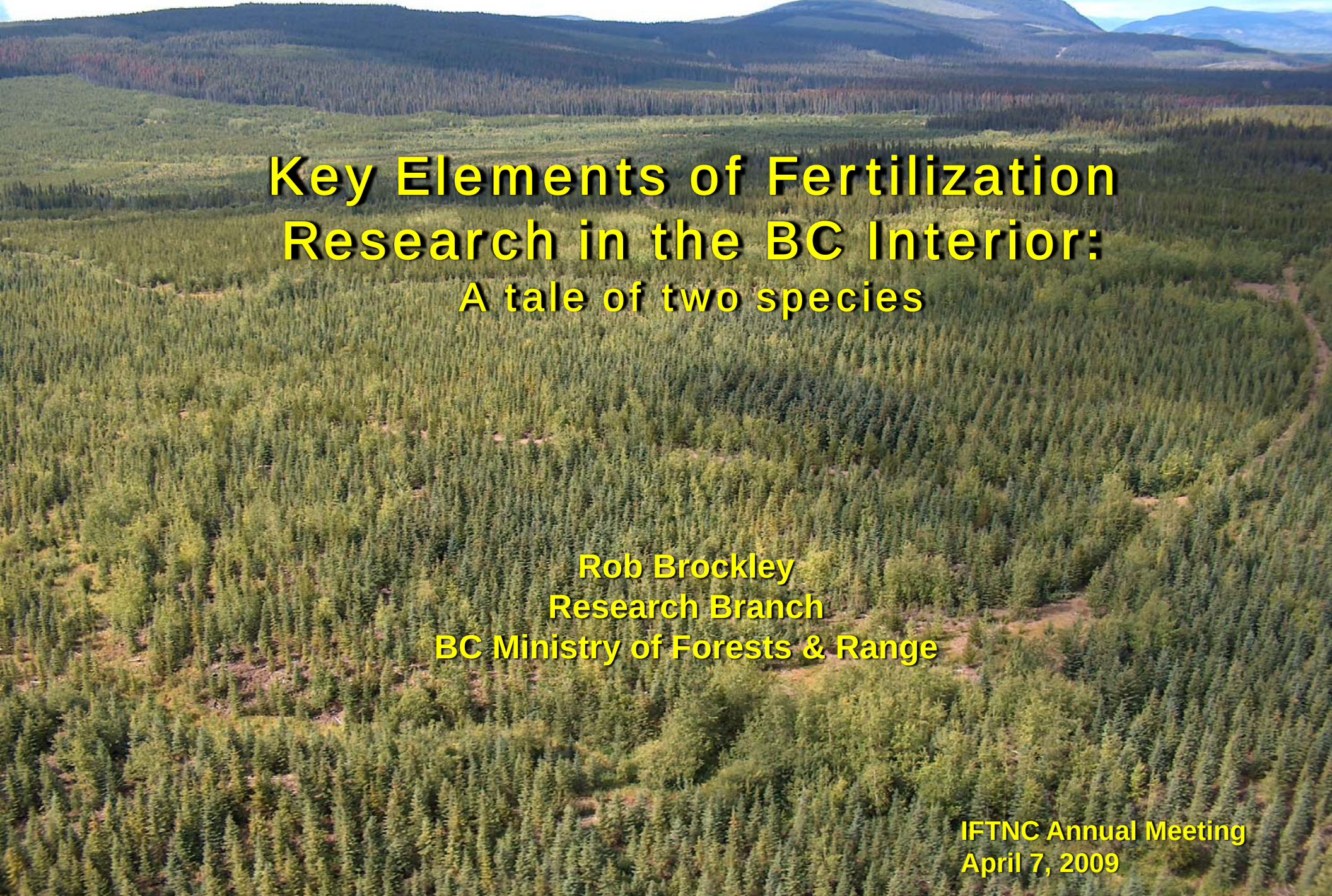

Key Elements of Fertilization Research in the BC Interior:

A tale of two species

Rob Brockley
Research Branch
BC Ministry of Forests & Range

IFTNC Annual Meeting
April 7, 2009

Topics

- Fertilization as a mitigation strategy

Topics

- Fertilization as a mitigation strategy
- Key elements
  - N, S, B

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  - Pl and Sx

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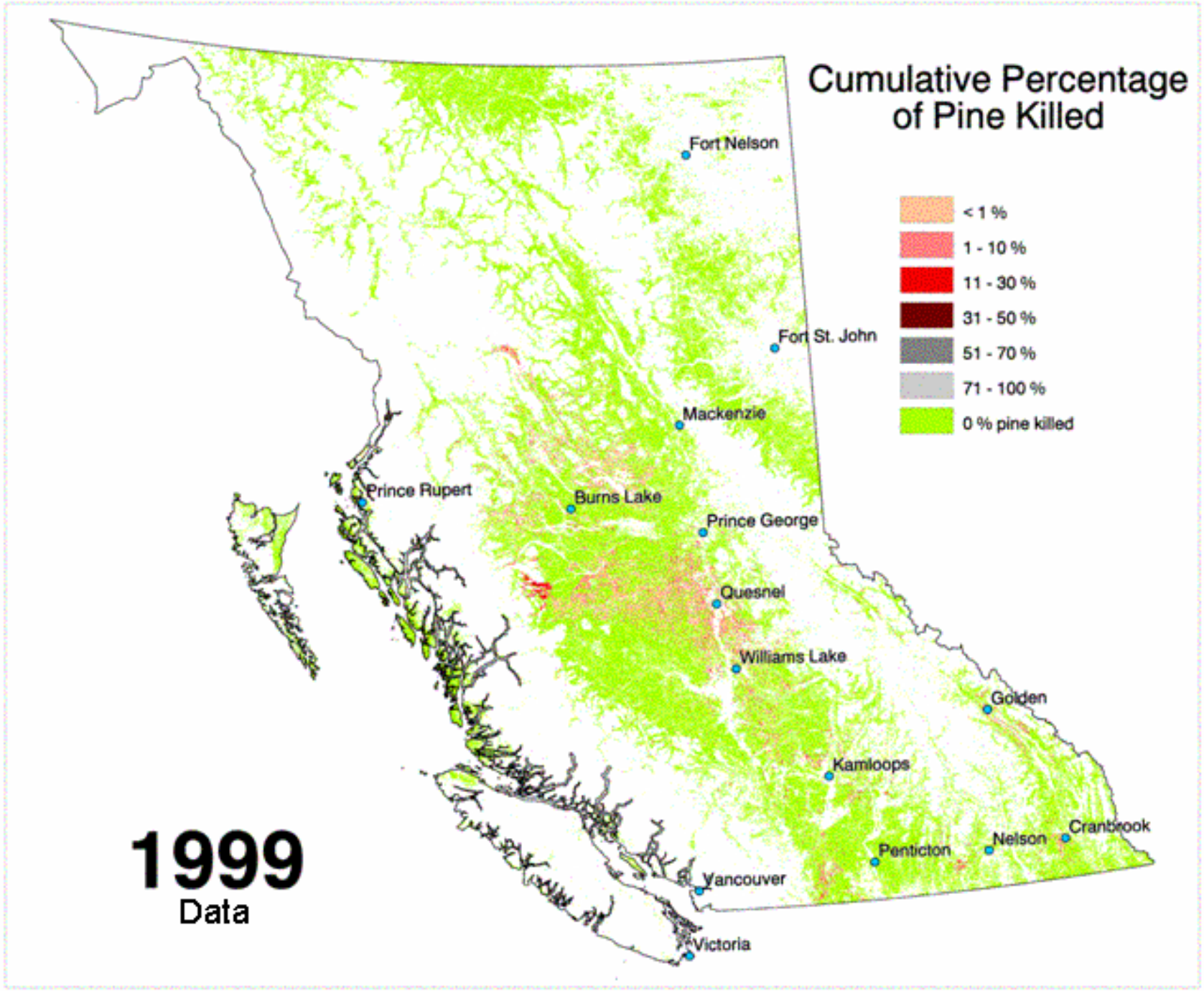
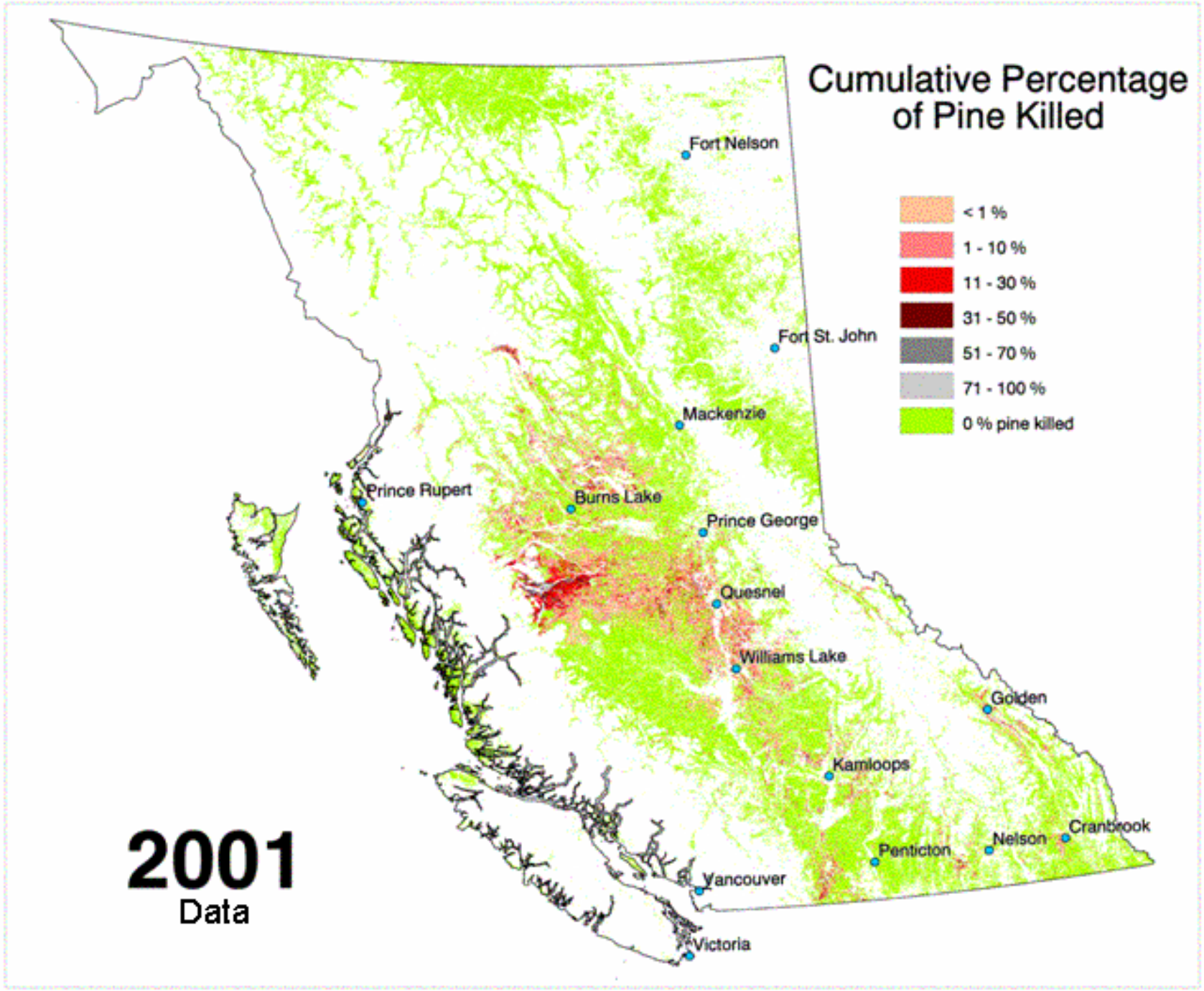
- “Conventional” vs. “Intensive” fertilization

Fertilization as a mitigation strategy


Cumulative Percentage of Pine Killed
< 1 %
1 - 10 %
11 - 30 %
31 - 50 %
51 - 70 %
71 - 100 %
0 % pine killed
Fort Nelson
Fort St. John
Mackenzie
Prince Rupert
Burns Lake
Prince George
Quesnel
Williams Lake
Golden
Kamloops
Cranbrook
Nelson
Penticton
Vancouver
Victoria
1999
Data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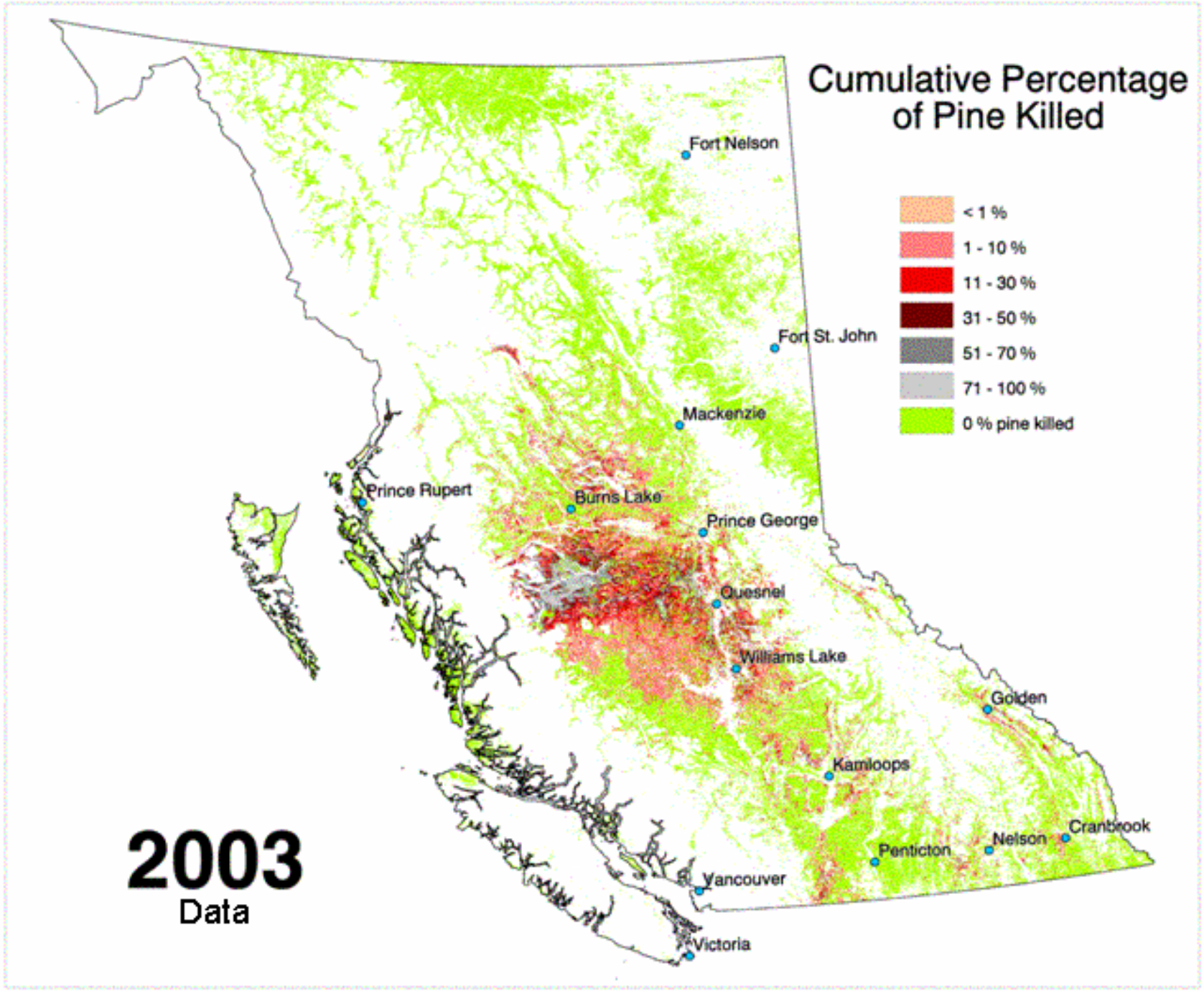
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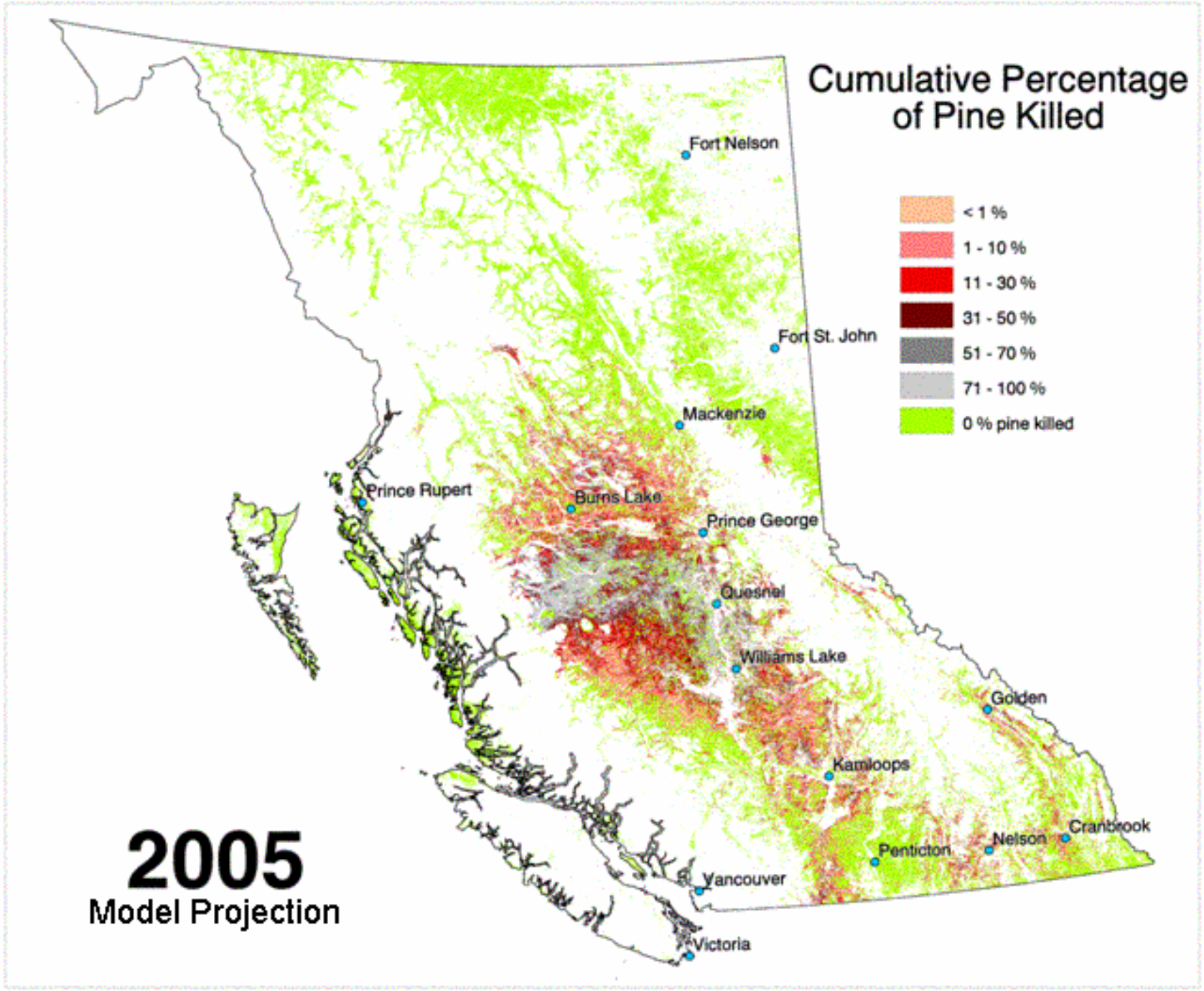
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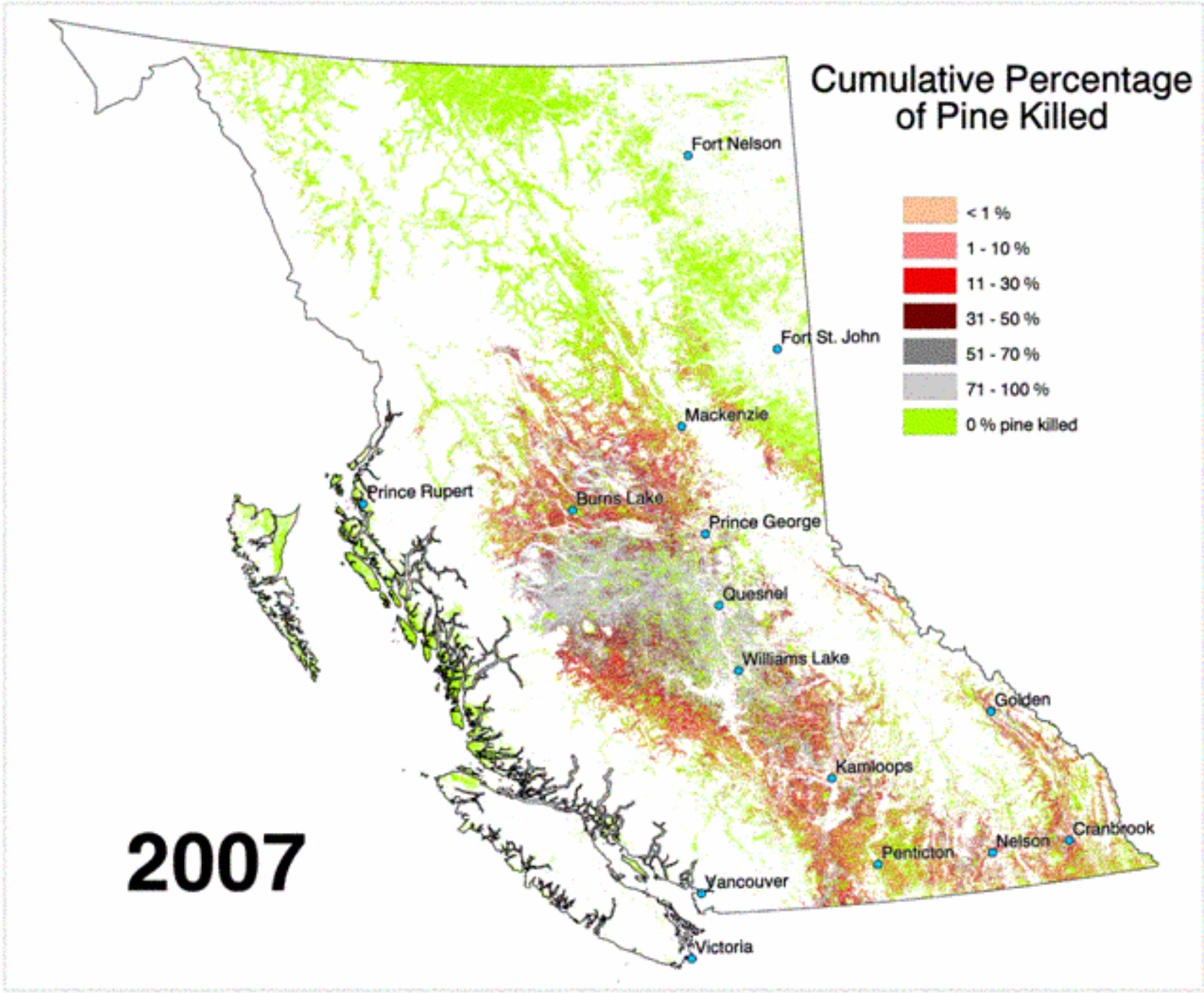
2005
Model Projection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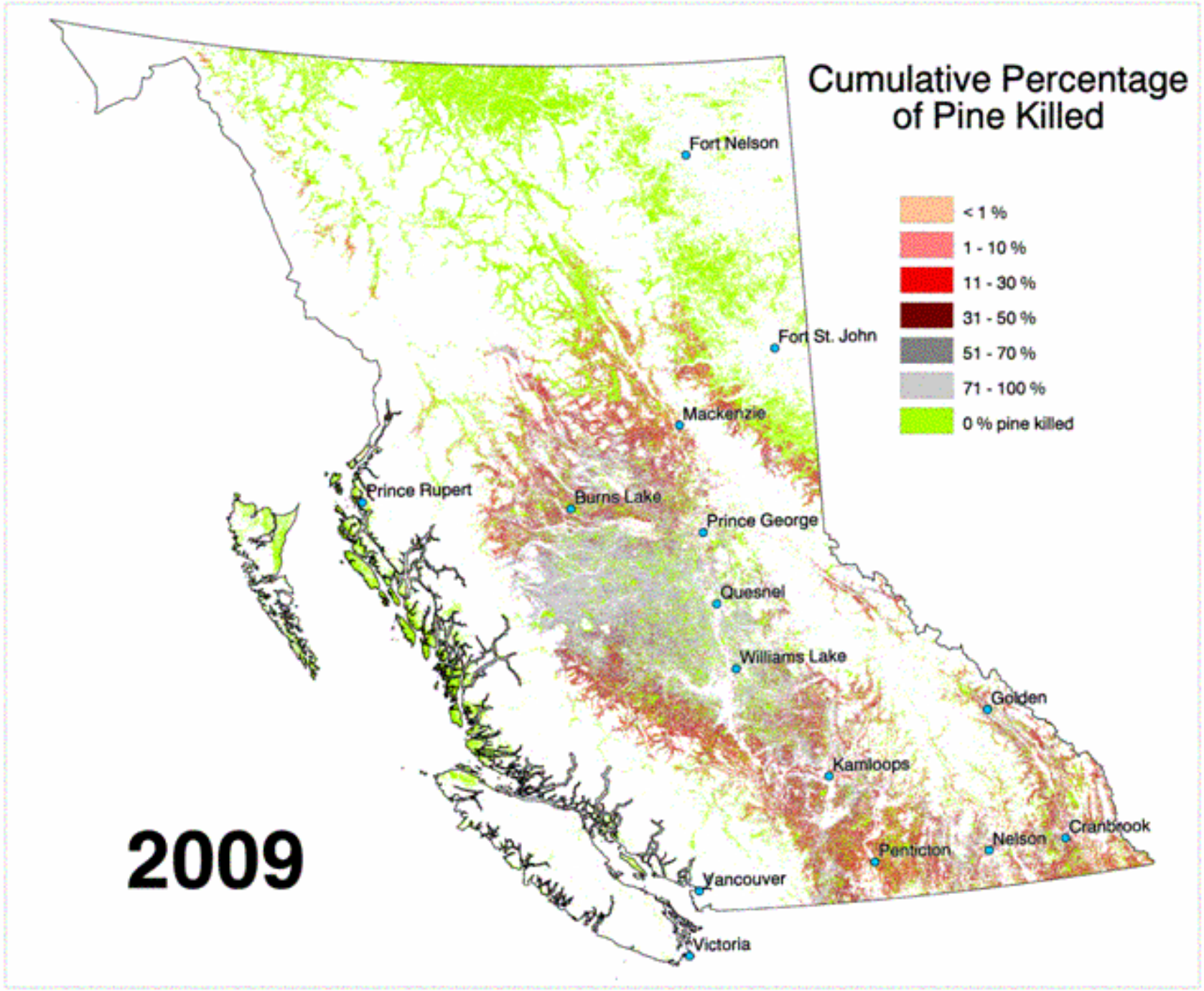
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Fertilization as a mitigation strategy

- Every tree to be harvested in the next 40-60 years is in the ground today

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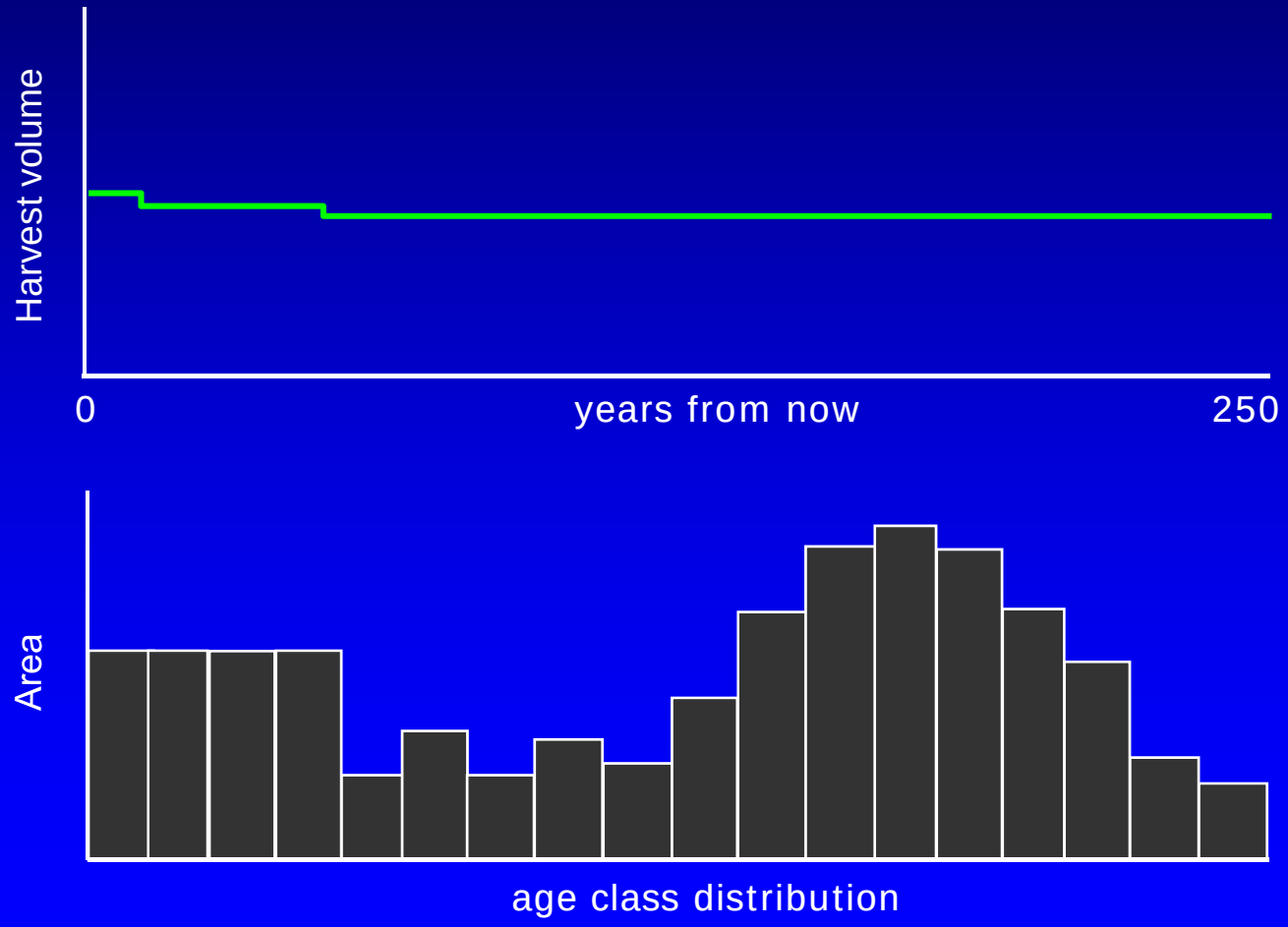
- Every tree to be harvested in the next 40-60 years is in the ground today
- Fertilization accelerates the operability of established stands
- Fertilization can be used strategically to impact the amount and timing of future harvests

How fertilization mitigates MPB mortality

Conceptual



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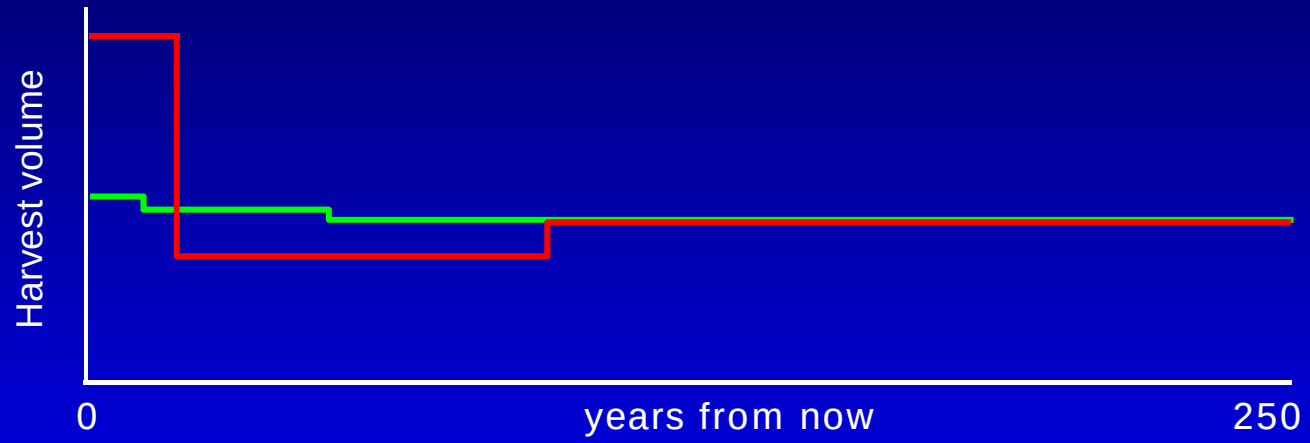

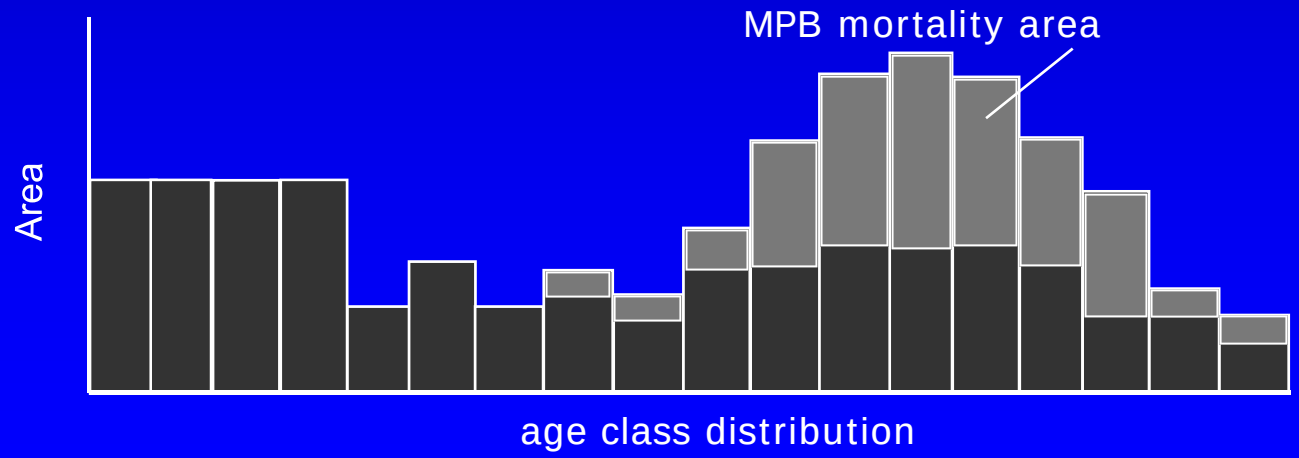

How fertilization mitigates MPB mortality

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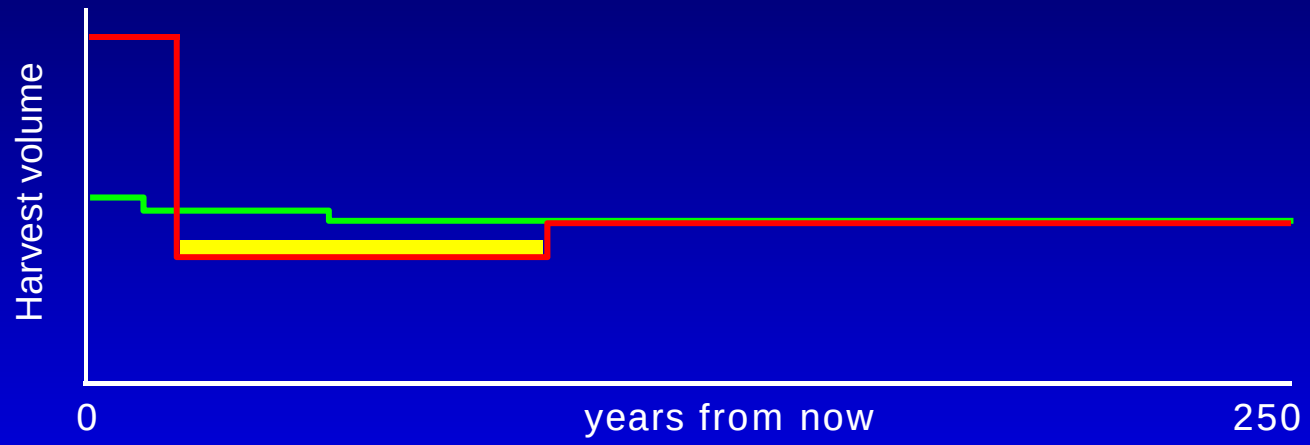
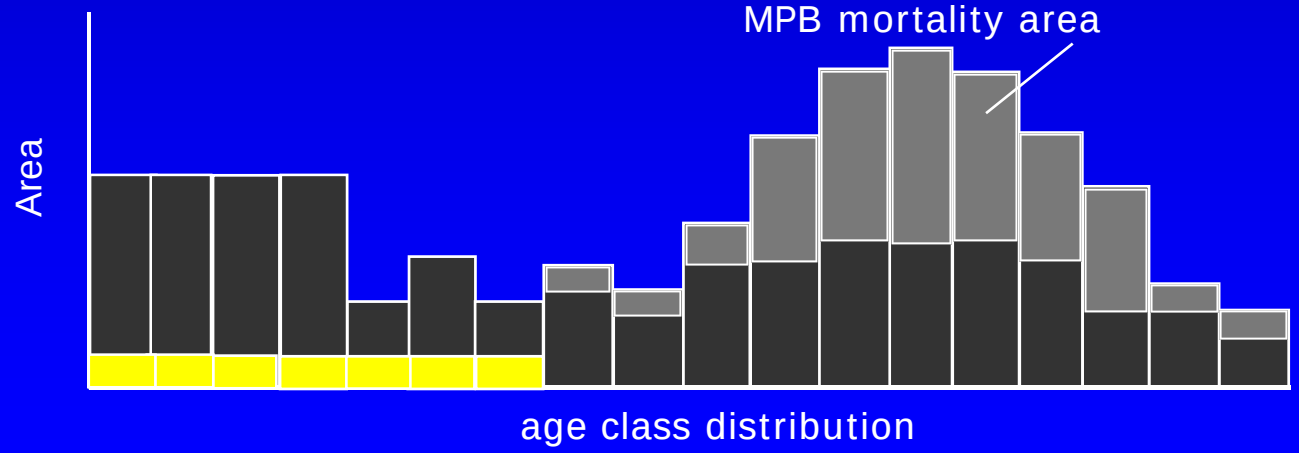
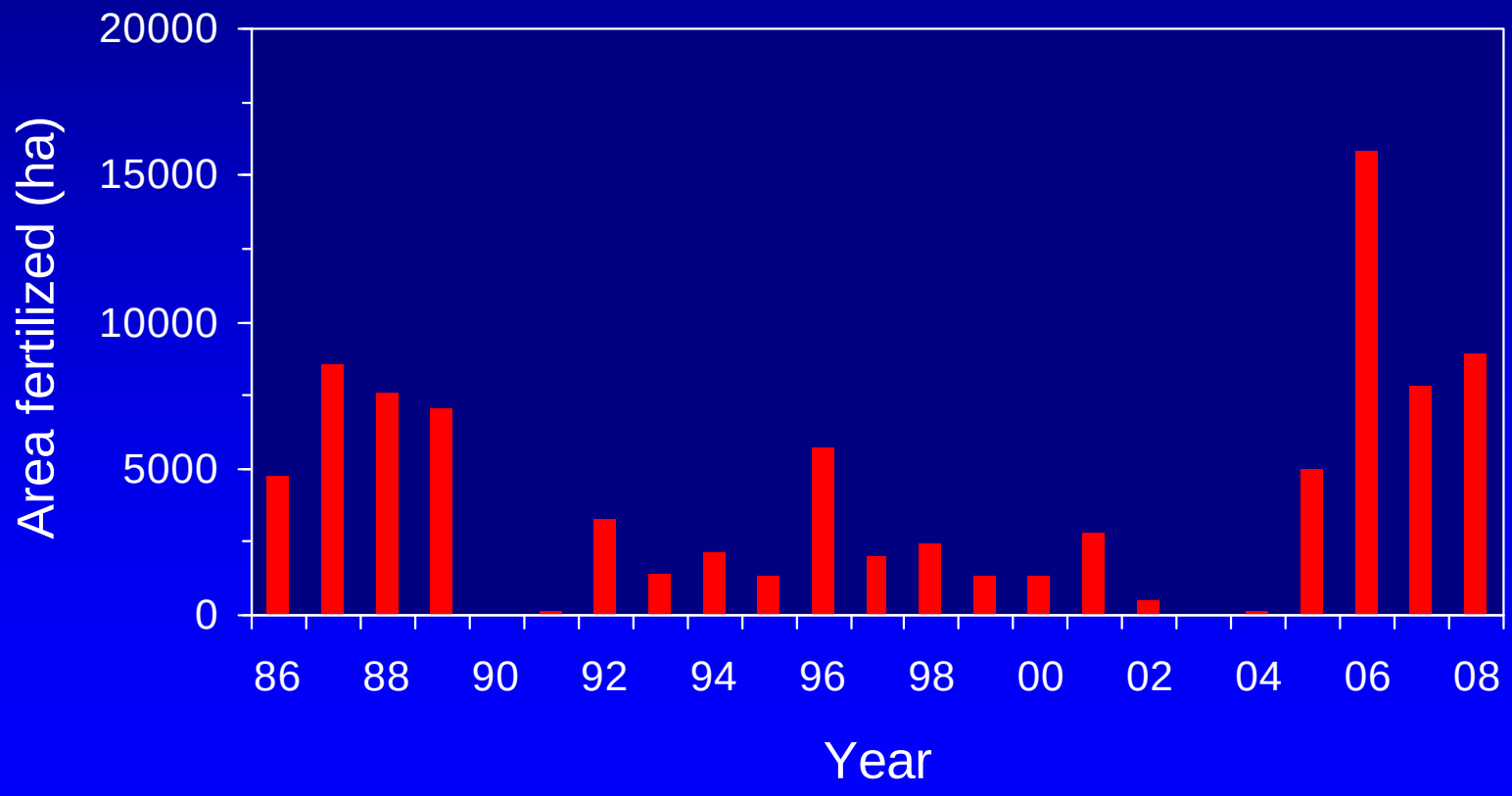




