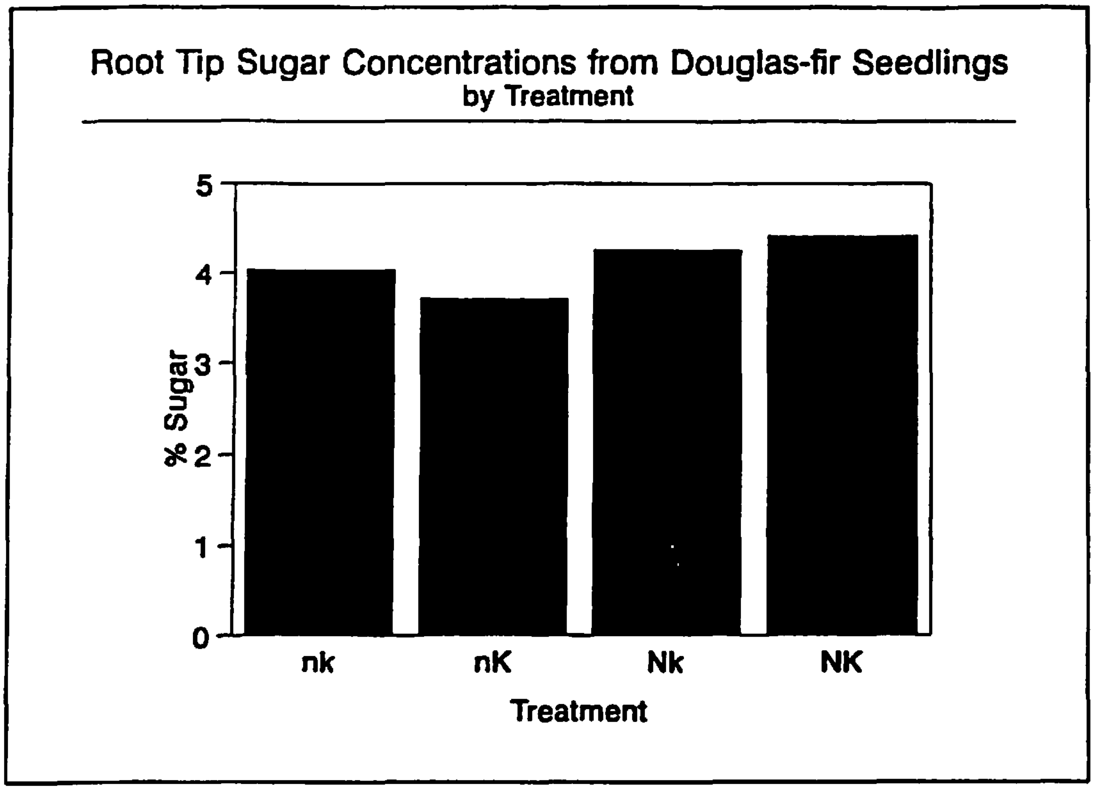


Treatment effects were similar at the root collar and root tip. Phenolic:sugar ratios tend to be lower in the low K treatments. This is especially true in the root tip area.

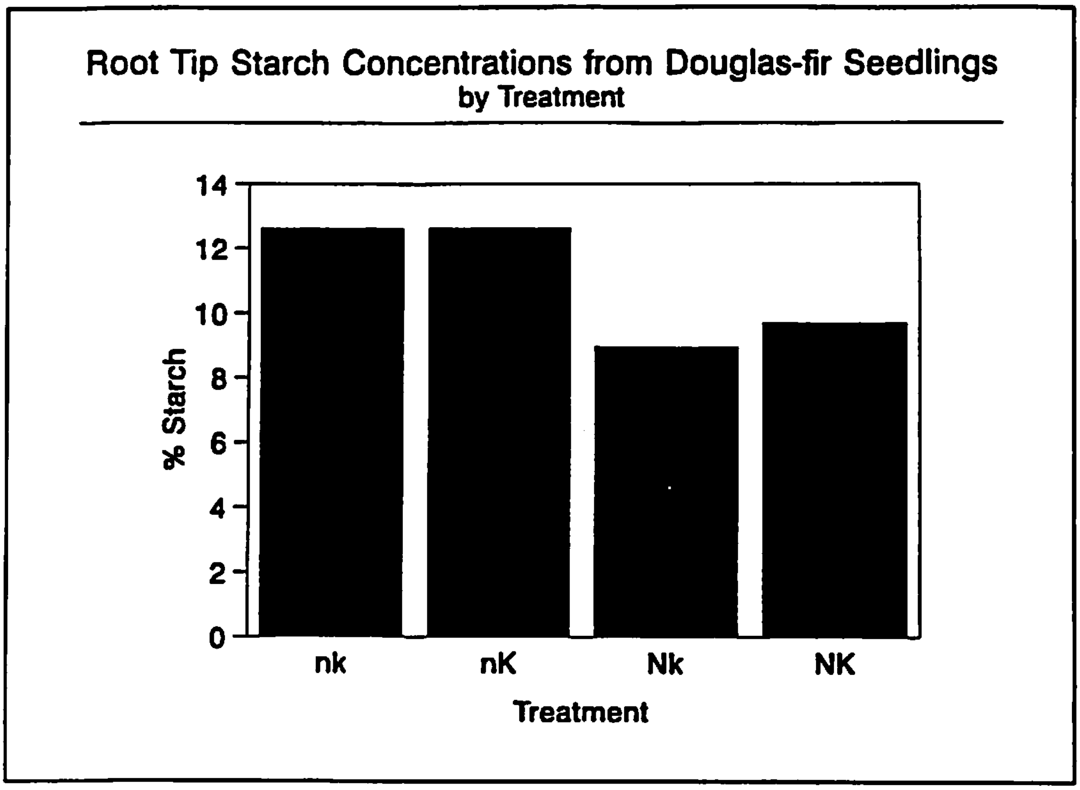
Given that a high ratio is bad for the fungus and good for the trees, this graph demonstrates that the root collar area would be less susceptible to infection by Armillaria than the root tip area.



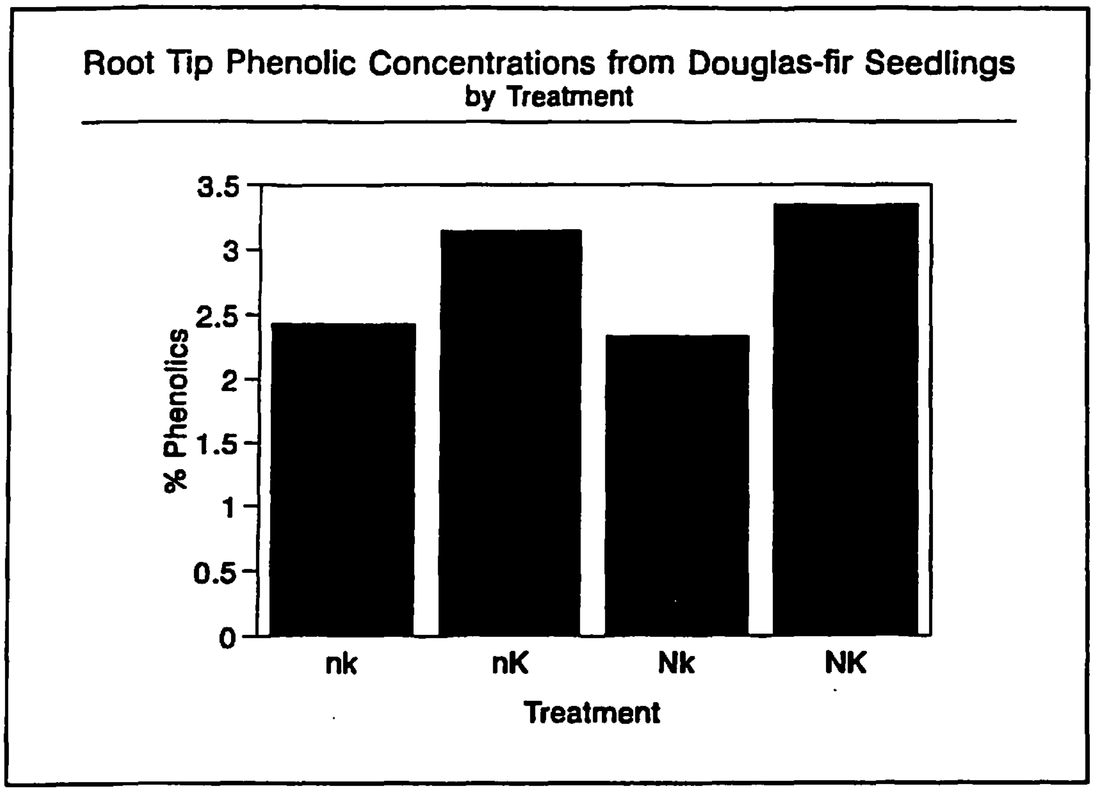
There were no significant treatment effects for sugar concentrations.



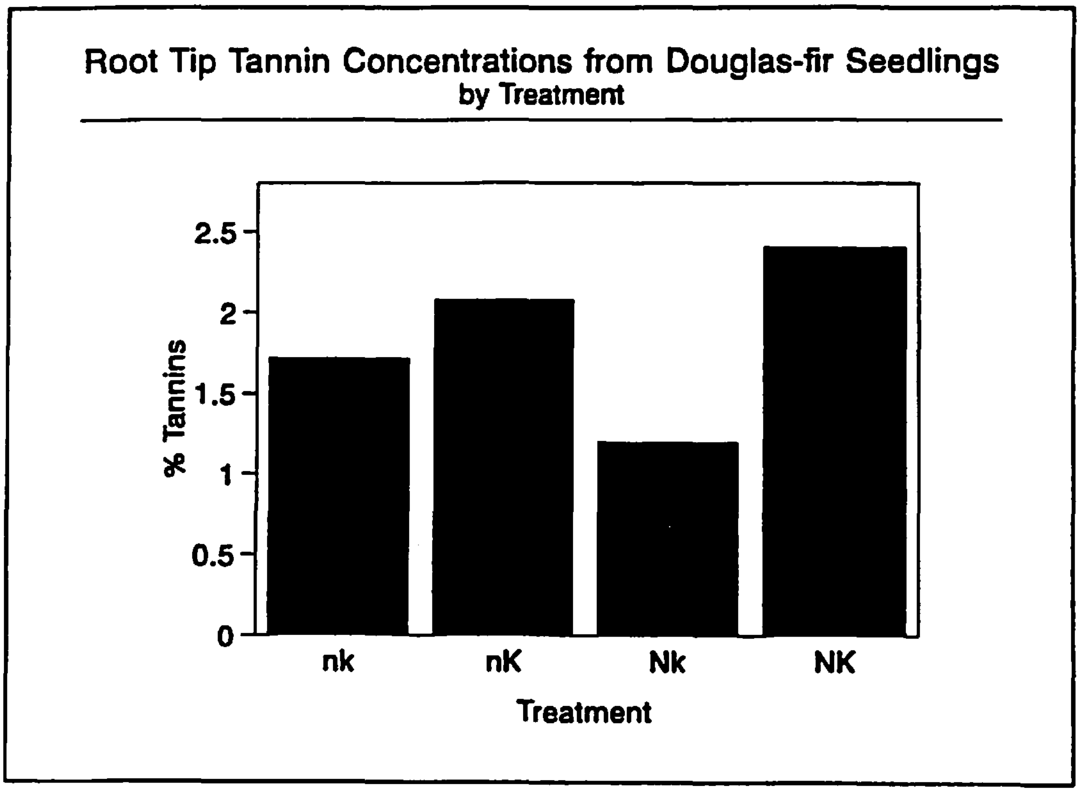
N has a significant effect on starch concentration with both low N treatments having significantly higher starch levels than both high N treatments. In contrast, potassium had no apparent effect on starch concentrations.



Phenolic levels in the low K treatments were significantly lower than the high K treatments.

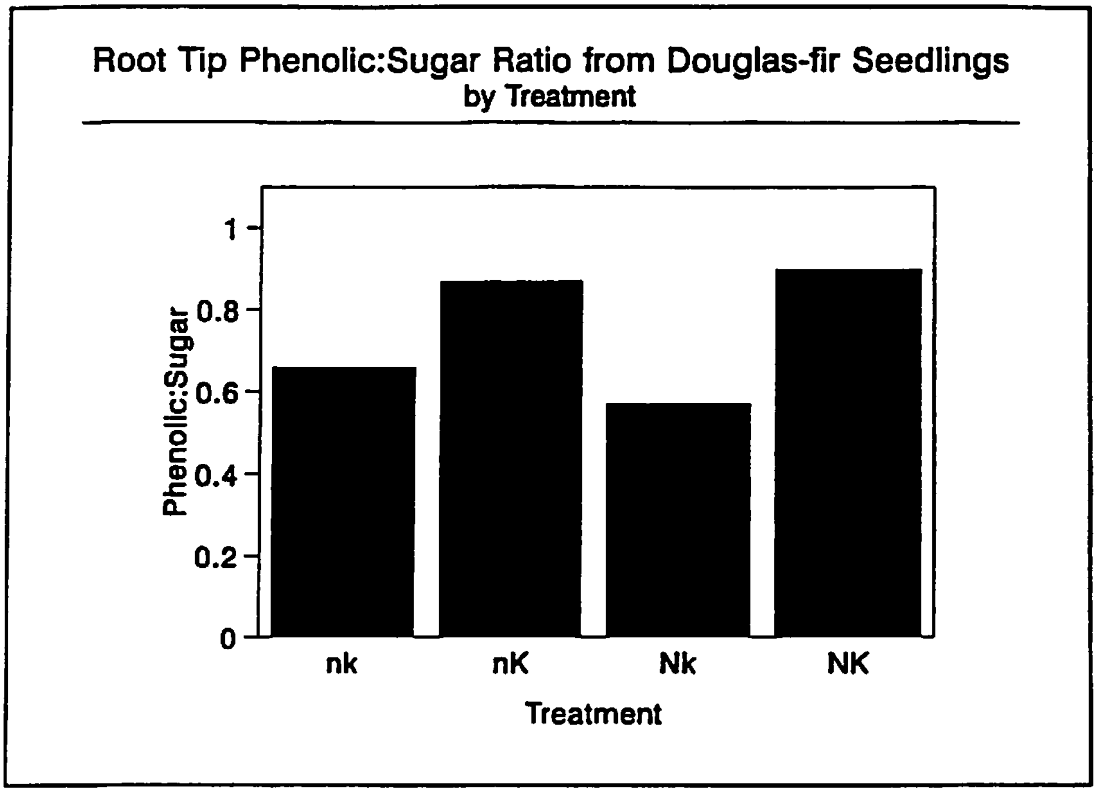


Both low K treatments tend to have lower tannin levels. This is significantly so in the high N low K treatment where tannin levels are only half as high as in the high N high K treatment.



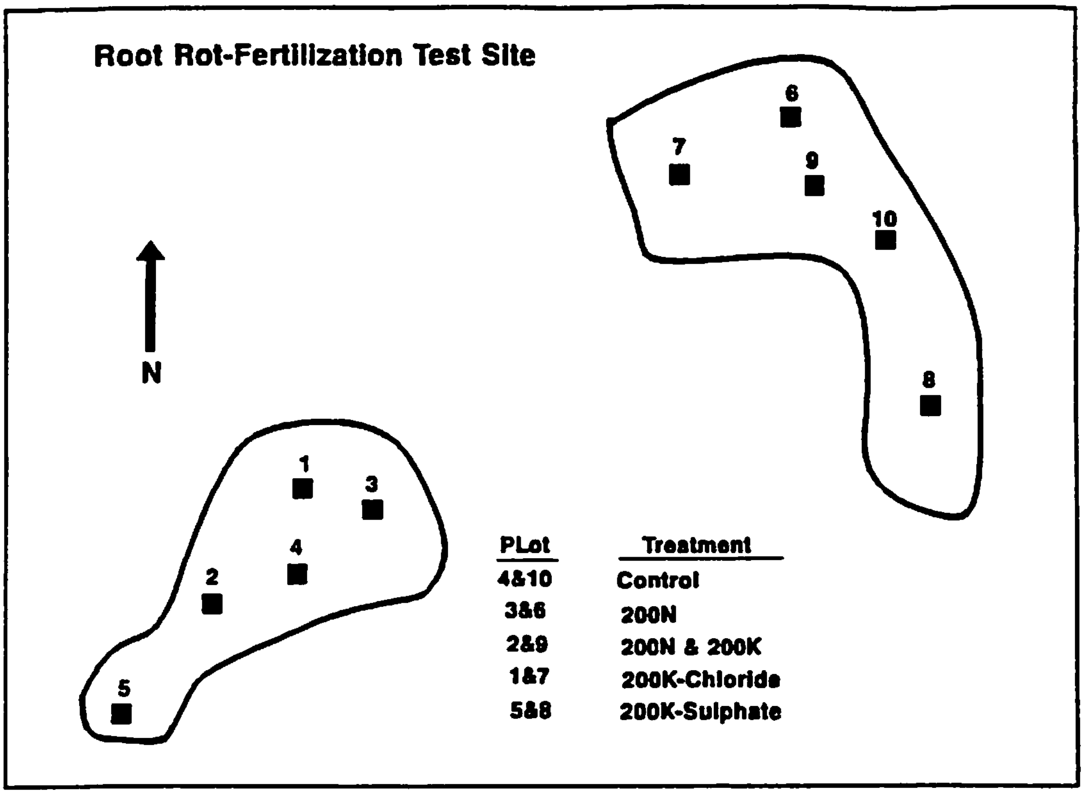
Significantly higher phenolic:sugar ratios were expressed in the high K treatments.

The ratio of phenols to sugars is strongly related to incidence of fungal (Armillaria) infection Entry et al. (1991). High ratios are bad for the fungus and good for the trees. This experiment demonstrates that high potassium results in high phenolic:sugar ratios, which may then lead to increased resistance to Armillaria attacks.



Douglas-fir Seedling Biochemistry Summary

- Biochemical levels were substantially higher in the root collar area than the root tip area, but did follow similar trends by treatments.
- Sugar concentrations were not significantly different between treatments.
- Starch concentrations were significantly different between the high nitrogen and low nitrogen treatments.
- A strong K effect was expressed in the high nitrogen treatments for both phenolic and tannin concentrations.
- The phenolic:sugar ratio was significantly lower in the Nk treatment than both the nK and NK treatments.
- The phenolic:sugar ratios tend to be lower in the low potassium treatments.