- Fertilizing 15- to 80-year-old stands (**yellow**) can increase harvest volumes 10–60 years from now

Fertilization of forest land in BC interior



BC Interior fertilization research

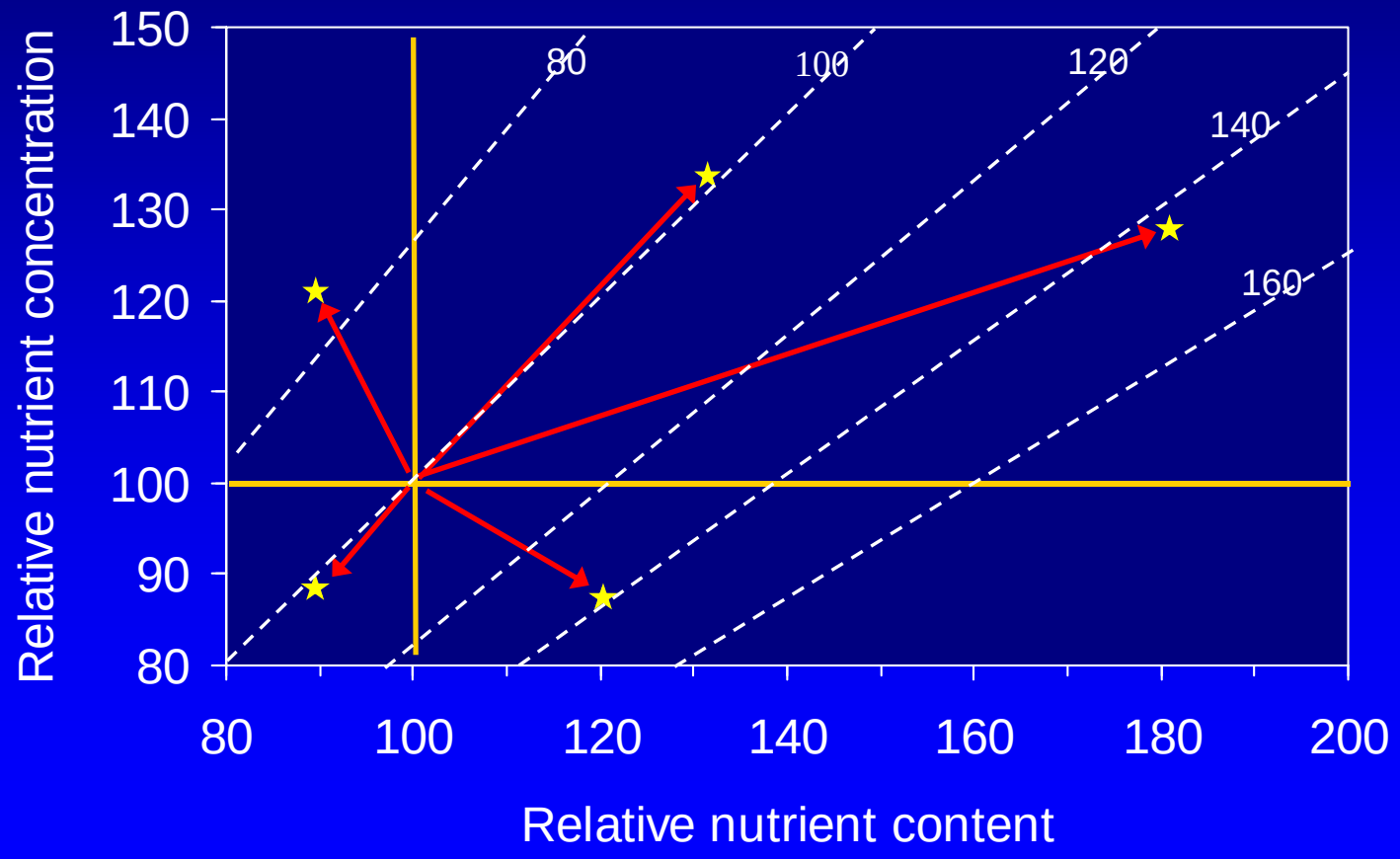
Two-pronged approach

BC Interior fertilization research

Two-pronged approach

- Single-tree screening trials

Foliar Graphical Vector Analysis



BC Interior fertilization research

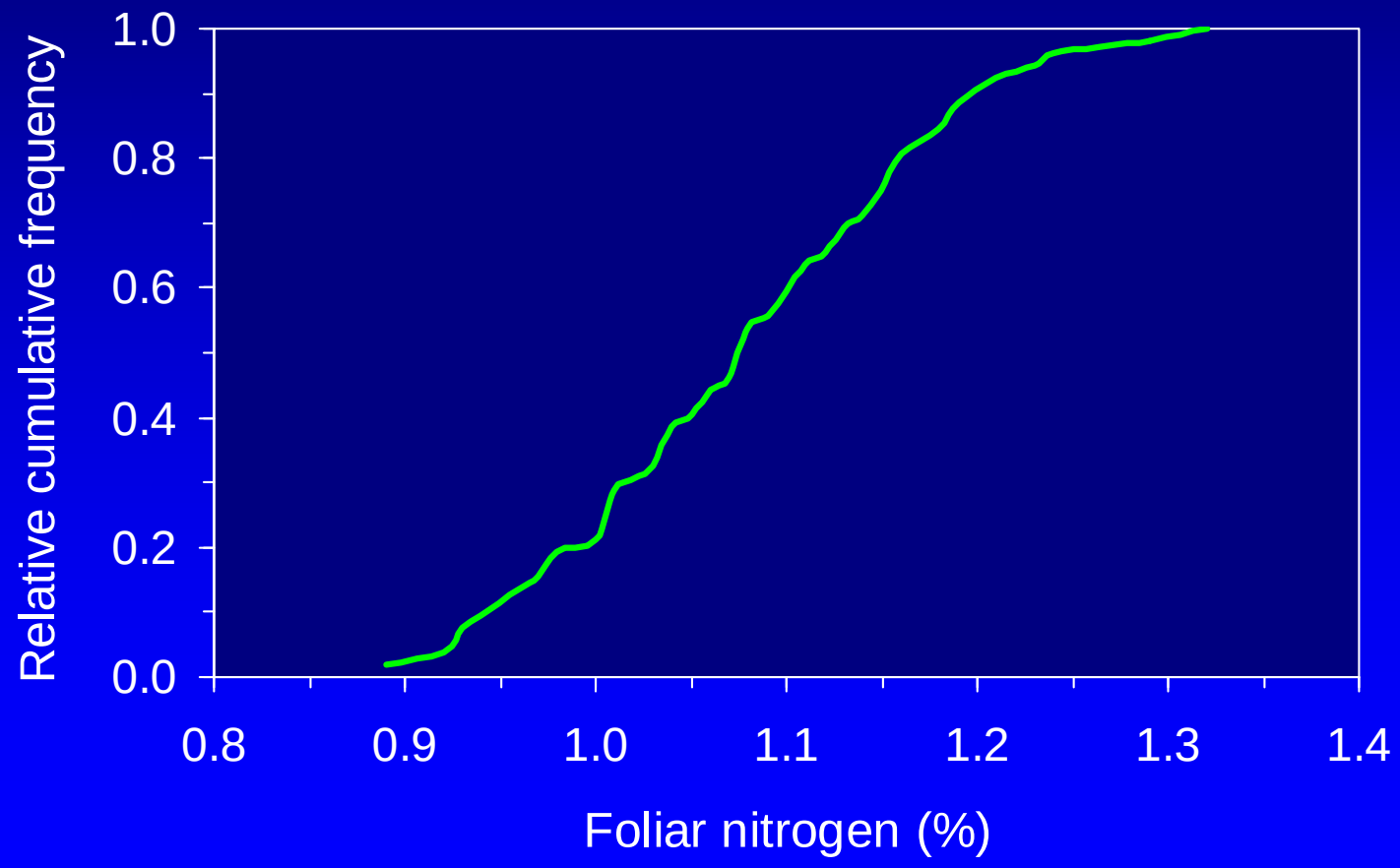
Two-pronged approach

- Single-tree screening trials
- Area-based G&Y installations

Lodgepole pine nutrition and fertilization research

Lodgepole pine foliar N concentration

Relative cumulative frequency distribution (from Brockley 2001)



Lodgepole pine foliar N concentration

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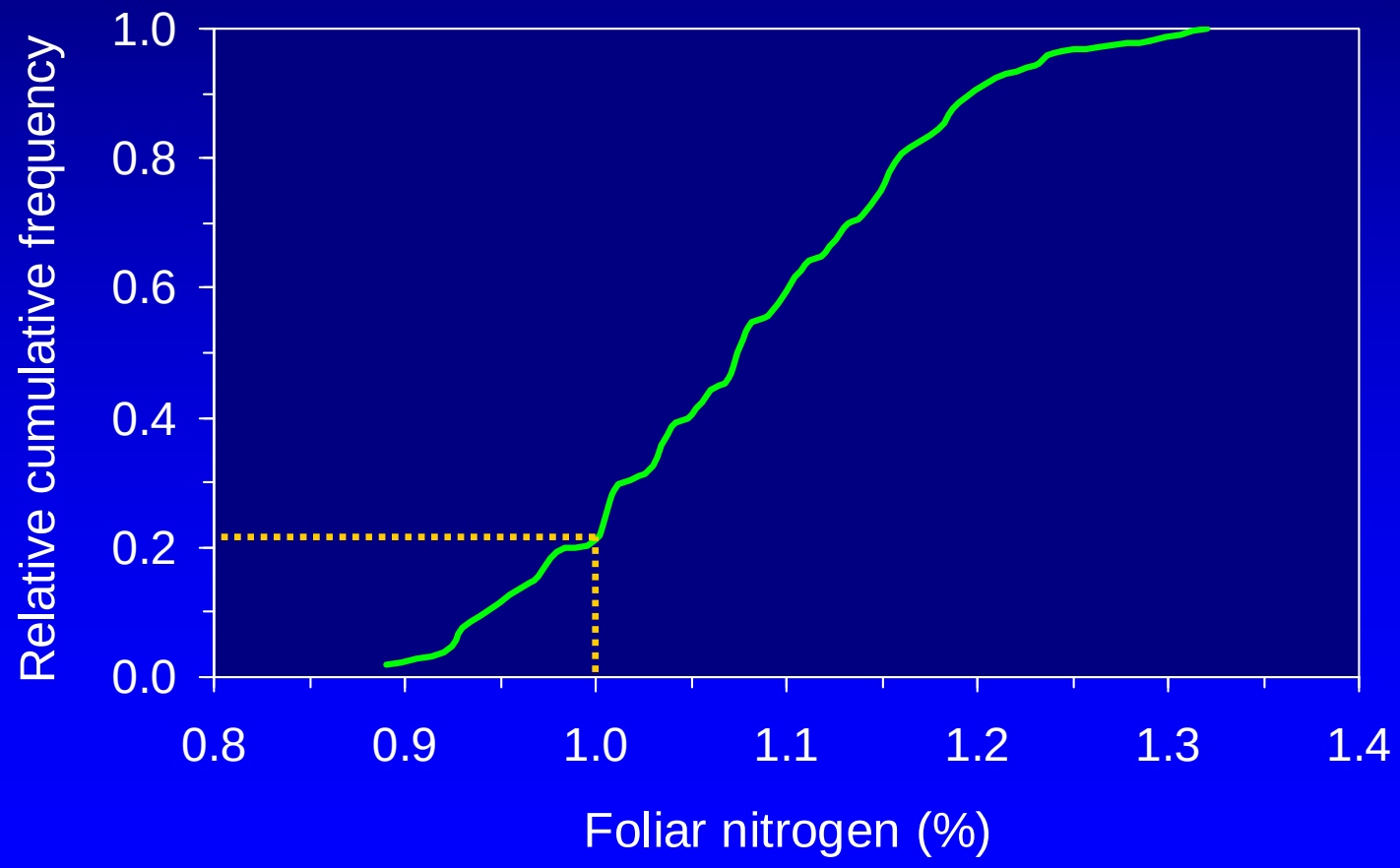

Lodgepole pine foliar N concentration

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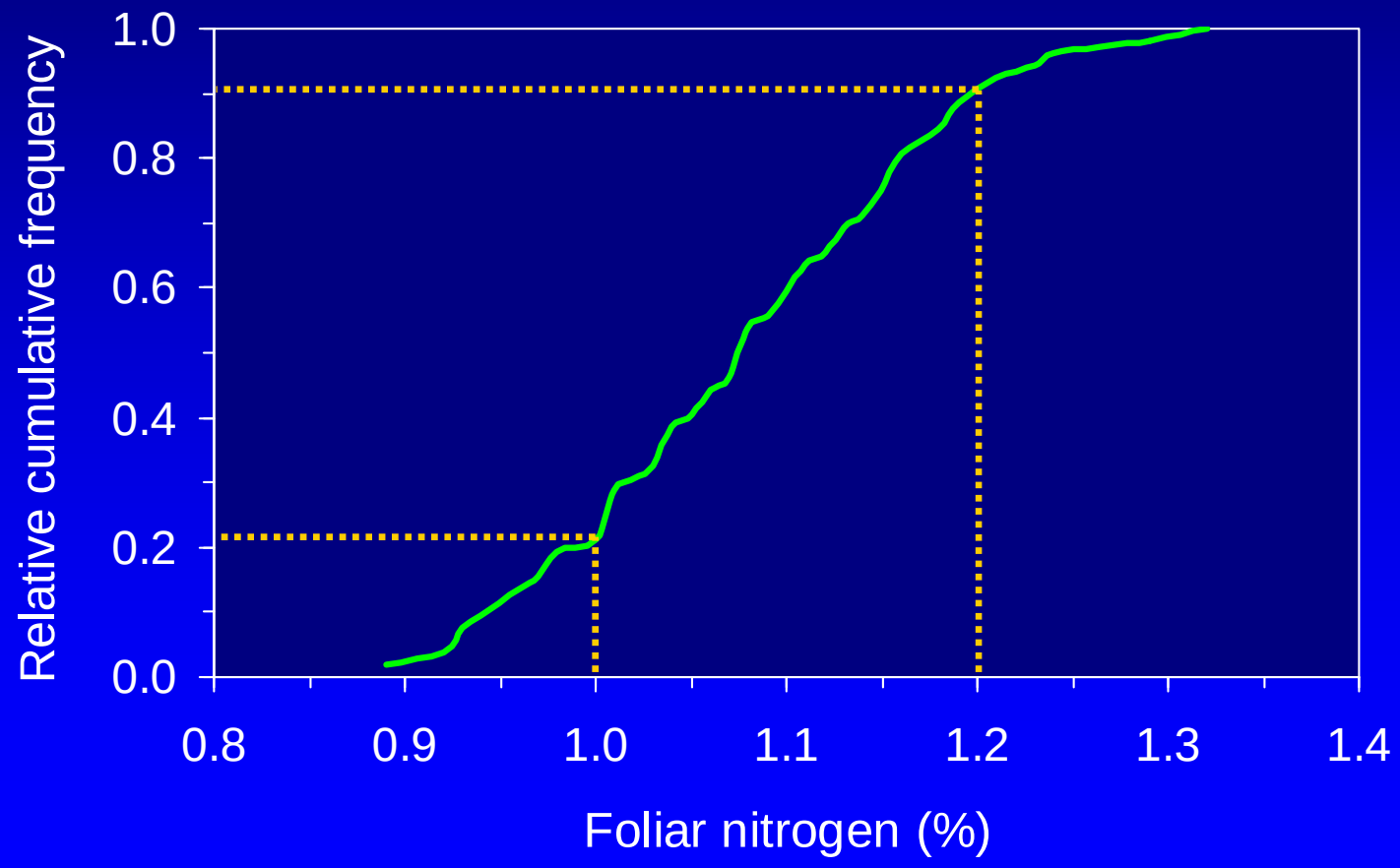
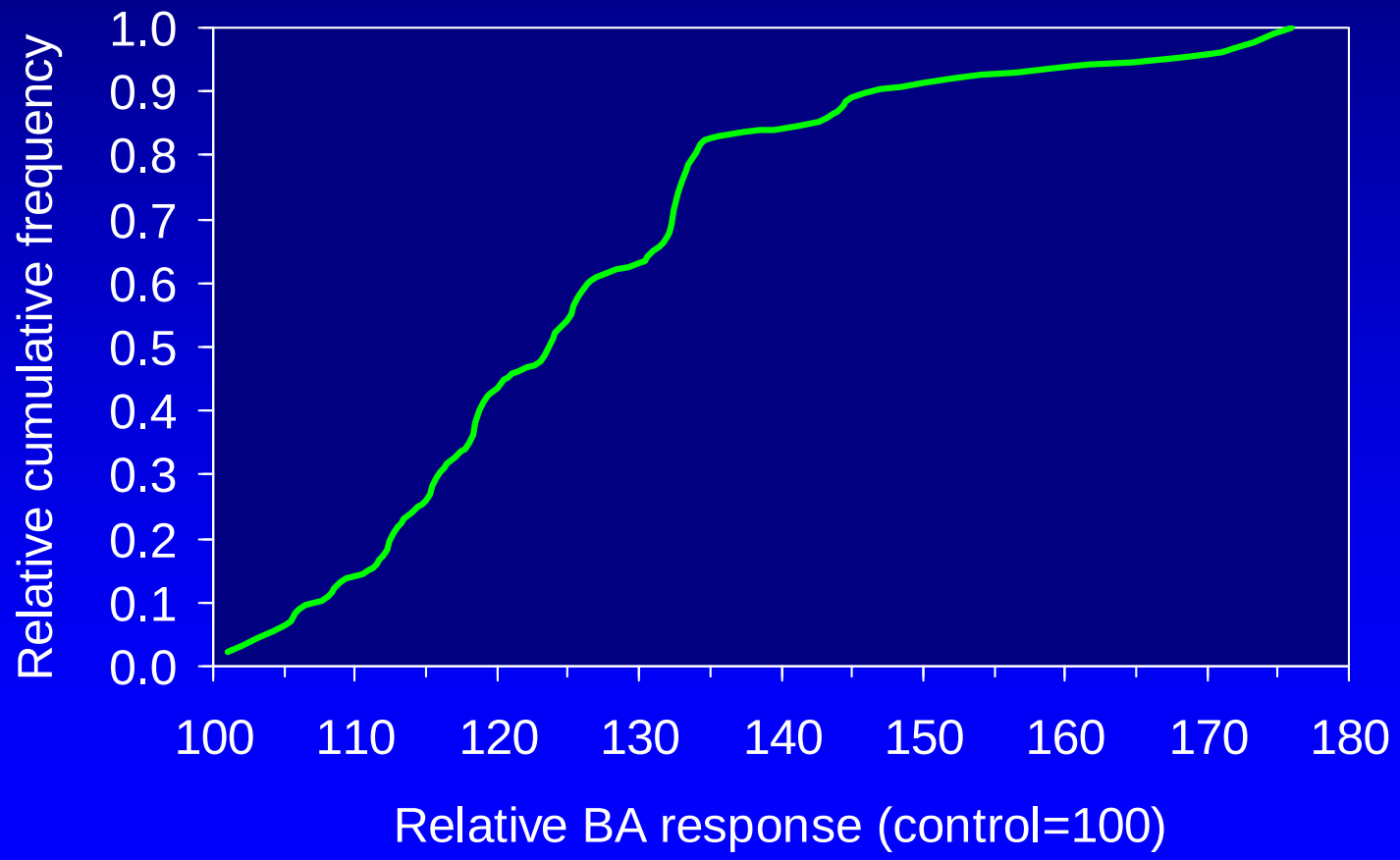


Relative 6-year BA response following N fertilization

Relative cumulative frequency distribution (n=46)



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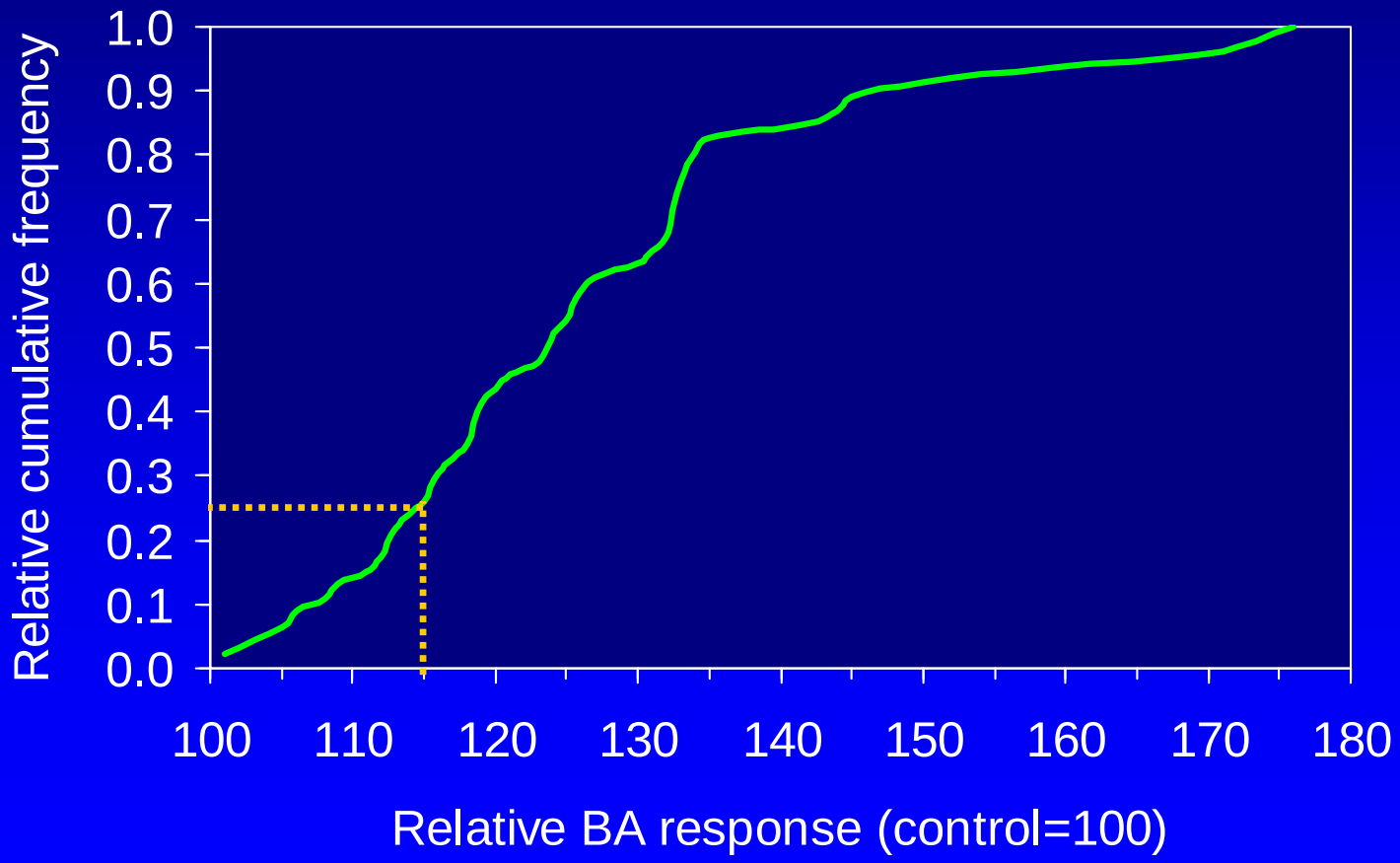

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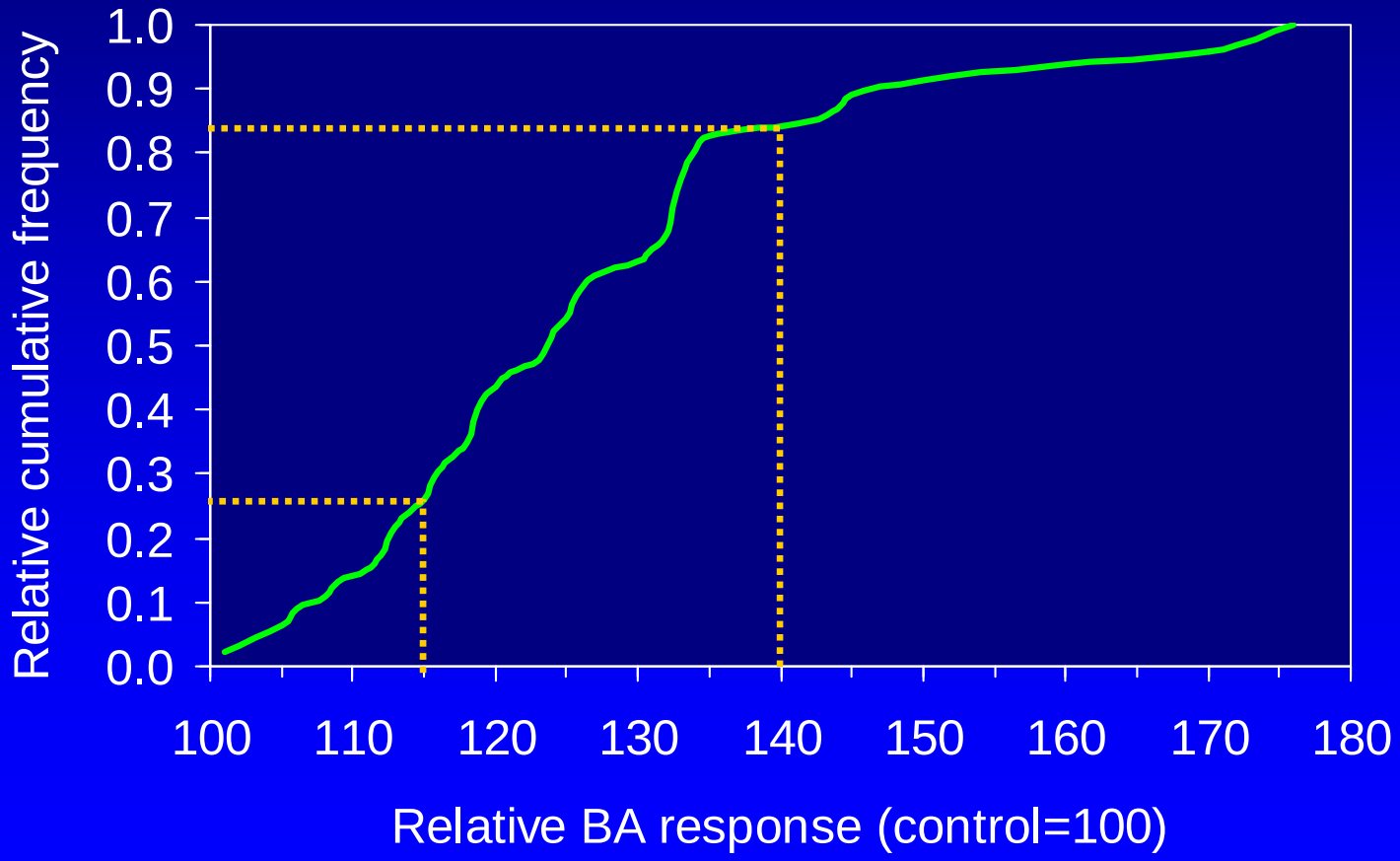
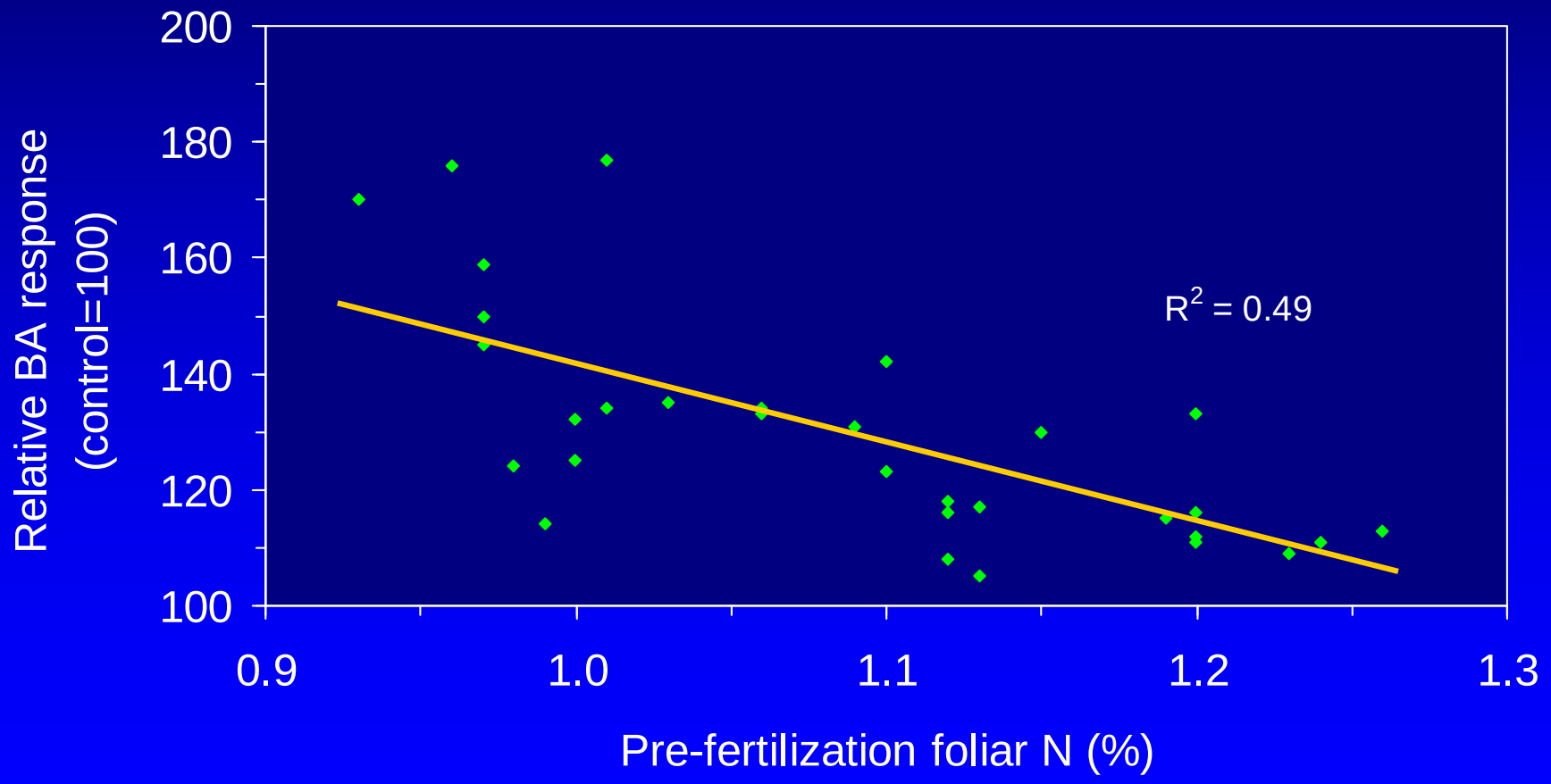


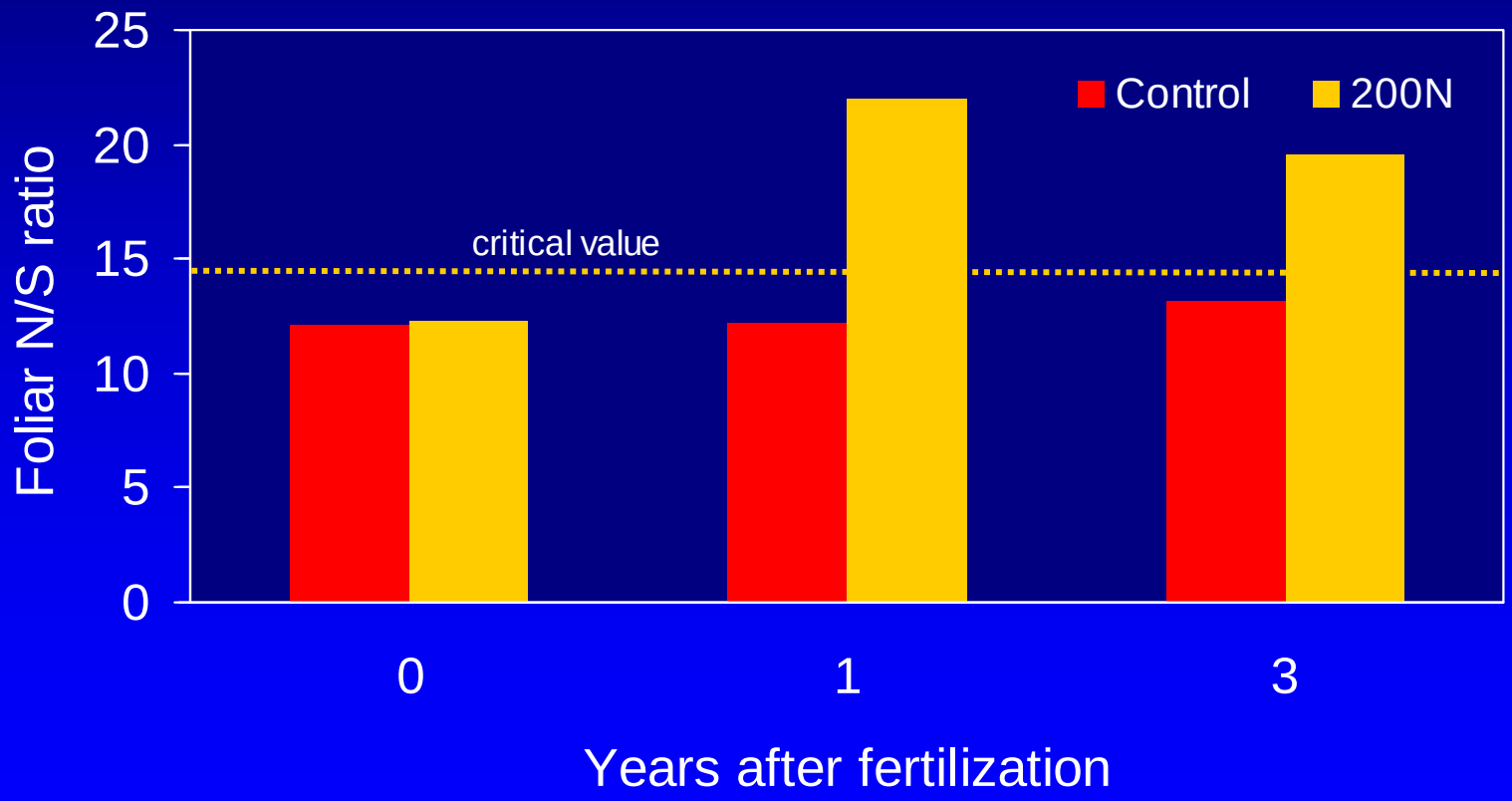
6-year relative BA response vs. initial foliar N

from Brockley (2000)



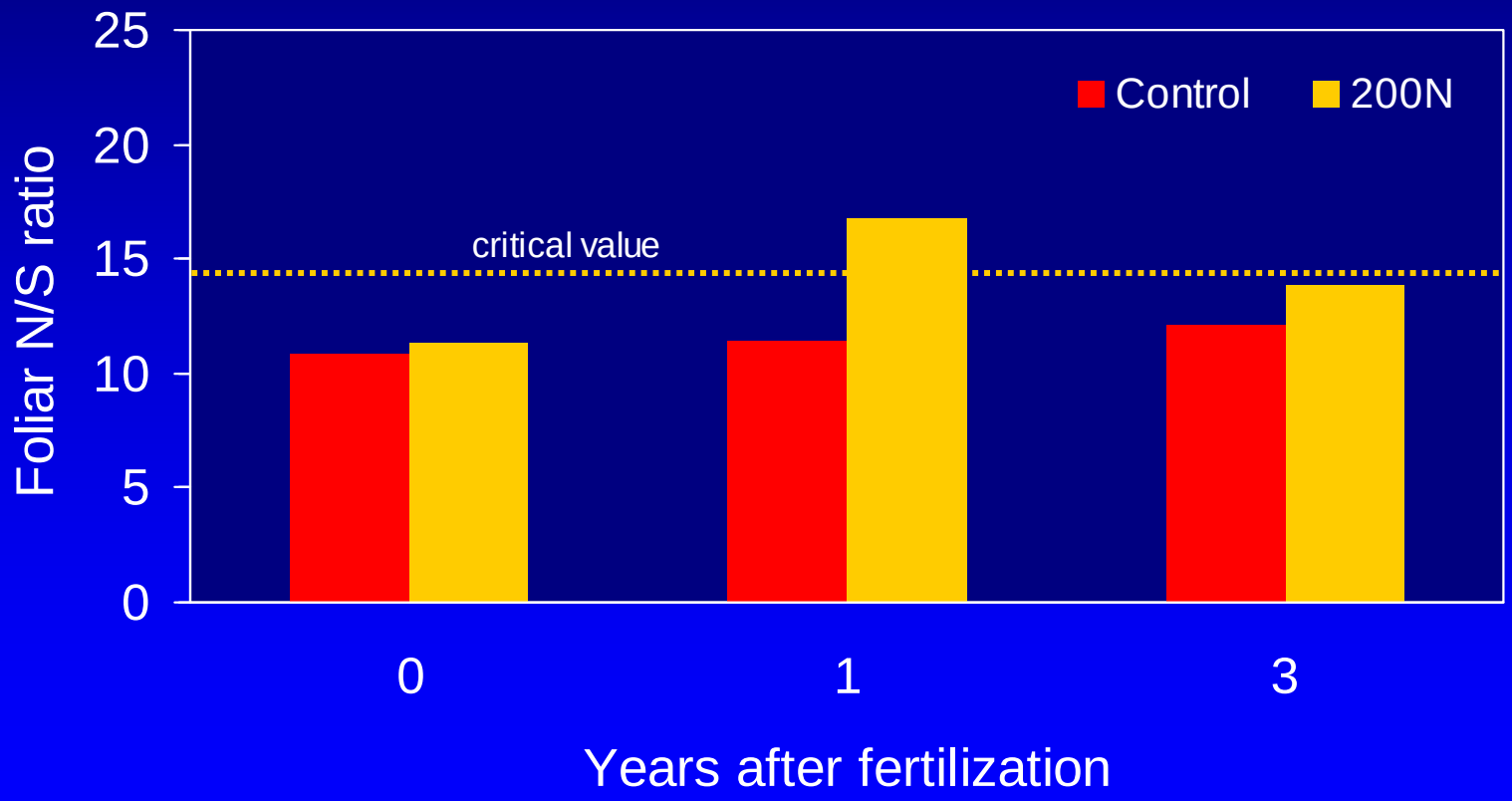
Foliar N/S ratio by treatment and year

Unresponsive to N fertilization (n=9)



Foliar N/S ratio by treatment and year

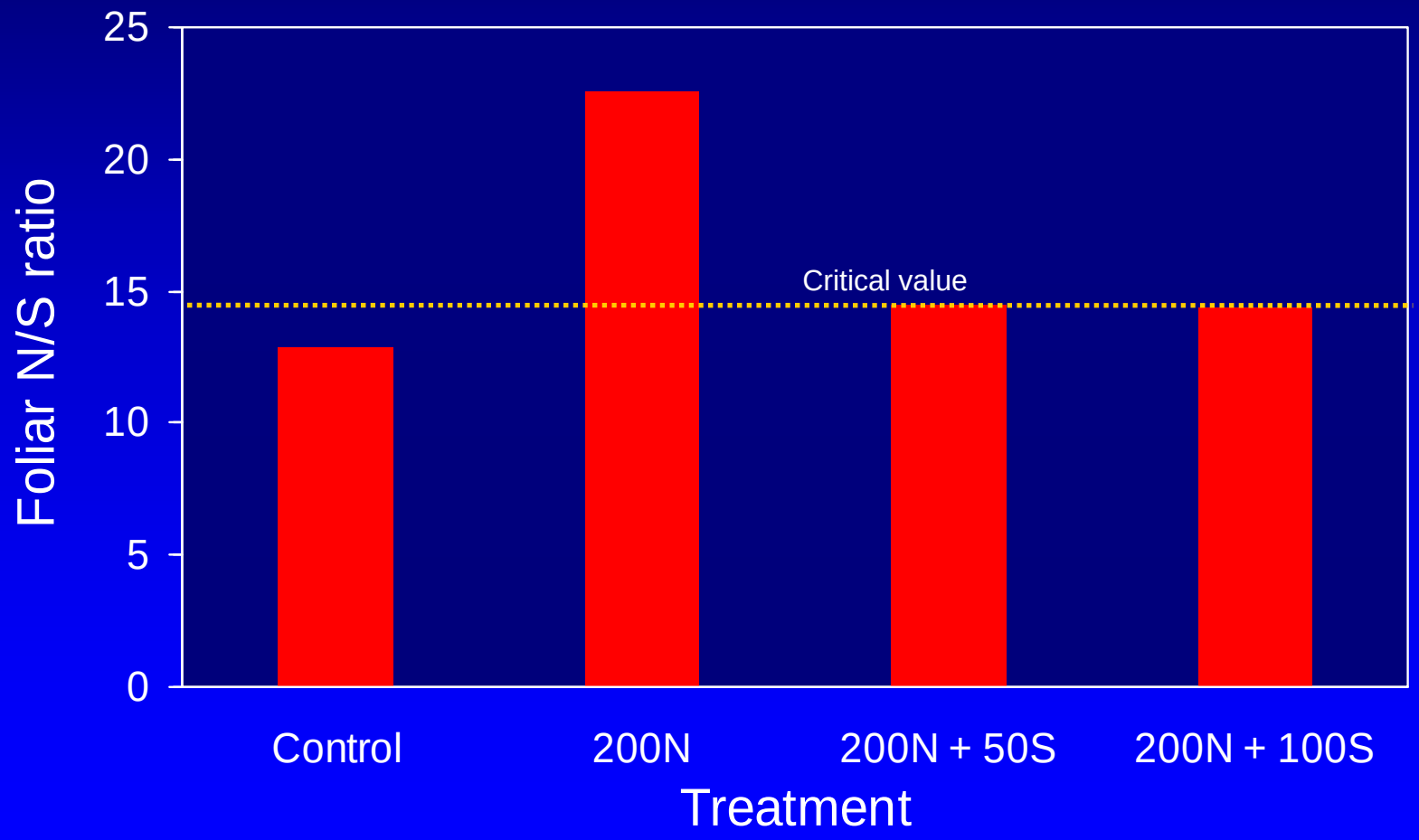
Responsive to N fertilization (n=13)




Control
200N
200N + 50S
200N + 100S

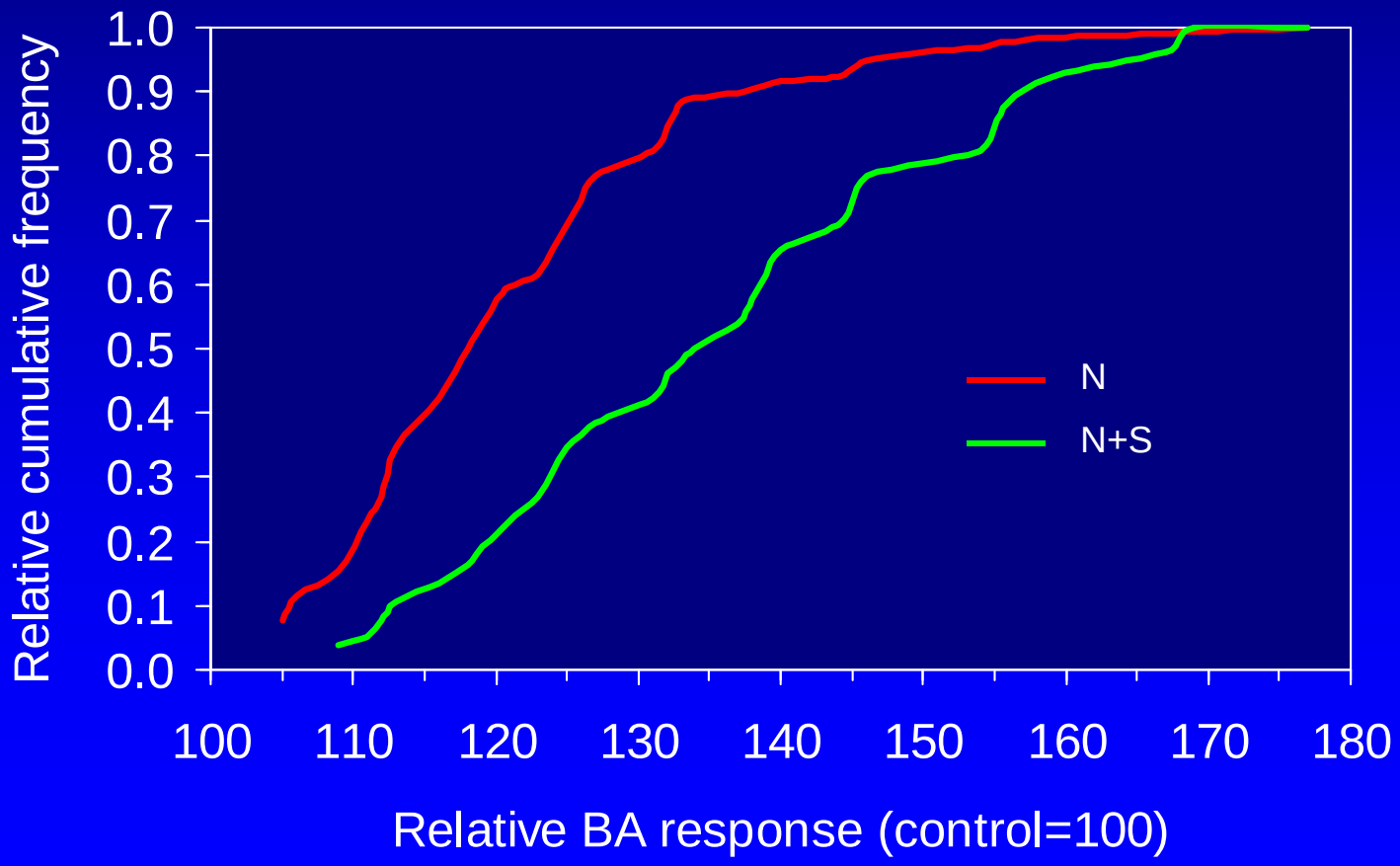
Effect of N and N+S fertilization on 1st year foliar N/S ratio

Brockley and Sheran (1994)



6-year relative BA response following N and N+S fertilization

Relative cumulative frequency distribution (n=26)



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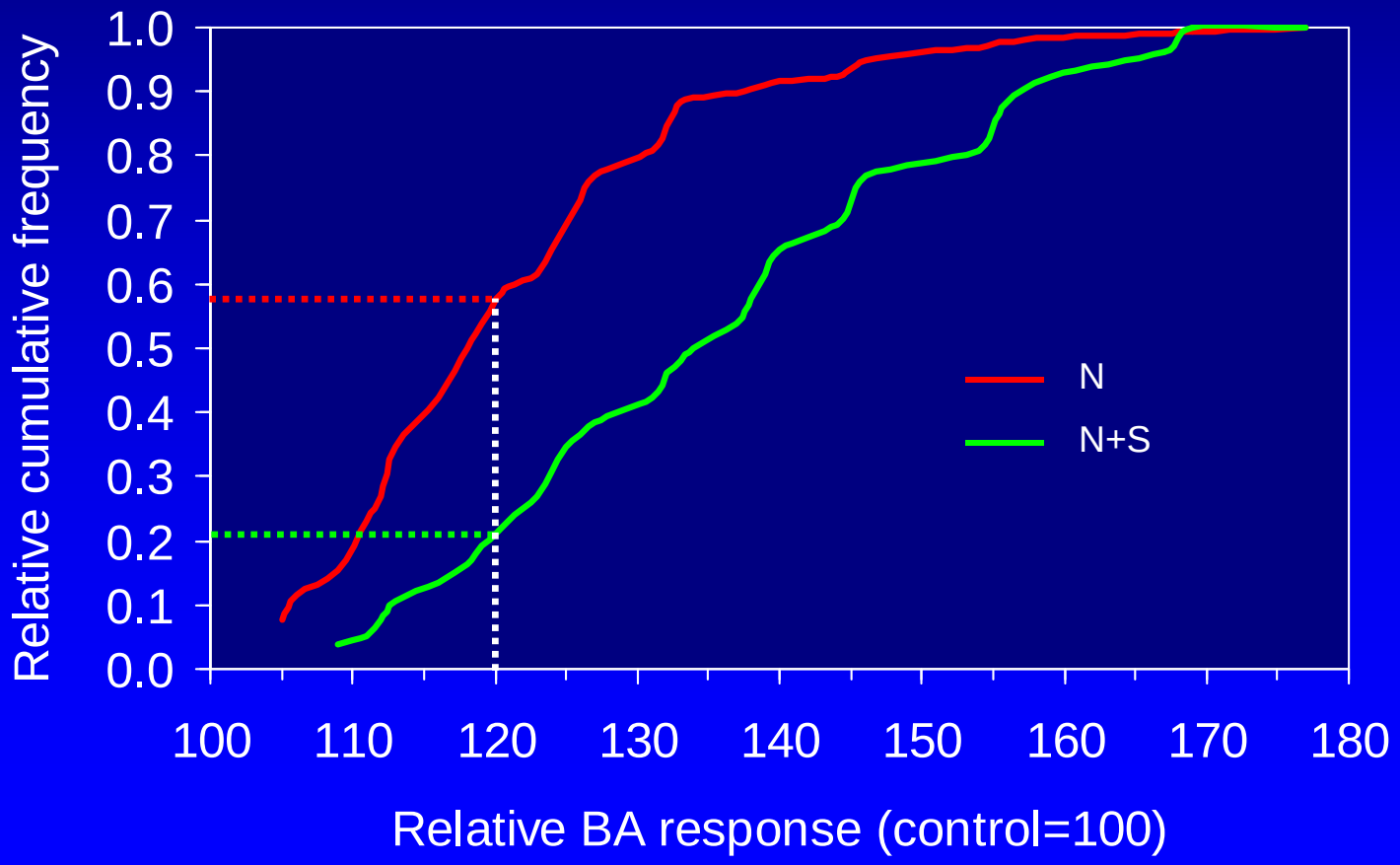

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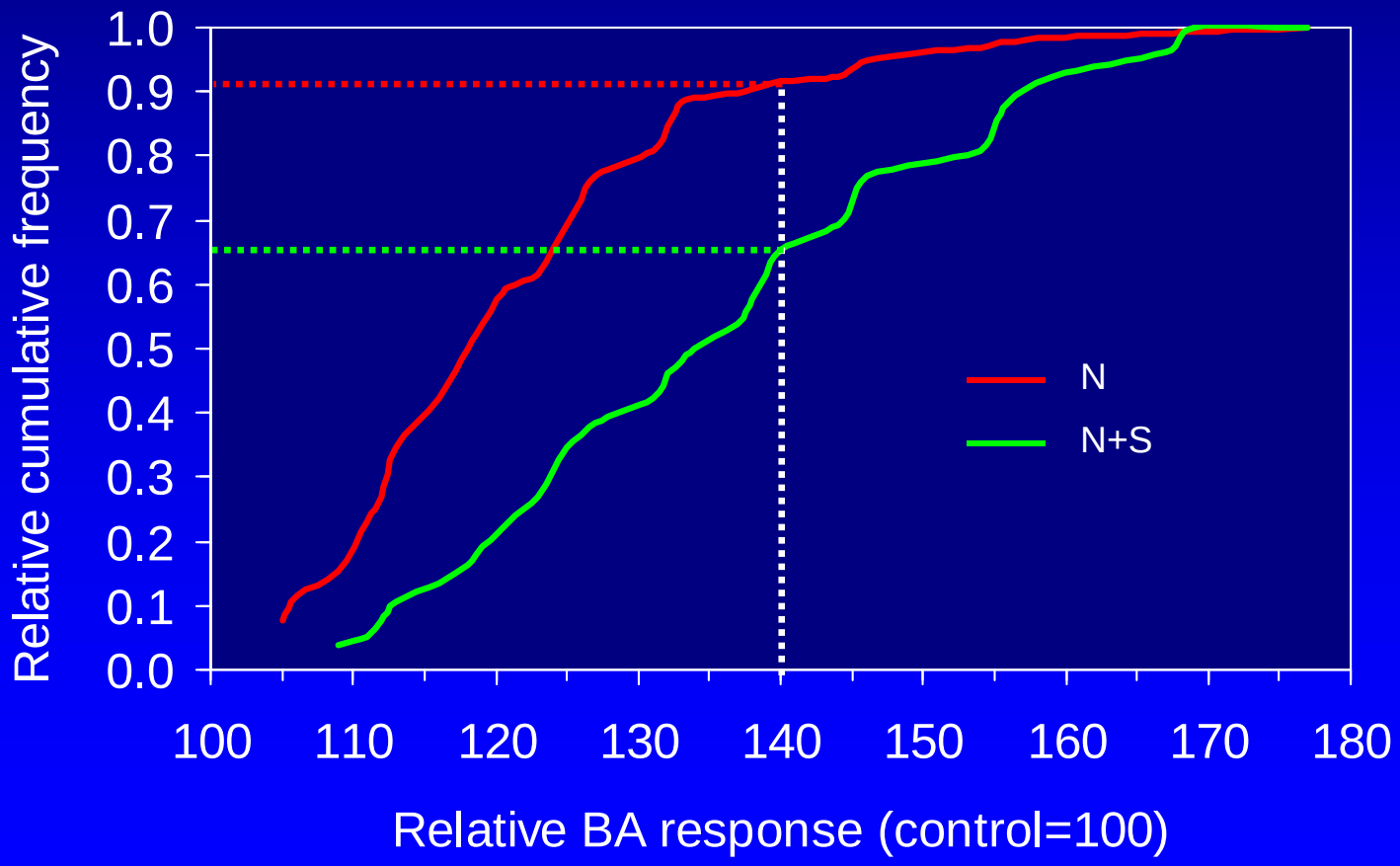
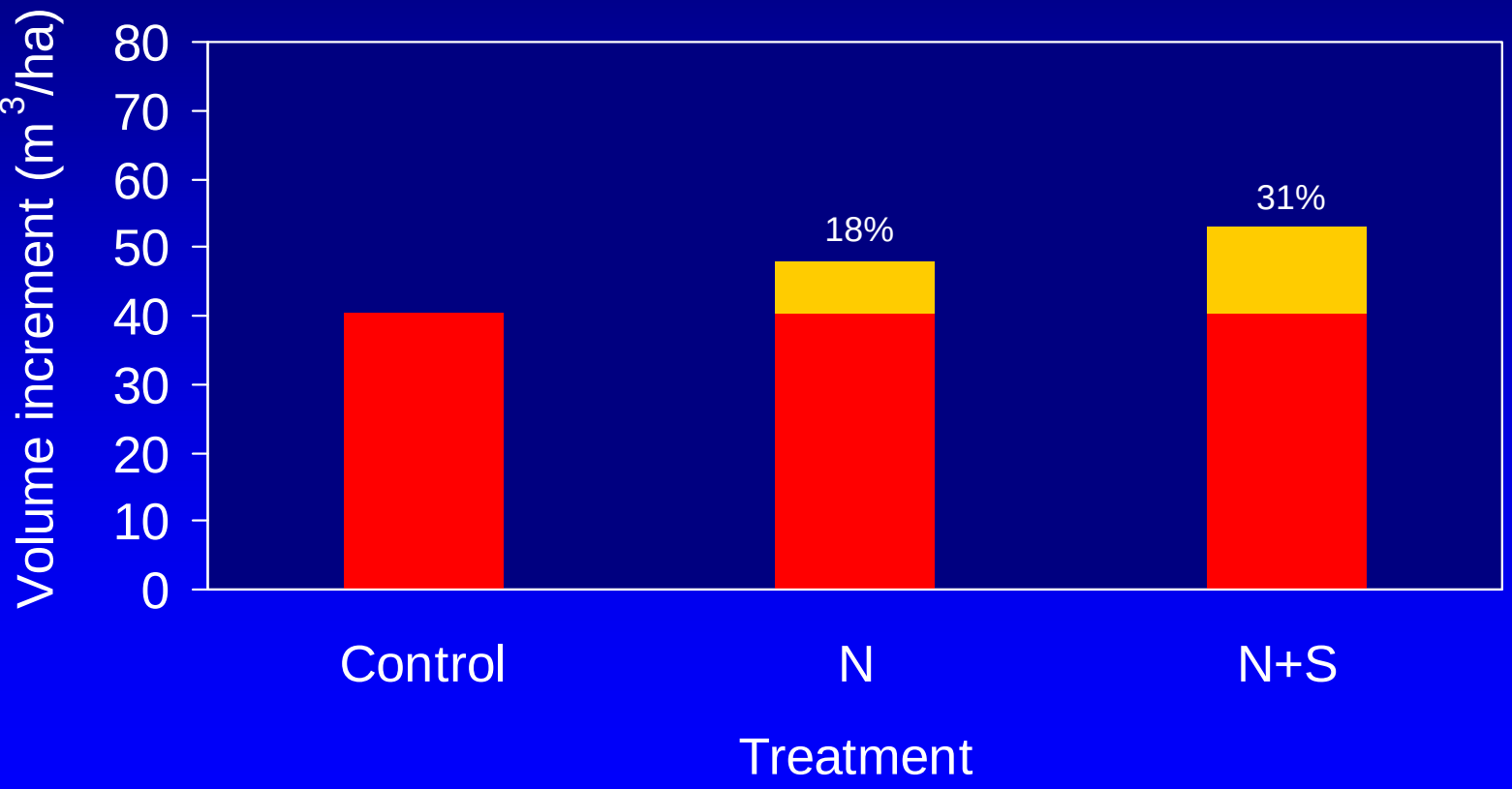


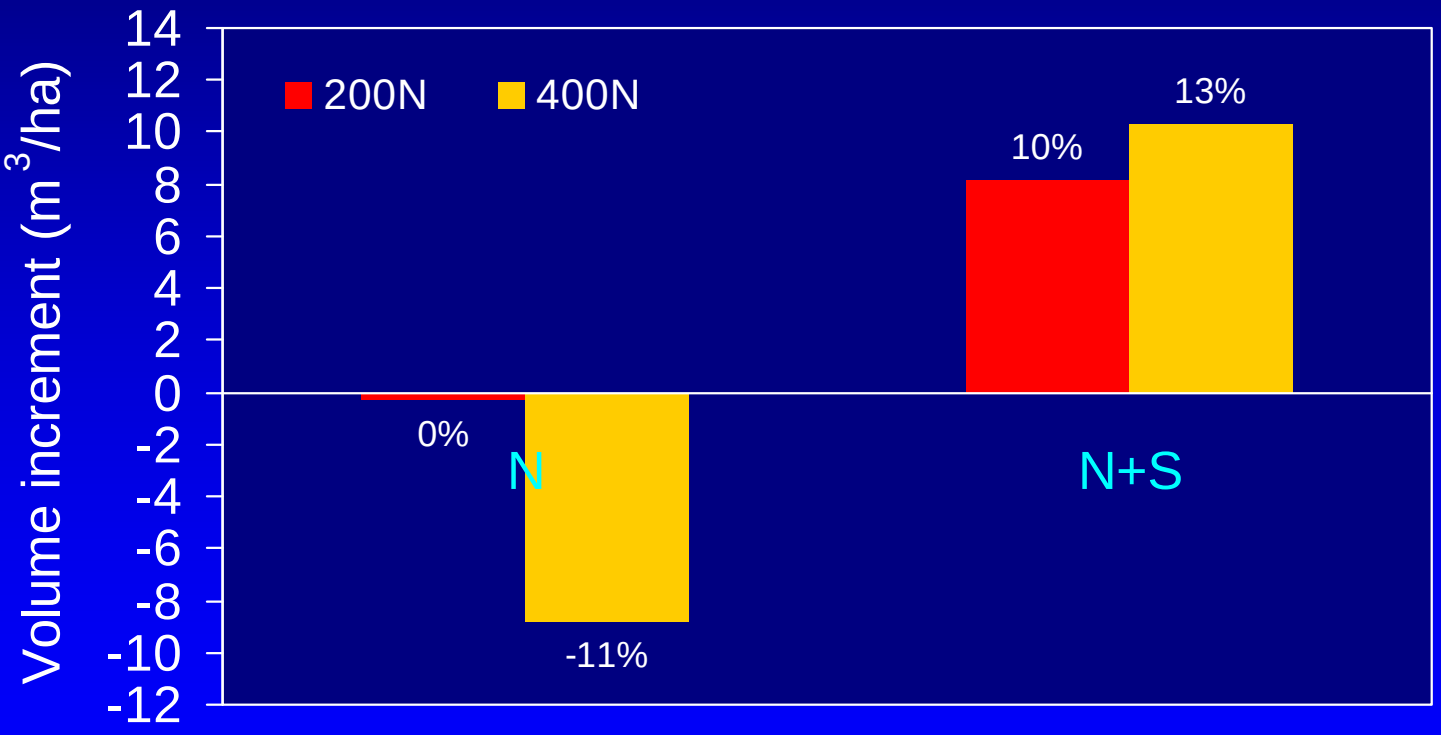
Effect of N and N+S fertilization on 6-year stand volume increment

All installations (n=15)



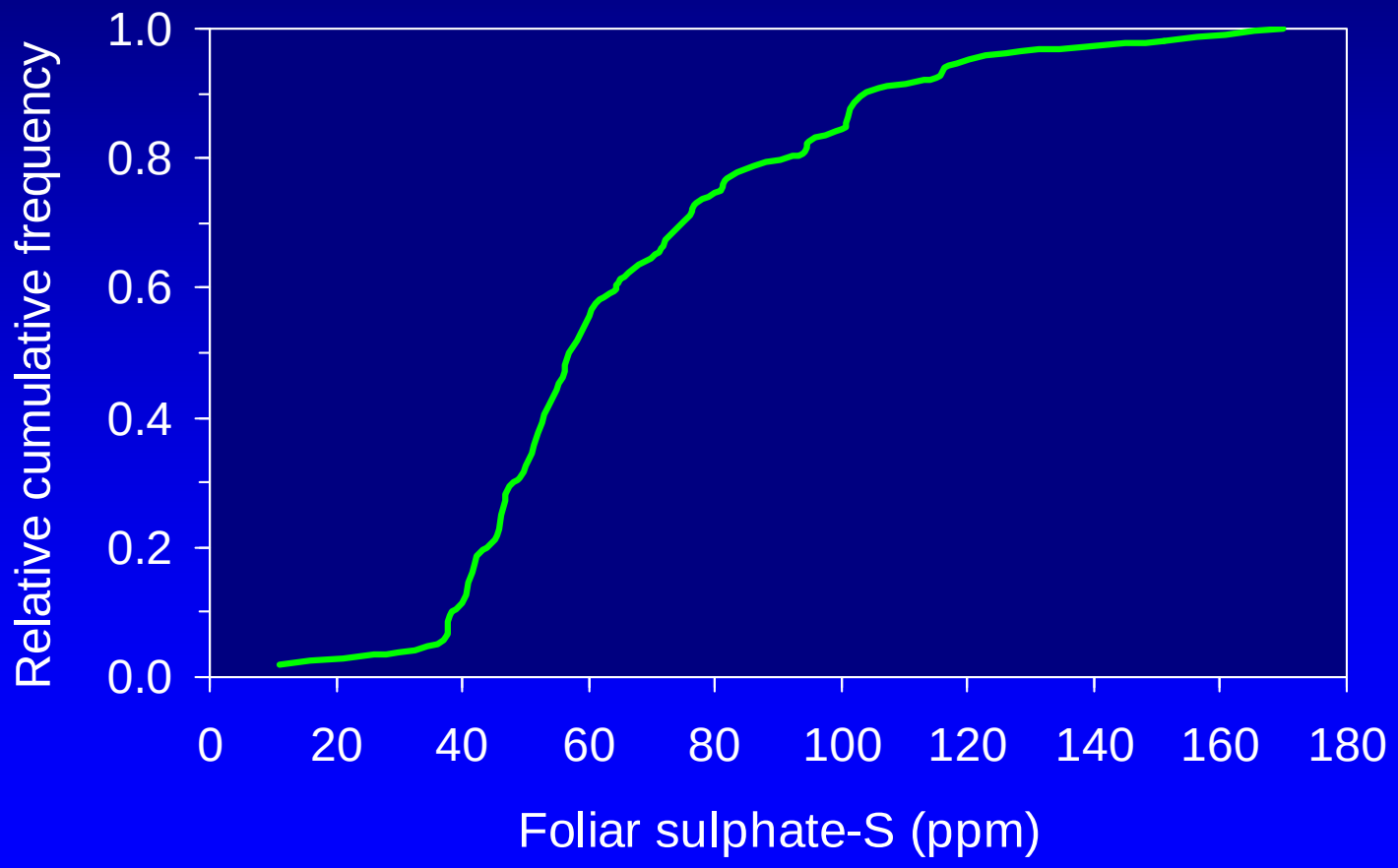
Effect of N application rate with and without added S on 6-year volume increment

EP 886.01- 43



Lodgepole pine foliar SO_4-S concentration

Relative cumulative frequency distribution (n=58)



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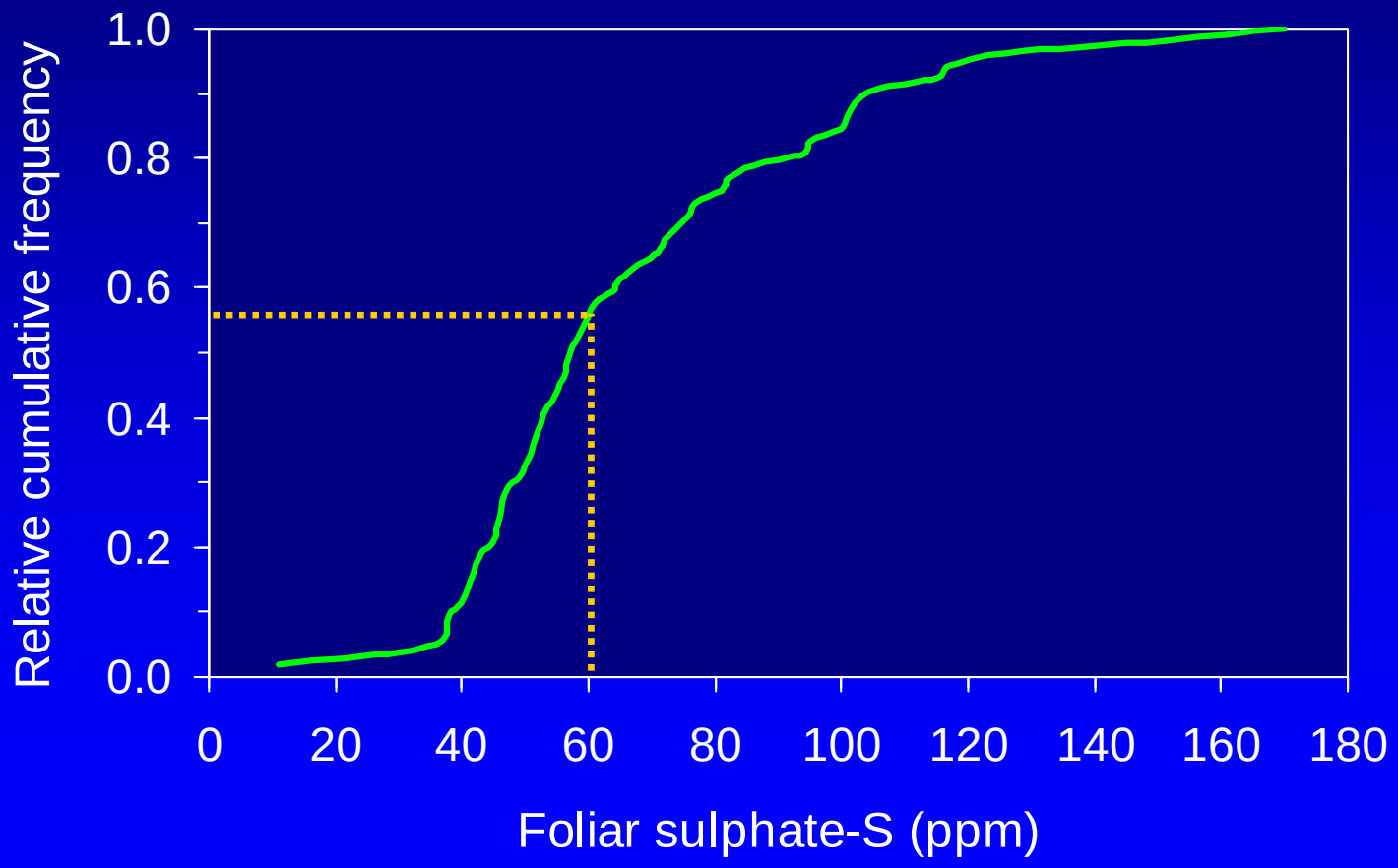
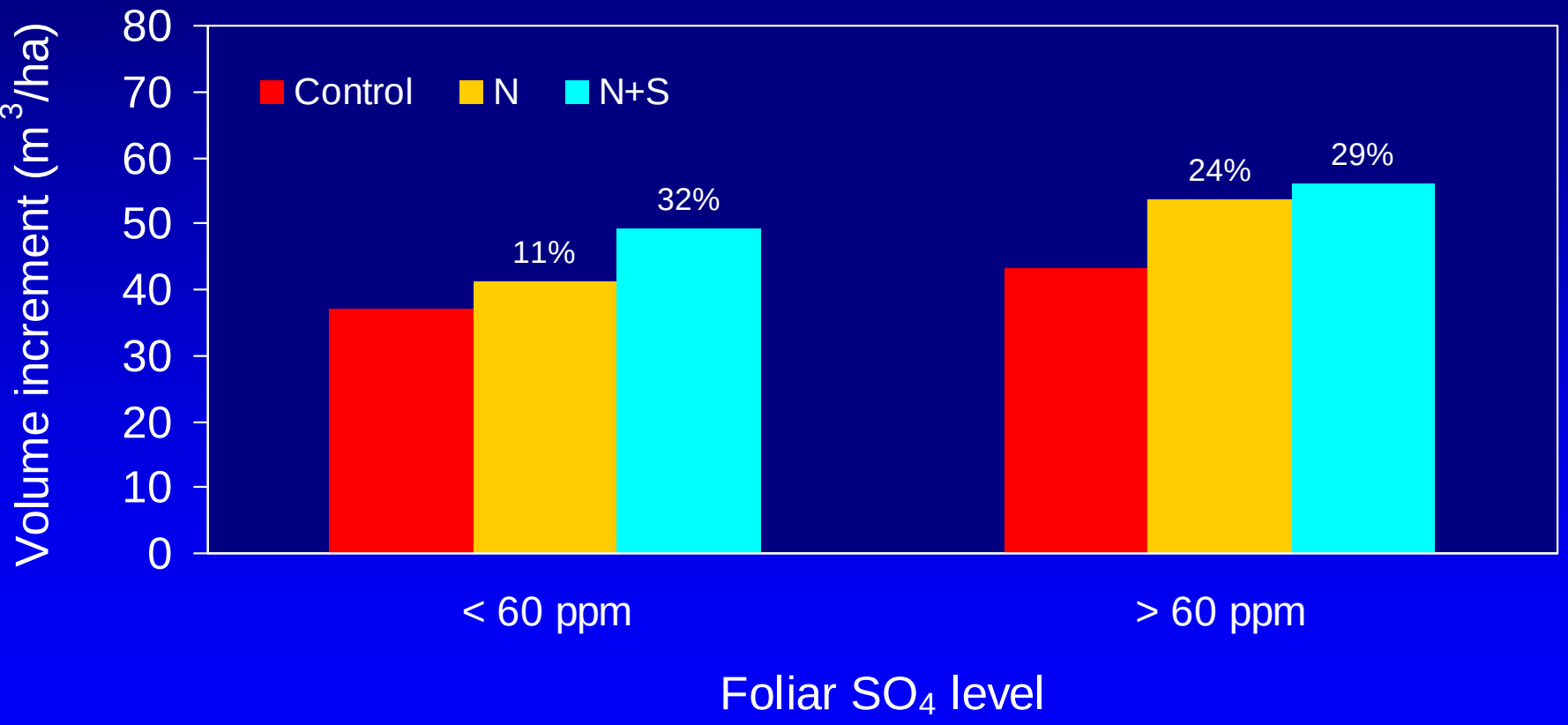