Root Rot-Fertilization Test Site
N
1
2
3
4
5
6
7
8
9
10
PLot
Treatment
4&10
Control
3&6
200N
2&9
200N & 200K
1&7
200K-Chloride
5&8
200K-Sulphate

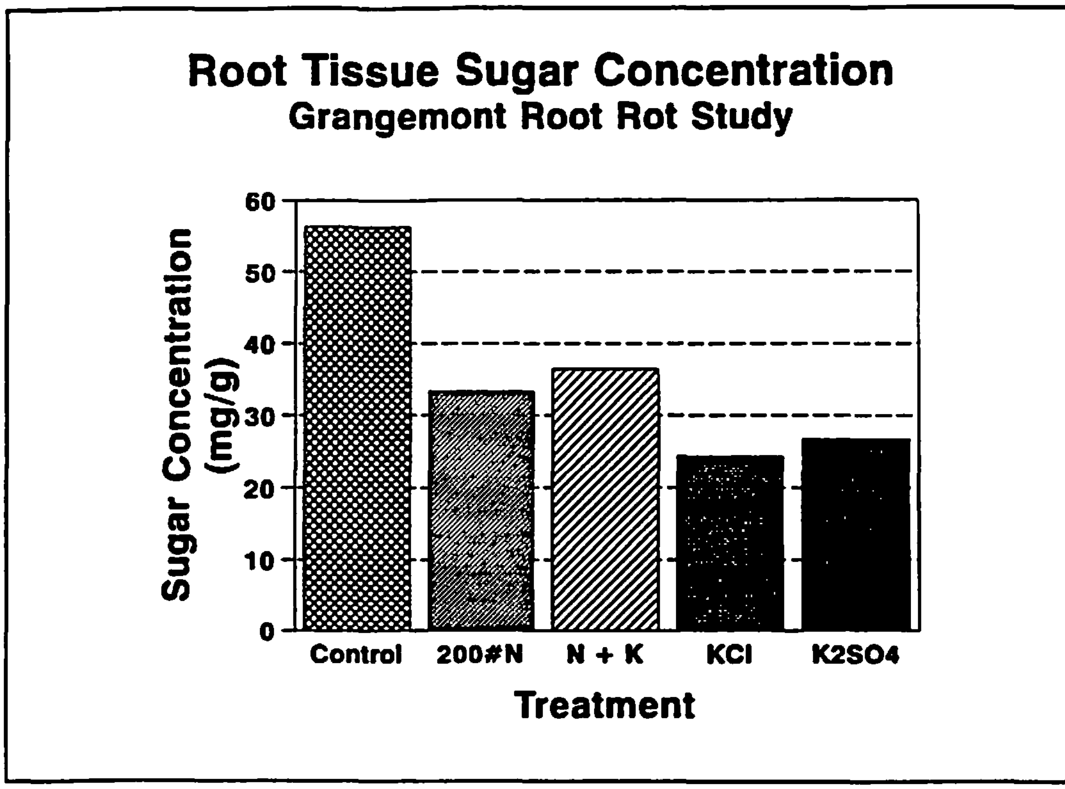
INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

THE EFFECT OF NITROGEN AND POTASSIUM FERTILIZATION ON DOUGLAS-FIR ROOT CHEMISTRY FROM THE GRANGEMONT ROOT ROT SITE

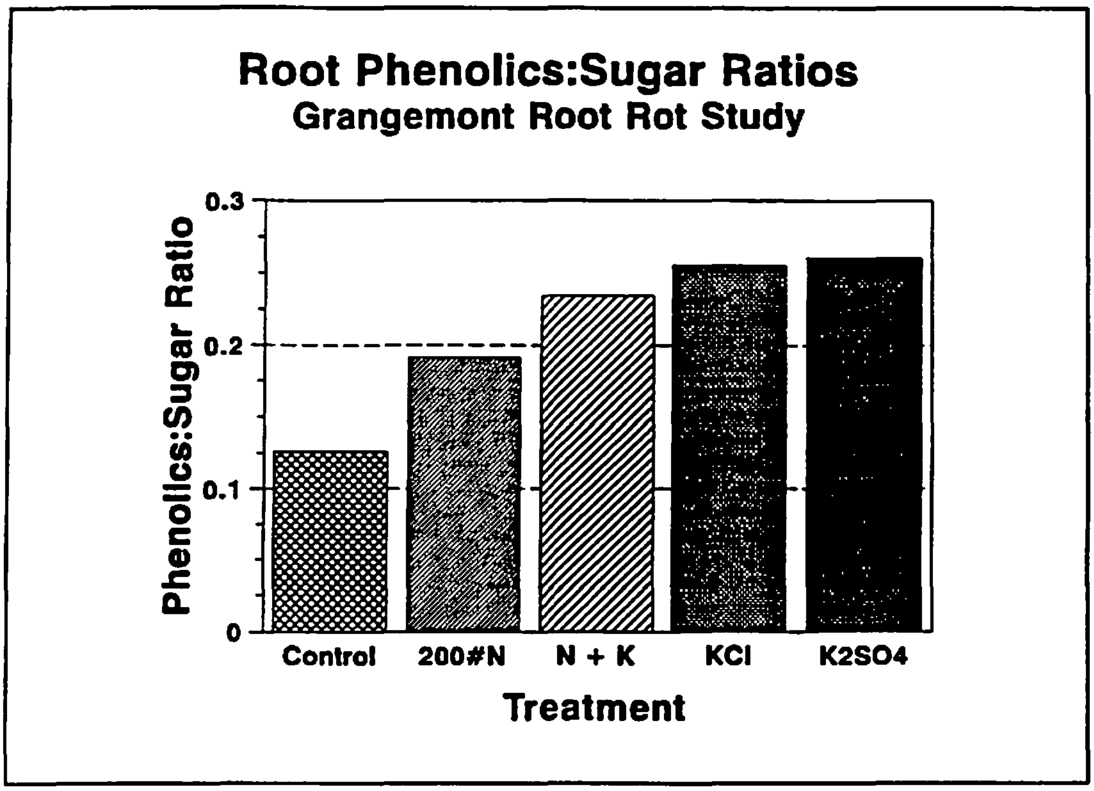
JOHN SCHWANDT

USDA FOREST SERVICE
COEUR D'ALENE, IDAHO

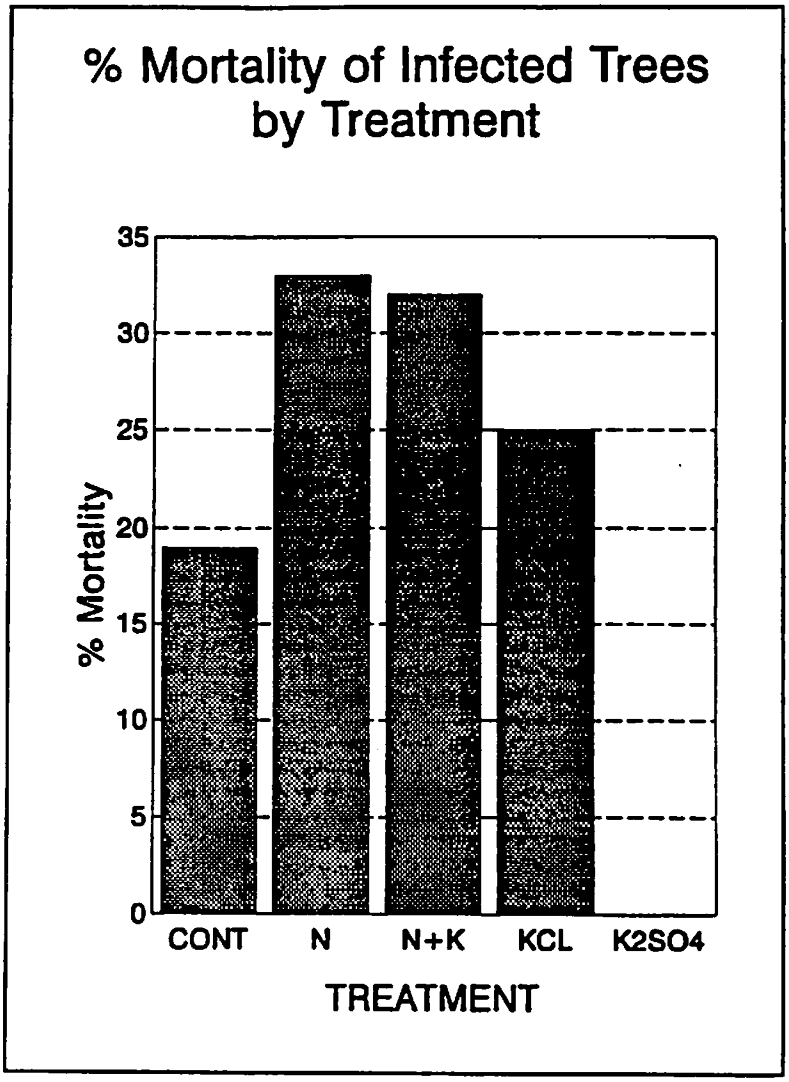
The fertilization treatments significantly reduced Douglas-fir root sugar concentrations four years after treatment. The potassium treatments reduced root sugar concentrations to one-half the control levels. High root sugar is bad for the trees and good for diseases.



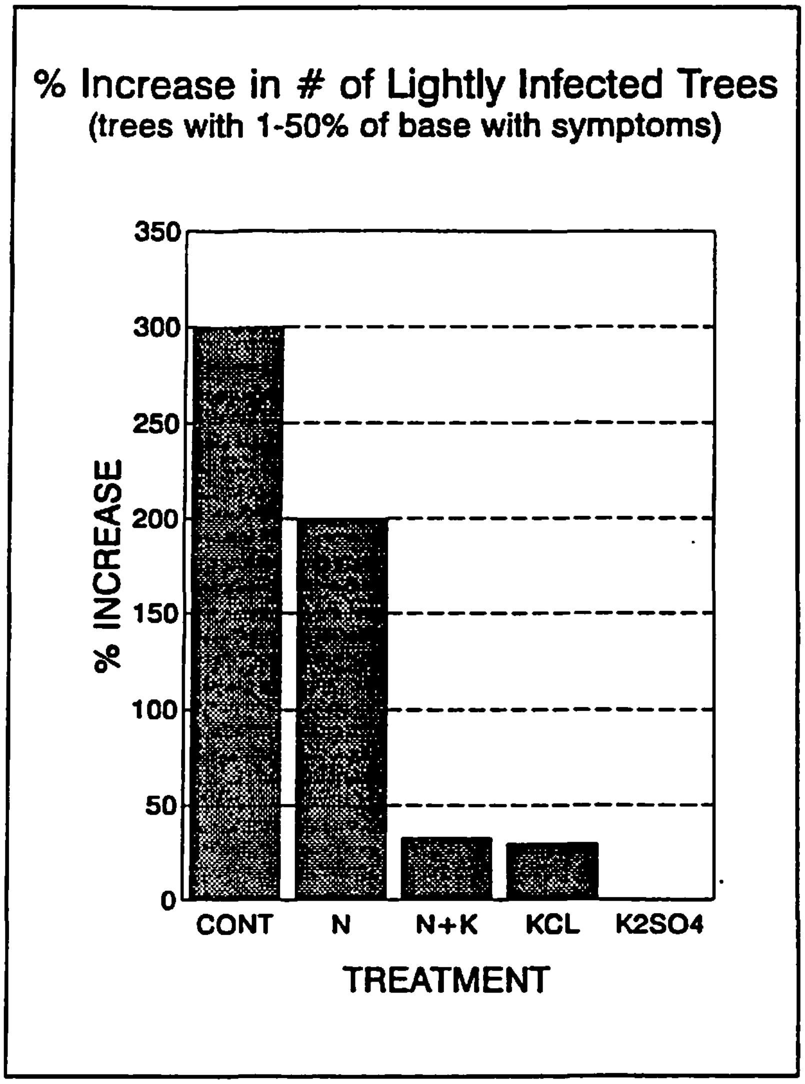
The results of this experiment suggests that it is possible to alter Douglas-fir biochemistry to the detriment of Armillaria by manipulating tree nutrition. The root phenolic / sugar ratio of the control plots trees would favor Armillaria infection; however, the fertilized plots should be more resistant to Armillaria infection.



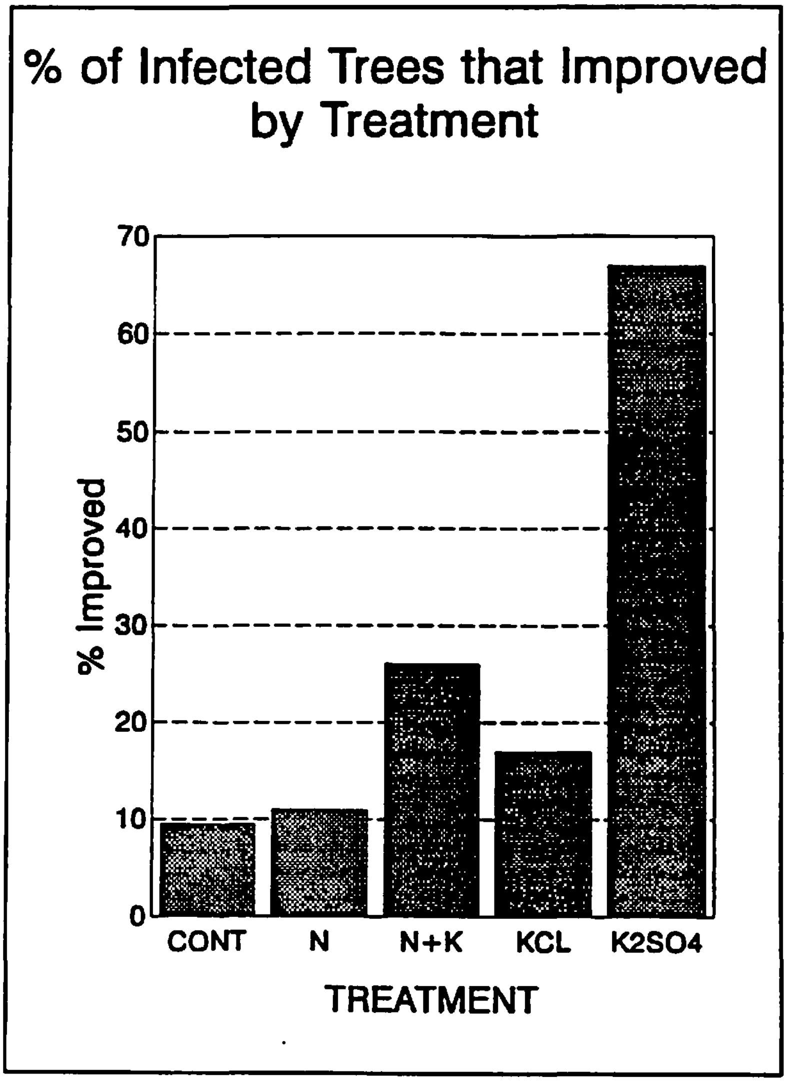
Some plot trees were quite heavily infected with Armillaria at the beginning of the experiment and most died within the first two years after treatment. The mortality rates are unrelated to treatment. This seems reasonable since the trees were probably too far gone for the fertilization treatments to have any beneficial effect. Notice that the K_2SO_4 treatment had no mortality; however, this is an artifact since those plots didn't have any severely infected trees at the start of the experiment. All other treatments did have severely infected trees at the start of the experiment.



The percent increase in the number of lightly infected trees (the number does not include trees that recovered during the period) was related to treatment. All treatments that included K in the fertilizer mix (N+K; KCL;and K_2SO_4) showed substantially lower increased infection than the controls. These results parallel the treatment effects on root chemistry.



The percent of Armillaria infected trees that improved in the symptoms of infection was also related to the fertilization treatments. About 65% of the infected trees on the K_2SO_4 treatment improved while less then 10% of the infected trees on the control plots got better.

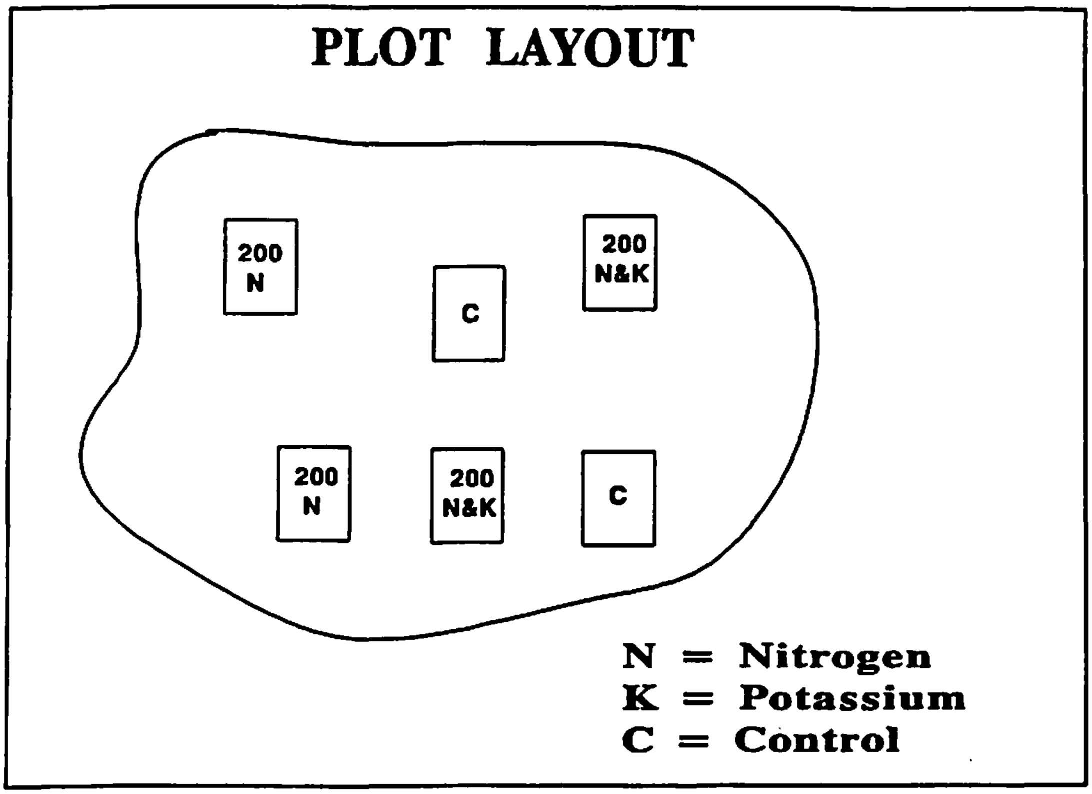


INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

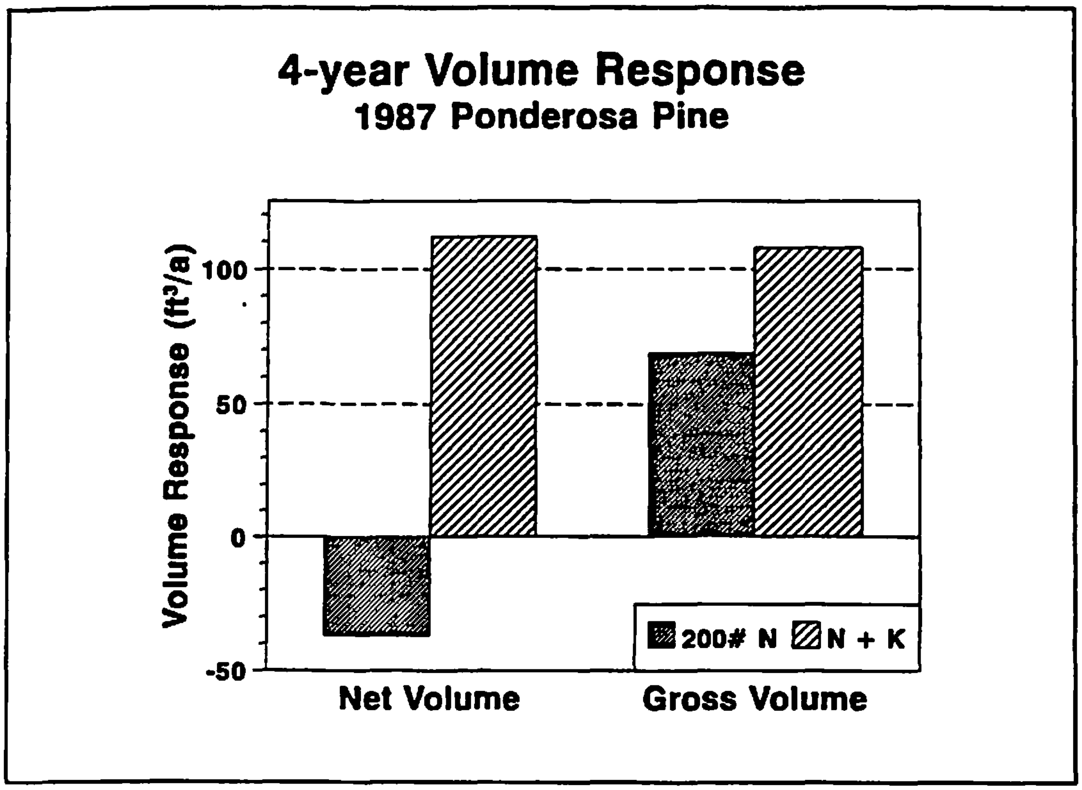
PONDEROSA PINE AND MOUNTAIN PINE BEETLE RESPONSE TO NITROGEN AND POTASSIUM FERTILIZATION IN MONTANA