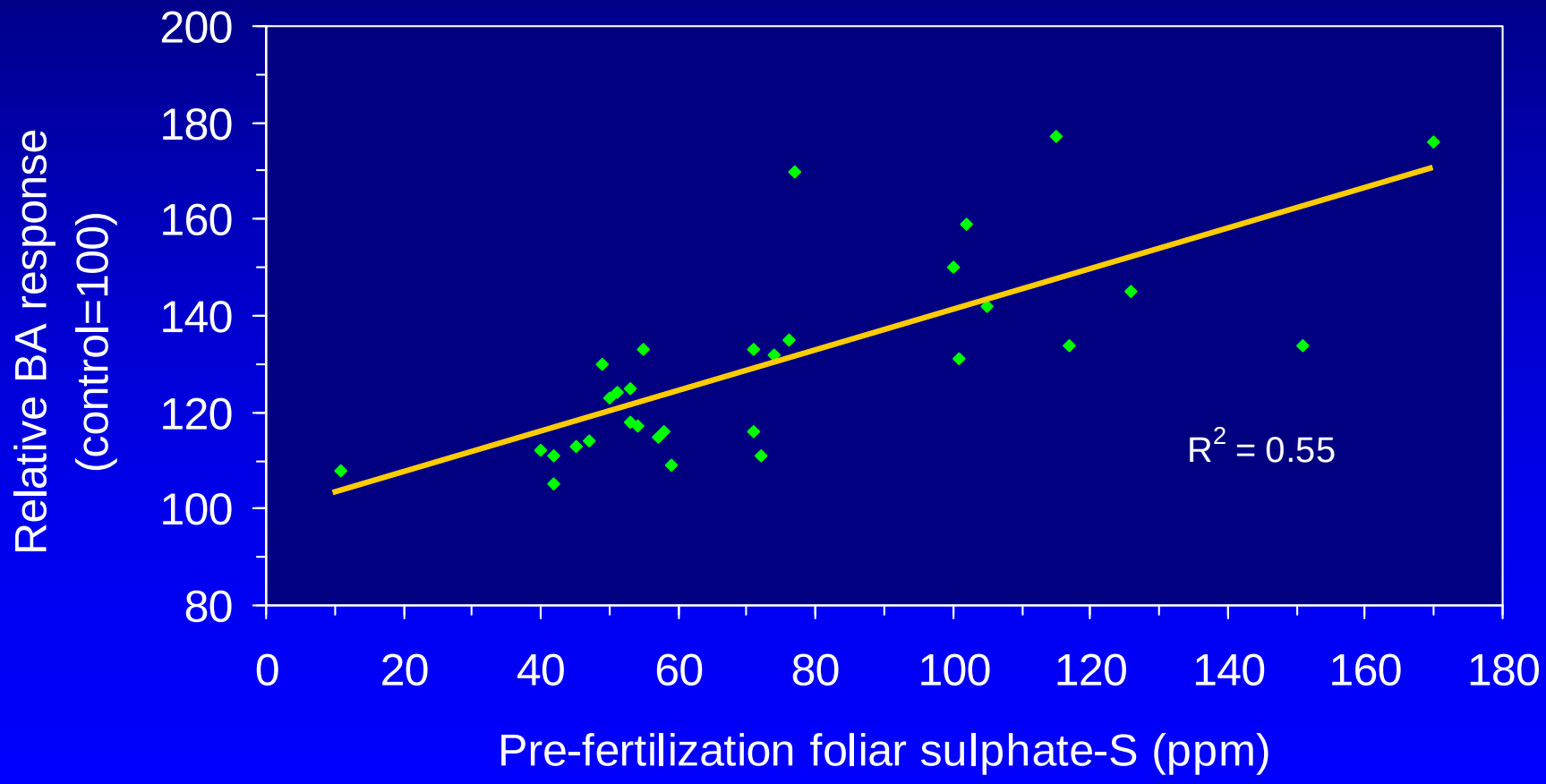
Effect of N and N+S fertilization on 6-year stand volume increment

by initial foliar SO_4-S



6-year relative BA response vs. initial foliar SO_4

from Brockley (2000)



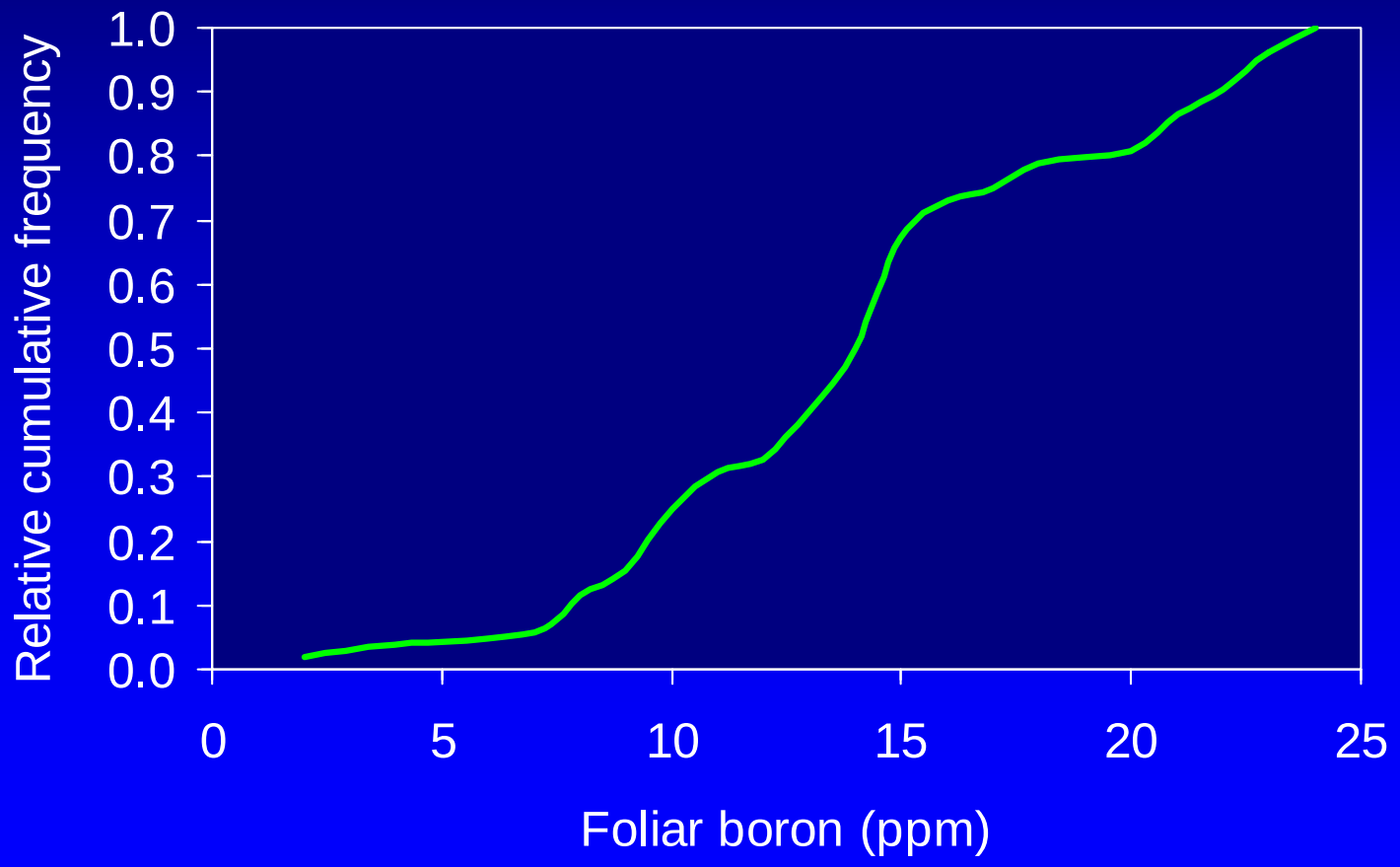
Predicting growth response to N and N+S fertilization from pre-fertilization foliar N and SO_4 levels

Brockley (2001)

	Foliar N			
	< 1.2%		1.2 – 1.3%	
Foliar SO_4	N	N+S	N	N+S
≤ 60 ppm	L - M (10 – 30%)	M - H (20 – 40%)	L (0 – 20%)	L - M (10 – 30%)
> 60 ppm	H (30 – 60%)	H (30 – 60%)	L - M (10 – 30%)	L - M (10 – 30%)

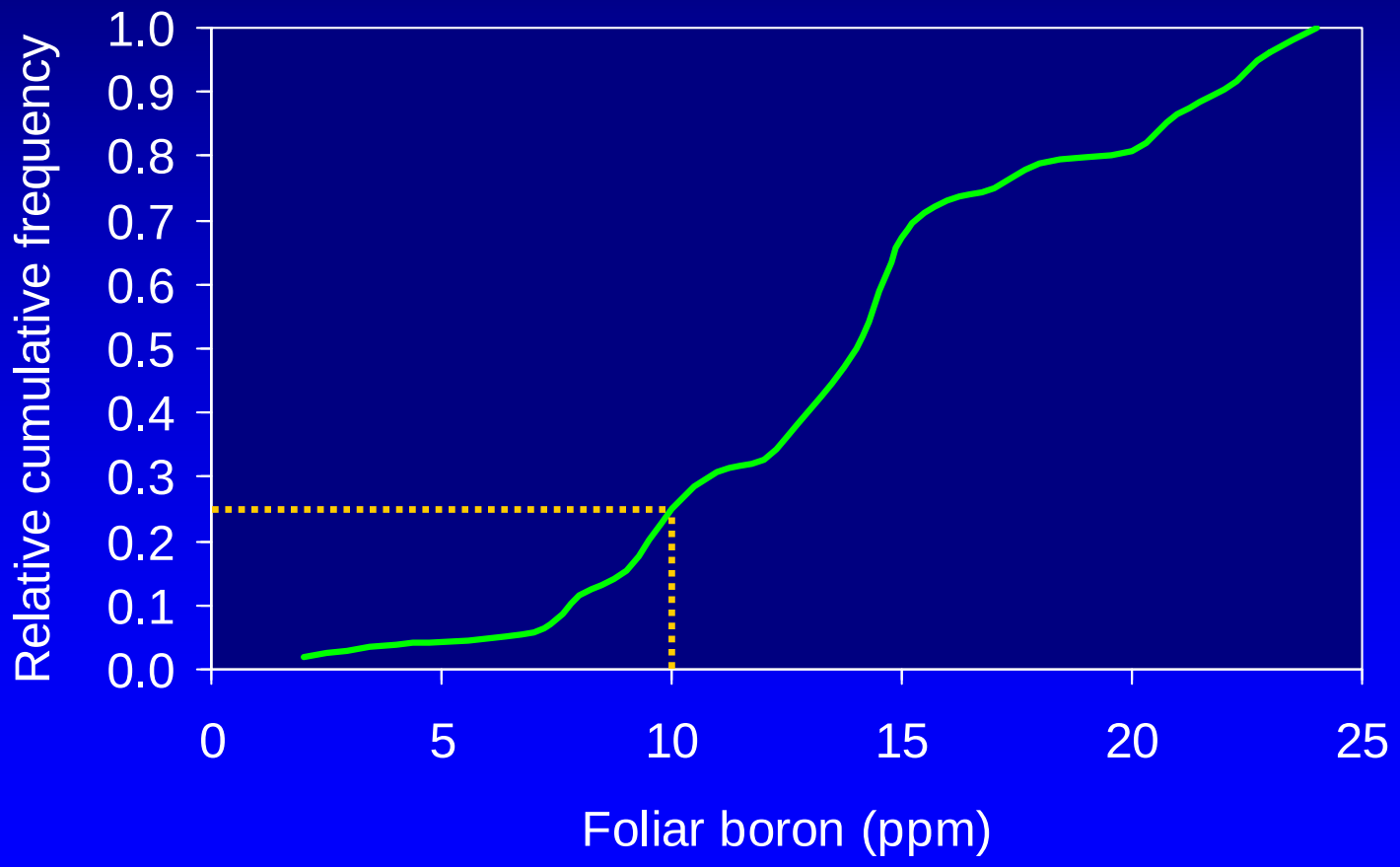
Lodgepole pine foliar B concentration

Relative cumulative frequency distribution (n=58)



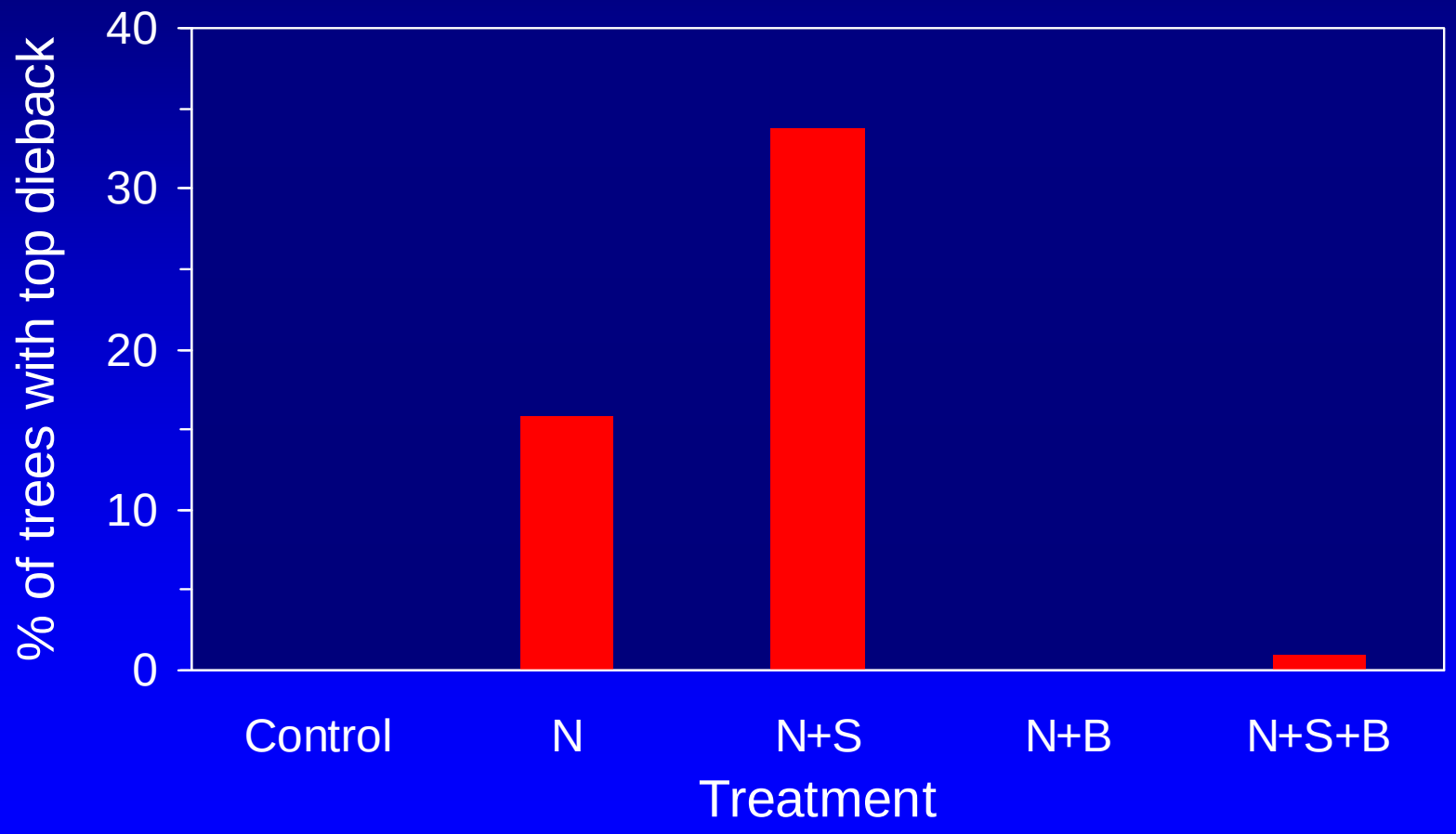
Lodgepole pine foliar B concentration

Relative cumulative frequency distribution (n=58)



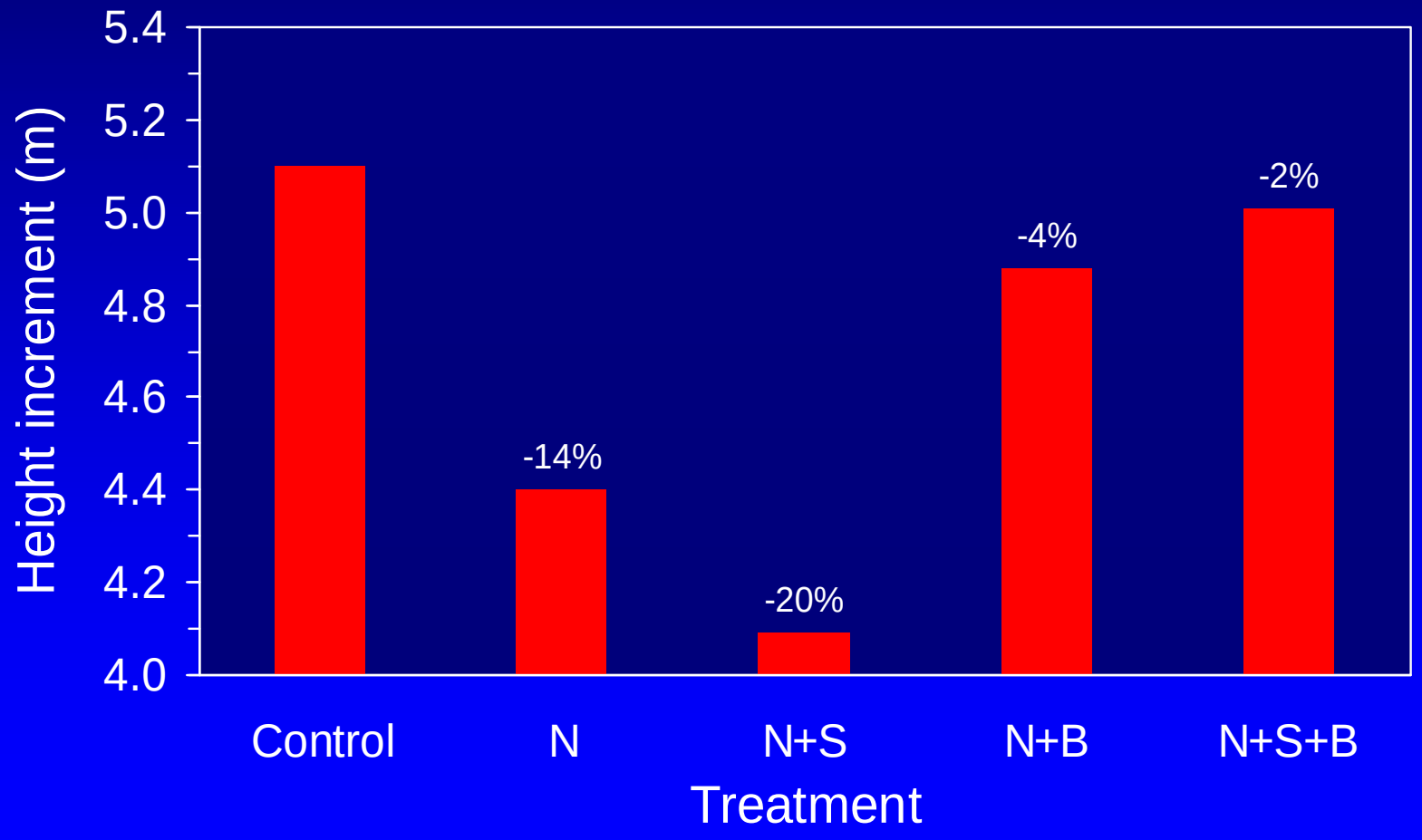
Effect of N and N+S, with and with added B, on the incidence of terminal leader dieback

Brockley (2003)



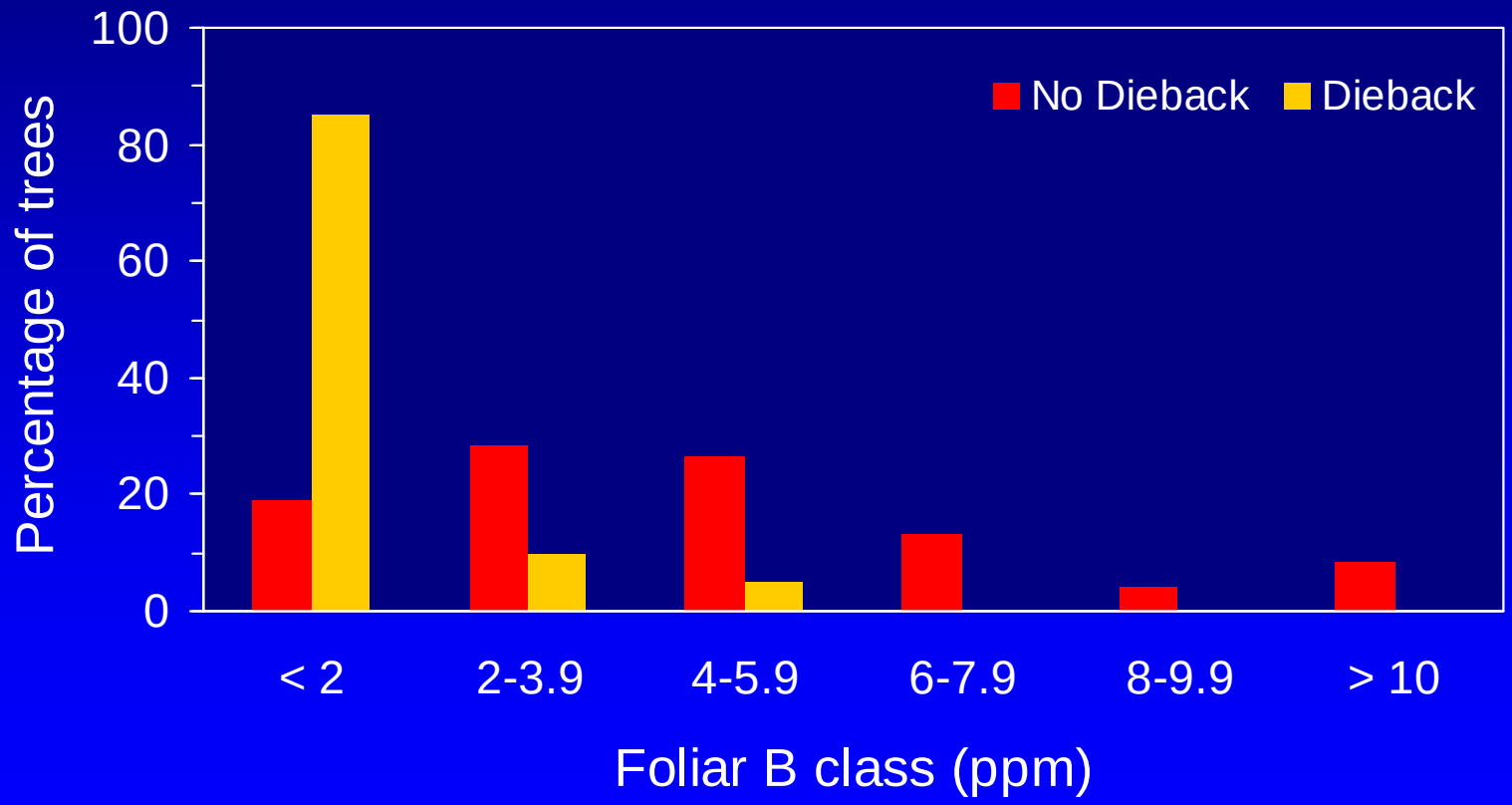
Effect of N and N+S, with and without added B, on 9-year height increment at Blackwater Creek

Brockley (2003)



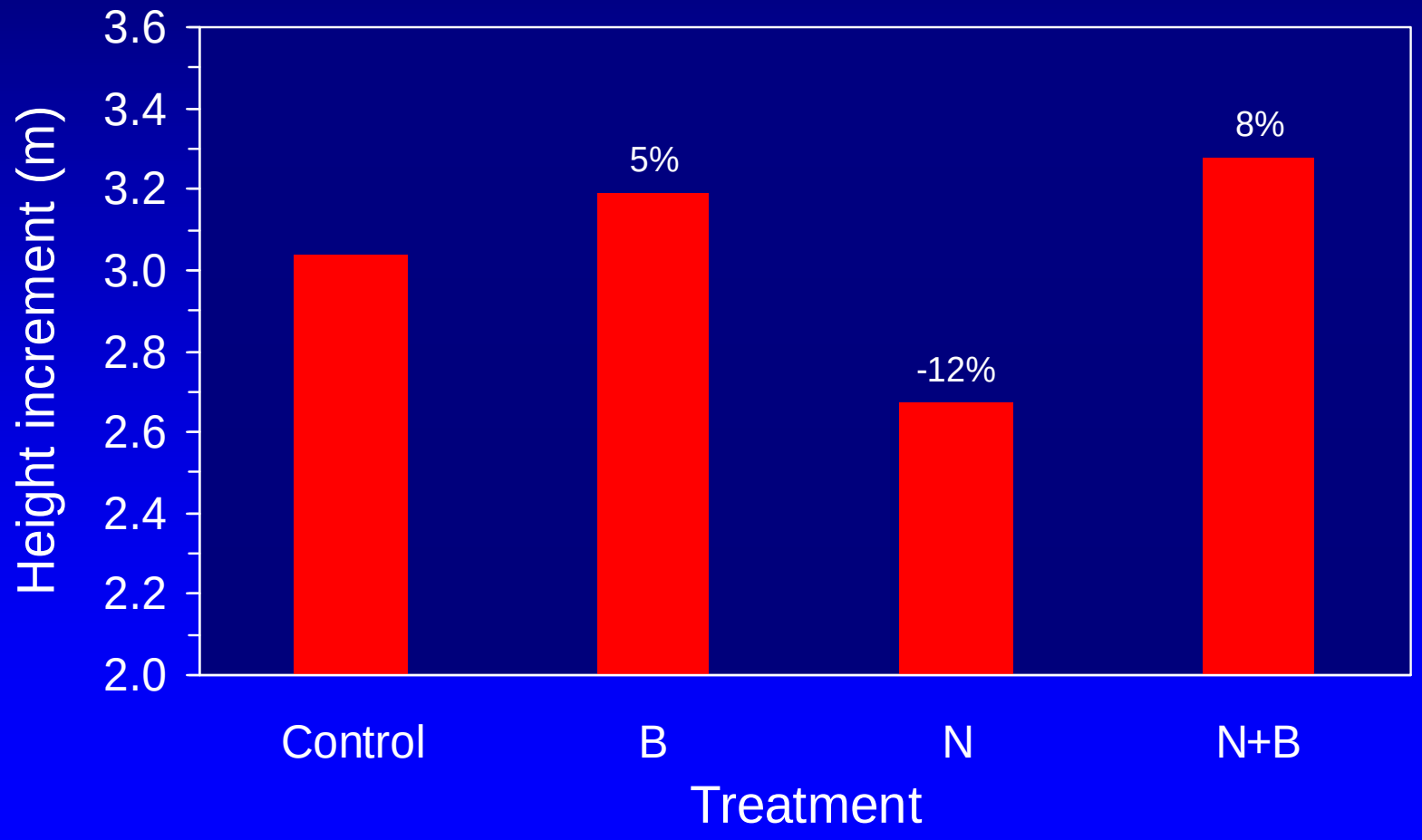
Terminal leader dieback by foliar B class following N or N+S fertilization

Brockley (2003)



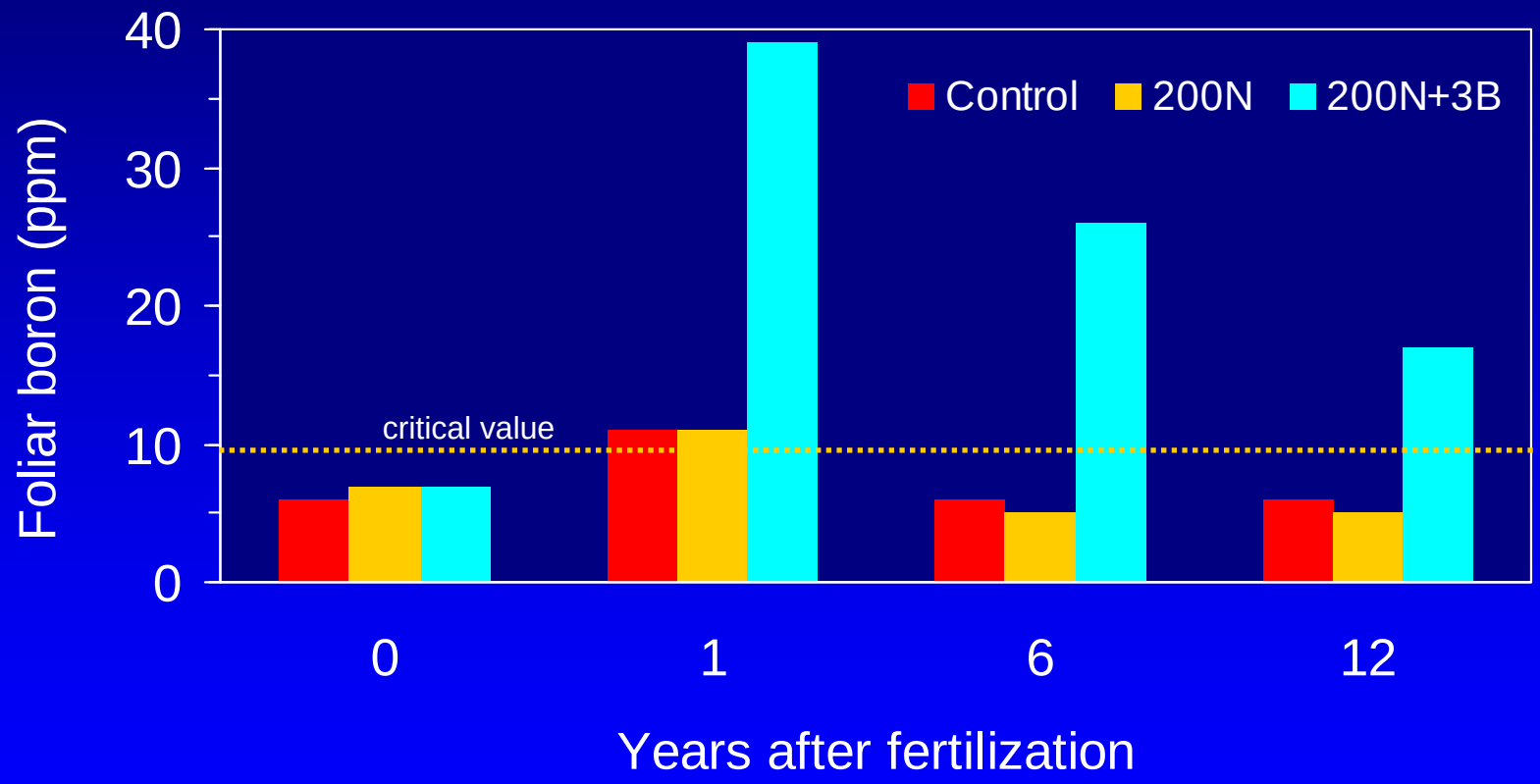
Effect of N and N+S, with and without added B, on 9-year height increment at Lord Lake

Brockley (2003)



Effects of N and B fertilization on foliar B levels

from Brockley (2003)



Lodgepole pine foliar nutrient interpretative criteria

Macronutrients (from Brockley 2001)

Diagnosis	Element (% dry weight)					
	N	P	K	Ca	Mg	S
Sev. deficient	< 1.00	< 0.08	< 0.30	< 0.06	< 0.04	< 0.06
Mod. to sev. deficient	1.00 – 1.15	0.08 – 0.10	0.30 – 0.35	0.06 – 0.08	0.04 – 0.06	0.06 – 0.08
Slight to mod. deficient	1.15 – 1.35	0.10 – 0.12	0.35 – 0.40	0.08 – 0.10	0.06 – 0.08	0.08 – 0.10
Adequate	> 1.35	> 0.12	> 0.40	> 0.10	> 0.08	> 0.10

Lodgepole pine foliar nutrient interpretative criteria

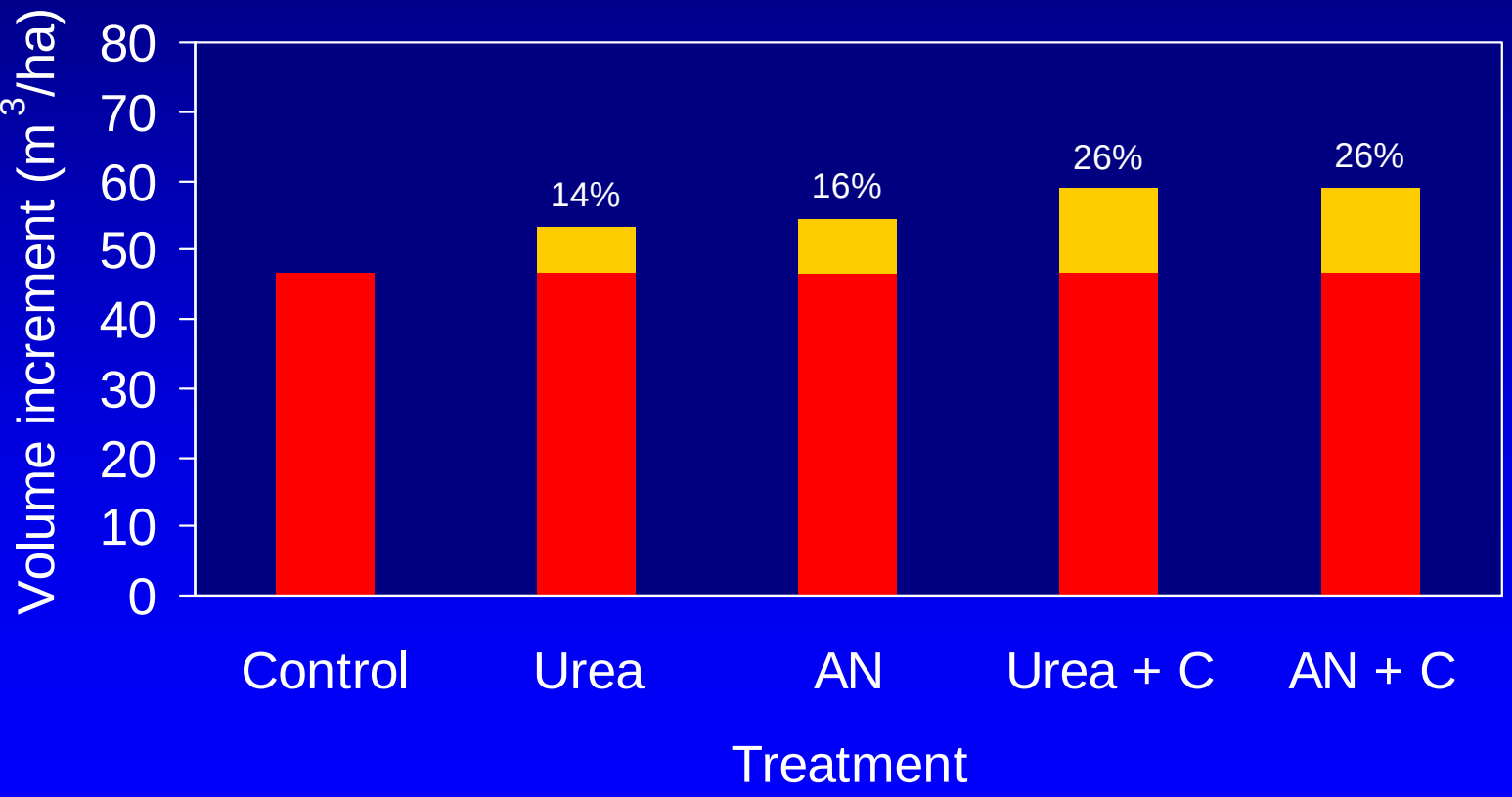
Nutrient ratios (from Brockley 2001)

	Nutrient Ratio			
Diagnosis	**N/P**	**N/K**	**N/Mg**	**N/S**
Sev. deficient				> 25
Mod. to sev. deficient	> 13	> 4.5	> 30	20 – 25
Slight to mod. deficient	11 – 13	3.5 – 4.5	20 – 30	14 – 20
Possible slight deficiency	9 – 11	2.5 – 3.5	15 – 20	
No deficiency	< 9	< 2.5	< 15	< 14

Effects of N source

Effect of N source on 6-year stand volume increment

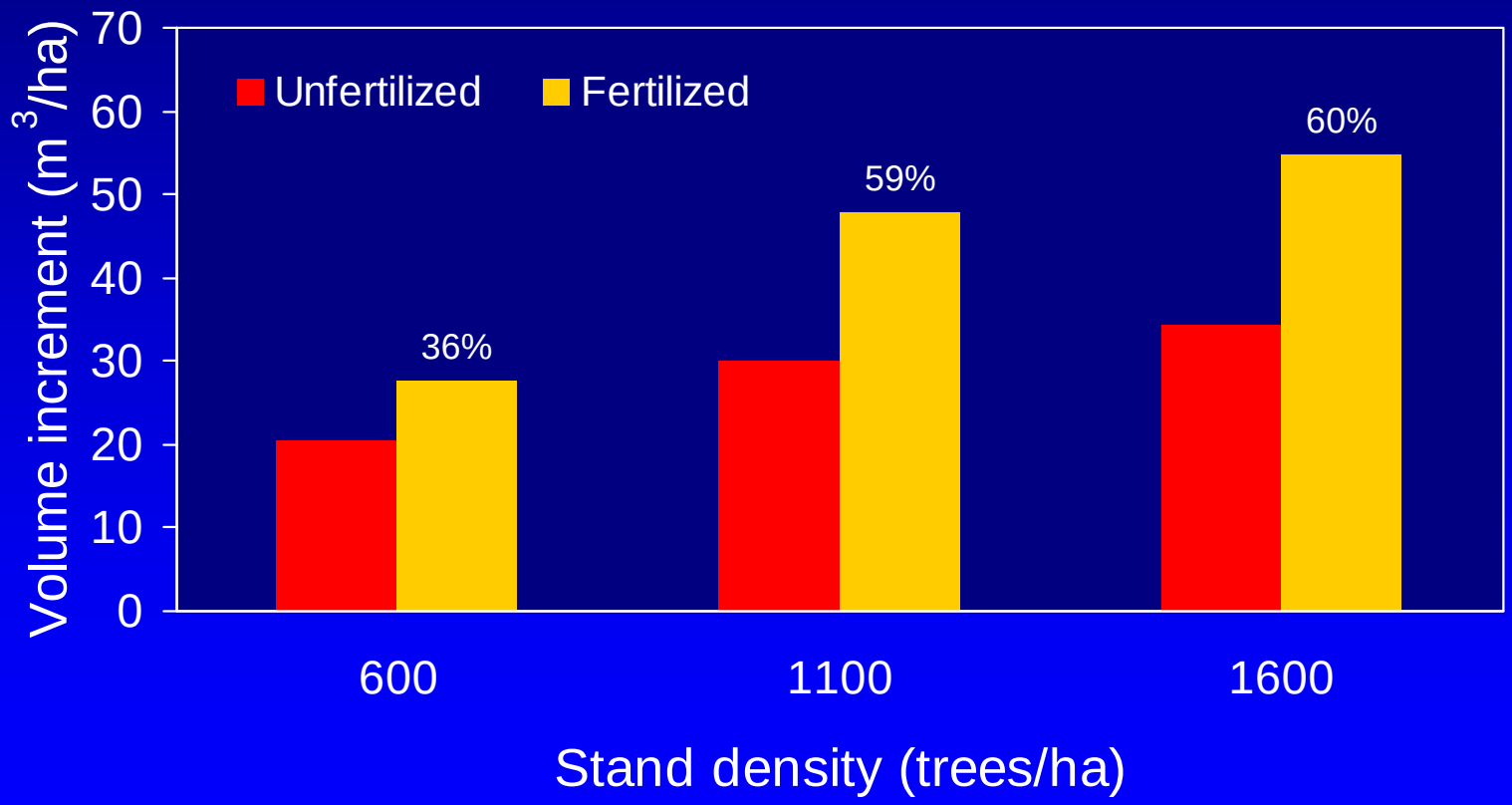
Brockley (2006)



Effects of post-thinning density

Effect of post-thinning density on 10-year stand volume increment of unfertilized and fertilized lodgepole pine

Brockley (2005)



Interior spruce fertilization research

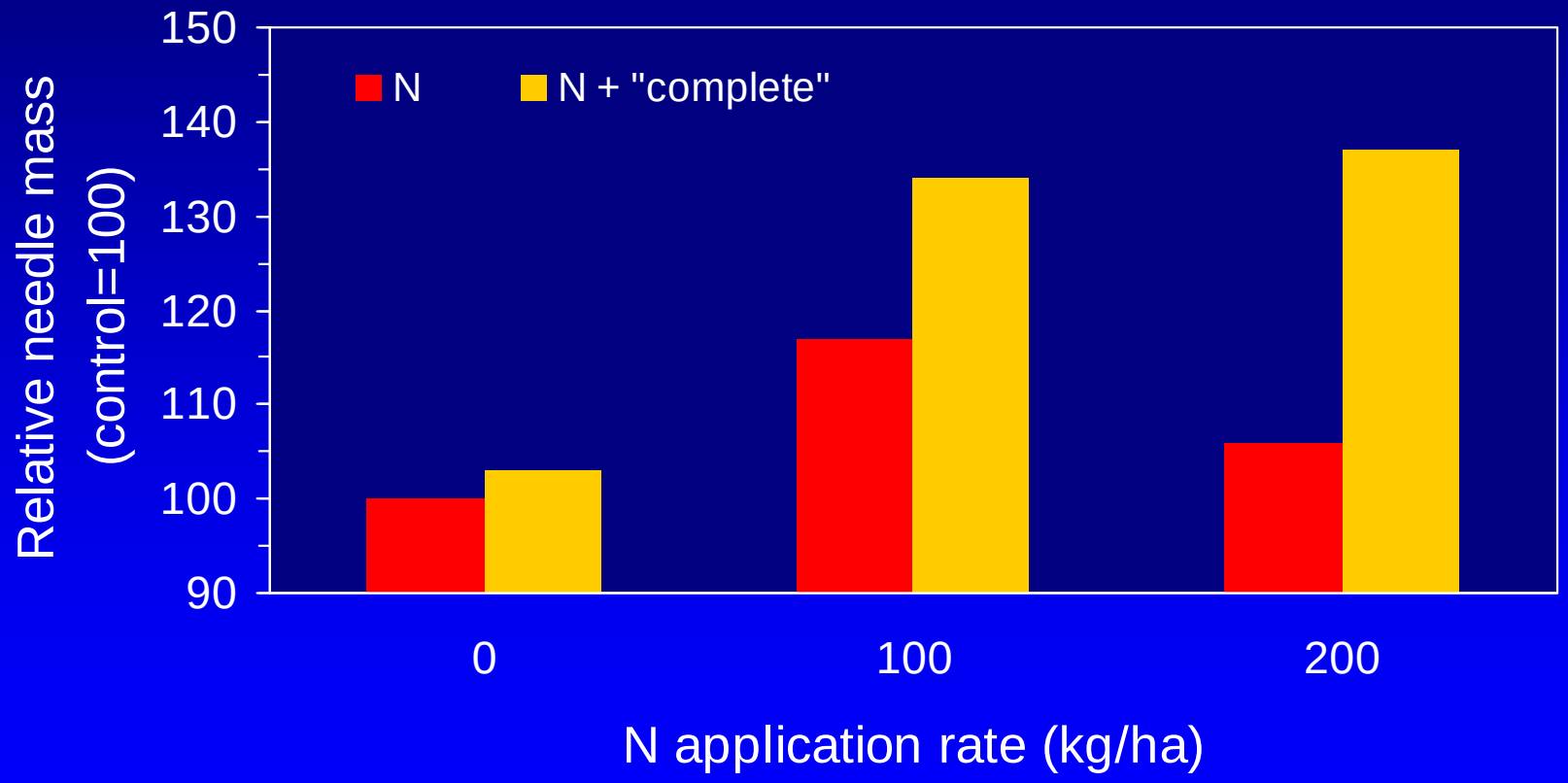
Effects of broadcast burning on foliar N status of white spruce plantations in the B.C. interior

Curran and Ballard (1990)

N nutrient status	Burned	Unburned	Total
Moderate to severe deficiency	8	0	8
Mild to no deficiency	3	5	8
Total	11	5	16

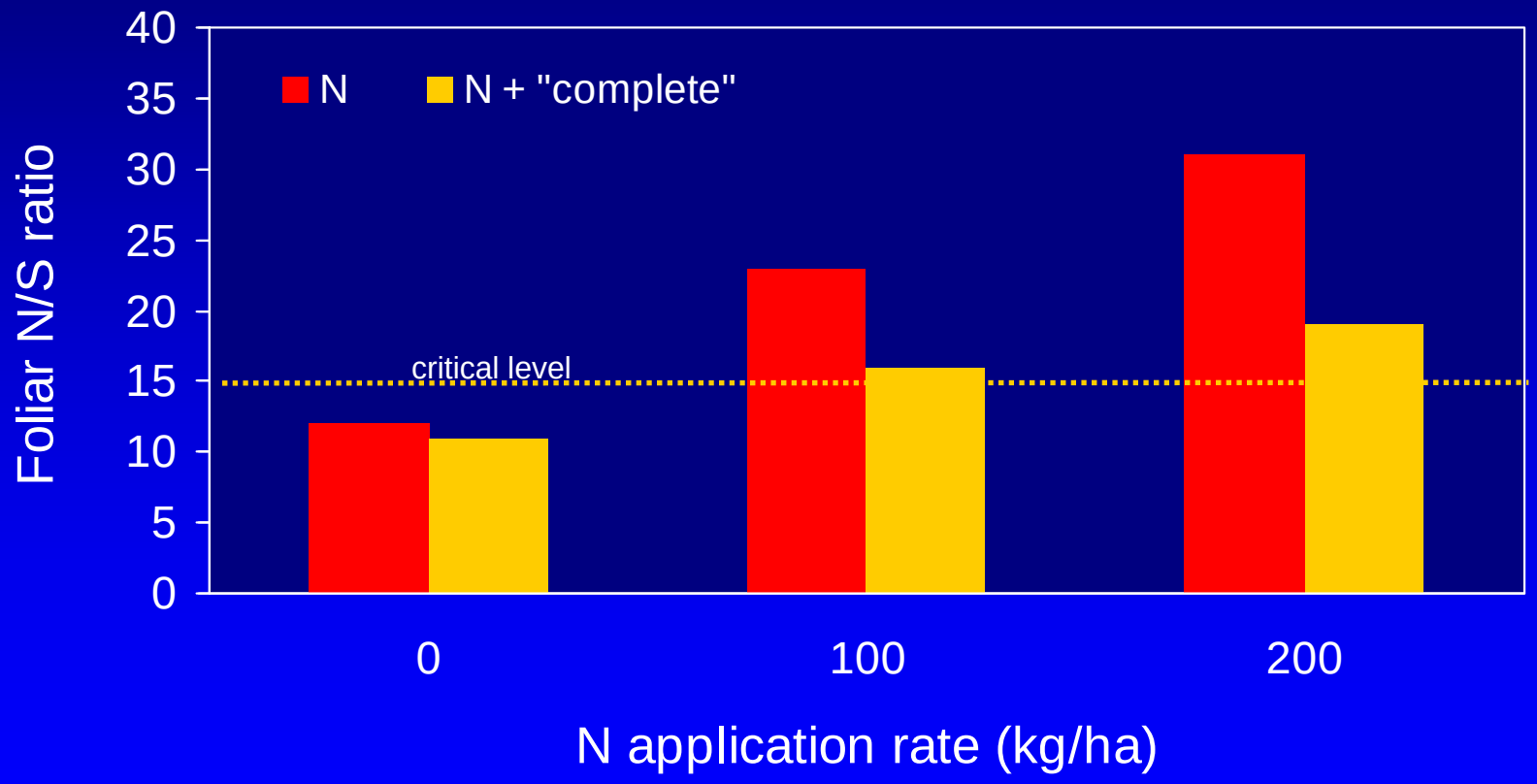
Effects of N and “complete mix” fertilizer on 1st year needle mass of interior spruce (n=10)

Swift and Brockley (1994)



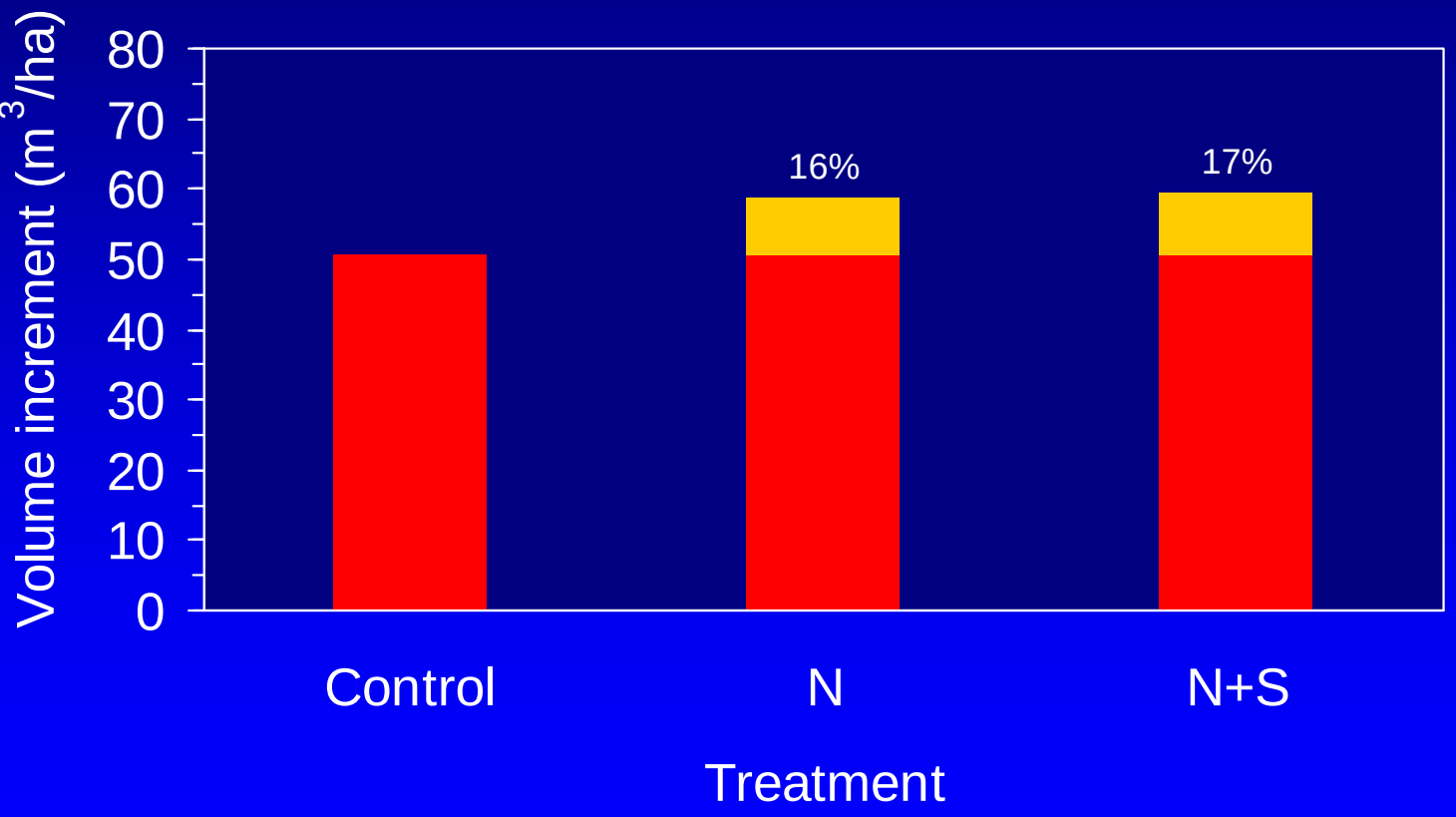
Effects of N and “complete mix” fertilizer on 1st year foliar N/S ratio in interior spruce (n=10)

Swift and Brockley (1994)



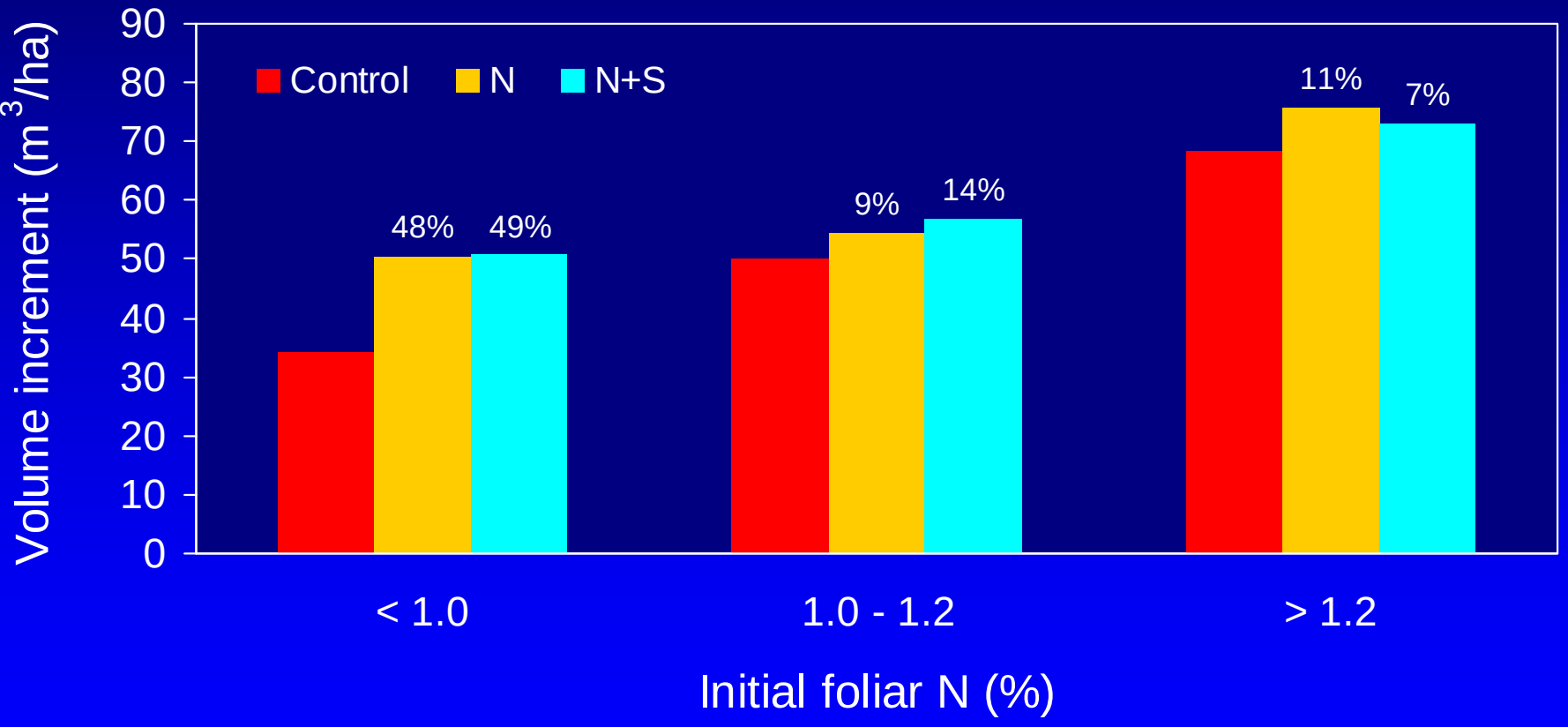
Effect of N and N+S fertilization on 6-year volume response of interior spruce

All installations (n=8)



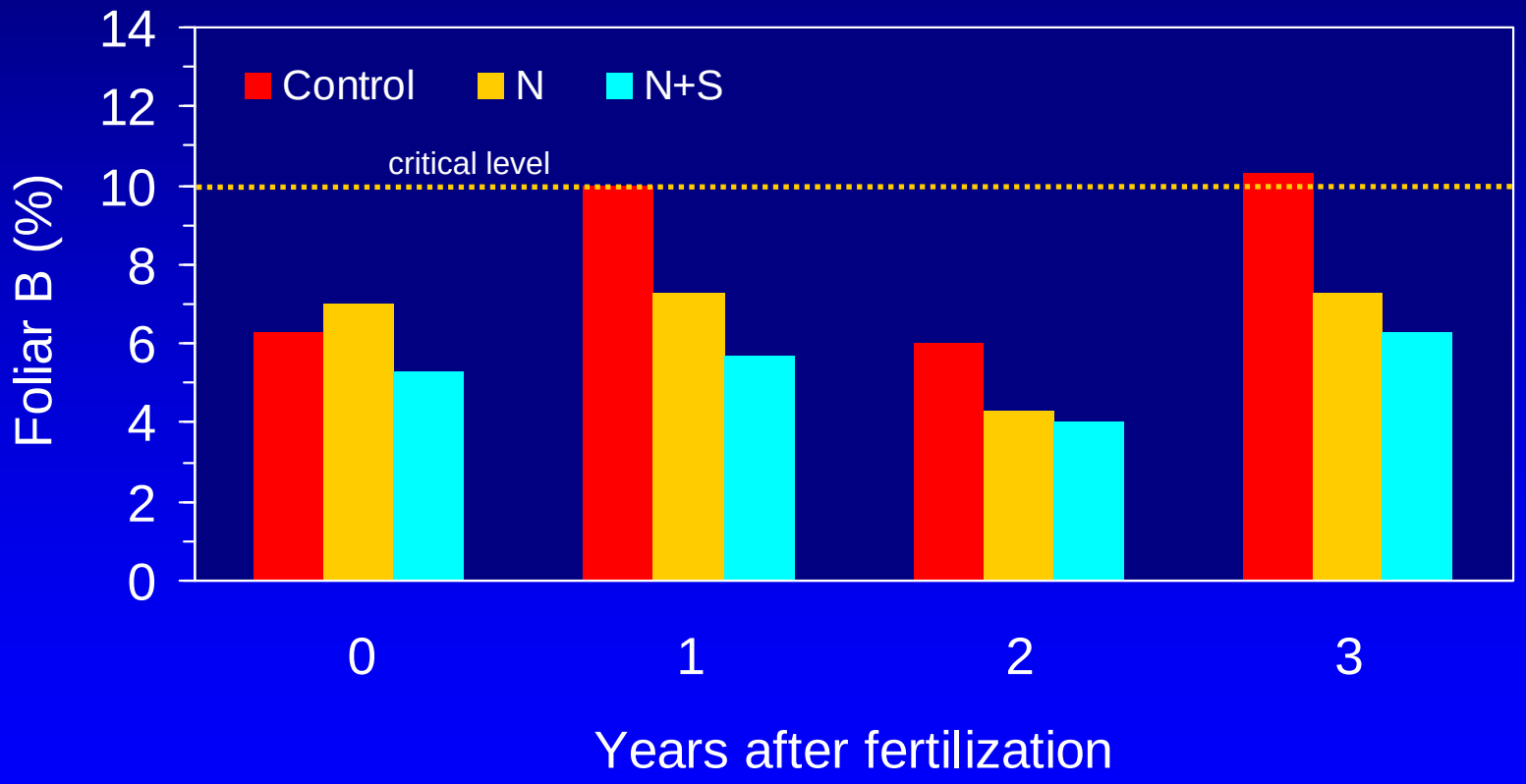
Effect of N and N+S fertilization on 6-year stand volume increment of interior spruce

by initial foliar N class



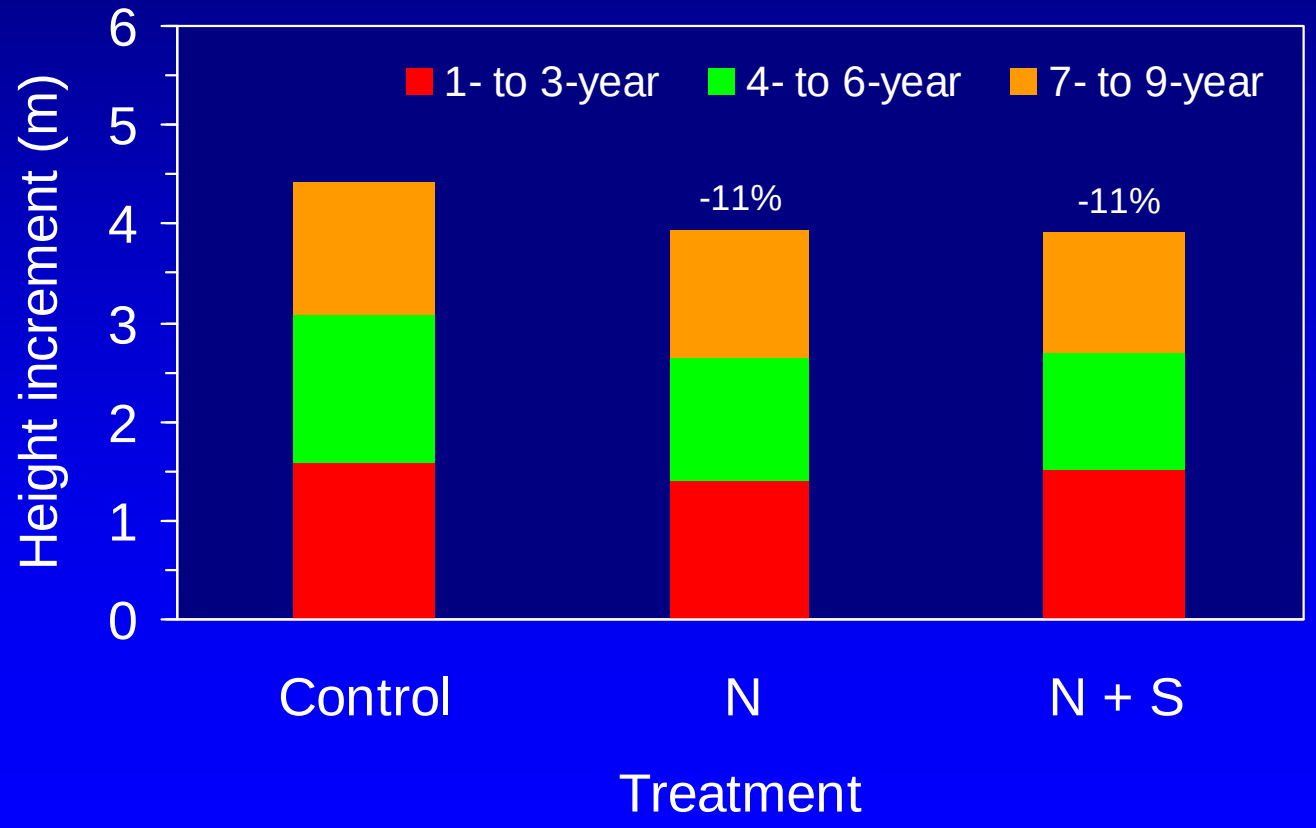
Foliar B concentration by treatment and year

EP 886.01 Inst. #19



Effect of N and N+S fertilization on 9-year height increment of interior spruce

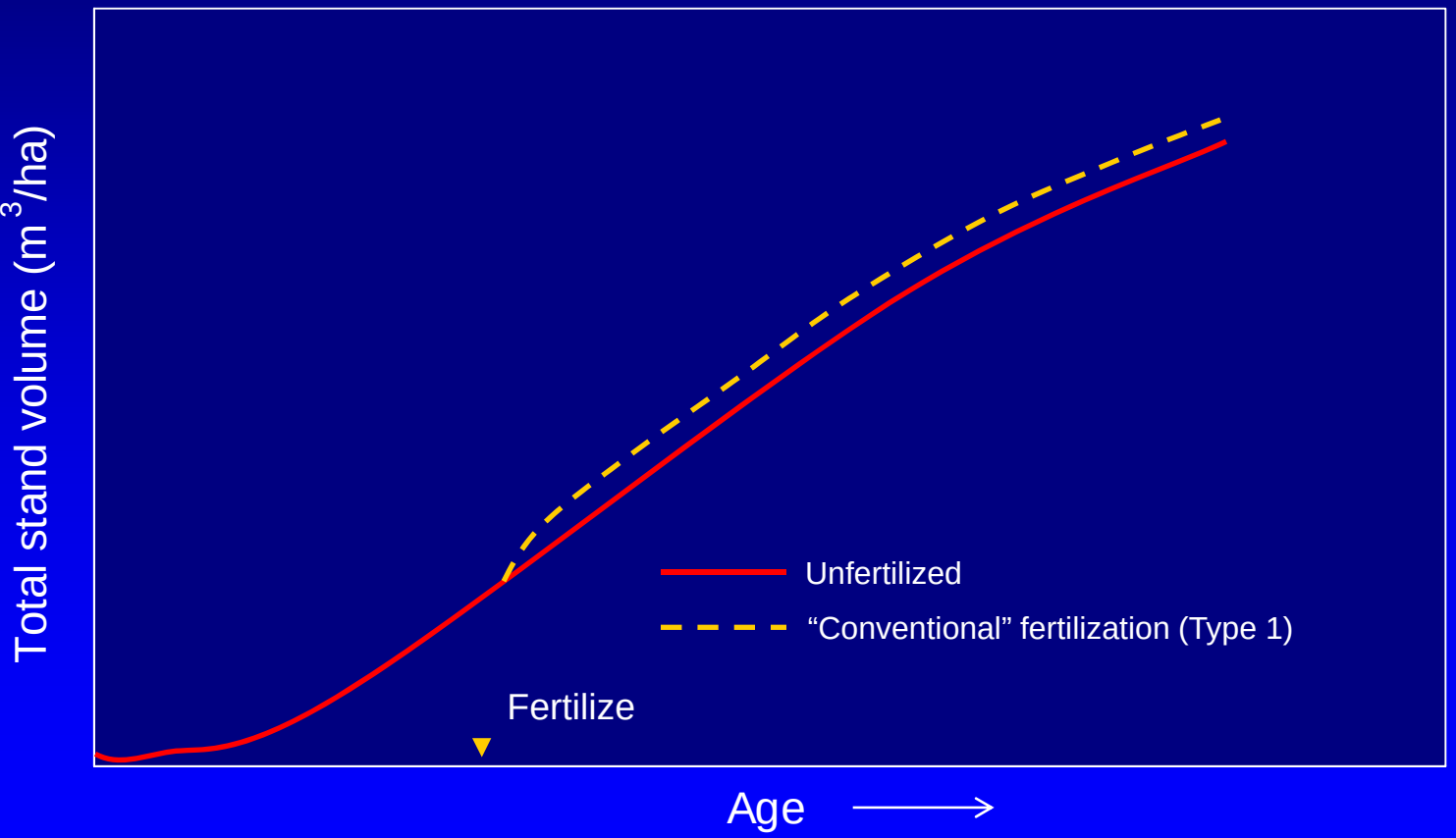
EP 886.01 Inst. #19



“Conventional” vs. “intensive” fertilization

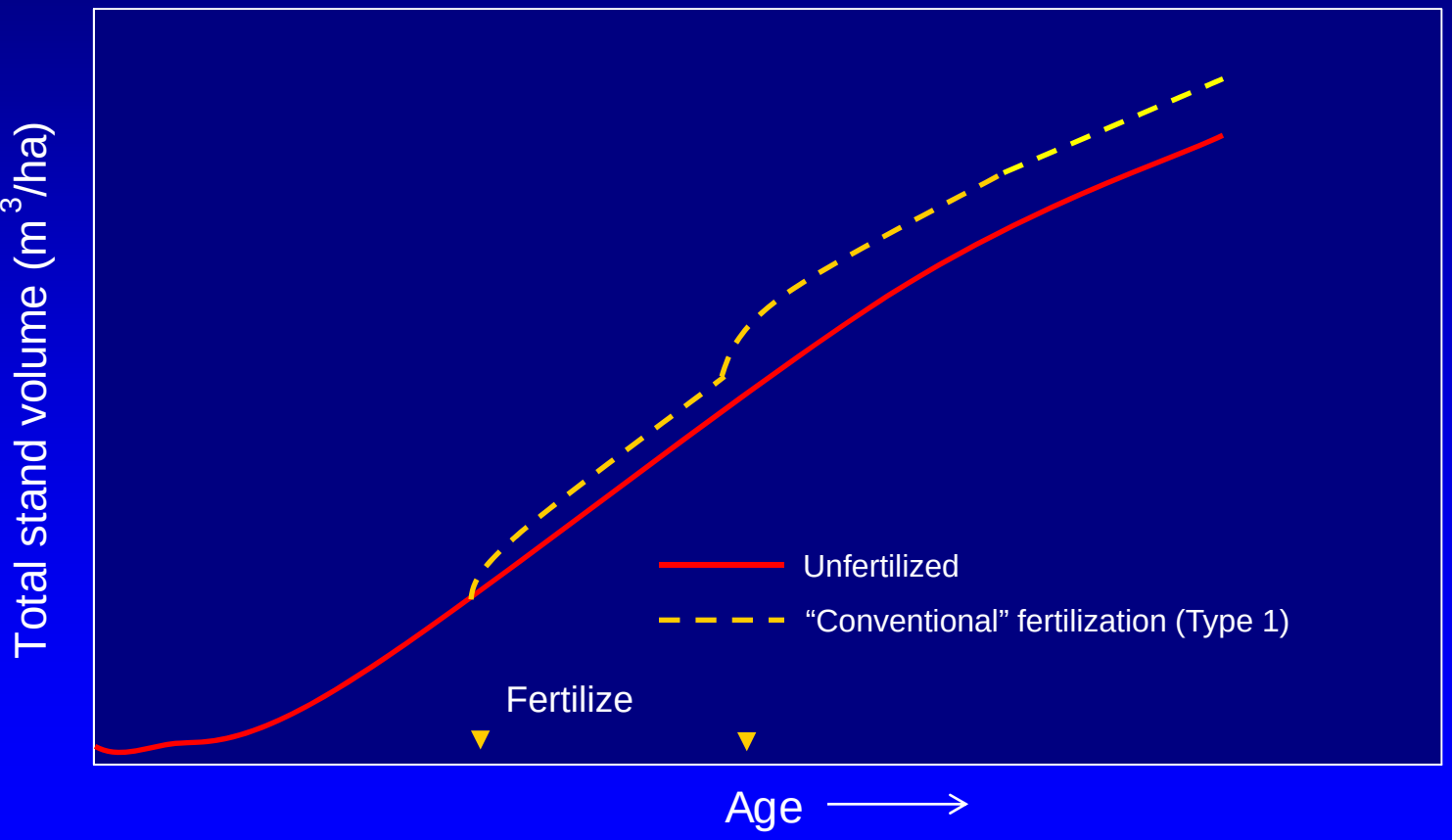
Typical pattern of growth response following “conventional” fertilization

Type 1 response



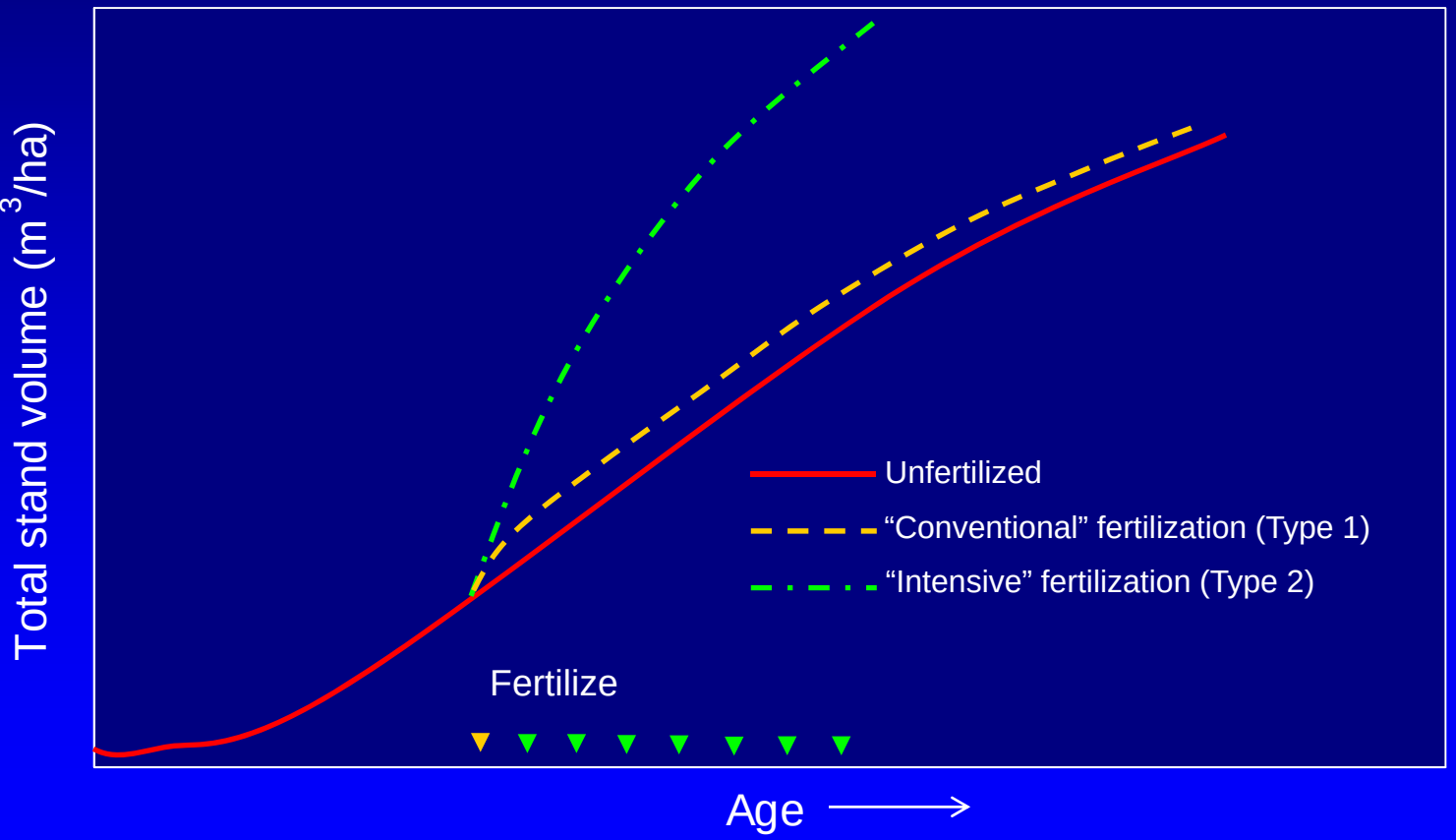
Typical pattern of growth response following "conventional" fertilization