JOHN M. MANDZAK

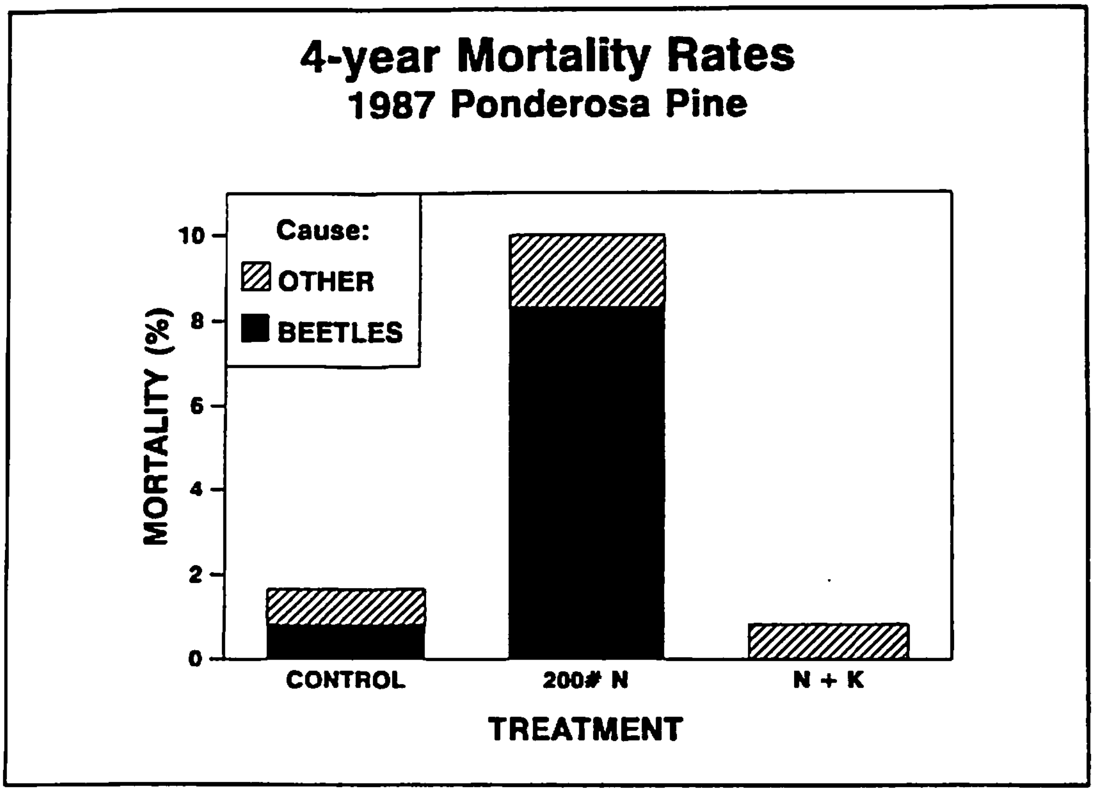
LAND & WATER CONSULTING, INC
MISSOULA, MONTANA


PLOT LAYOUT
200
N
C
200
N&K
200
N
200
N&K
C
N = Nitrogen
K = Potassium
C = Control

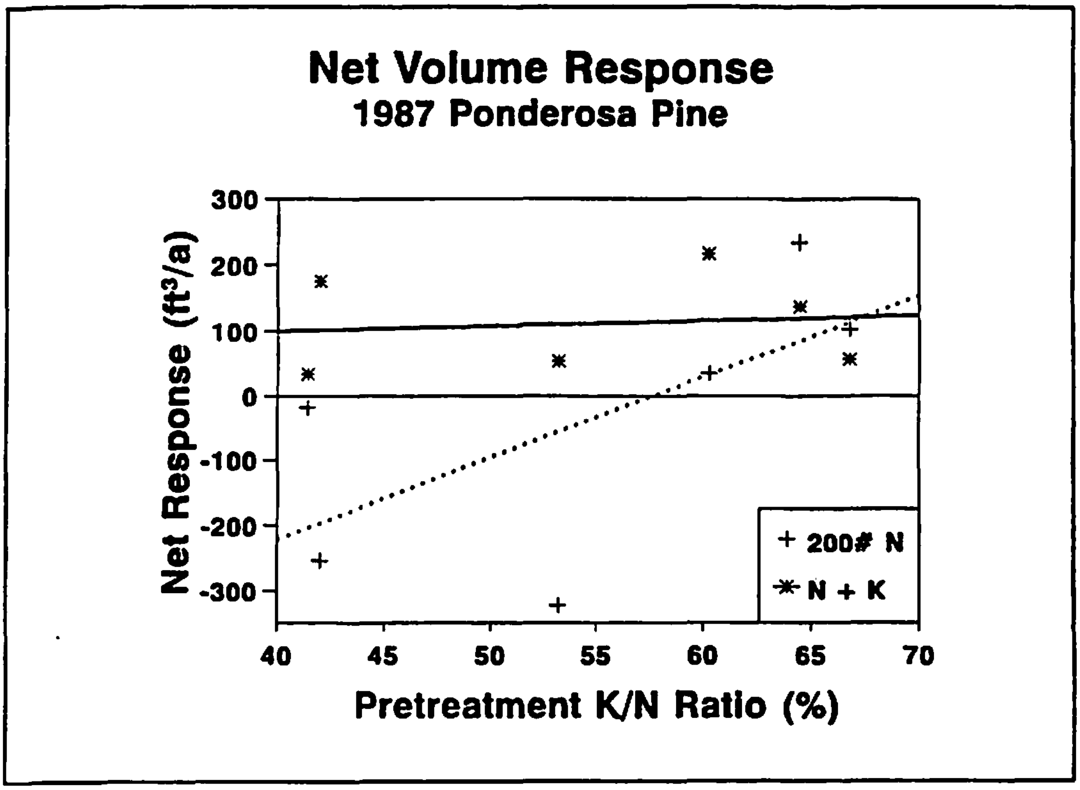
The results of the Montana ponderosa pine experiment strongly support the potassium hypothesis developed from the Douglas-fir experiment. The 200 # N alone treatment produced an average negative net response after 4 years; however, the 200 # N plus 200 # K treatment was strongly positive. The treatment response difference is due to tree mortality on the N -alone plots that did not occur on the N plus K treatment.



The mountain pine beetles came and sought out the trees on the 200 # N alone fertilized plots, but not a single tree was killed by beetles during the 4 year period on the adjacent 200 # N plus 200 # K treated plots.



The N alone treatment-induced MPB-caused mortality was associated with those sites that had pre-treatment foliar K/N ratios below 50. However, when both N and K were included in the fertilizer mix, no negative response occurred regardless of the pre-treatment foliar K/N value.



INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

NUTRITIONAL DIFFERENCES BETWEEN TREE SPECIES

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MOSCOW, IDAHO

Umatilla

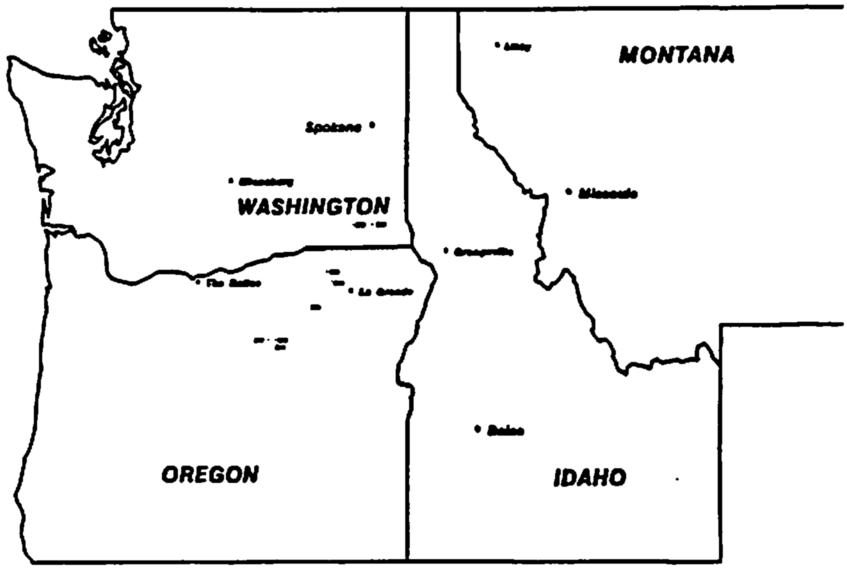
National Forest

Mixed Conifer

Foliar Concentrations

Geographic locations in S.E. Washington and N.E. Oregon for the Umatilla National Forest N and S nutrition study (Installations 313-320).

INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE



Mixed Species Umatilla Study Site

Site characteristics by installation for the Umatilla National Forest nutrition study.

Site Characteristics

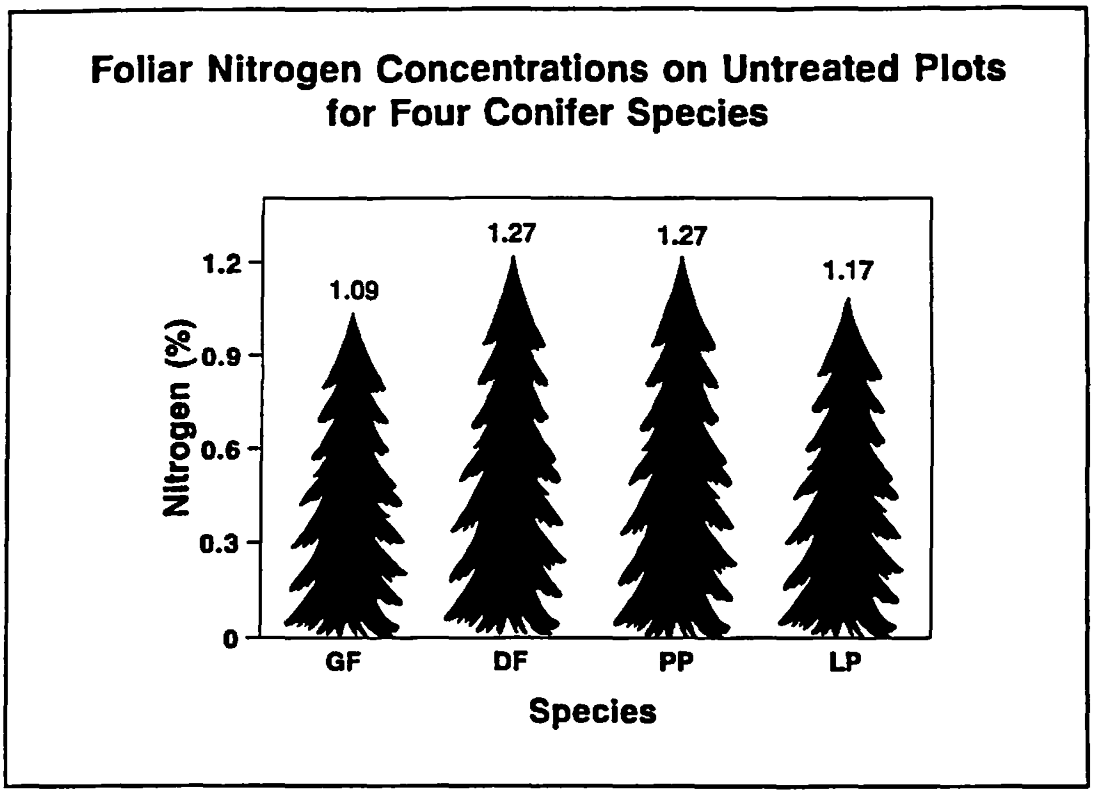
Site	Age	Veg. Series	Parent Material
313	26	ABLA	Basalt
314	23	ABGR	Basalt
315	26	ABGR	Basalt
316	24	ABGR	Basalt
317	10	ABGR	Basalt
318	10	ABGR	Basalt
319	10	ABGR	Basalt
320	11	ABGR	Basalt

Treatments for the Umatilla National Forest nutrition study.

TREATMENTS

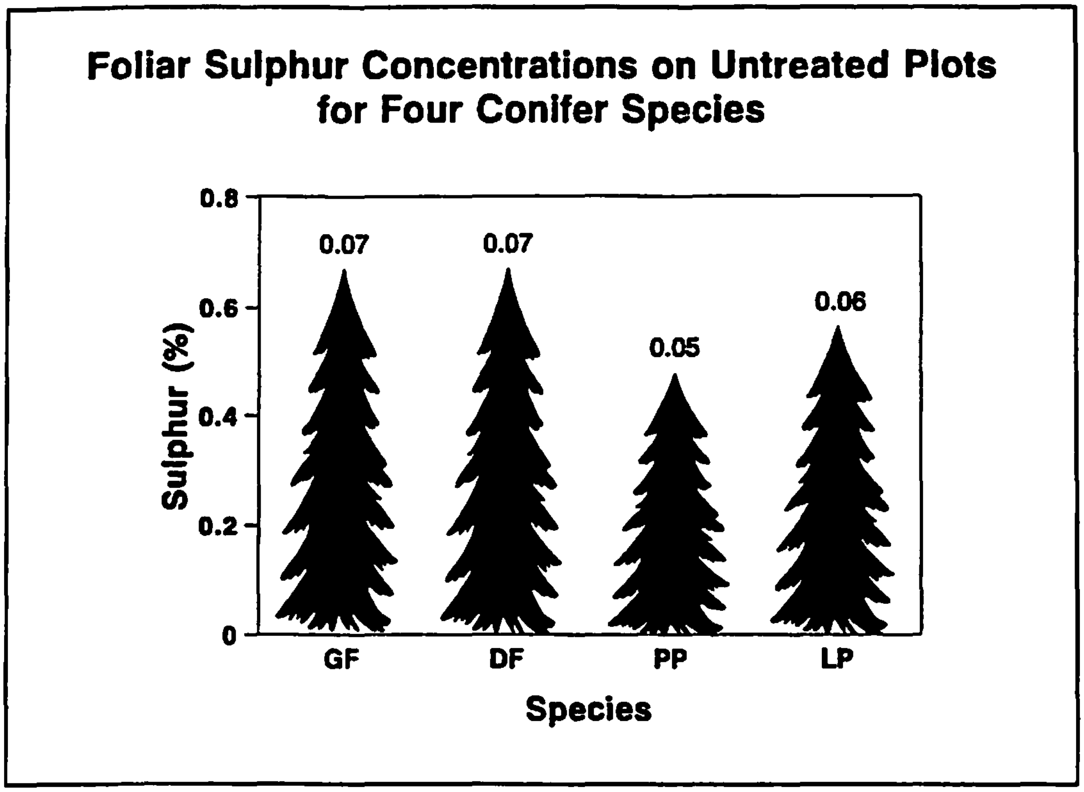
- Control
- 200 # Nitrogen
- 200 # Nitrogen plus 100 # Sulfur

Grand fir has the lowest average foliar nitrogen concentrations on the untreated plots, but the nitrogen concentrations do tend to be similar between all four conifer species and are not significantly different.

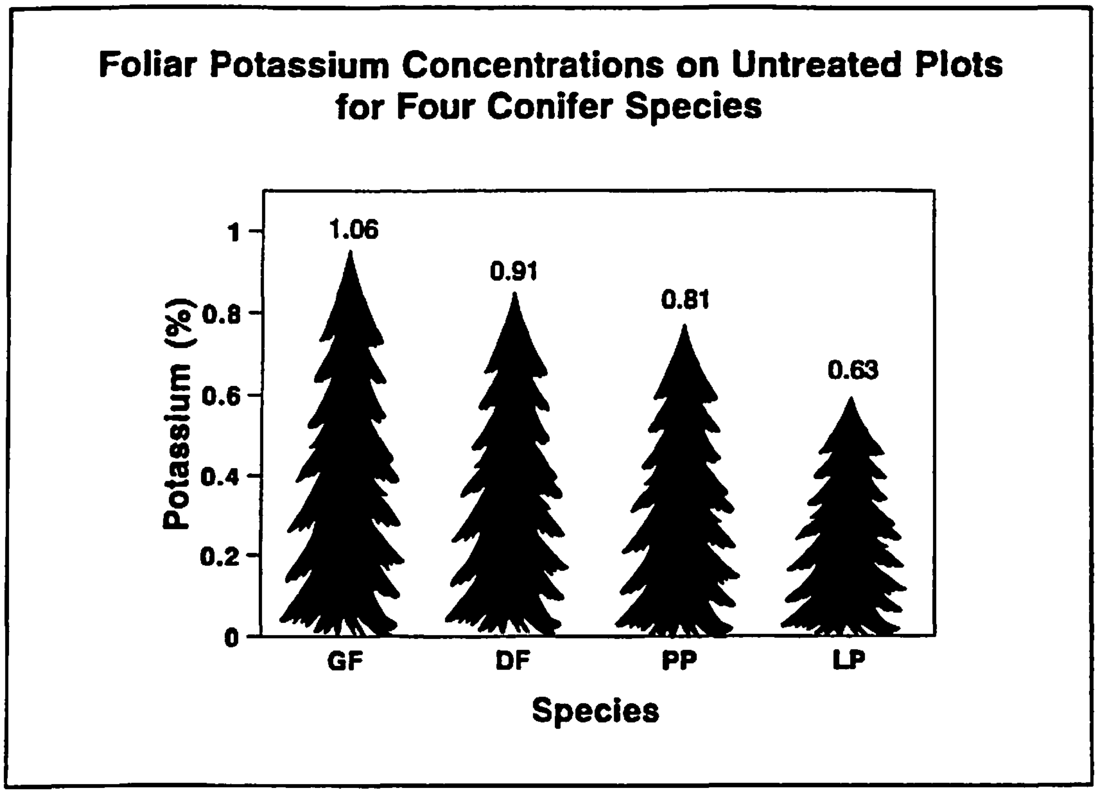


Foliar sulphur concentrations are higher in the late successional species (Douglas-fir and grand fir) than in the early successional species (lodgepole pine and ponderosa pine).