Type 1 response



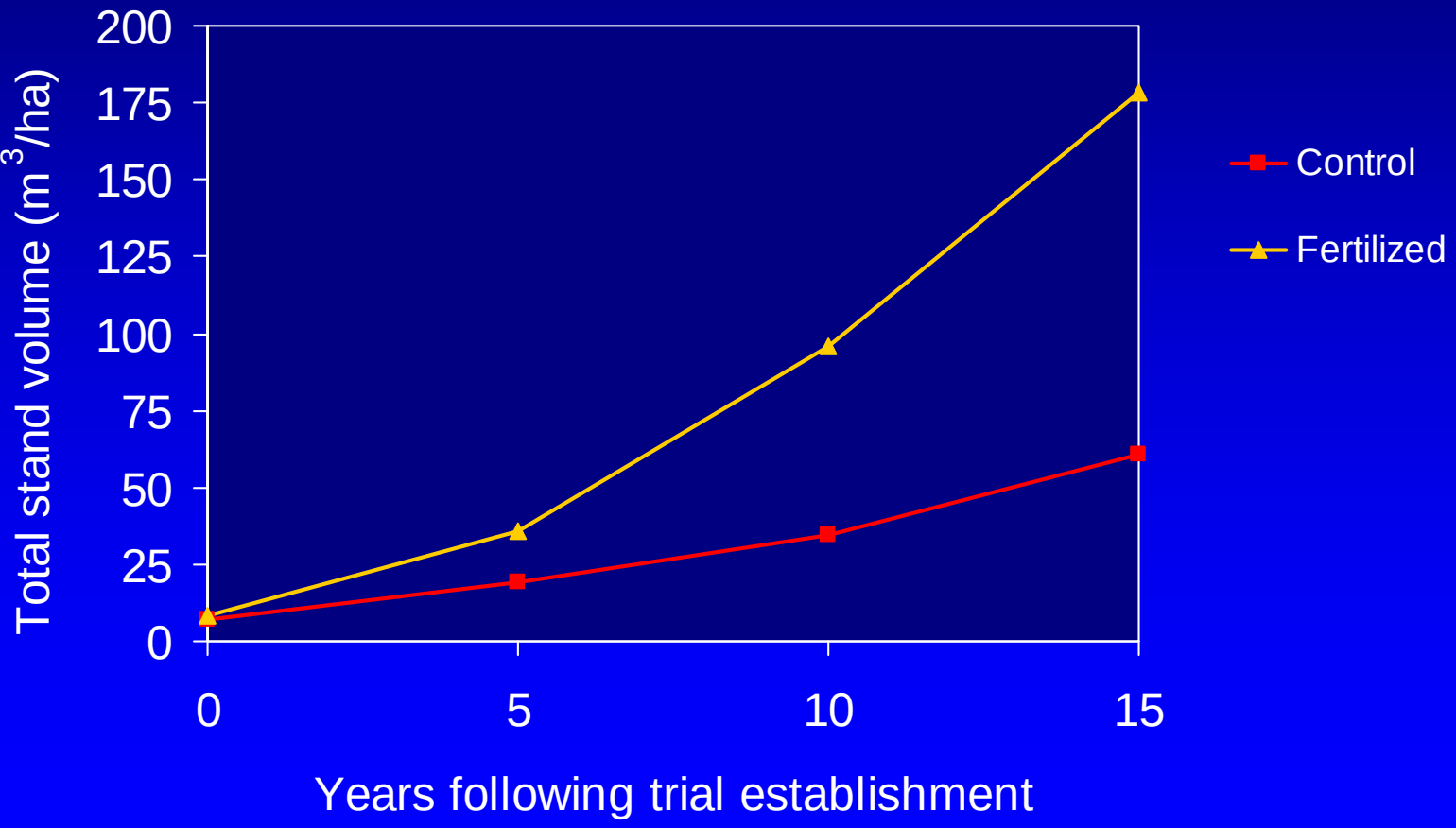
Typical pattern of growth response following "intensive" fertilization

Type 2 response

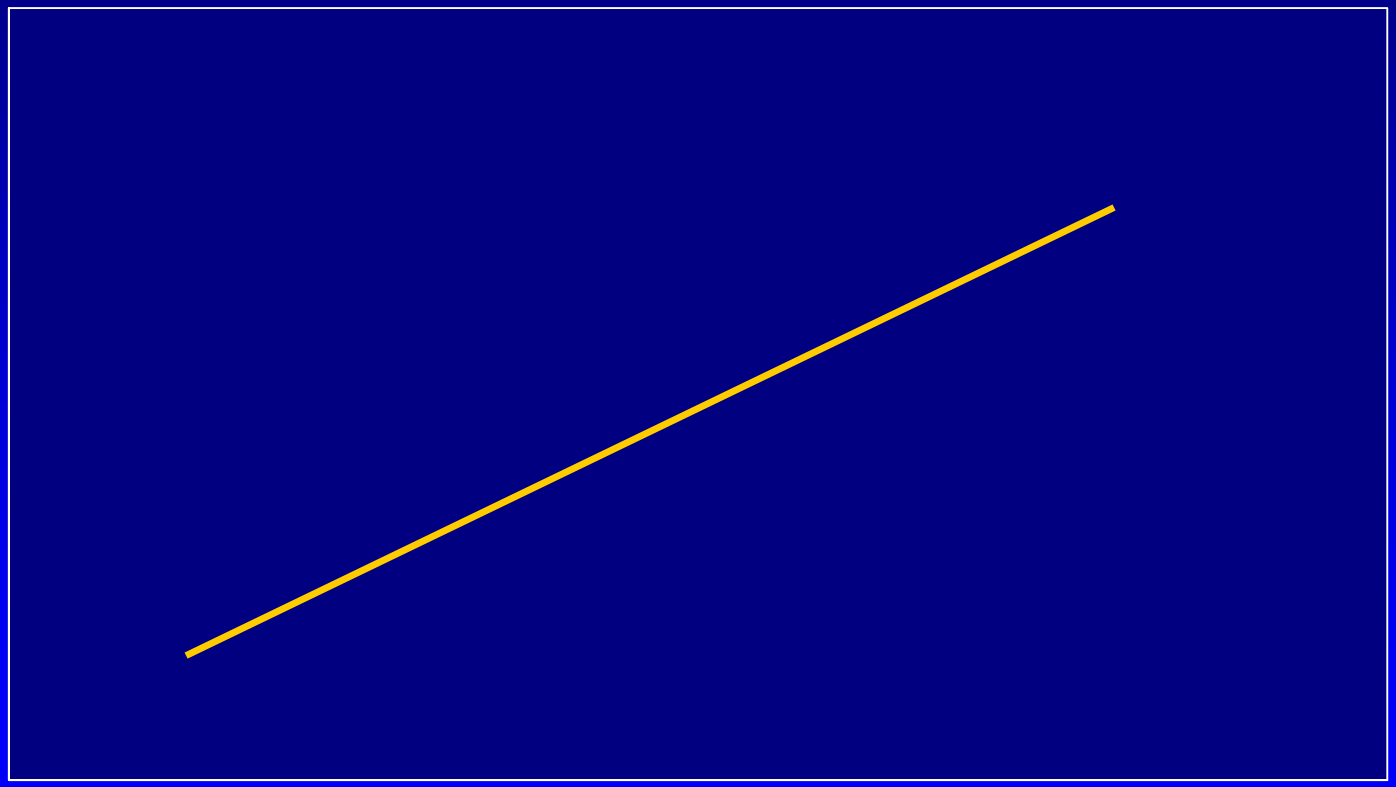


Effects of yearly fertilization on the growth of Norway spruce in northern Sweden

from Bergh et al. (2005)



Relationship between stem wood production and light interception by forest canopy



How can light interception be maximized?

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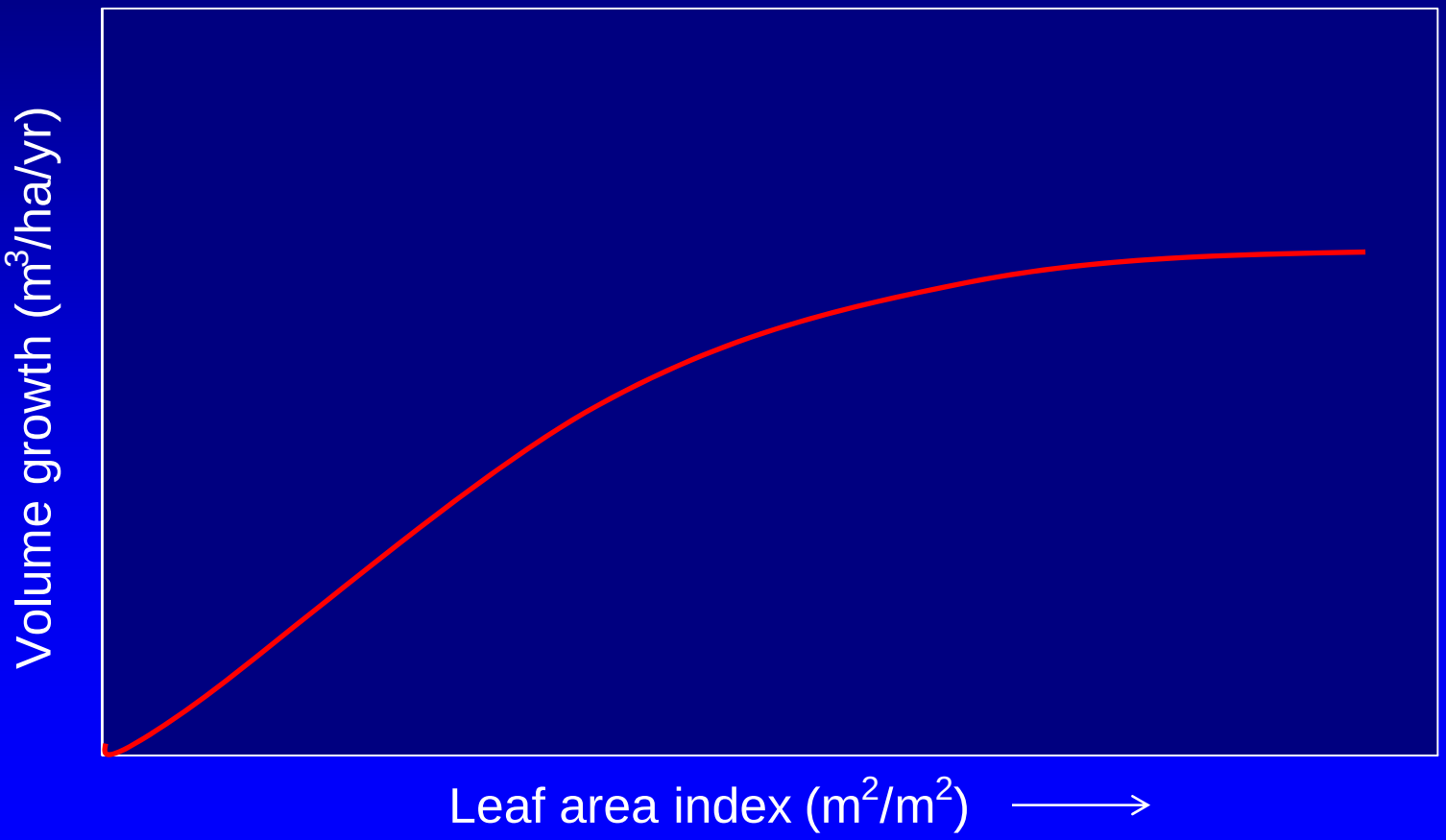
- Increase the length of the growing season
- Increase the amount of leaf area

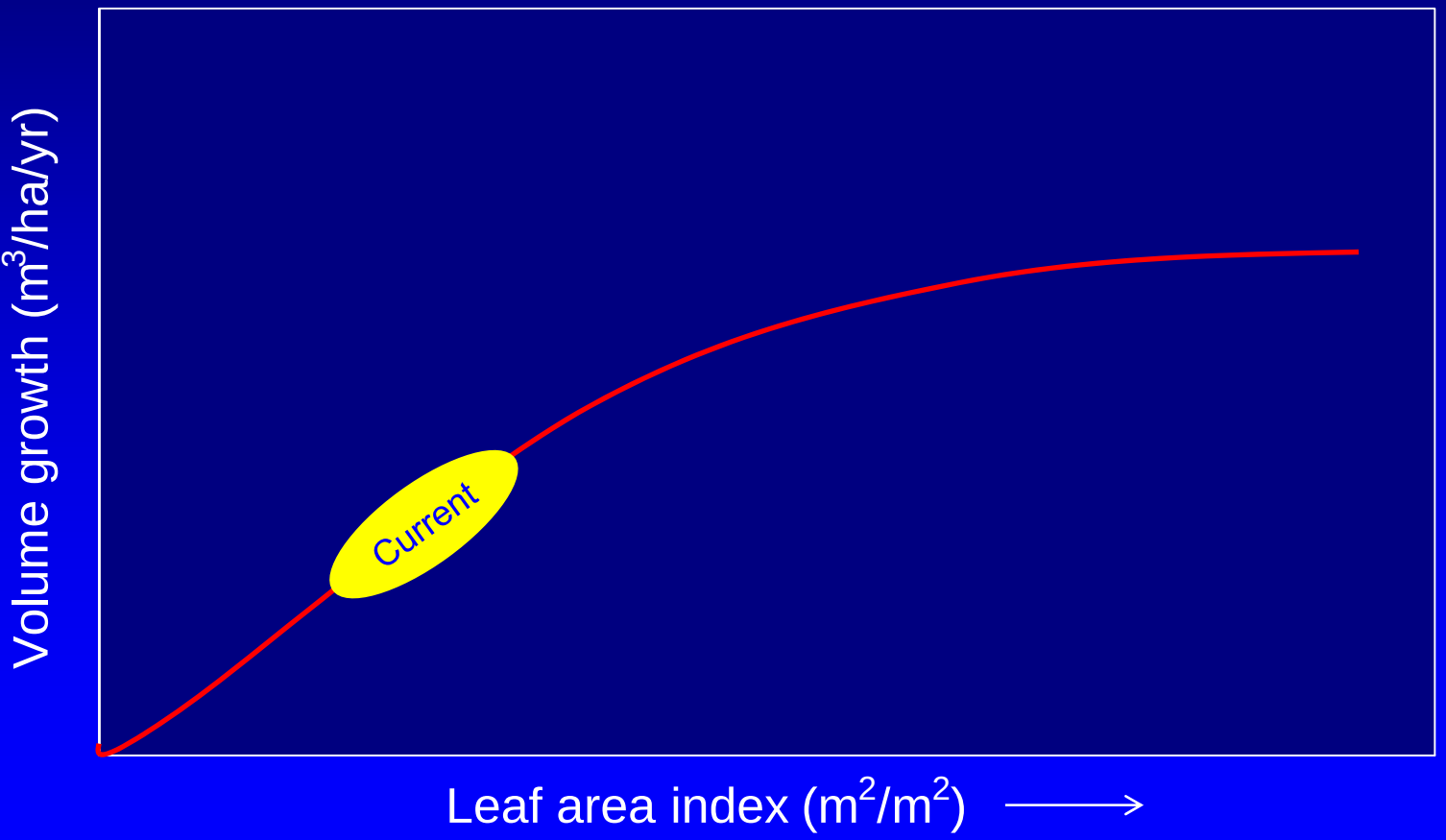
How can light interception be maximized?

- Increase the length of the growing season
- Increase the amount of leaf area
- Leaf area is strongly influenced by nutrient availability

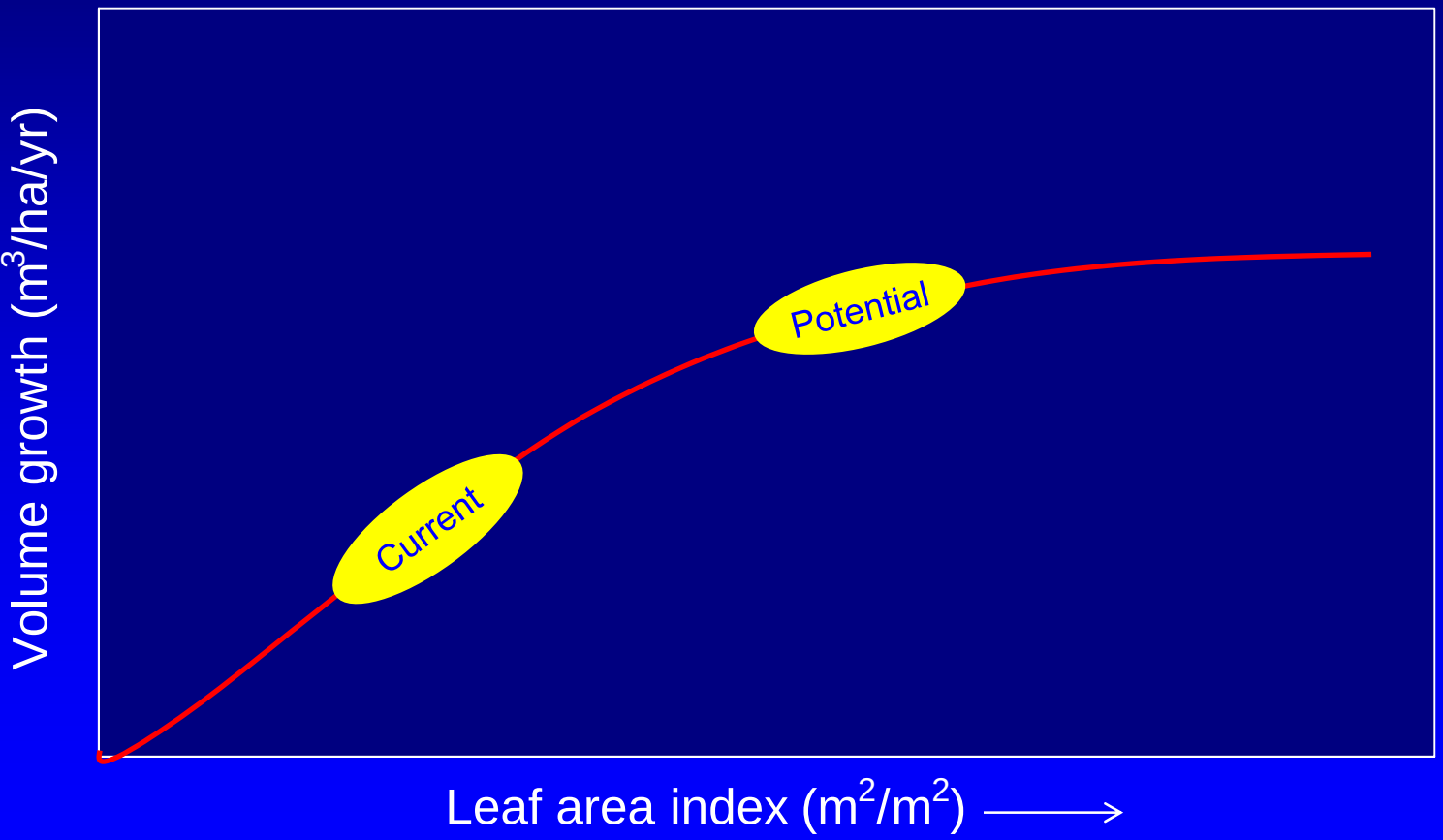
Relationship between annual volume growth and leaf area



Relationship between annual volume growth and leaf area



Relationship between annual volume growth and leaf area



“Maximum Productivity” fertilization research

EP 886.13

- Objectives
  - determine the effects of different regimes and frequencies of repeated fertilization on the growth and development of young, managed interior forests

“Maximum Productivity” fertilization research

EP 886.13

- Objectives
  - determine the effects of different regimes and frequencies of repeated fertilization on the growth and development of young, managed interior forests
  - document the long-term effects of intensive, repeated fertilization on above- and below-ground timber and non-timber resources

Study sites

Sheridan Creek

- Lodgepole pine
- SBSdw2
- 13 years old, natural regeneration

Study sites

Sheridan Creek

- Lodgepole pine
- SBSdw2
- 13 years old, natural regeneration

Crow Creek

- Interior spruce
- SBSmc2
- 10 years old, planted

Treatments

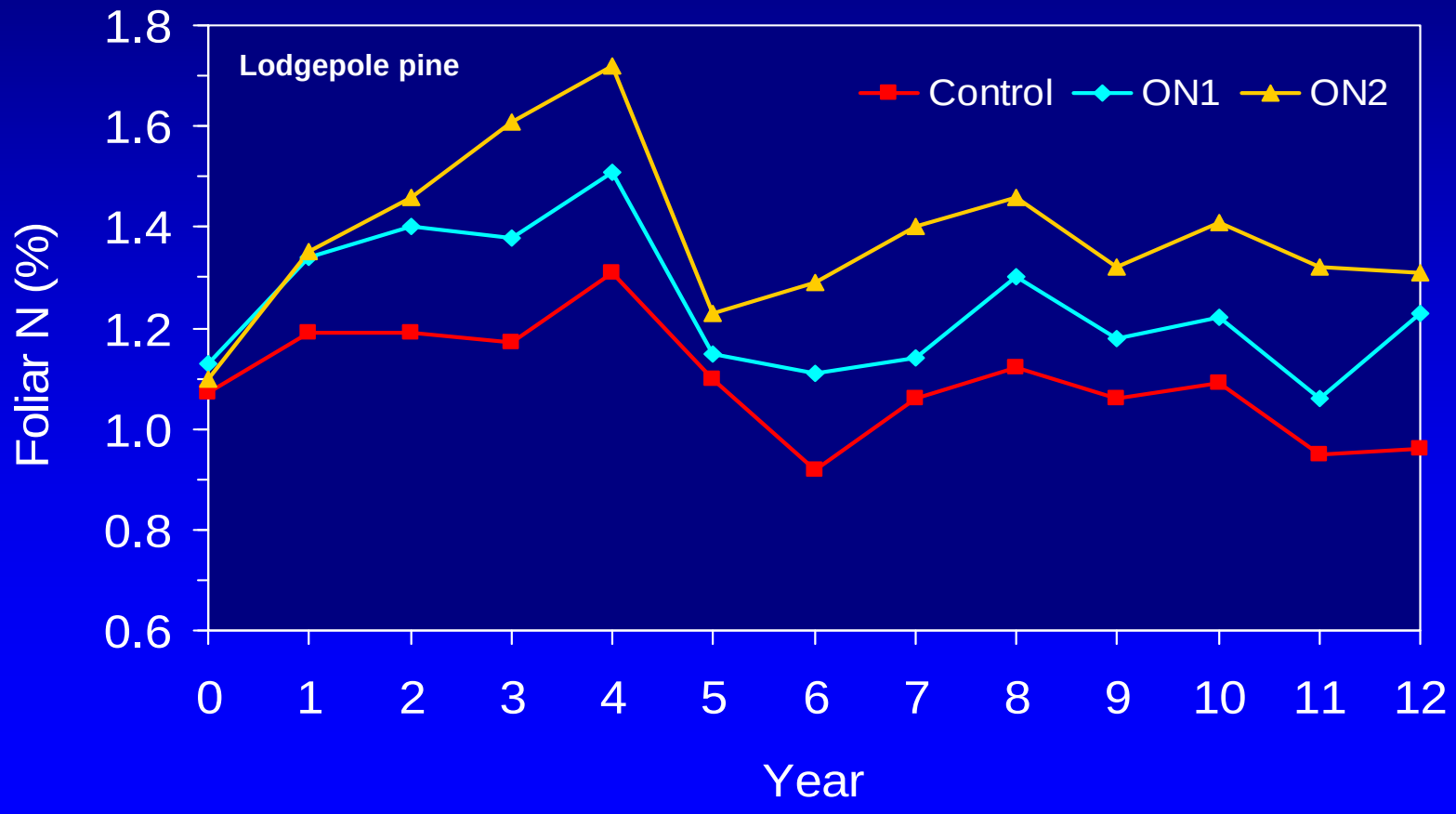
- Control
- N+B
- N+S+B
- “Complete blend”

} every 6 years

- Optimum Nutrition 1 (1.3%N)
- Optimum Nutrition 2 (1.6%N)

Foliar nitrogen by treatment and year

Lodgepole pine (Brockley 2007)



Foliar nitrogen by treatment and year

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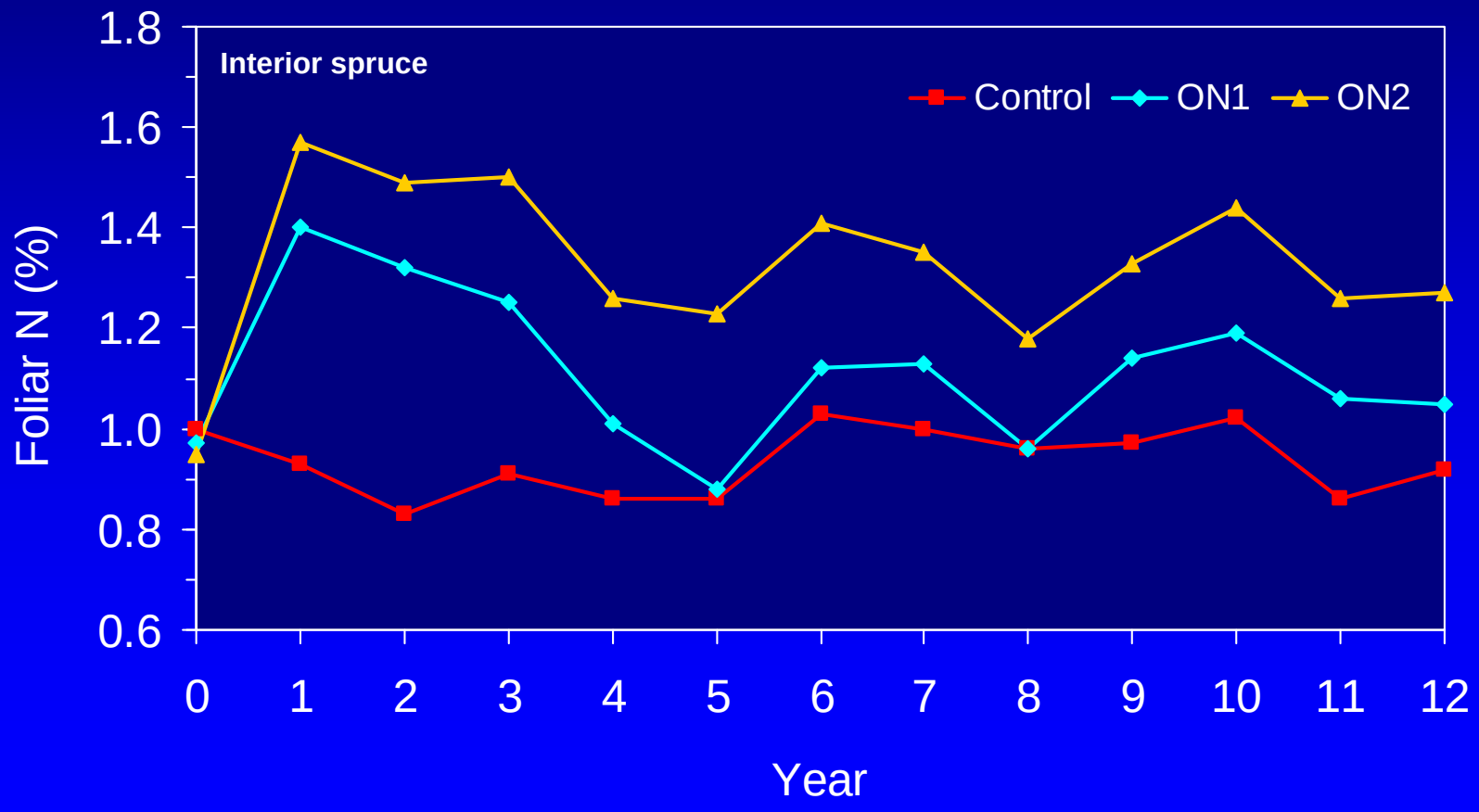
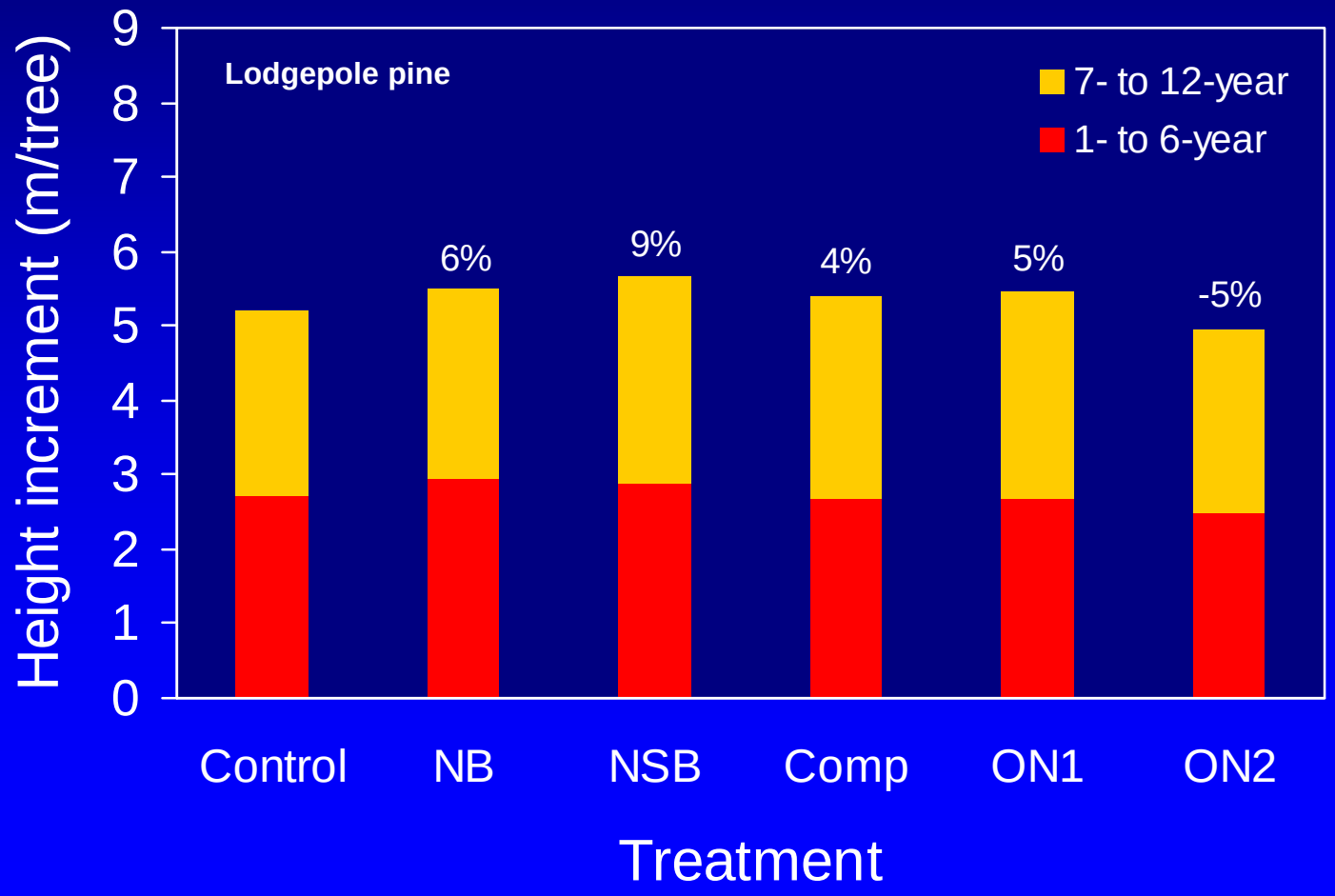


12-year tree height increment by treatment

Lodgepole pine (Brockley 2007)



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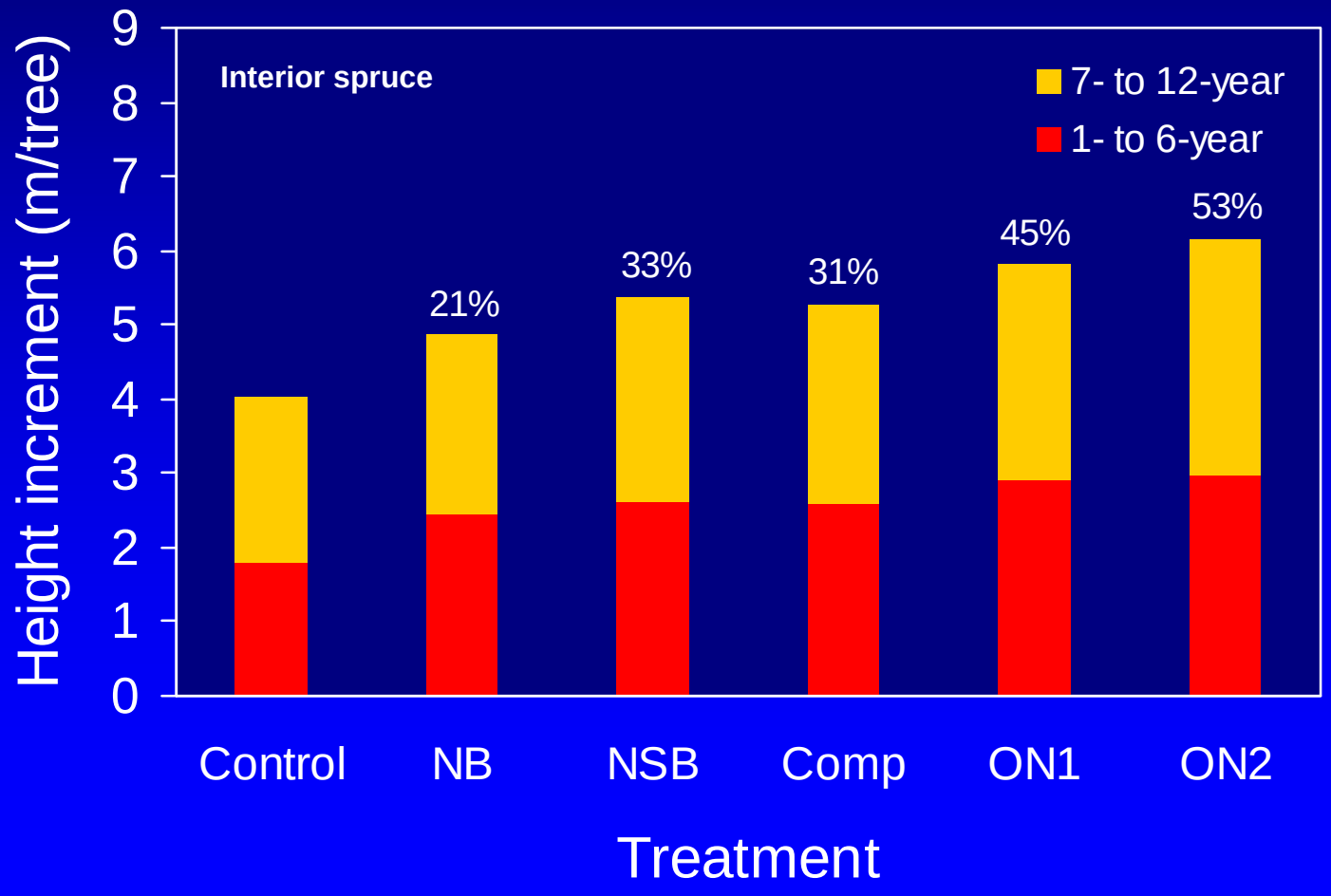

12-year stand volume increment by treatment

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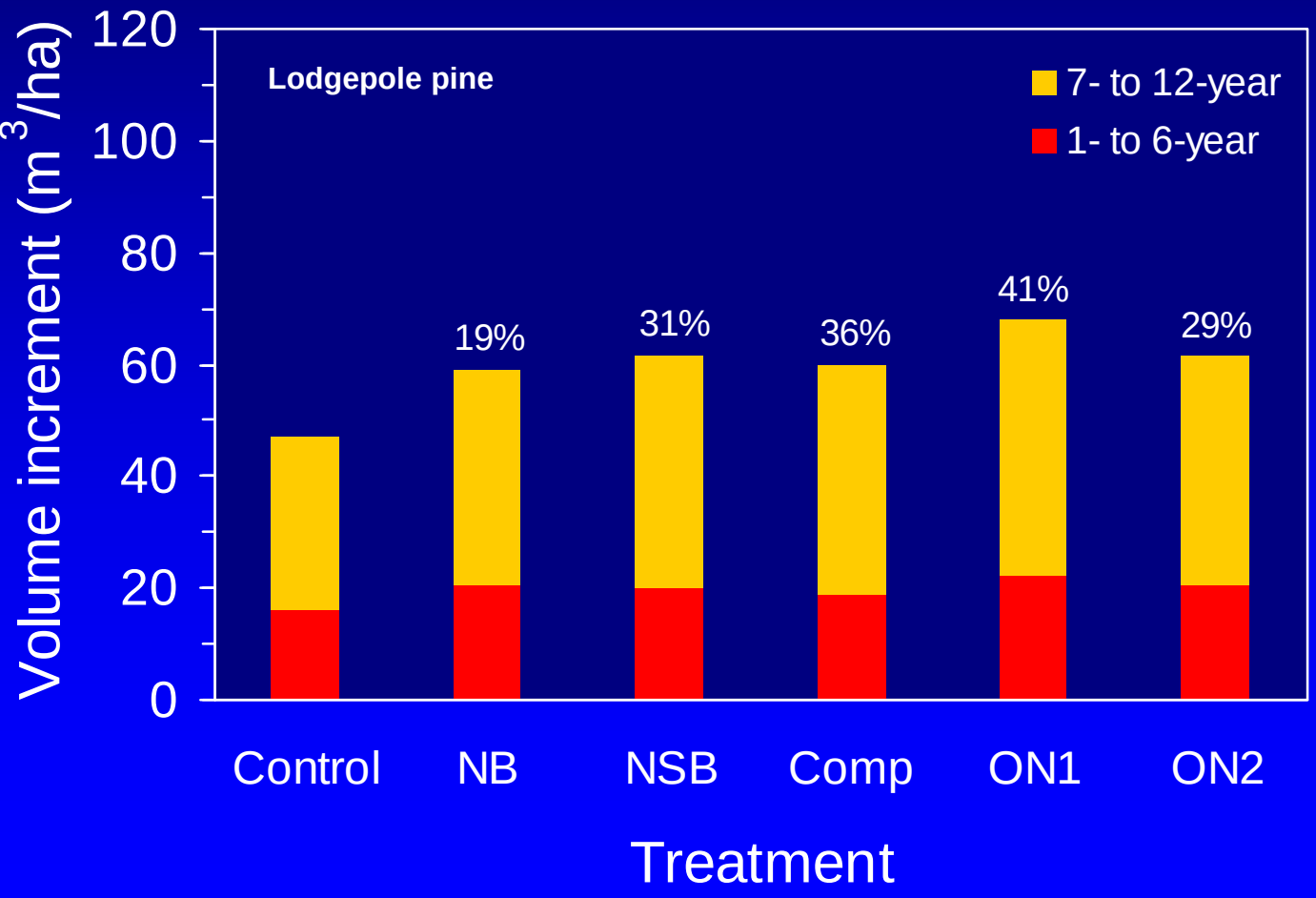