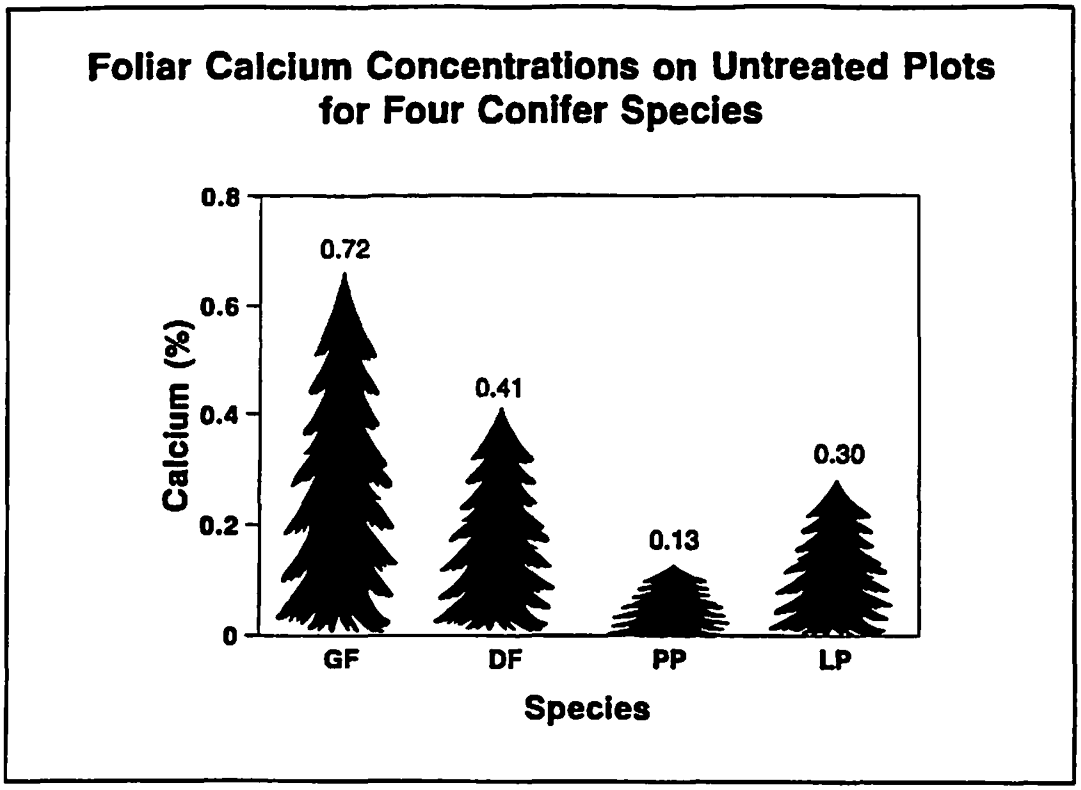
Although the sulphur concentrations are low for all species, Douglas-fir and grand fir seem to be the dominant S sinks between species.



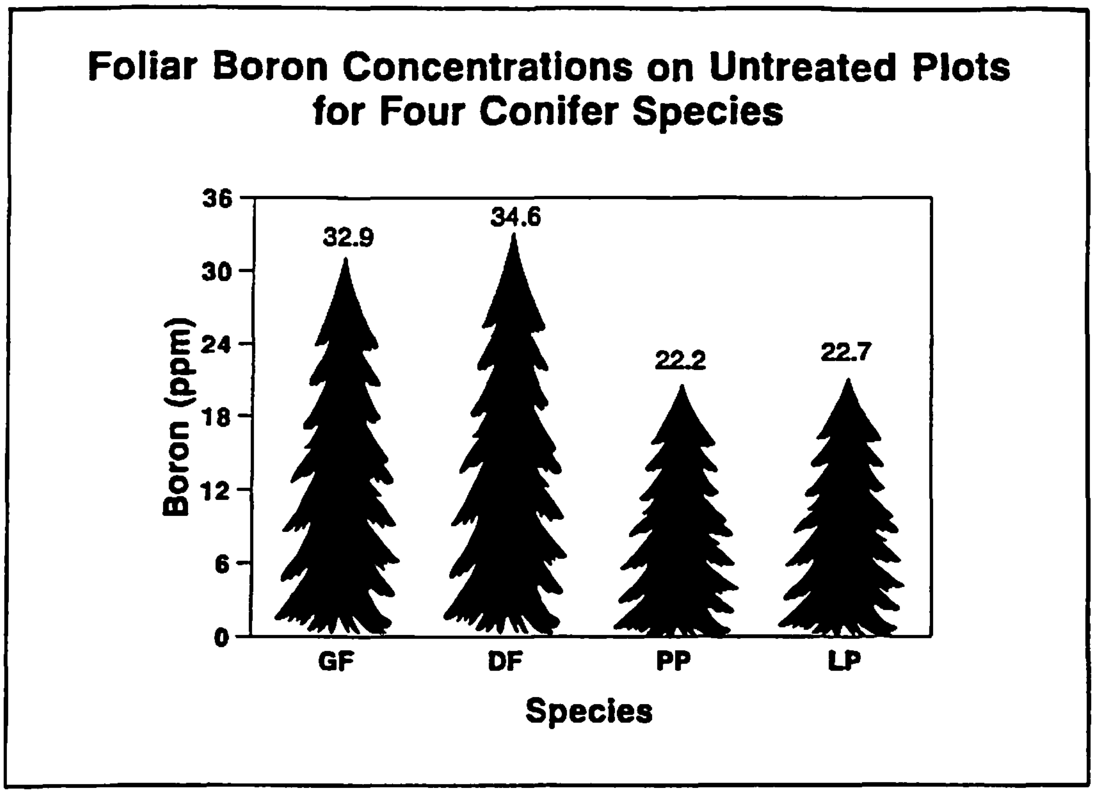
Foliar K concentration follow the same trends as S with Douglas-fir and grand fir having higher levels than ponderosa pine or lodgepole pine. Grand fir was the largest K sink with 1.06% K and lodgepole pine the lowest with 0.63% K.



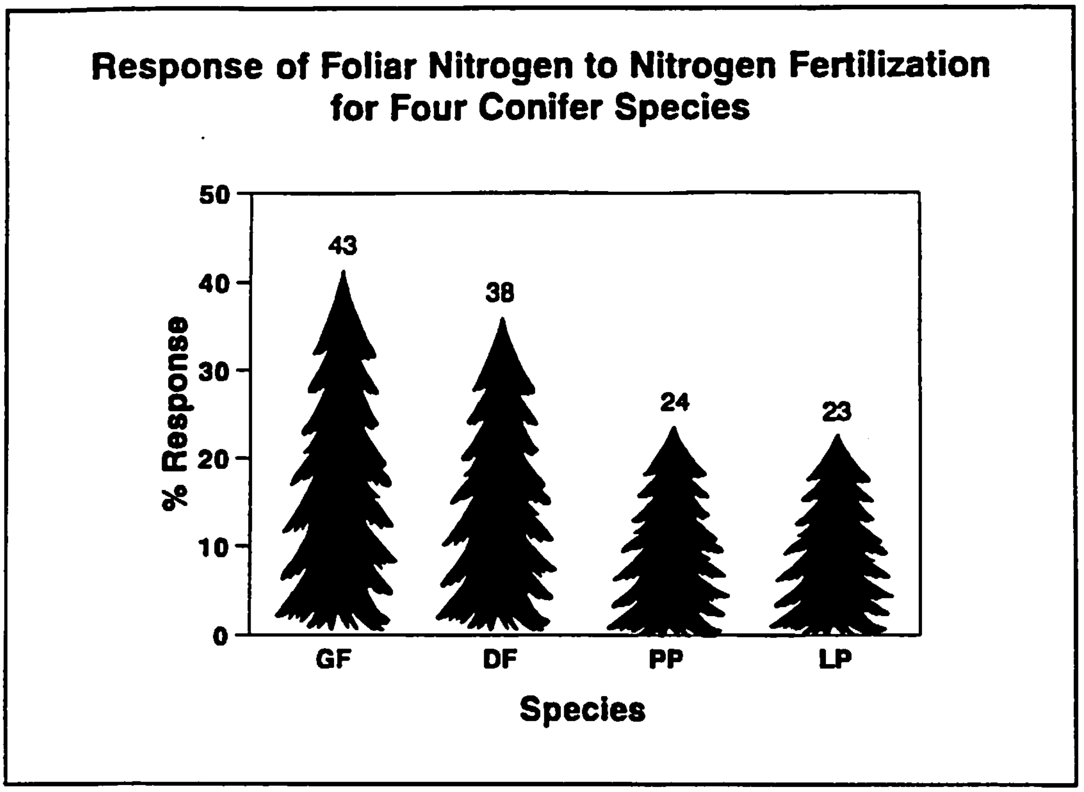
Calcium concentrations were substantially higher in the late successional species (grand fir and Douglas-fir) than the early successional (ponderosa pine and lodgepole pine). Grand fir concentrations were more five times higher than ponderosa pine concentrations.



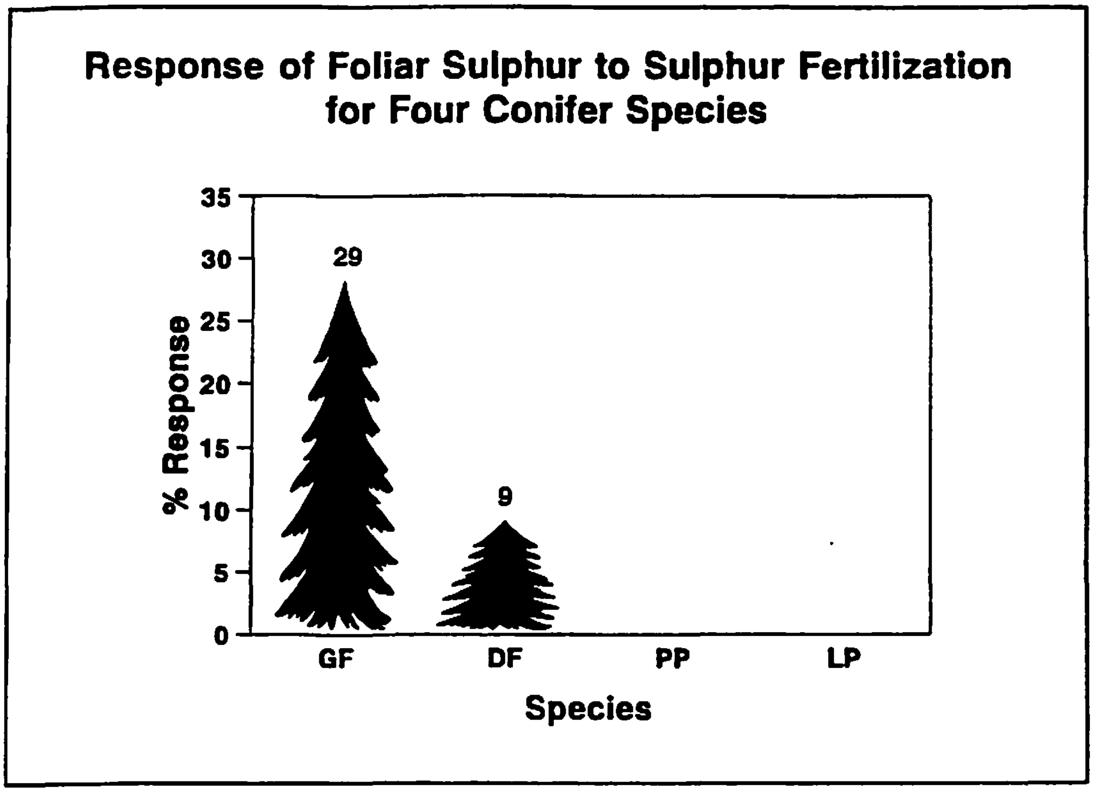
Foliar boron concentrations expressed the same trends as the other foliar elements with Douglas-fir and grand fir having higher levels that ponderosa pine or lodgepole pine.



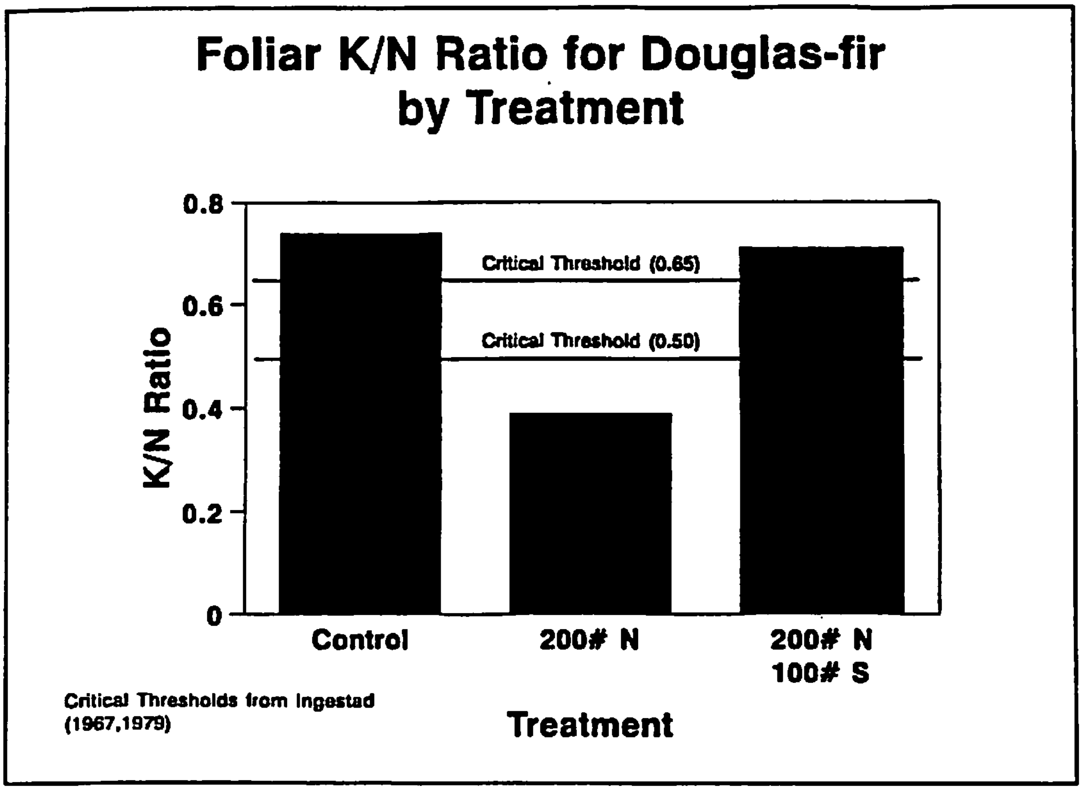
Foliar nitrogen concentrations on the N treatments did increase over the controls for all species. The foliar N response was higher for Douglas-fir and grand fir than for ponderosa pine or lodgepole pine. Again, grand fir was the largest nutrient sink with a 43% increase after fertilization.



Foliar sulphur responses were strikingly different between early and late successional species. Foliar sulphur concentrations for ponderosa pine and lodgepole pine did not increase over the controls. In contrast, sulphur concentrations for Douglas-fir increased 9% and grand fir a notable 29% over the controls.

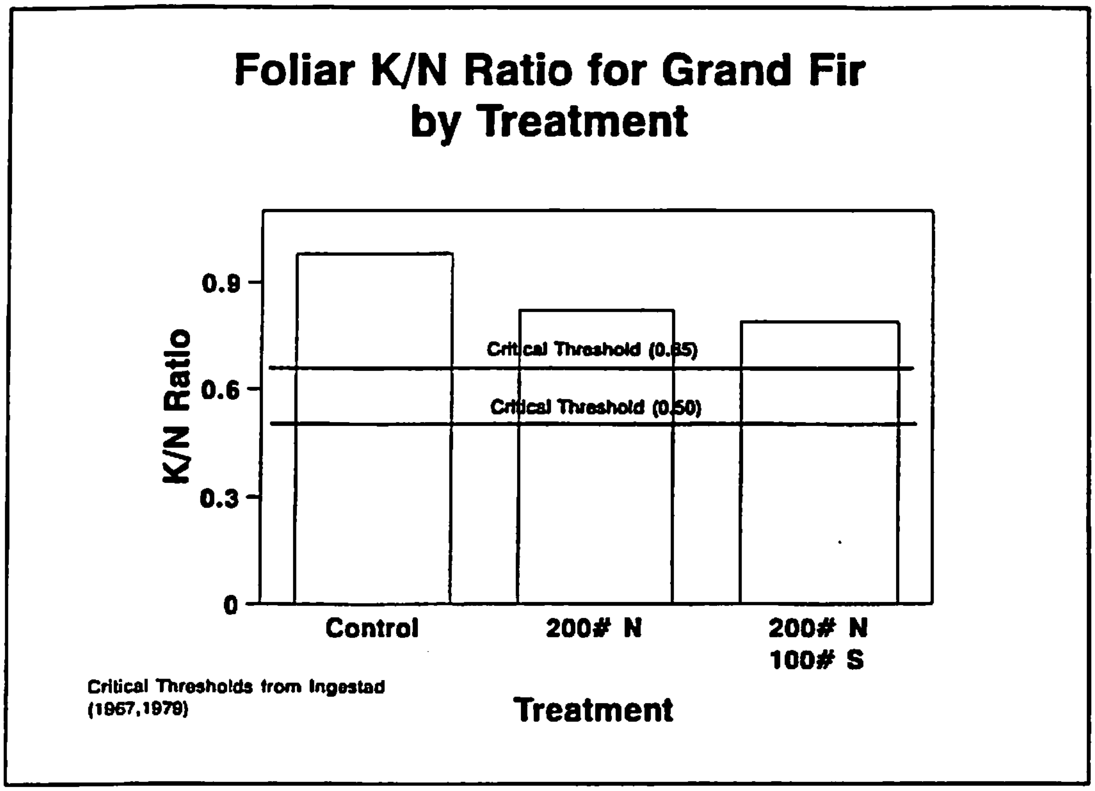


The K/N ratio decreased significantly when N was applied alone. However, when N and S were applied together this effect seemed to be buffered and the K/N ratio was similar to the control.

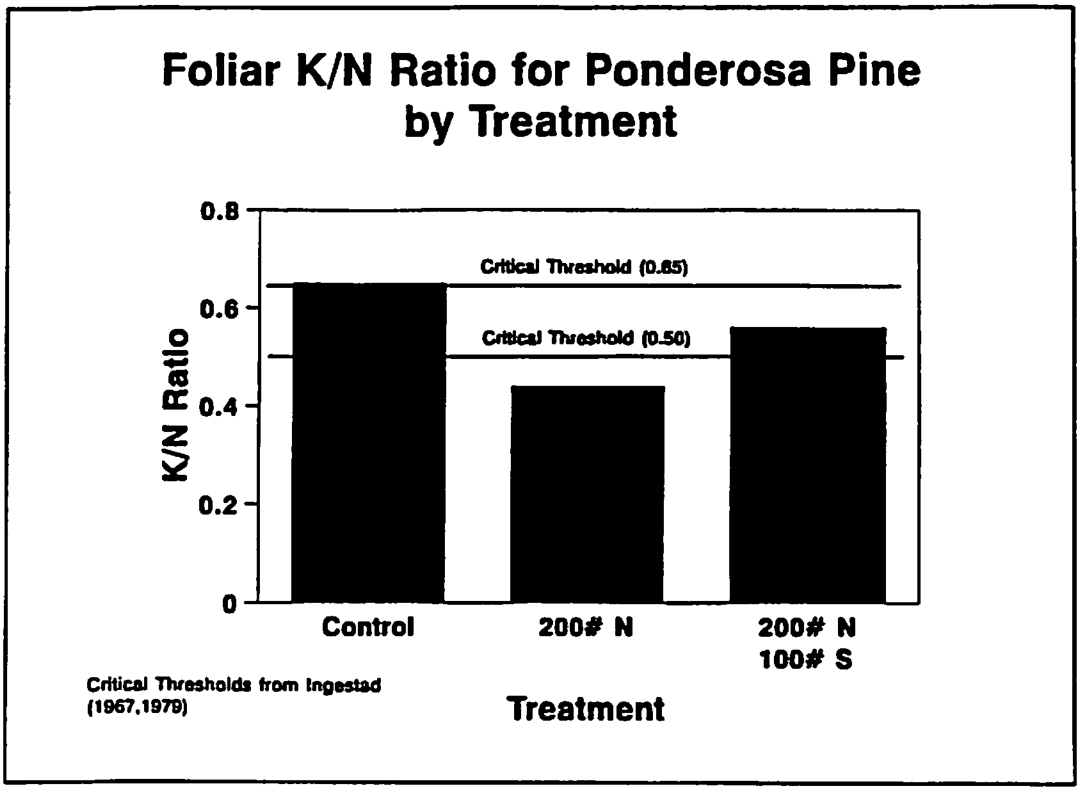


All grand fir K/N ratios are above the 0.65 threshold, indicating high amounts of K in the foliage.

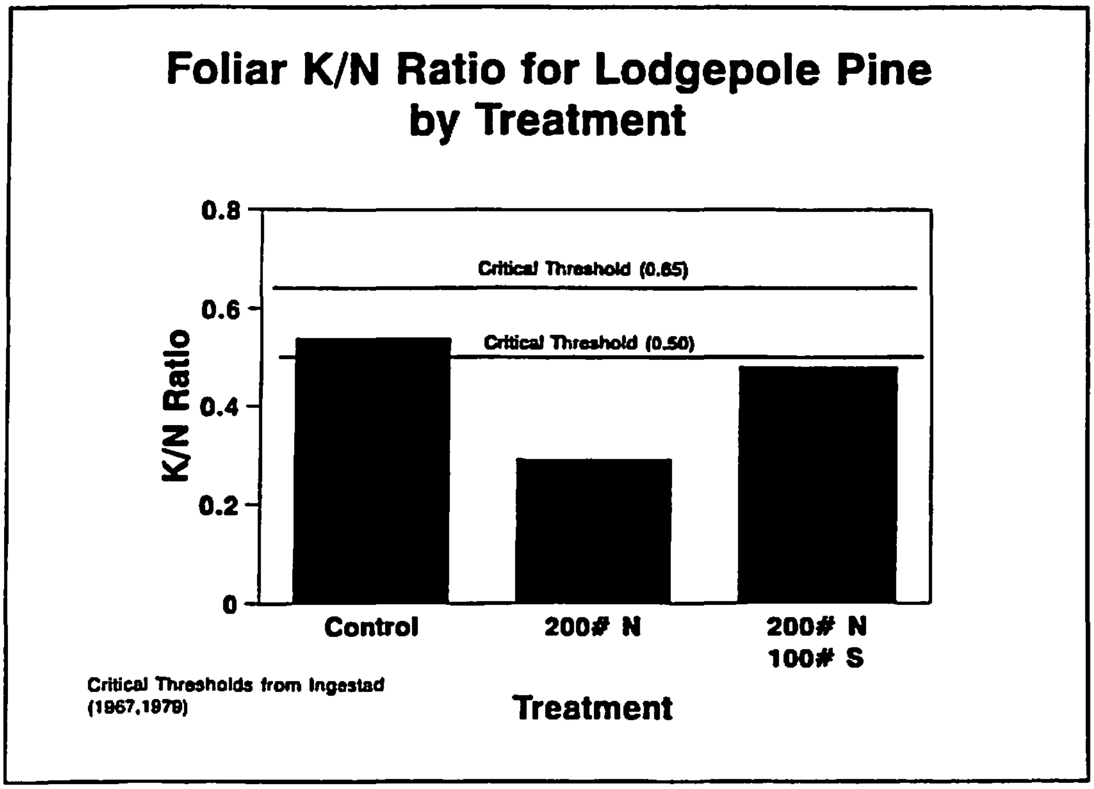
The K/N ratios did tend to decrease on both N fertilization treatments.



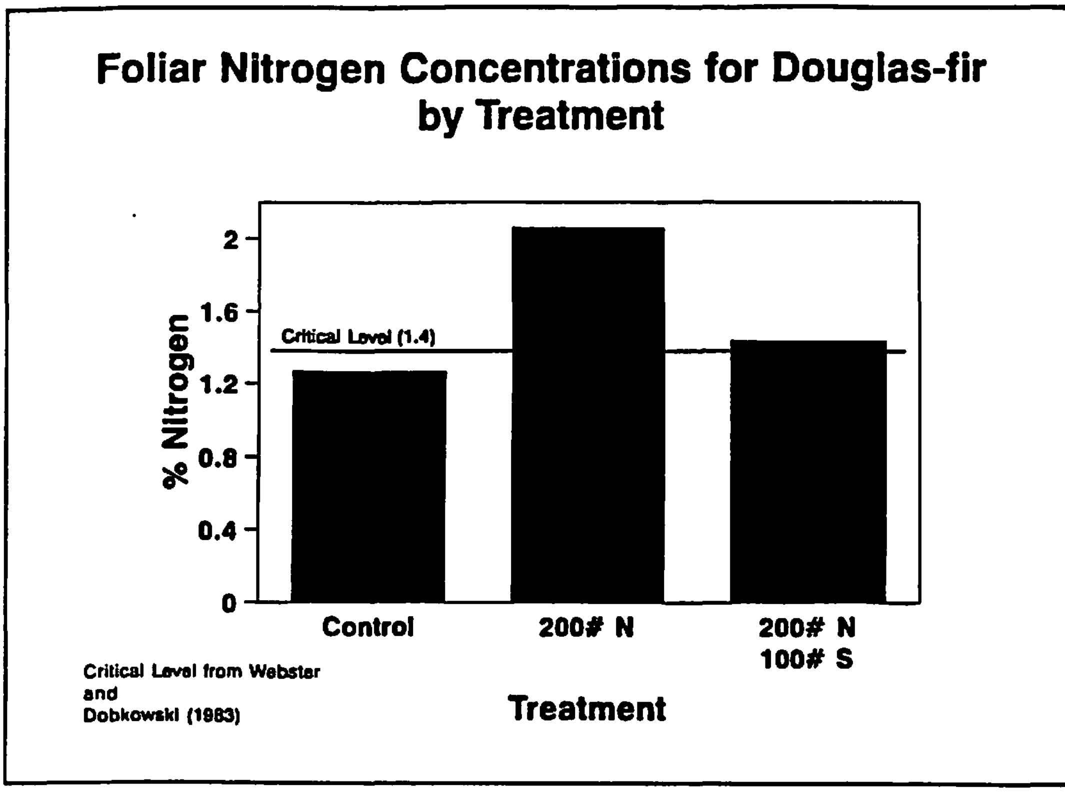
Ponderosa pine K/N ratios were similar to the Douglas-fir K/N ratios where the N alone treatment caused the K/N ratio to decrease below the 0.50 threshold. Again, the addition of S with N has buffered the treatment effects and the K/N ratio did not decrease below the critical level.



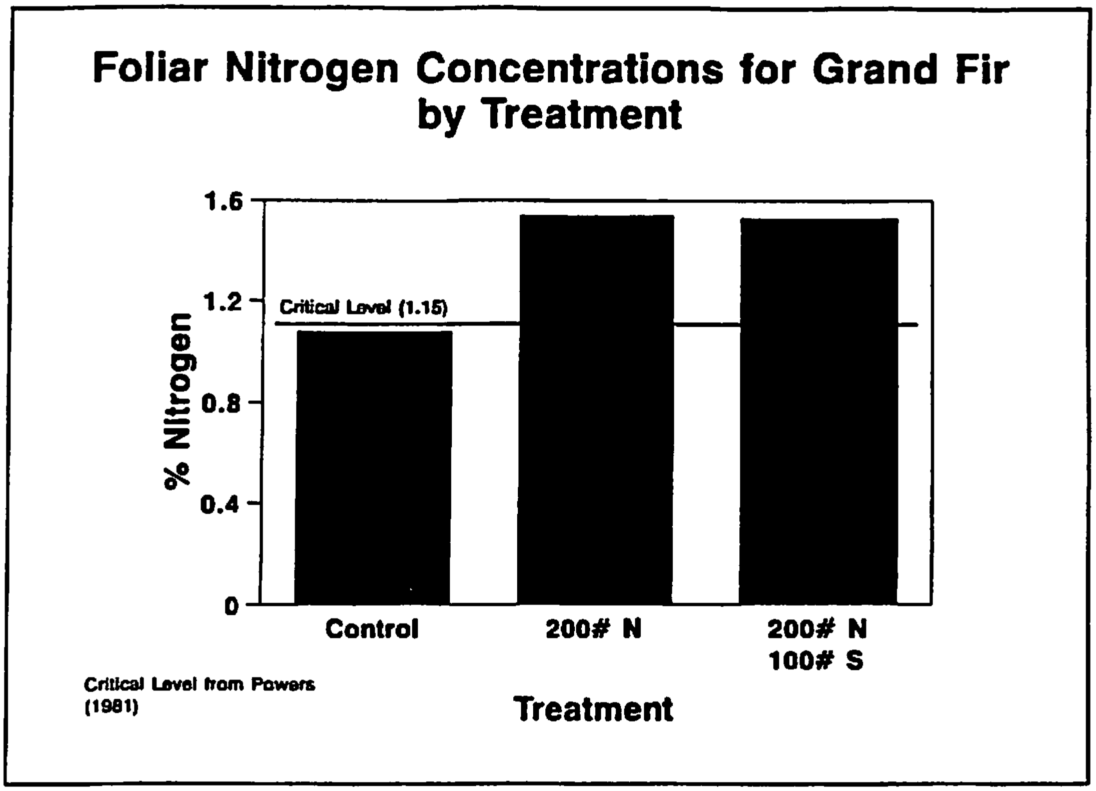
Lodgepole pine K/N ratios were lower than all of the other species in this study. Again, the N alone treatment decreased far below the 0.50 critical level. In addition, the NS treatment also fell below the 0.5 critical threshold.



Foliar N concentration on the control plots were deficient for Douglas-fir, but after fertilization N foliar levels increased above the 1.4 critical level. Foliar response was better for the N alone treatment than the NS treatment.

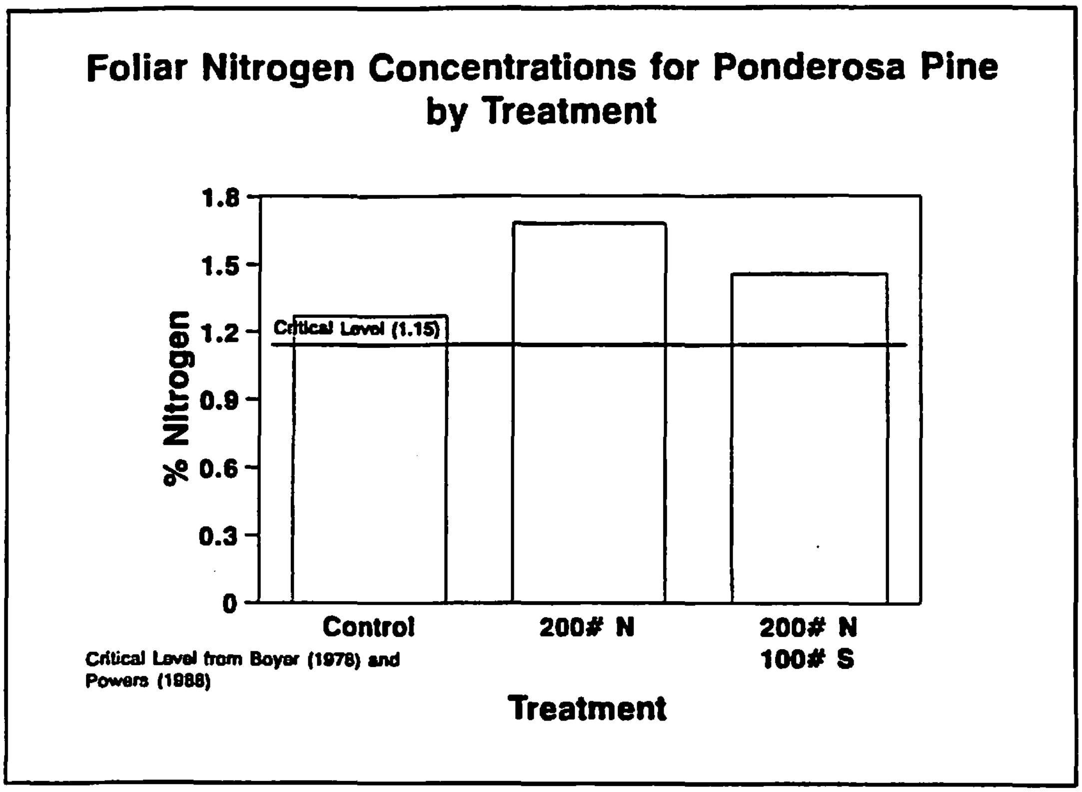


Grand fir foliar N levels were deficient on the control plots but increased substantially above inadequate levels on both the N and NS treatments.

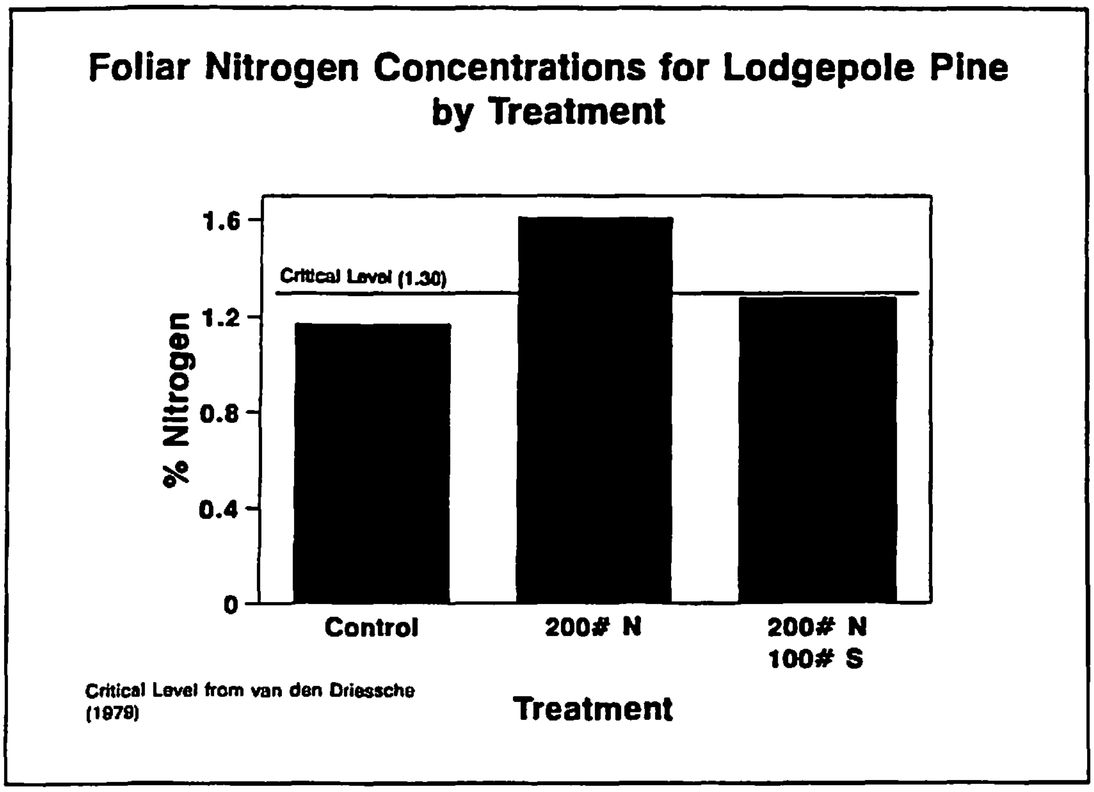


Ponderosa pine foliar nitrogen was above inadequate for all three treatments.

Although foliar response was expressed on both fertilizer treatments, the N alone response was higher than the NS response.



Lodgepole pine foliar nitrogen levels were deficient on the controls but increase above the inadequate critical level on the N alone treatment. There was a weak response to N fertilization on the NS treatment but foliar N was still below the inadequate.



Mixed Conifer Foliar Concentration Summary

- Most foliar nutrient concentrations tend to be higher in grand fir and Douglas-fir.
- Nitrogen and sulphur uptake after fertilization was highest in grand fir and lowest in lodgepole pine.
- Nitrogen concentrations on the untreated plots were deficient for all species except for ponderosa pine.
- K/N ratios on the N alone treatment fell below critical thresholds for all species except for grand fir.

INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

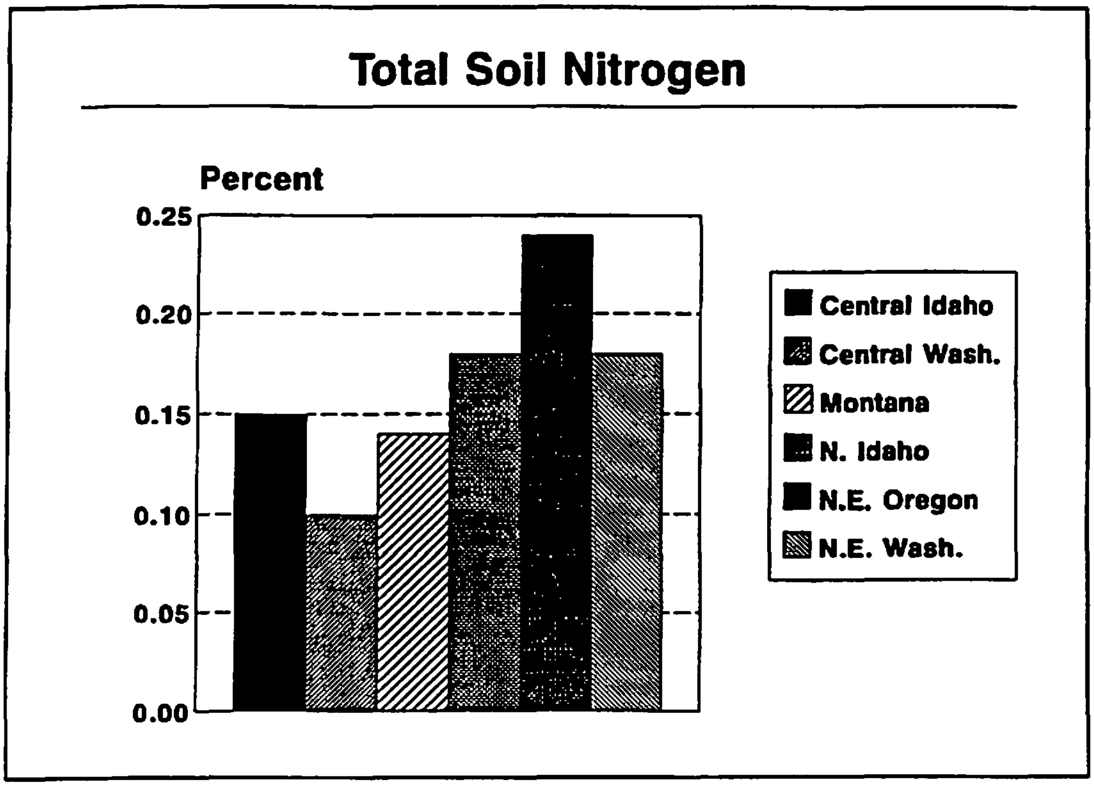
SOILS AND TREE NUTRITION IN THE INLAND NORTHWEST

JOHN SHUMWAY

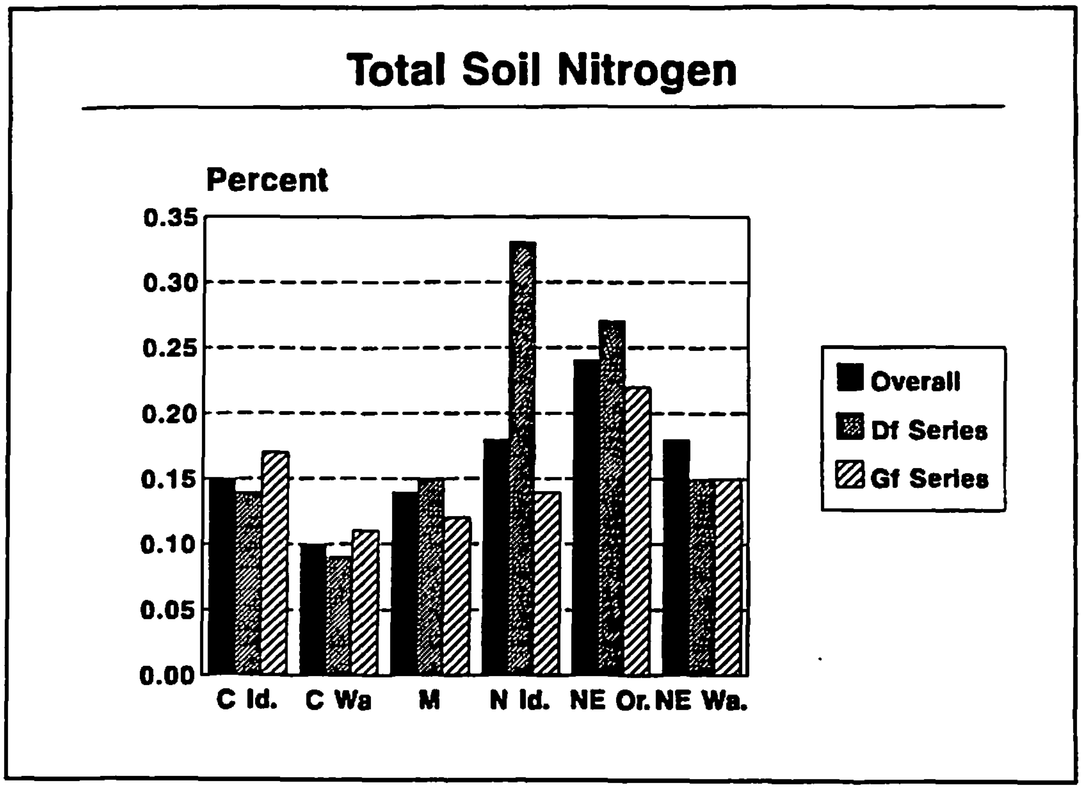
WASHINGTON DEPARTMENT OF NATURAL RESOURCES
OLYMPIA, WASHINGTON

Central Washington had the lowest pretreatment soil total nitrogen while northeast Oregon was the lowest of all IFTNC geographic regions.

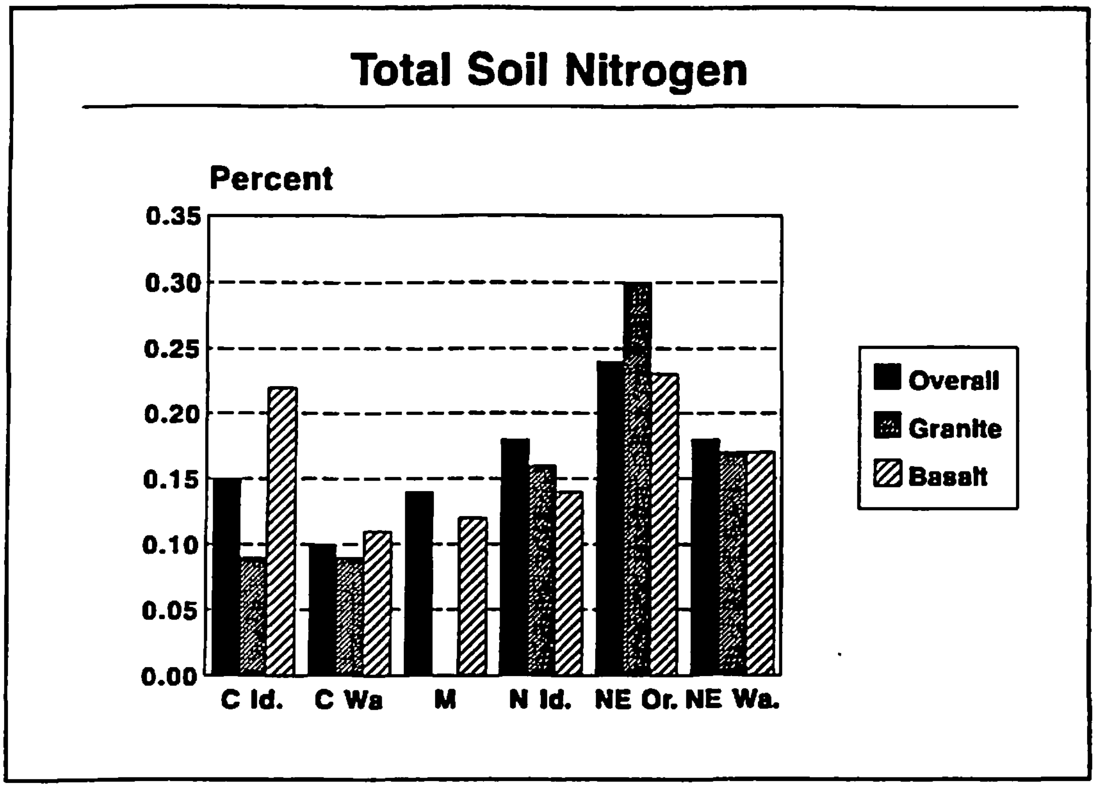
Further, central Washington produced the highest average response to nitrogen fertilization treatments while northeast Oregon had the lowest nitrogen response of all IFTNC regions.



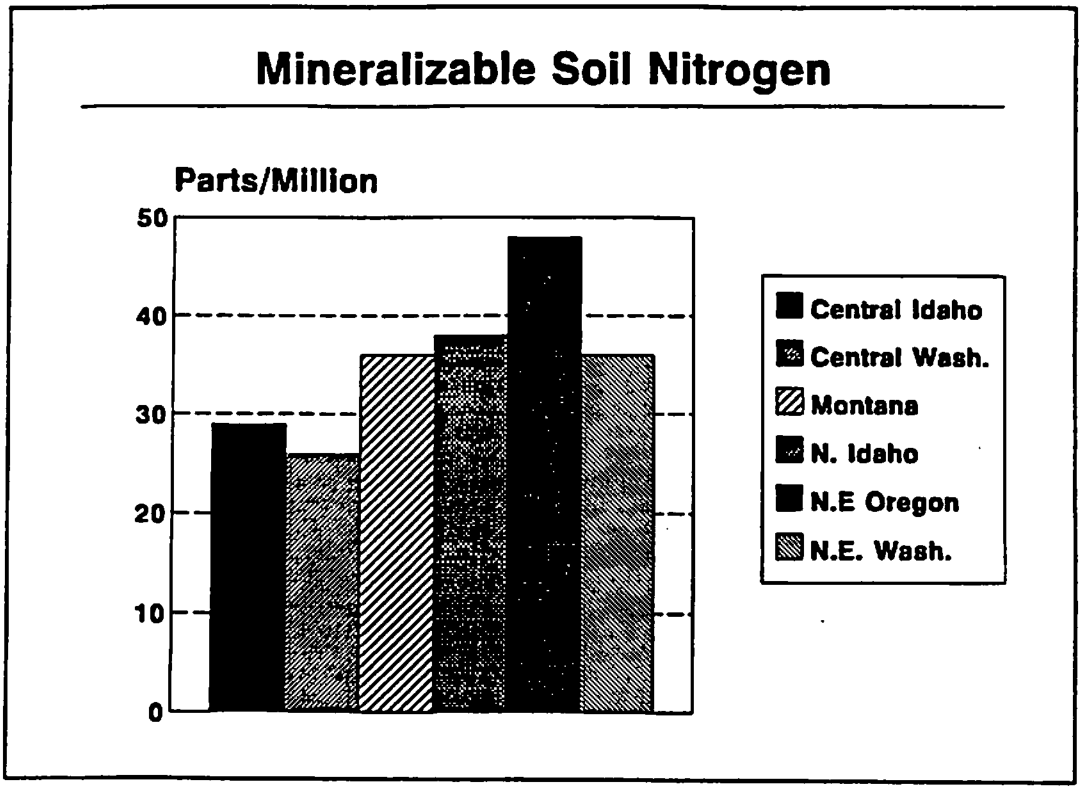
Except for northern Idaho, there is little difference in pretreatment total soil nitrogen for Douglas-fir and grand fir habitat series.



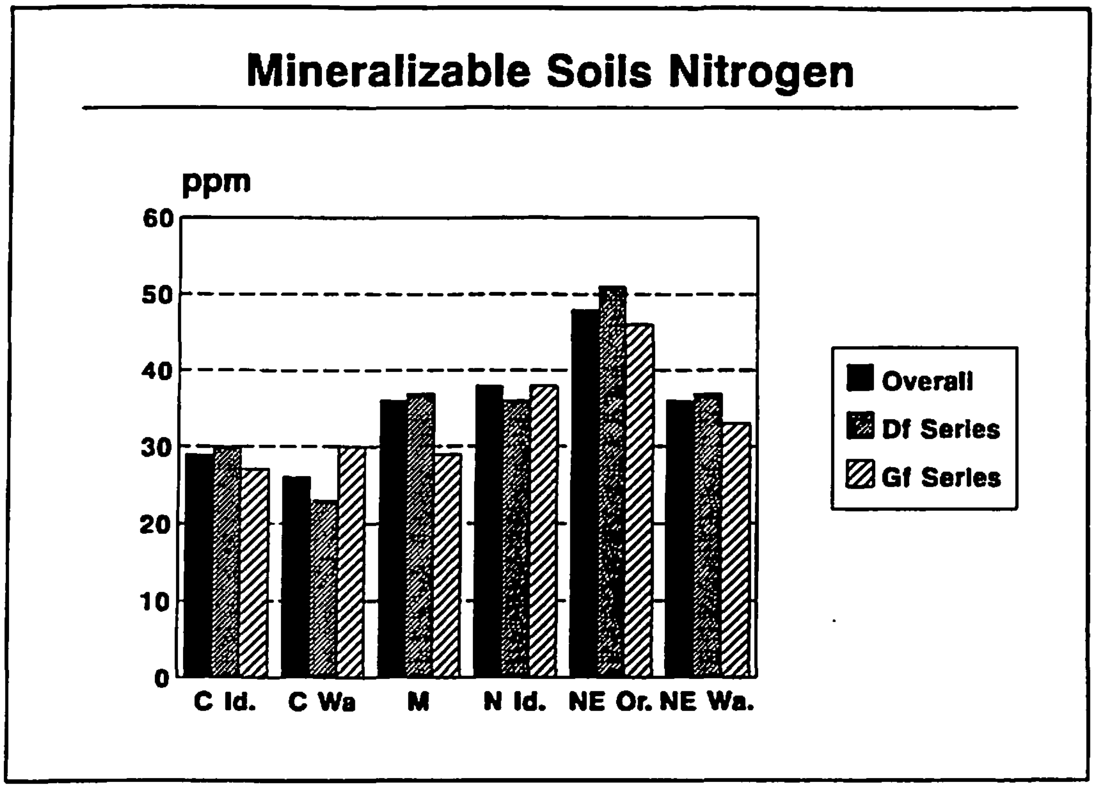
Northeast Oregon soils were highest in pretreatment soil total nitrogen. In central Idaho, basalt soils were significantly higher than granitics in total soil nitrogen.



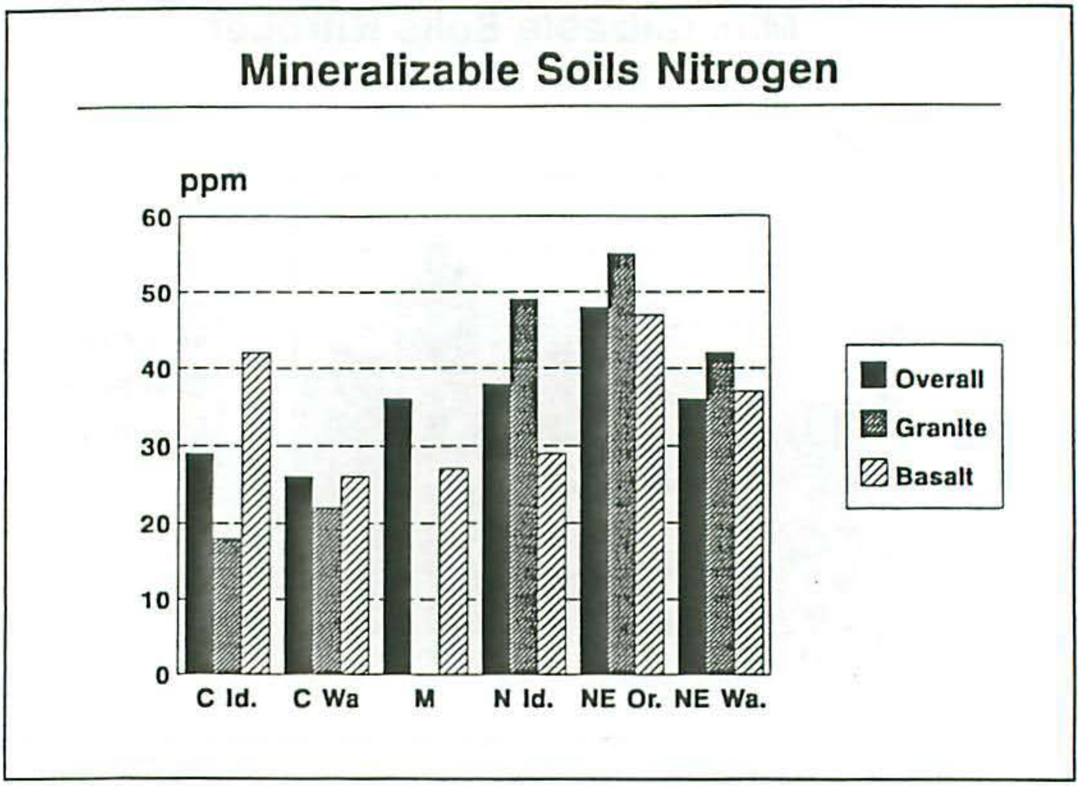
Mineralizable soil nitrogen is highest in northeast Oregon and lowest in central Washington and central Idaho.



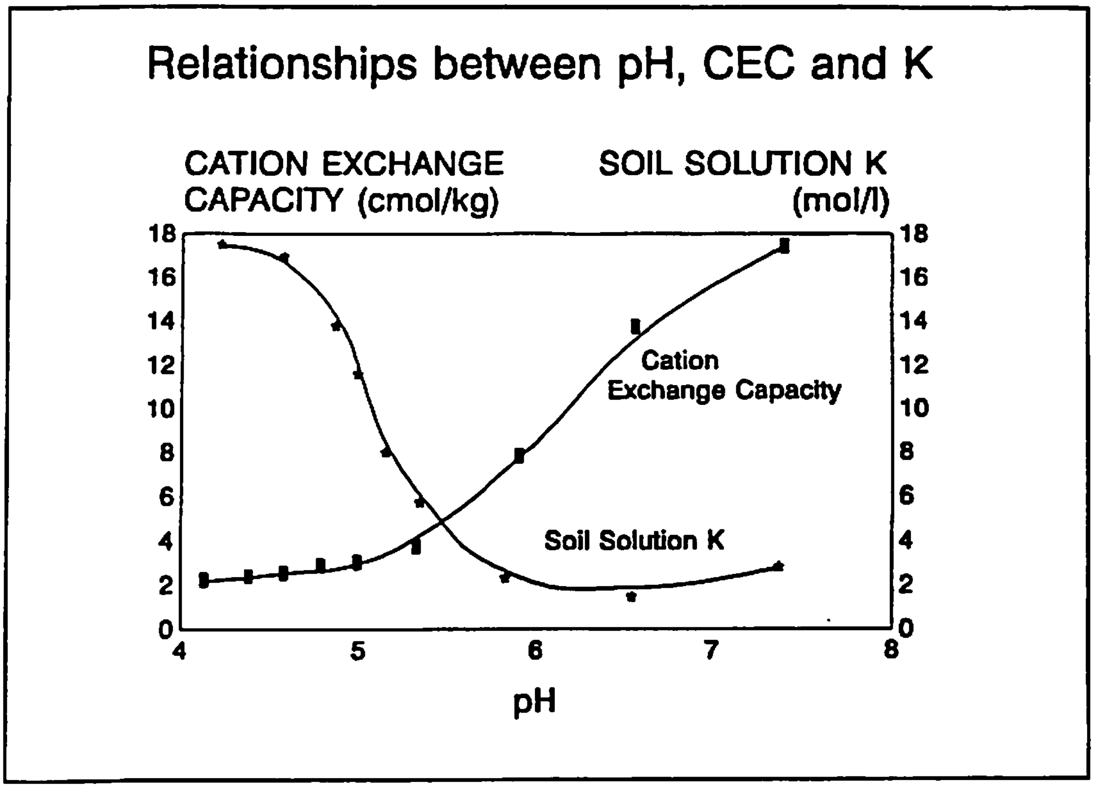
There is no significant difference between Douglas-fir and grand fir habitat series across all IFTNC geographic regions.