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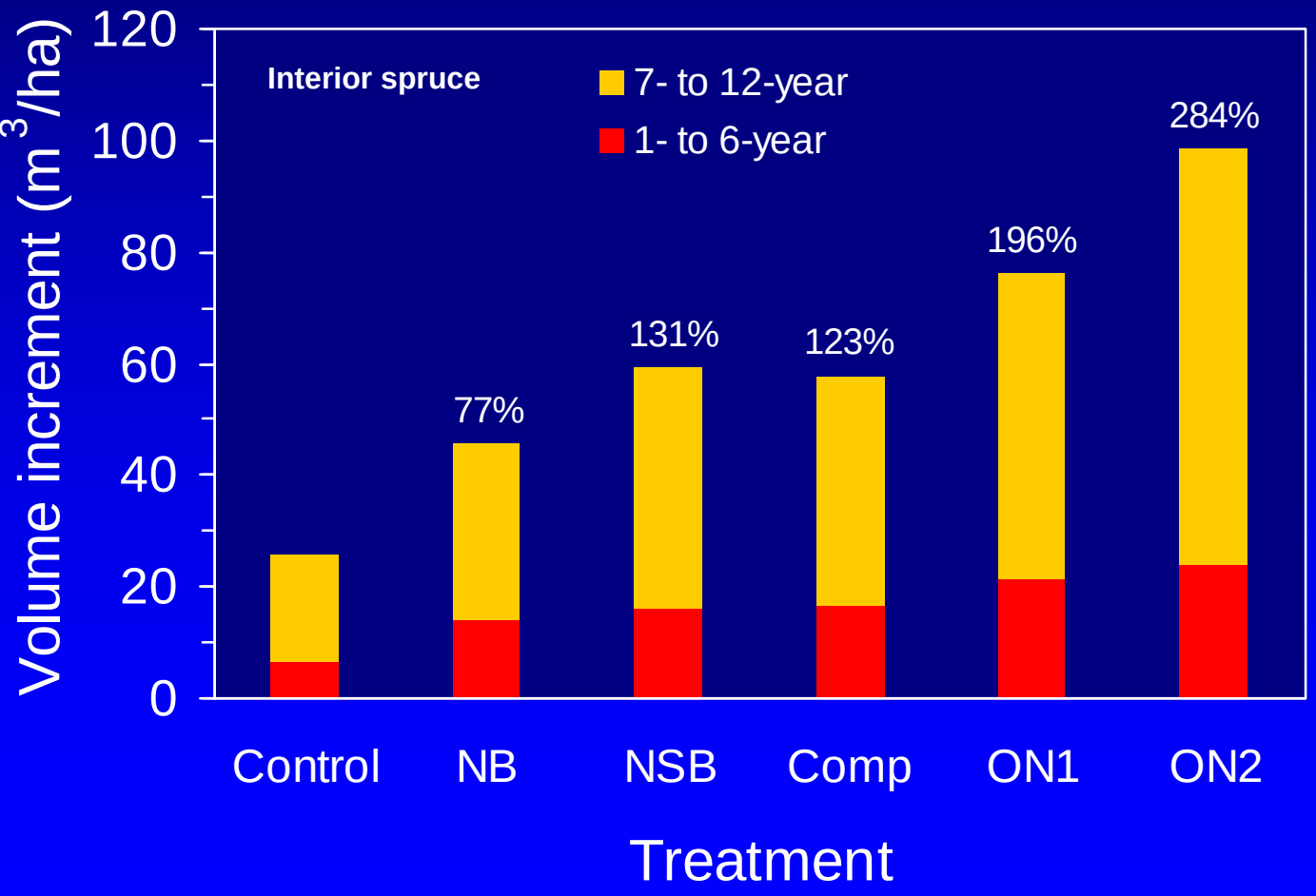
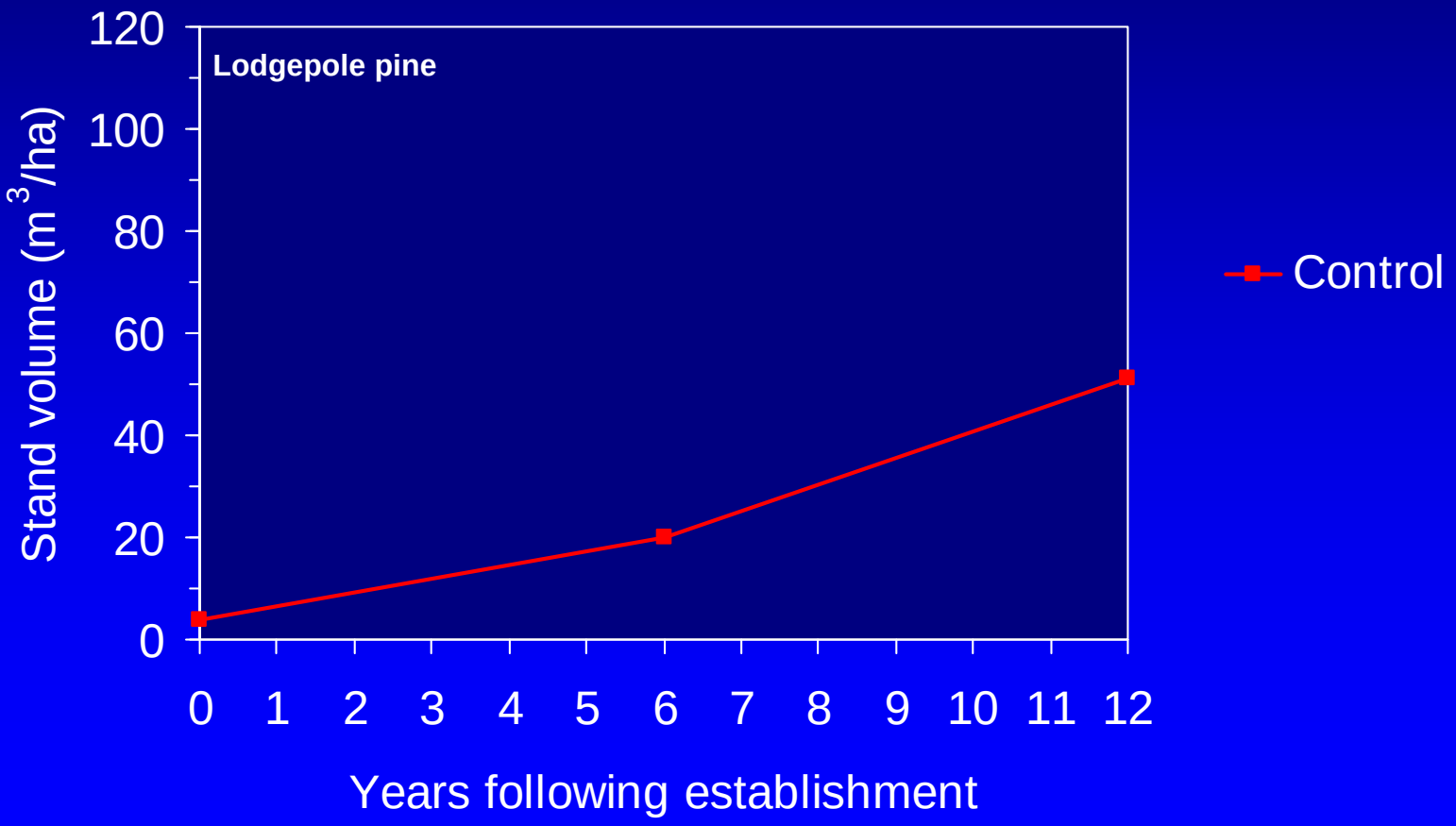


12-year stand volume development by treatment

Lodgepole pine (Brockley 2007)



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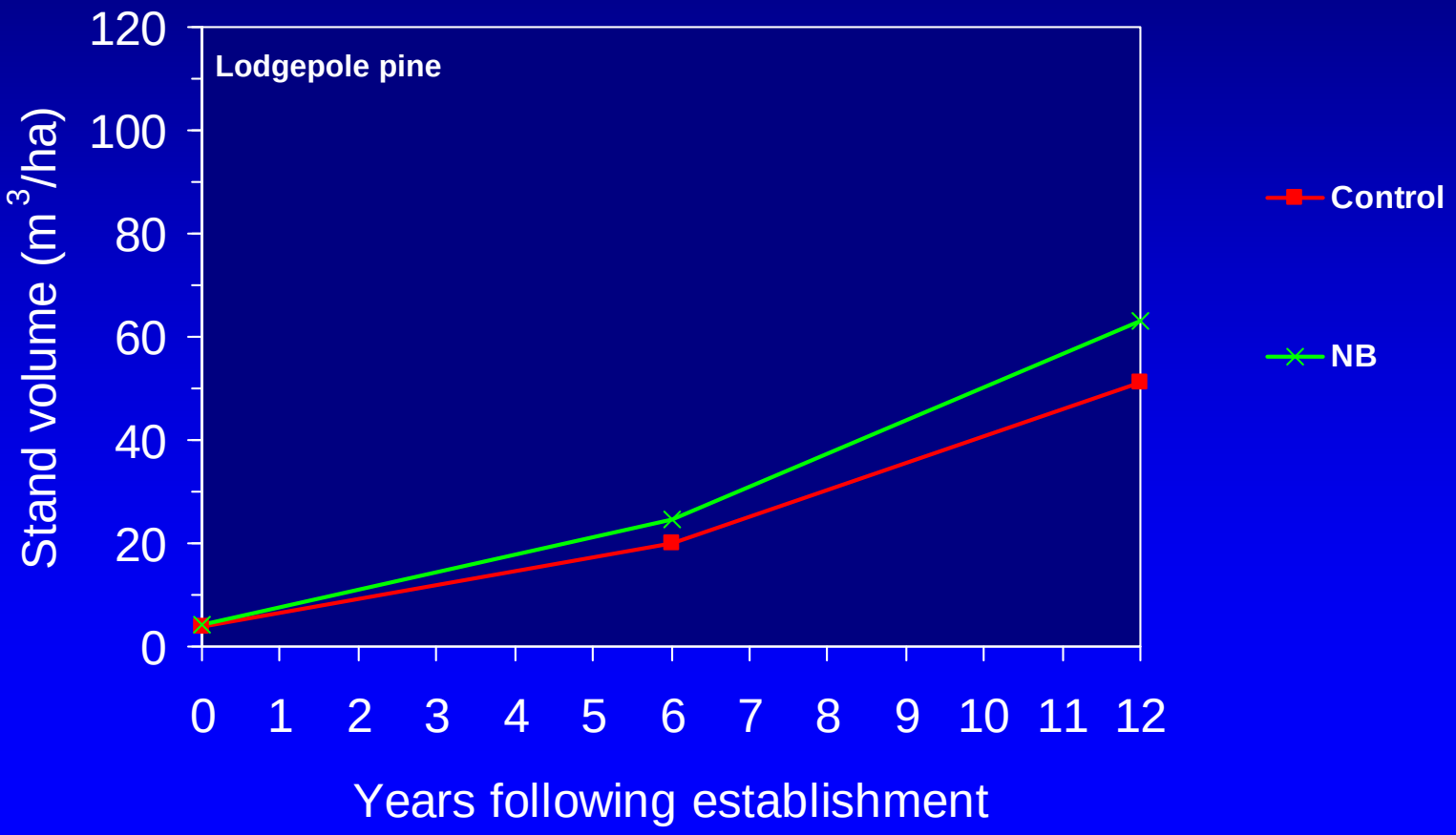

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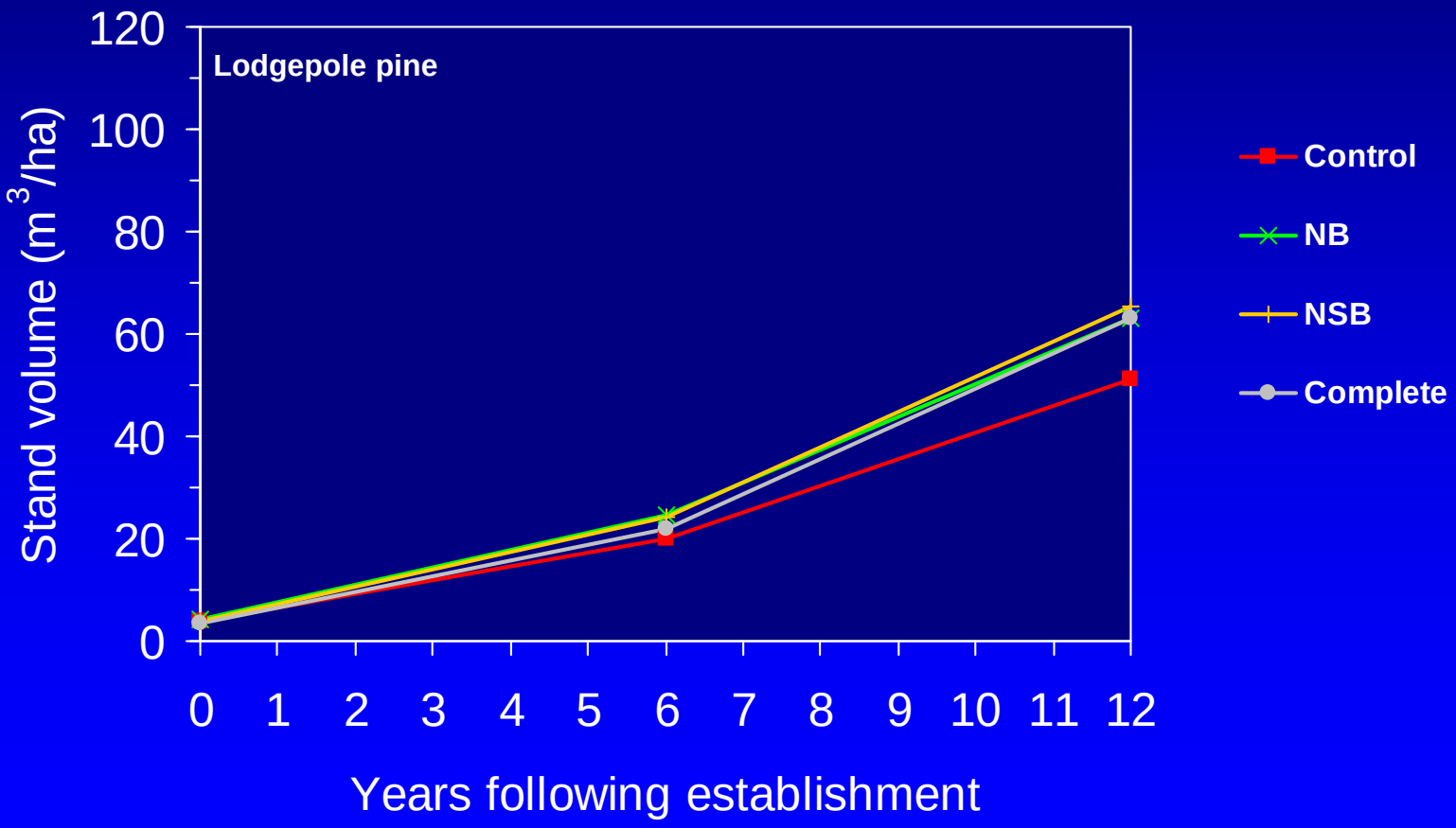

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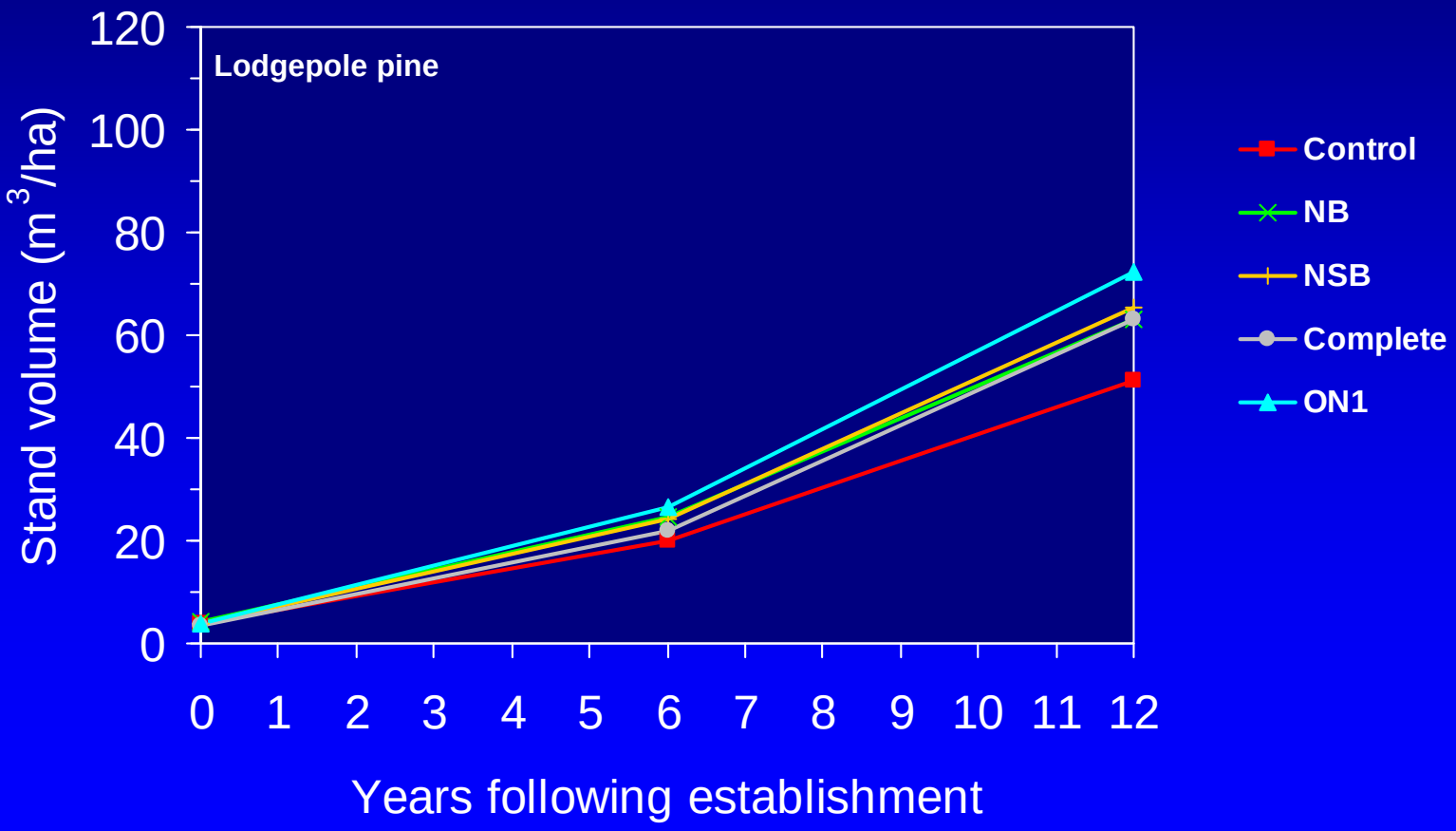

12-year stand volume development by treatment

Lodgepole pine (Brockley 2007)

13-year stand volume development following different intensities of yearly fertilization

Scots pine (Tamm 1985)

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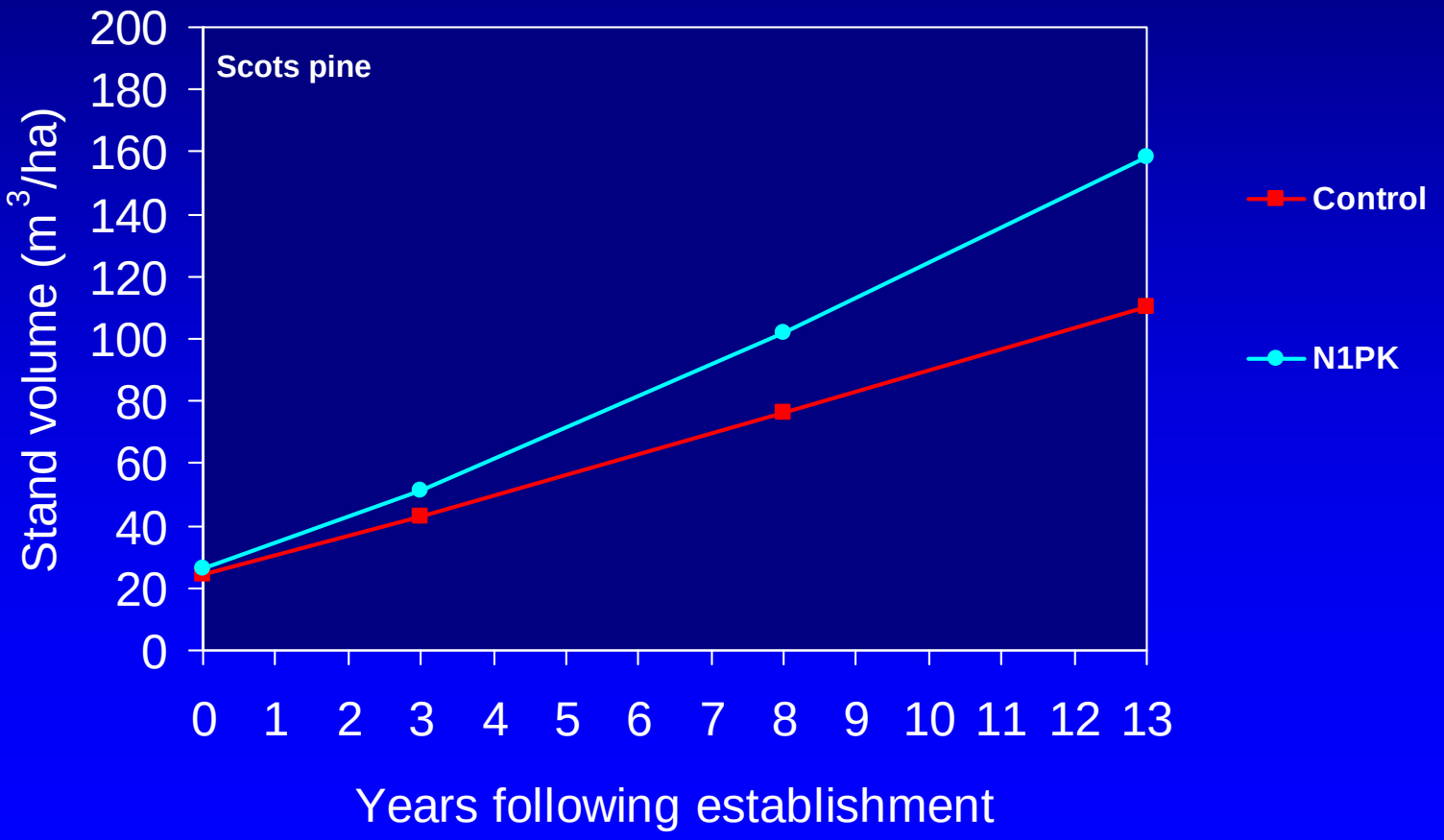

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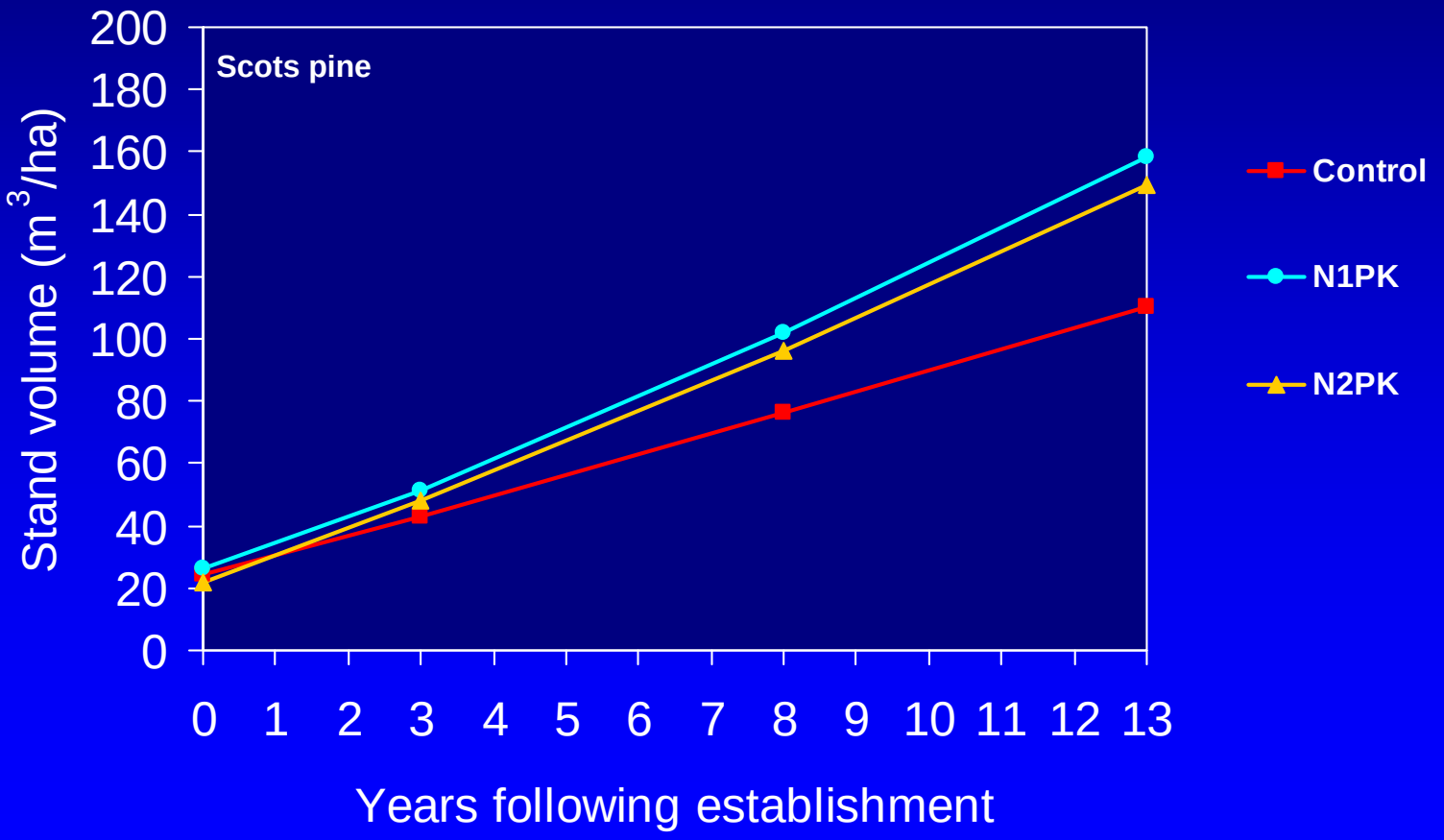

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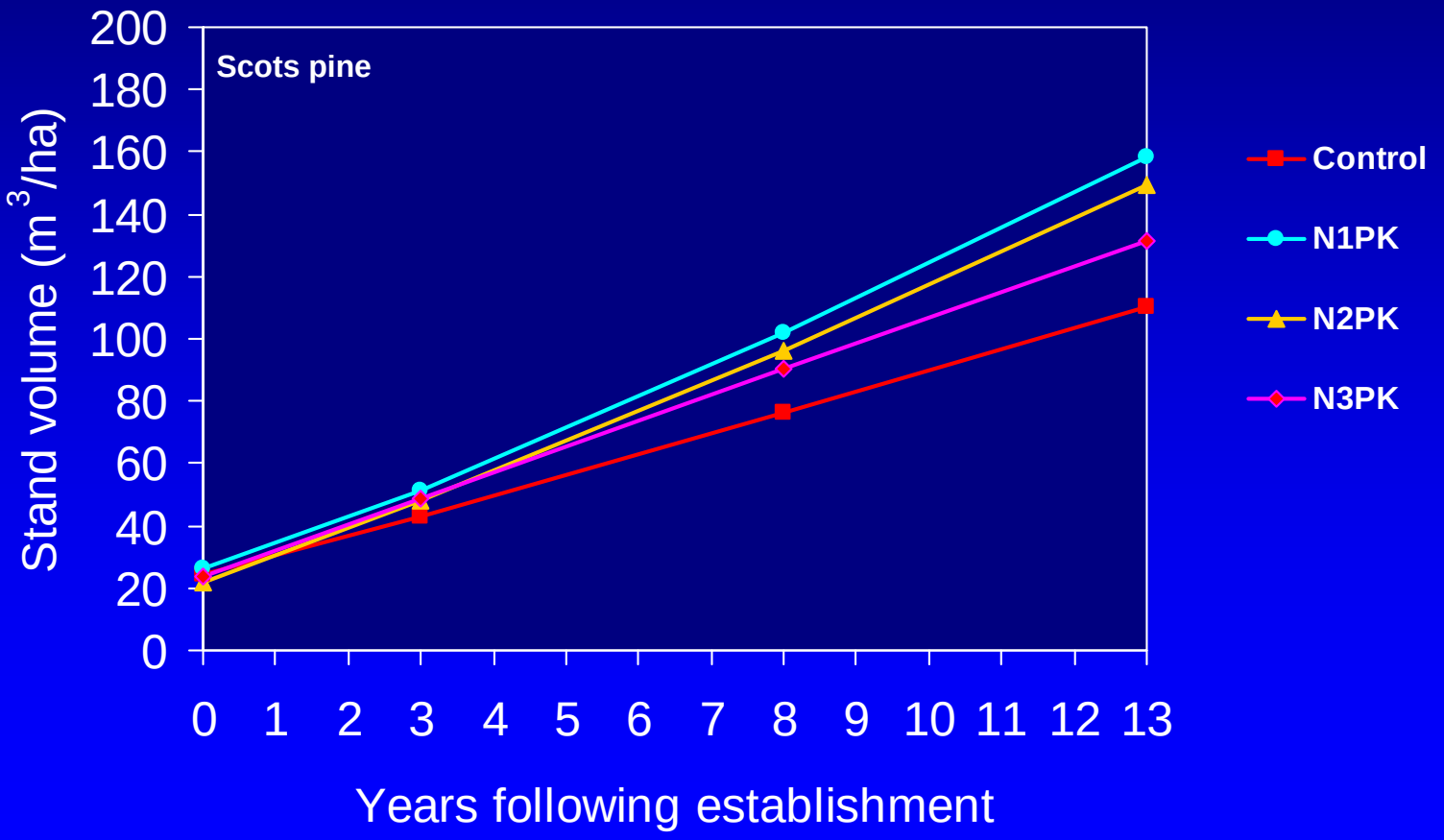

12-year stand volume development by treatment

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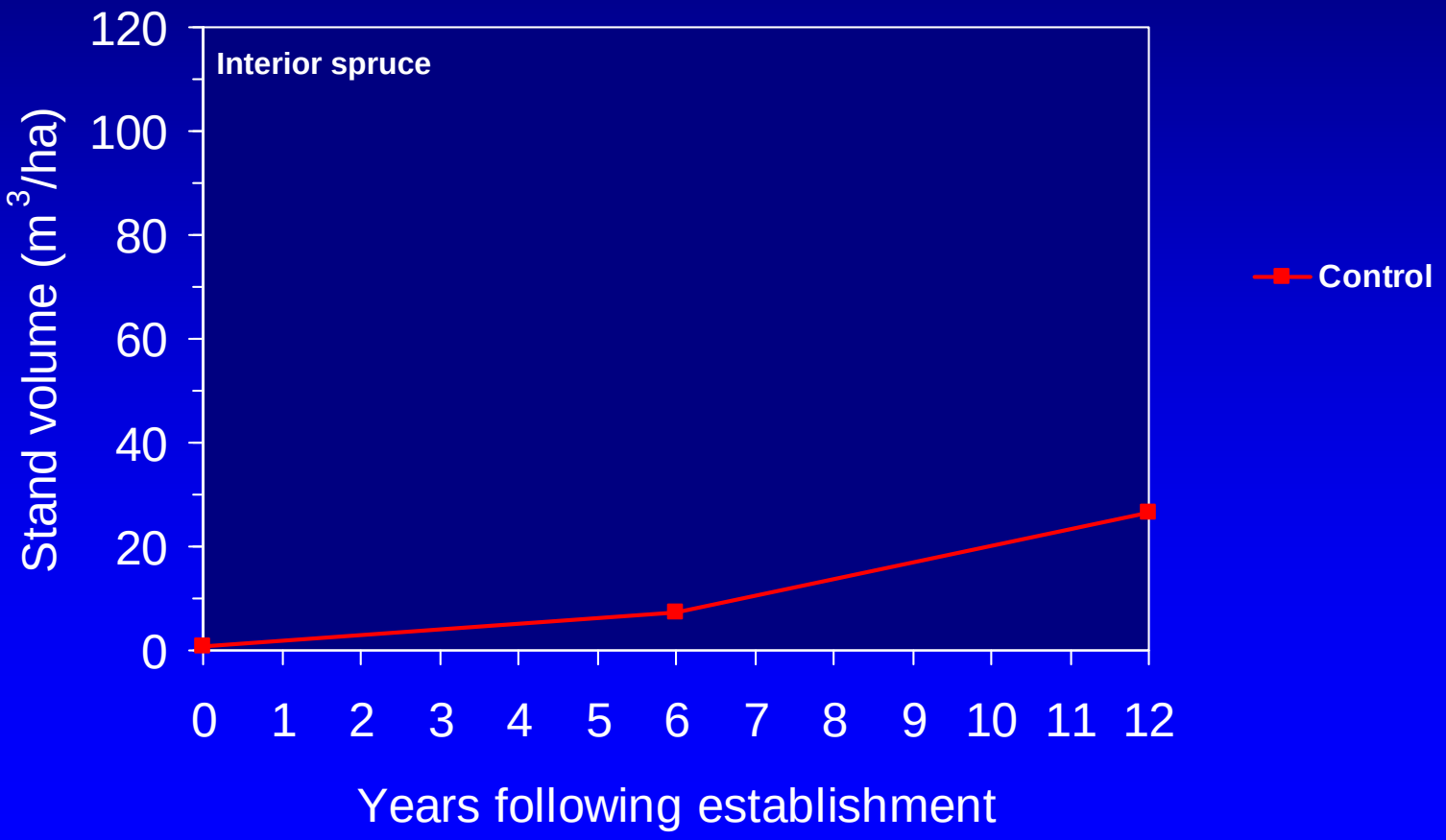

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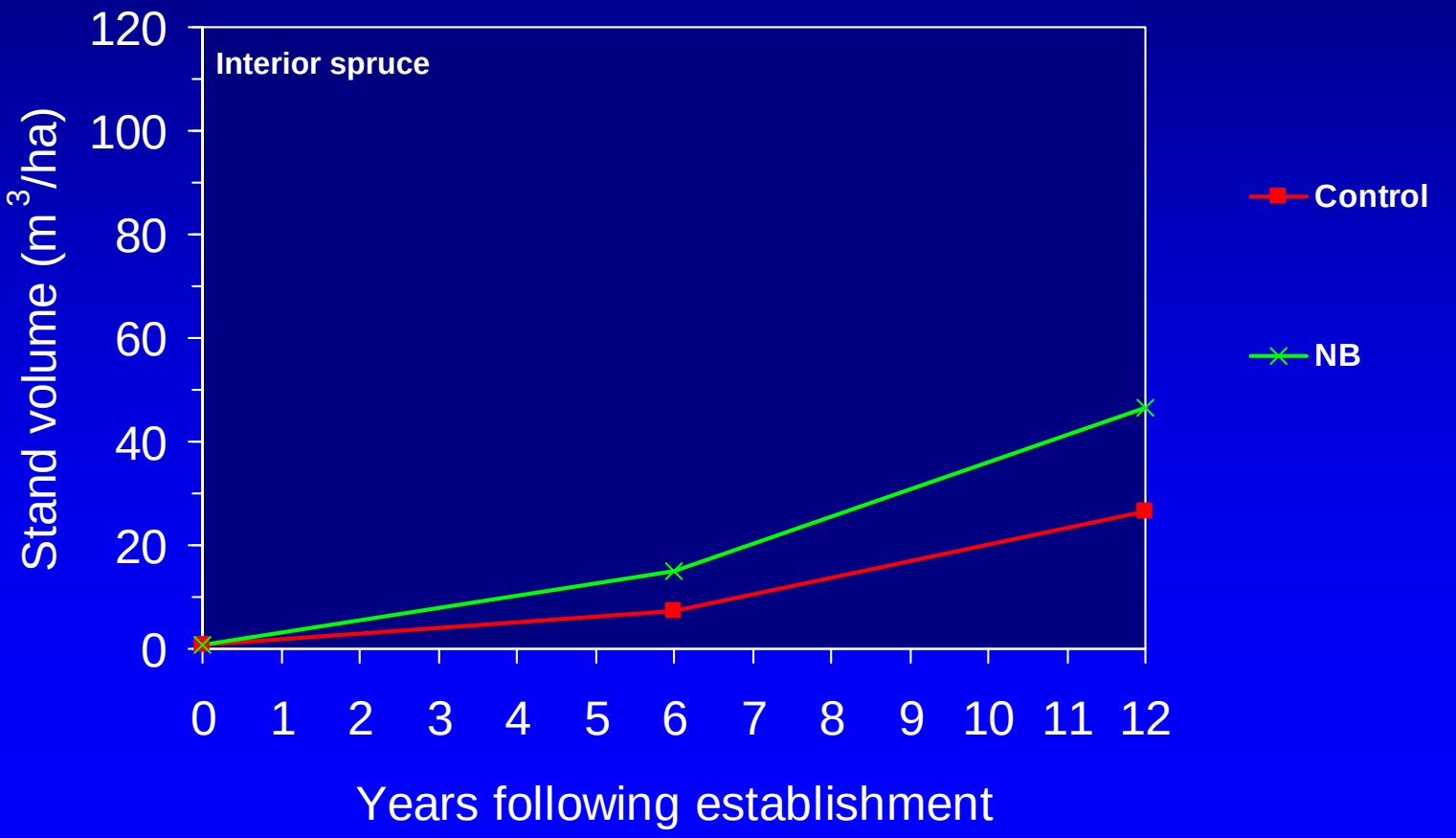