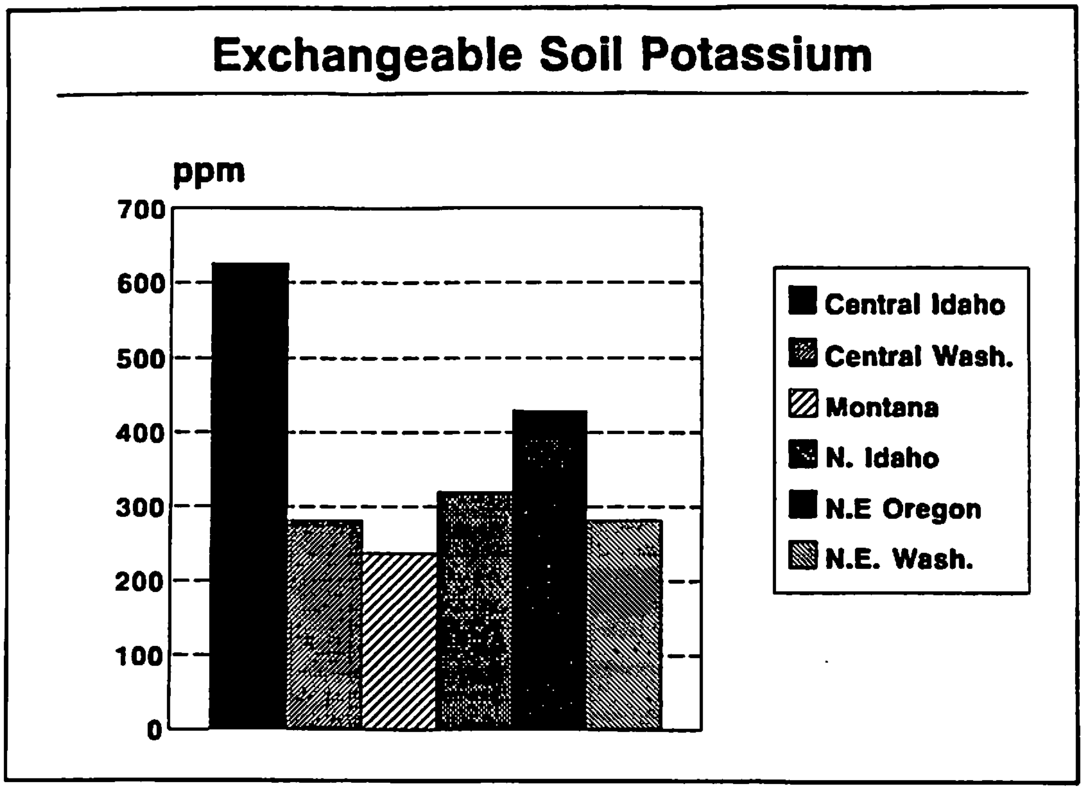
Mineralizable soil nitrogen is highest in northeast Oregon and lowest in central Washington. Basalt soils in central Idaho have significantly higher mineralizable nitrogen than granites, but just the opposite in north Idaho.



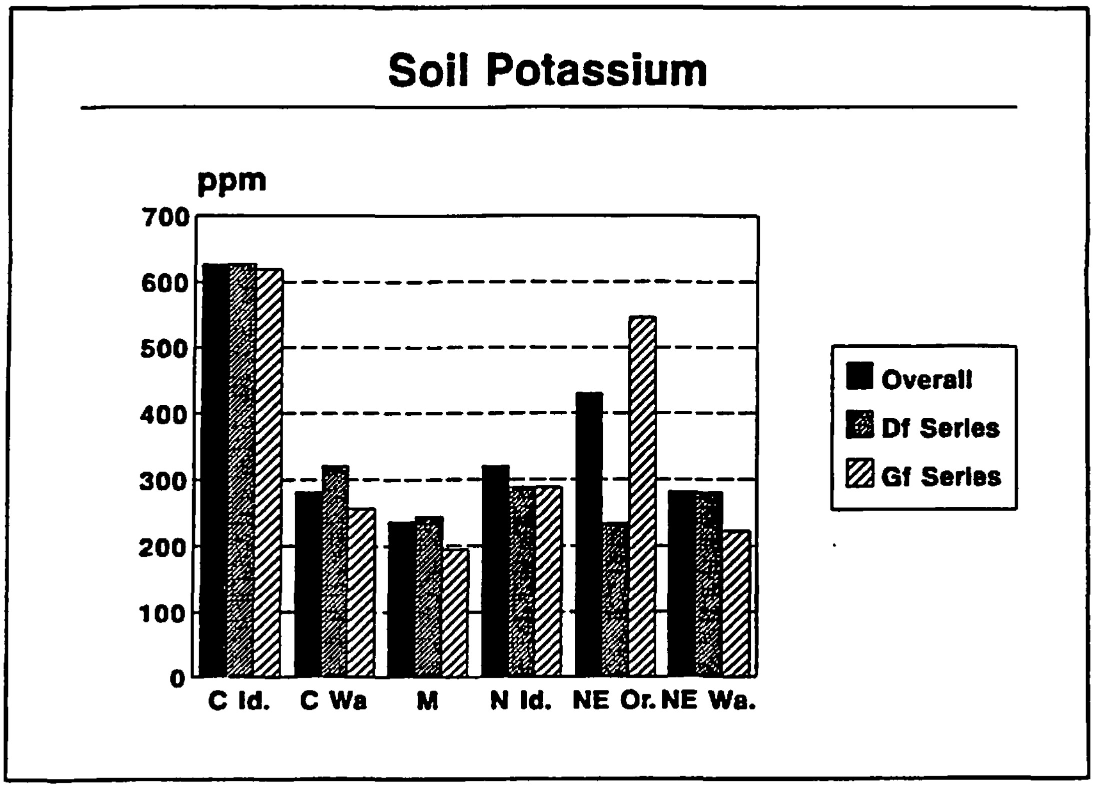
As soil PH increases soil solution K decreases. The average PH of all the IFTNC Douglas-fir sites is about 6.1.



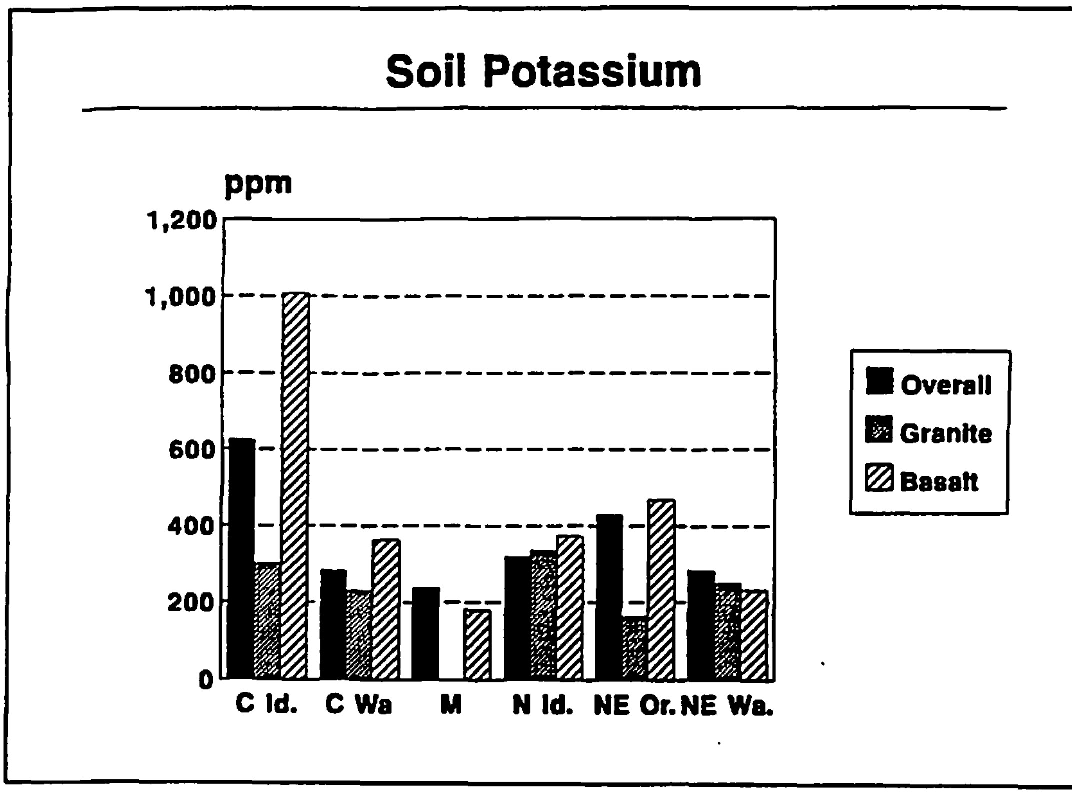
Exchangeable soil potassium was highest in central Idaho. Northeast Oregon was next highest but substantially less then central Idaho. The other geographic regions are all about the same.



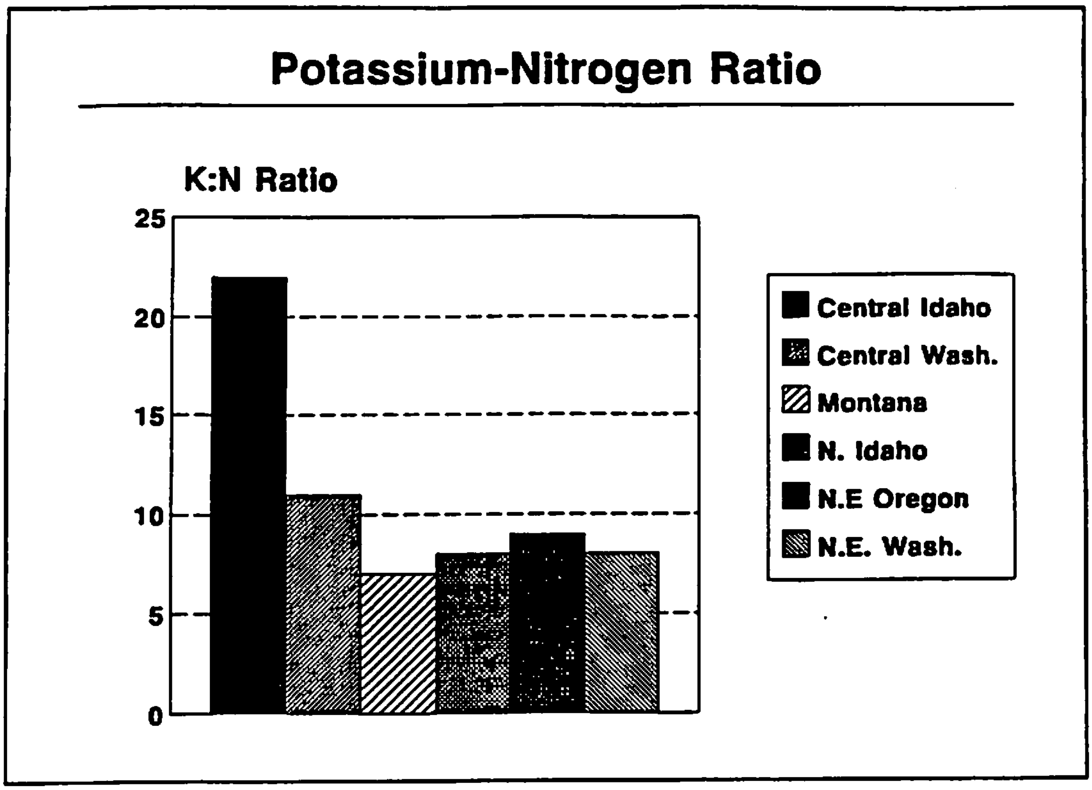
Soil exchangeable potassium is highest in central Idaho and lowest in Montana. Only in northeast Oregon is there a significant difference in soil exchangeable potassium between Douglas-fir and grand fir habitats.



Soil exchangeable potassium for basalt soils are significantly higher than granitics in central Idaho, central Washington, and northeast Oregon; and greatly so in central Idaho.



Central Idaho and central Washington had the first and second highest soil exchangeable potassium / mineralizeable nitrogen ratio of the IFTNC geographic areas.



INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

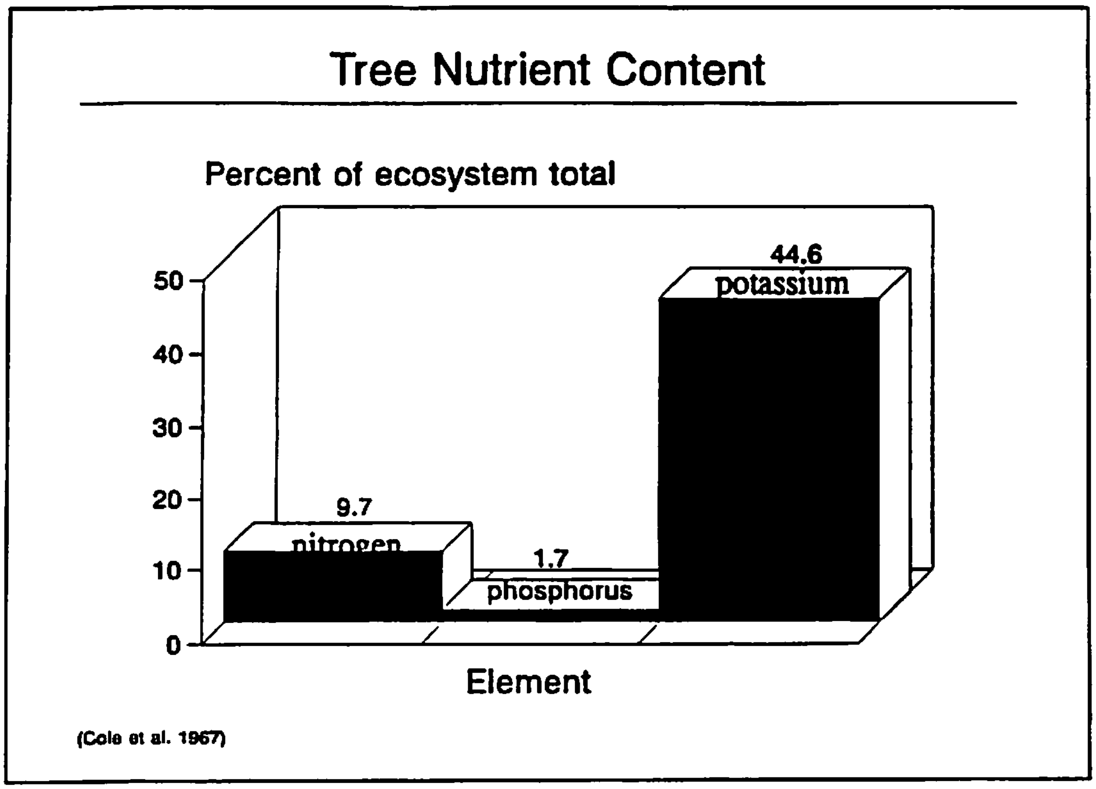
BIOMASS REMOVAL, SLASH DISPOSAL AND SITE NUTRIENT EFFECTS ON SITE NUTRIENT CAPITAL

DENNIS PARENT

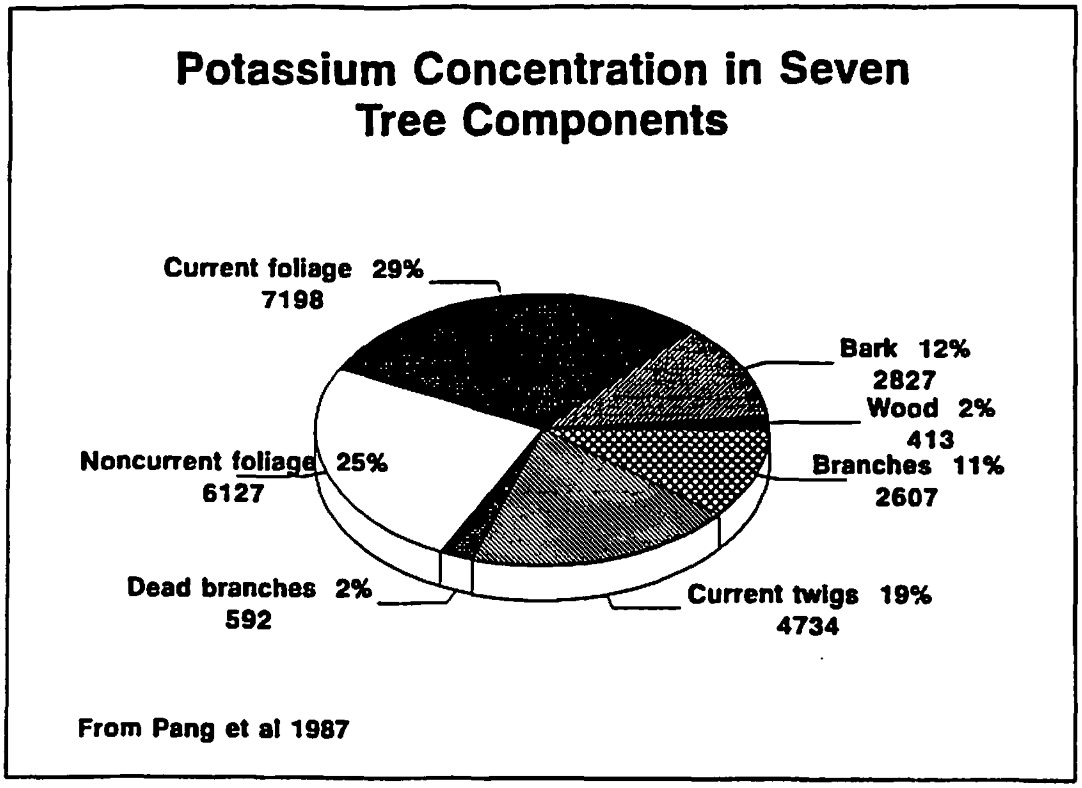
INLAND EMPIRE PAPER
SPOKANE, WASHINGTON

About 45% of the total available potassium in a Douglas-fir forested ecosystem is in the trees versus in the soil. The percent in the trees is much less for nitrogen (~10%) and phosphorus (~2%).

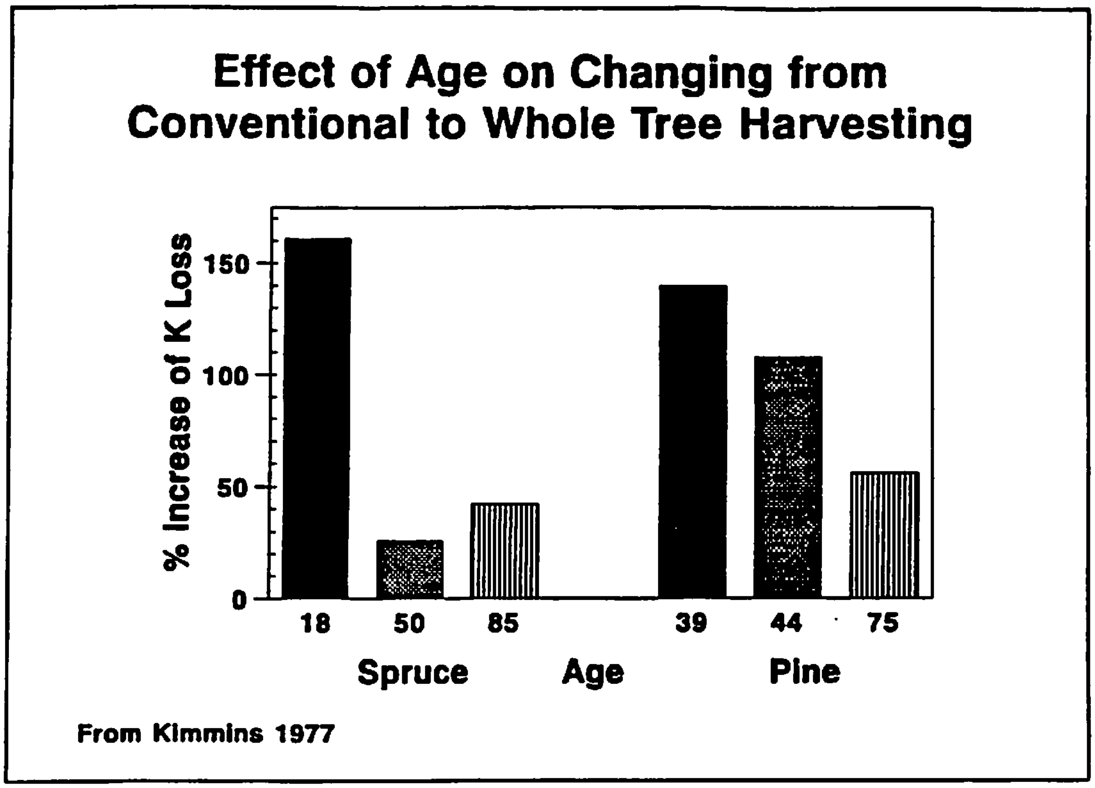
Tree biomass removal therefore has a much larger impact on potassium supplies than on nitrogen or phosphorus.



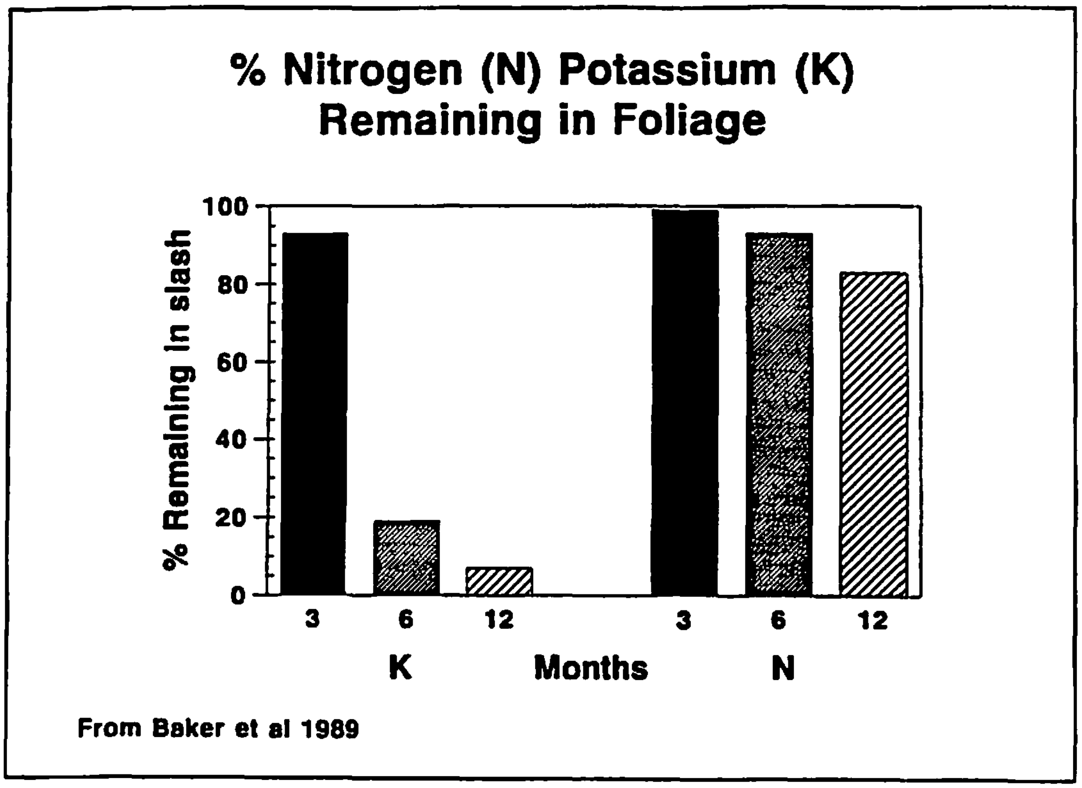
Most of the potassium (~75%) in a Douglas-fir tree is in the foliage and fine branches (these figures exclude roots).



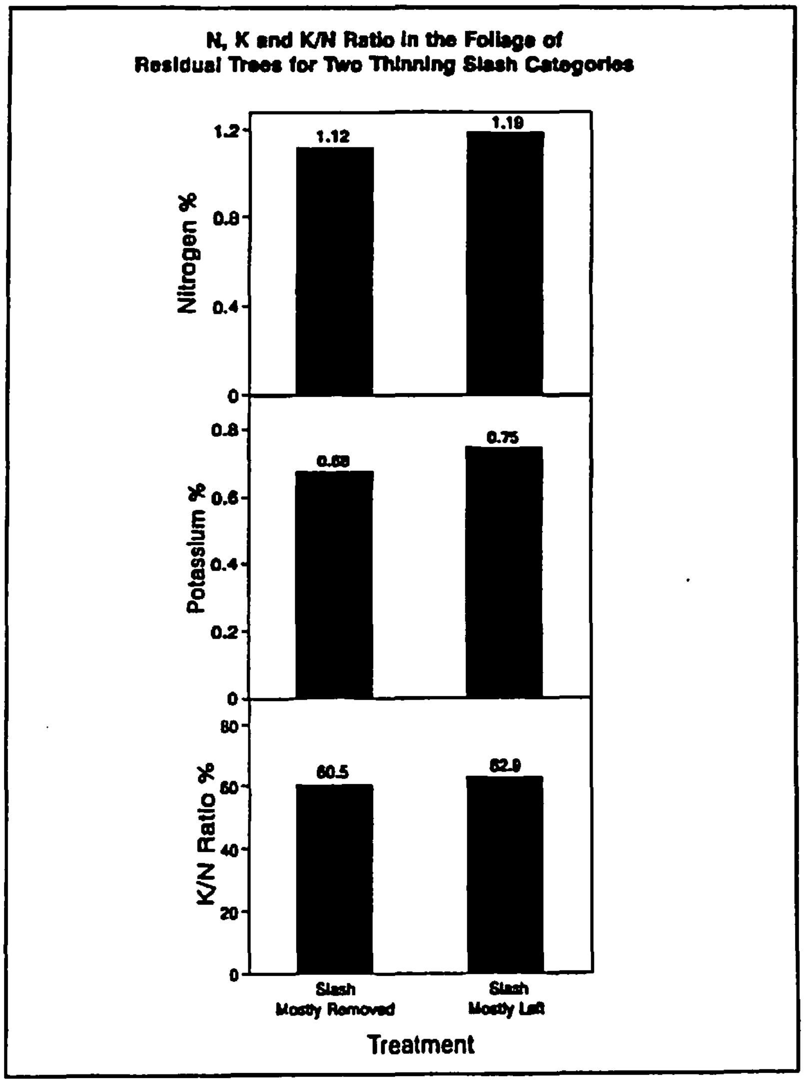
Younger stands have higher potassium loss in whole tree versus conventional logging since they have a higher proportion of their total biomass composed of foliage and there is less breakage of tops and branches during falling and skidding in younger stands.



Most (~80%) potassium leaches from radiata pine foliage in thinning slash within six months. Nitrogen leaches more slowly. In our region, allowing slash to "over-winter" before other slash treatments were applied would conserve most of the potassium.



From the IFTNC Douglas-fir experiment, removing or leaving thinning slash on plots had a small but statistically significant effect on foliar nitrogen and potassium concentrations of residual trees an average 8 years after treatment.



TRANSFERRING THE PRINCIPLES OF NUTRIENT MANAGEMENT FROM THE RESEARCH LAB TO THE WOODS

Nutrient Management Principles:

Principle #1: Potassium is a limiting nutrient in many Inland Northwest forests.

Principle #2: Available potassium is mobile in forest ecosystems.

1. Much of ecosystem K resides in living vegetation.
2. Majority of K is located in small limbs & foliage.
3. Relative foliage K concentration varies with tree age.
4. K leaches & recycles rapidly from foliage.
5. K can be lost during hot broadcast burns.

Principle #3: K/N ratio may be more critical than K itself.

Principle #4: Large woody debris becomes a future ecological nutrient source.

Slash Management Practices:

Practice #1: Conserve potassium on the site.

1. Pile & burn slash sparingly.
2. Leave more limbs & foliage in the woods especially when thinning in younger stands.
3. Wait six months to pile logging slash.
4. Use underburning on dry sites and cool broadcast burns on moist sites to reduce slash hazard, conserve K/N rations & recycle nutrients.

Practice #2: Conserve K/N ratios.

→ Use cooler slash burns.

Practice #3: Leave some large woody material in the woods.

INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

BEST MANAGEMENT PRACTICES FOR NUTRITION

JOHN BRUNA

IDAHO DEPARTMENT OF LANDS
COEUR D'ALENE, IDAHO

RULE 2 - GENERAL RULES

2.a.i.(c): All practices authorized under this procedure shall provide for equivalent or better results over the long term to insure site productivity, water quality, and fish and wildlife habitat.

RULE 3 - TIMBER HARVESTING

3.a.: Purpose - It is the purpose of these rules to establish minimum standards for forest practices that will maintain the productivity of forest land.

RULE 3 - TIMBER HARVESTING (cont.)

3.c.: Soil Protection - Select for each harvesting operation the logging method and type of equipment adapted to the given slope, landscape and soil properties in order to minimize soil erosion.

3.c.ii. - Limit the grade of constructed skid trails on geologically unstable, saturated, or highly erodible or easily compacted soils to a maximum of thirty percent (30%).

RULE 3 - TIMBER HARVESTING (cont.)

3.c.iii. - Skid trails shall be kept to the minimum feasible width and number.

3.c.iv. - Uphill cable yarding is preferred over downhill cable yarding to minimize downhill movement of slash and debris.

RULE 3 - TIMBER HARVESTING (cont.)

3.h.: Maintenance of Productivity and Related Values

Harvesting practices will first be designed to assure the continuous growing and harvesting of forest tree species by suitable economic means and also to protect soil, air, water, and wildlife values.

RULE 5 - REFORESTATION

5.a. The purpose is to provide for reforestation that will maintain a continuous growing and harvesting of tree species.

ACCEPTABLE MINIMUM STOCKING
(Trees 2.9" DBH and less)

Ponderosa Pine Type: 150/acre

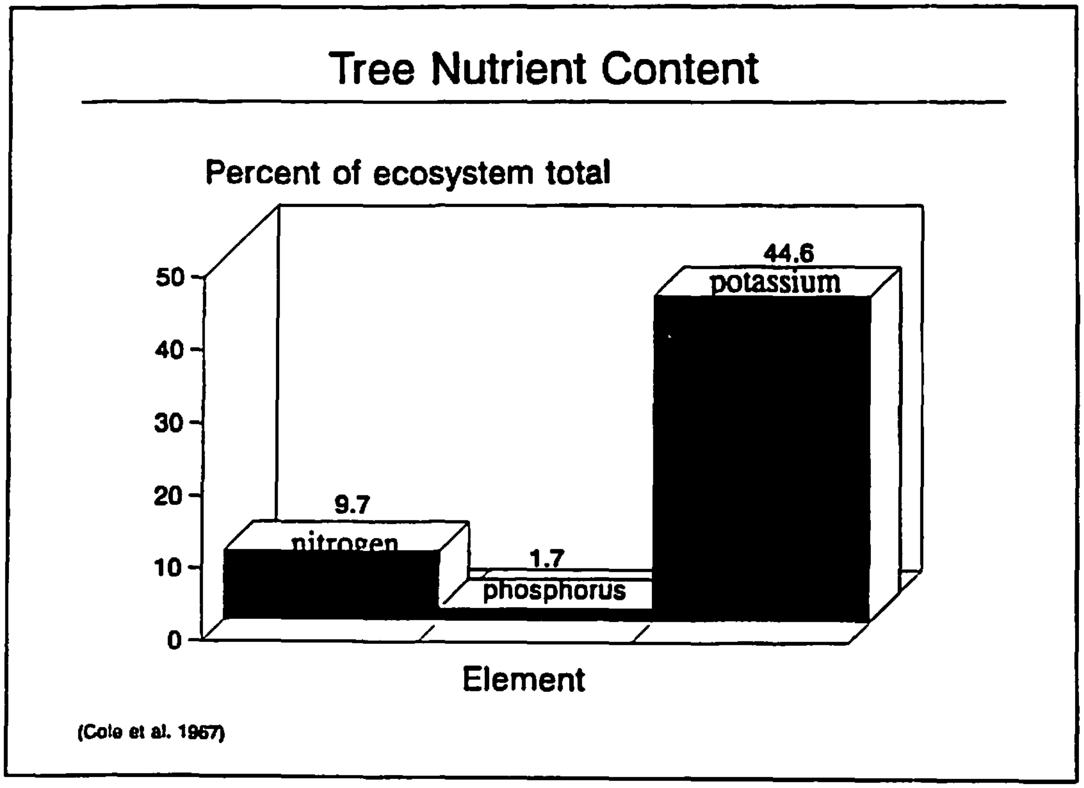
Mixed Species Type: 200/acre

RULE 7 - SLASHING MANAGEMENT

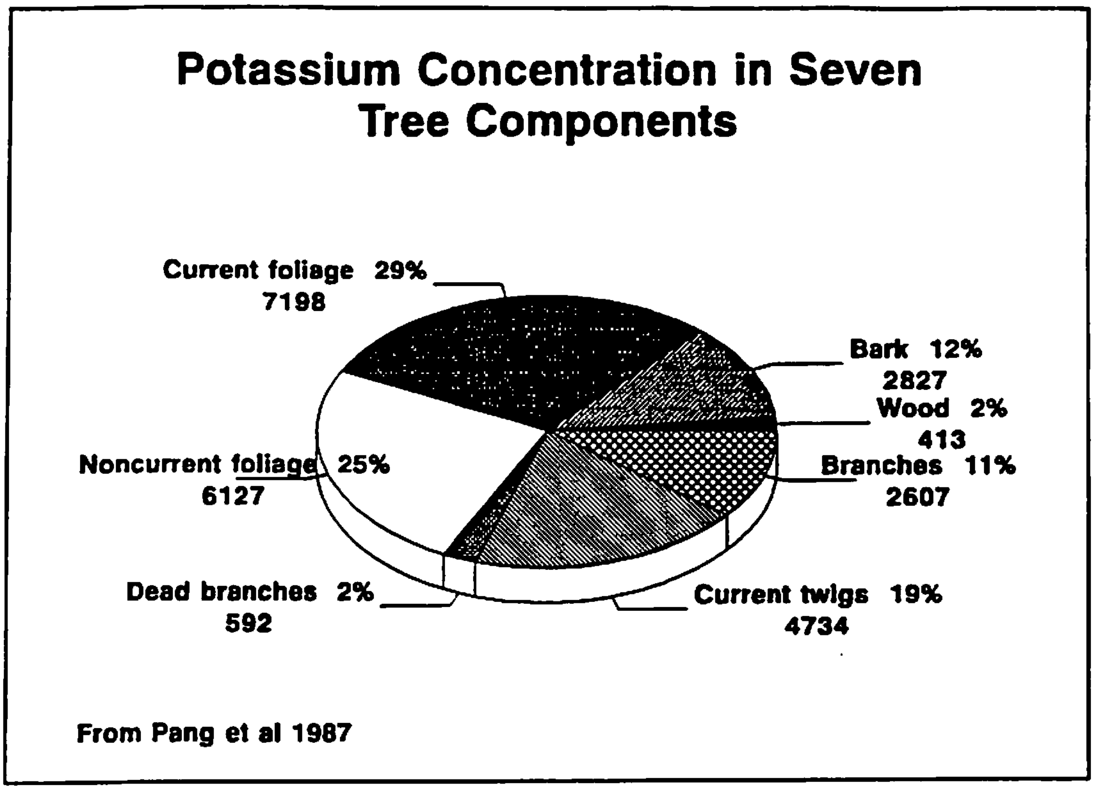
7.a. The purpose is to provide for management of slashing and fire hazard resulting from harvesting forest management, or improvement of tree species in that manner necessary to protect reproduction and residual stands, reduce risk from fire, insects and disease and to optimize the condition for future regeneration of forest tree species.

About 45% of the total available potassium in a Douglas-fir forested ecosystem is in the trees versus in the soil. The percent in the trees is much less for nitrogen (~10%) and phosphorus (~2%).

Tree biomass removal therefore has a much larger impact on potassium supplies than on nitrogen or phosphorus.

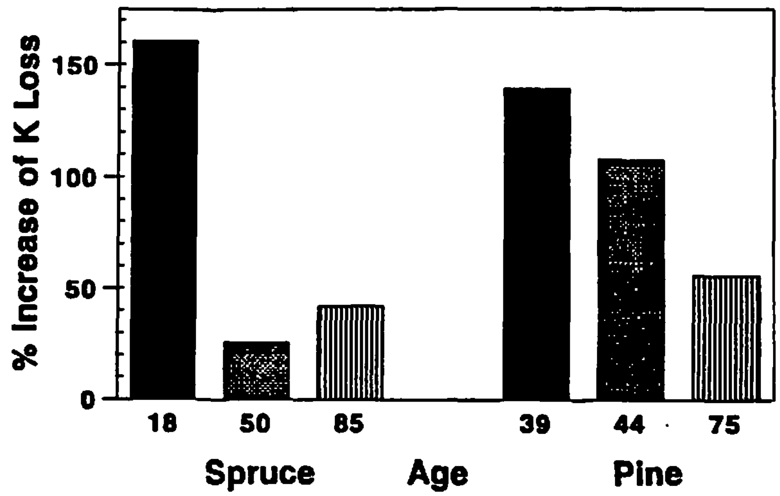


Most of the potassium (~75%) in a Douglas-fir tree is in the foliage and fine branches (these figures exclude roots).



Younger stands have higher potassium loss in whole tree versus conventional logging since they have a higher proportion of their total biomass composed of foliage and there is less breakage of tops and branches during falling and skidding in younger stands.

Effect of Age on Changing from Conventional to Whole Tree Harvesting



From Kimmins 1977

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