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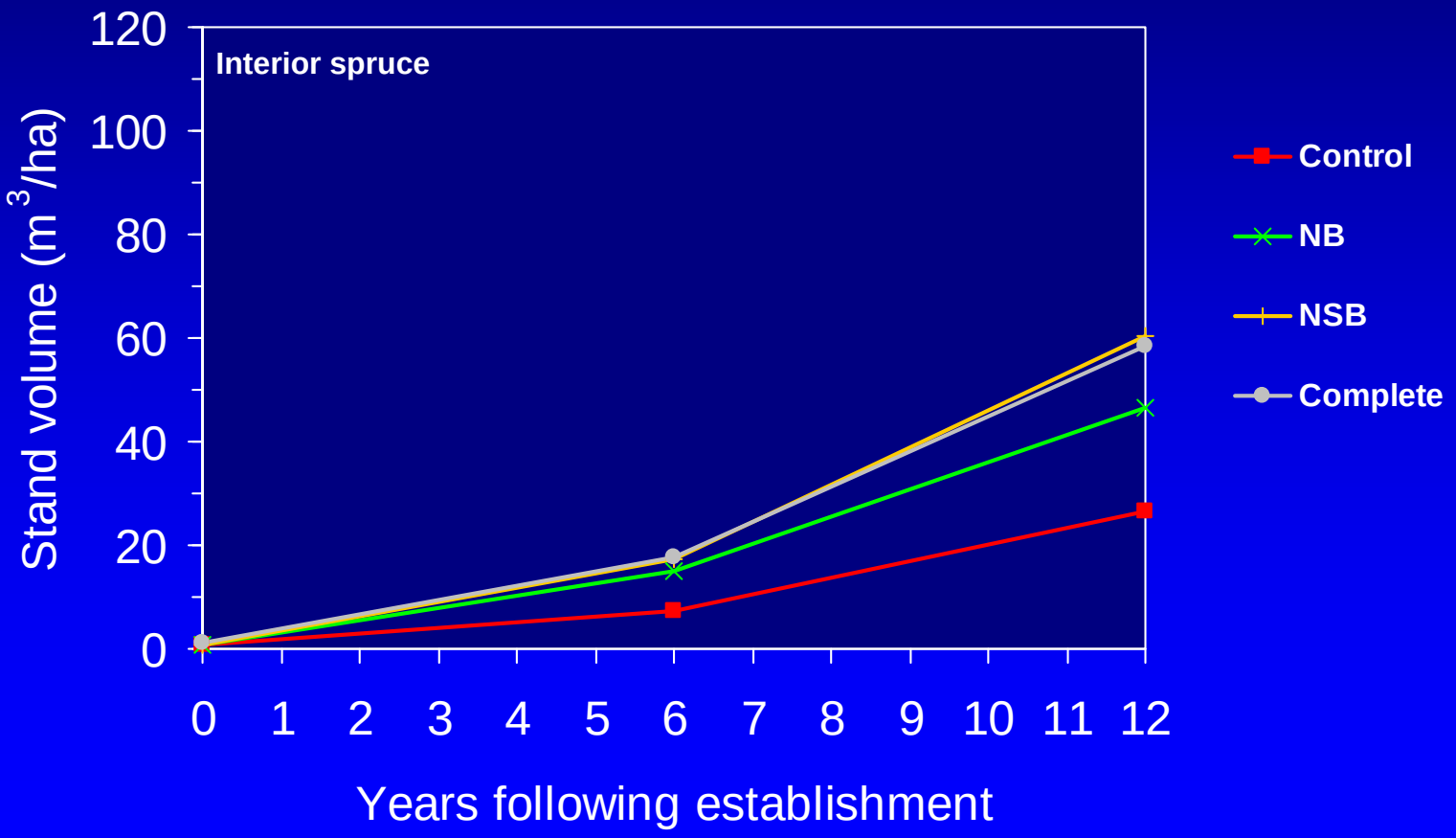

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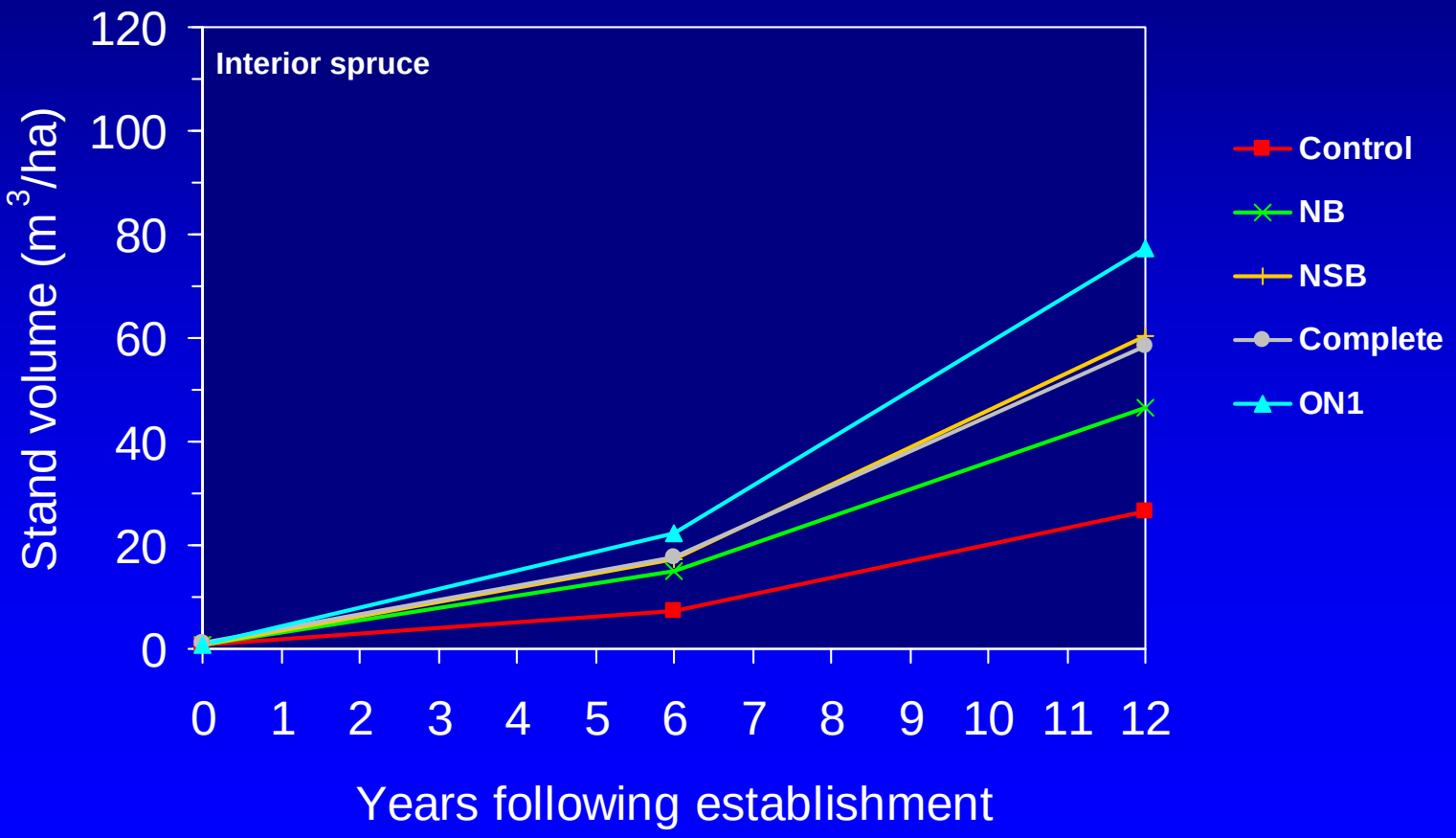

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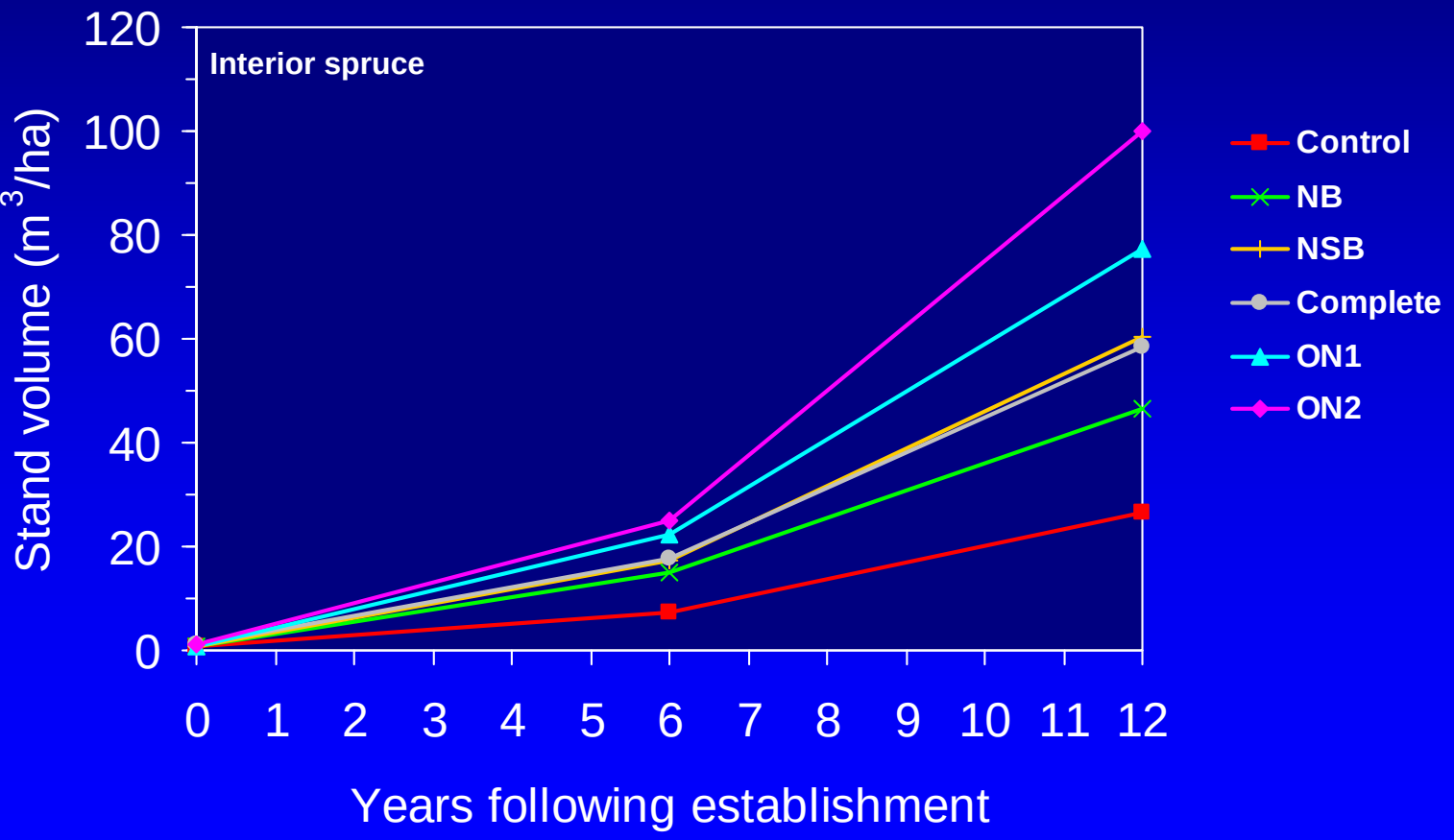
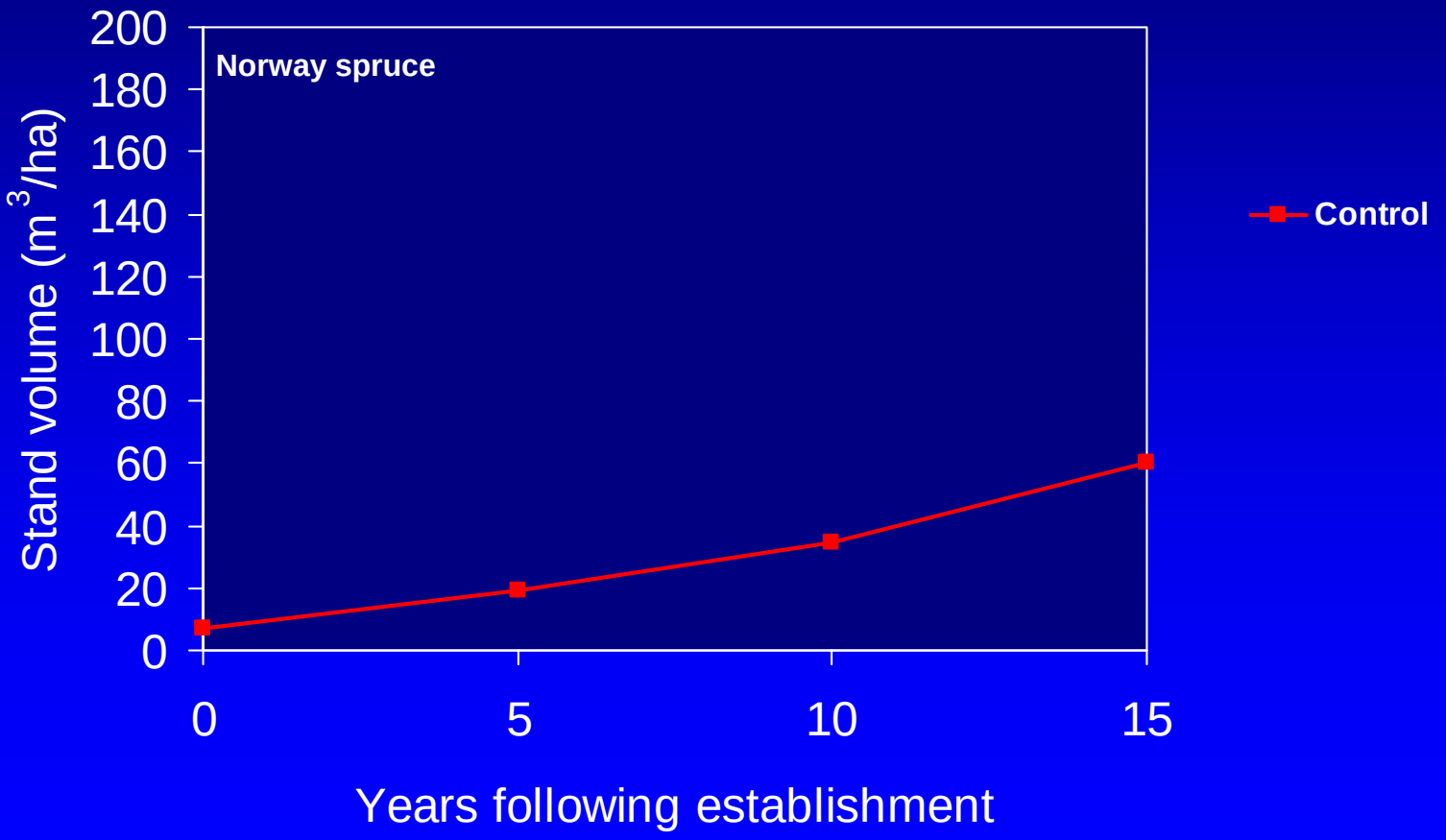


Effects of yearly fertilization on the growth of Norway spruce in northern Sweden

from Bergh et al. (2005)



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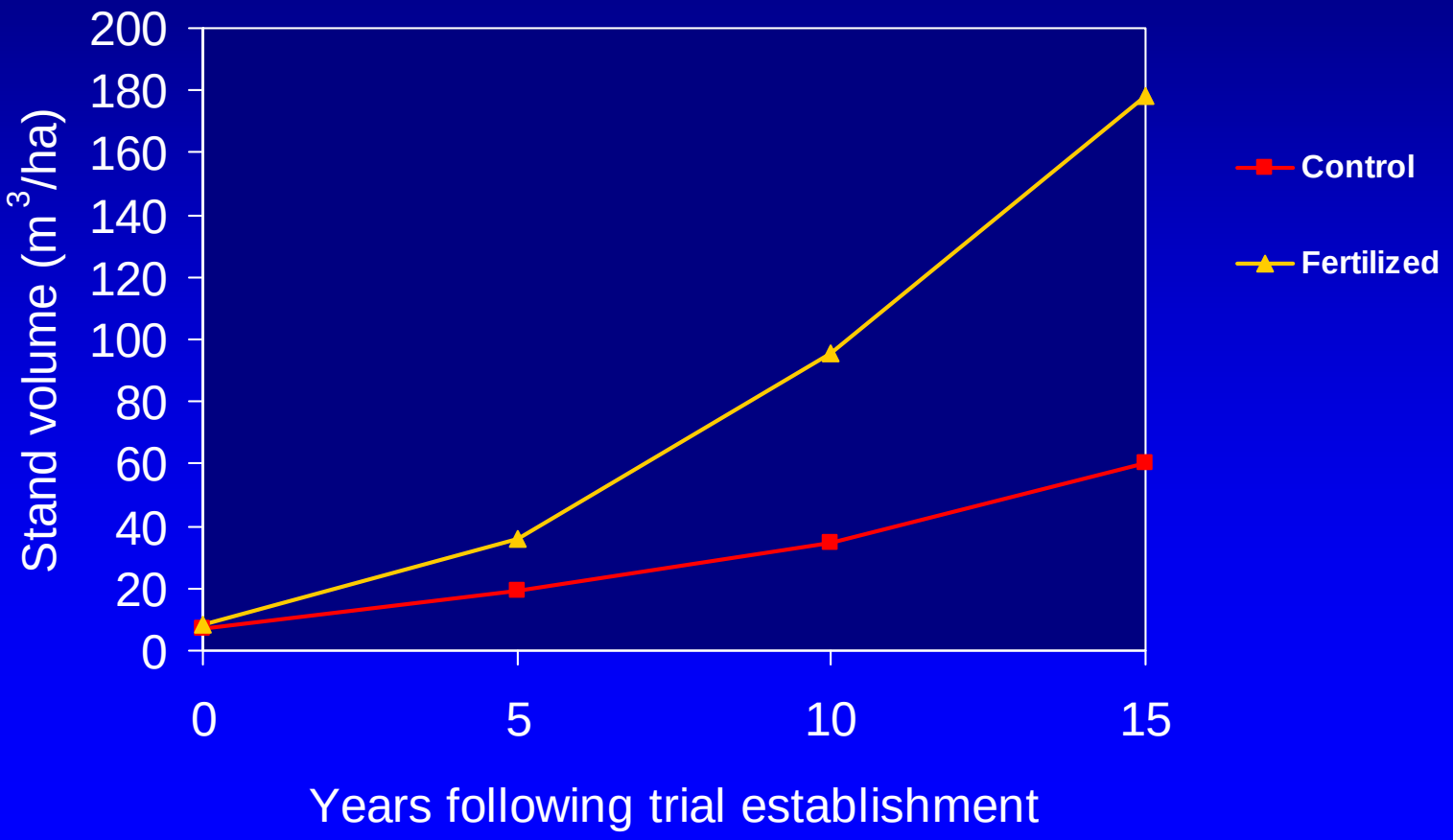
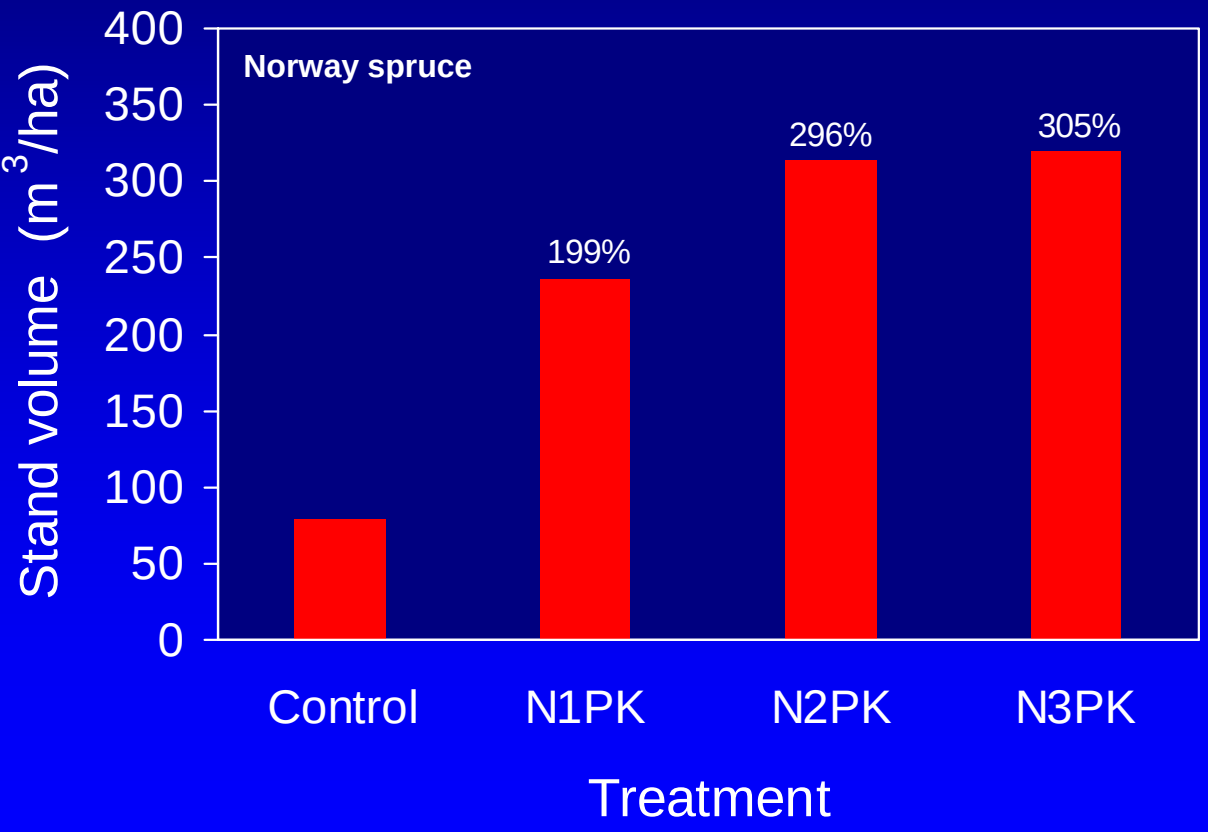
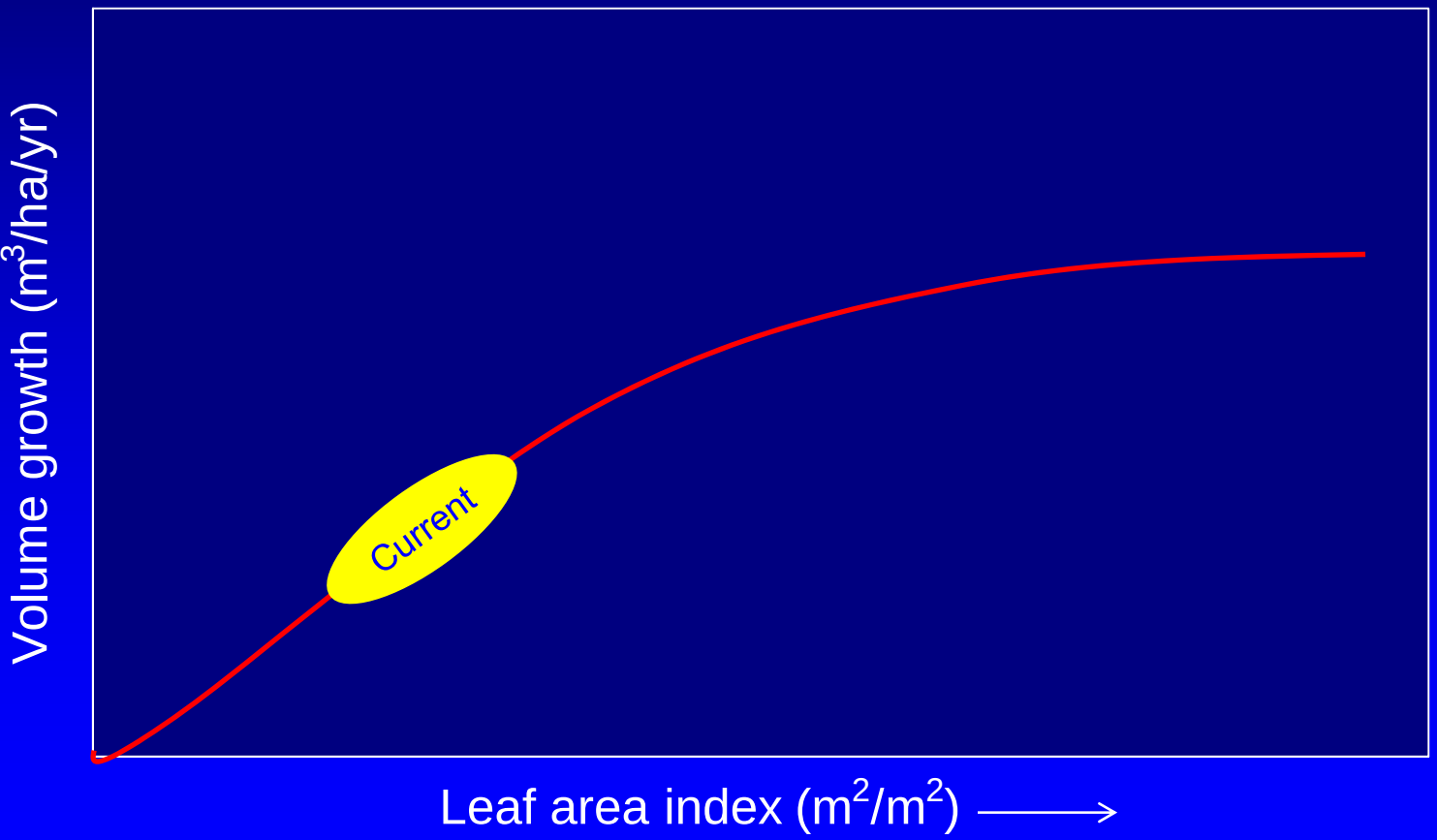


Effects of 20 years of annual fertilization on the growth of Norway spruce in central Sweden

Tamm (1991)



Relationship between annual volume growth and leaf area



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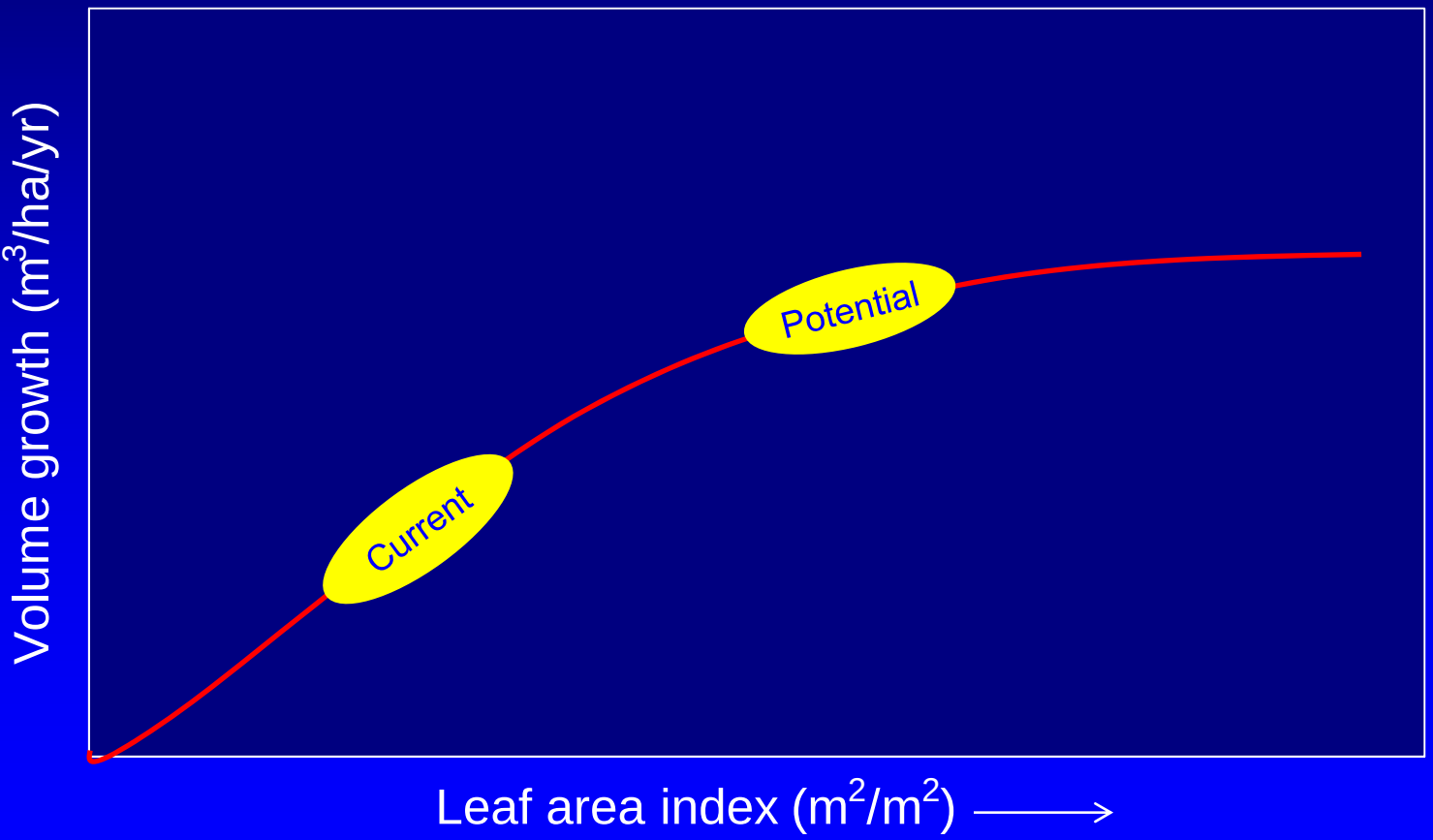
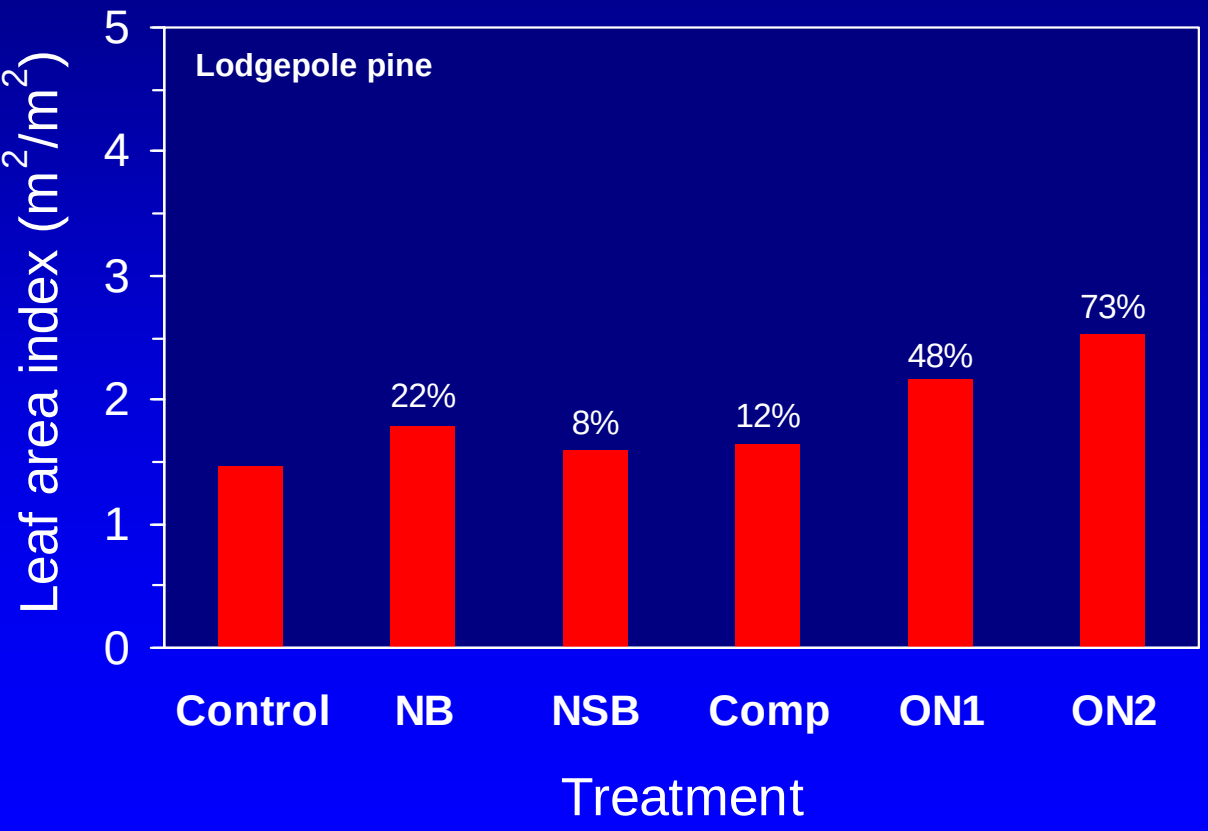


Leaf area index by treatment at year 12

Lodgepole pine (Brockley 2007)



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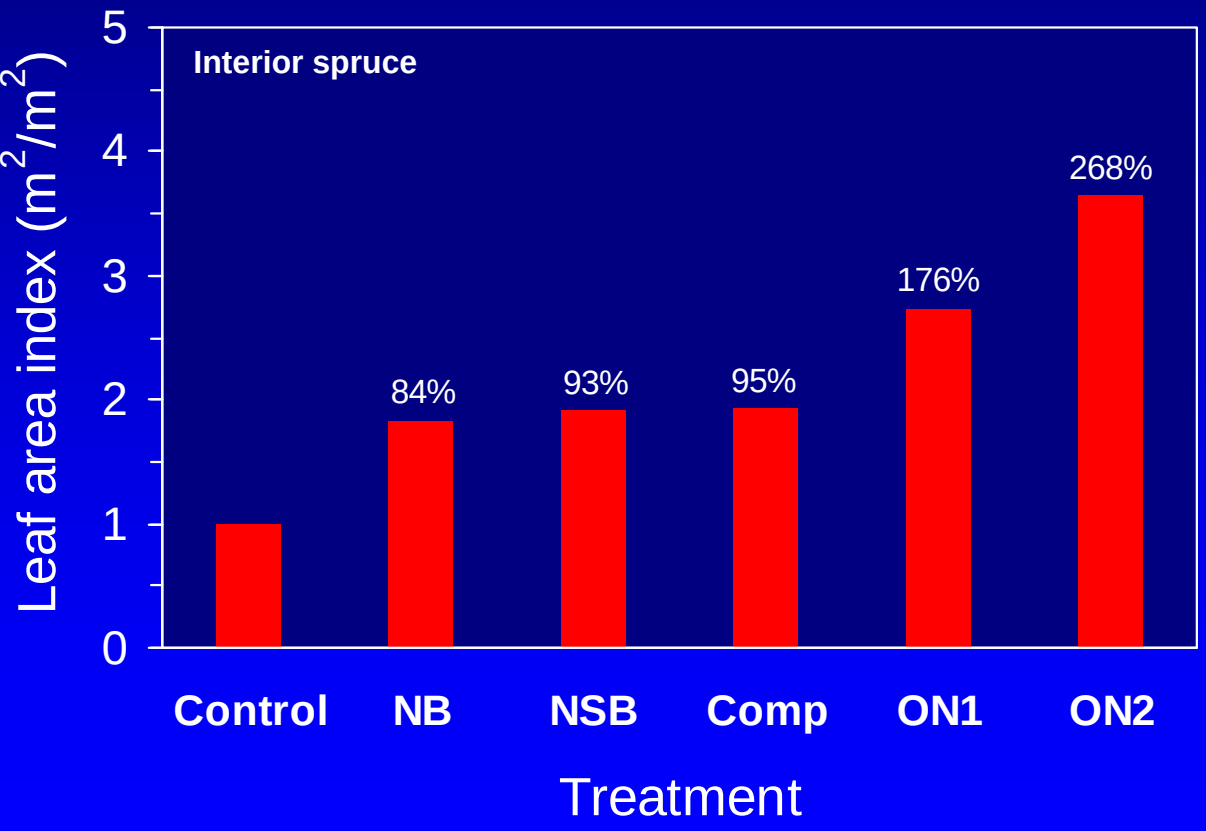
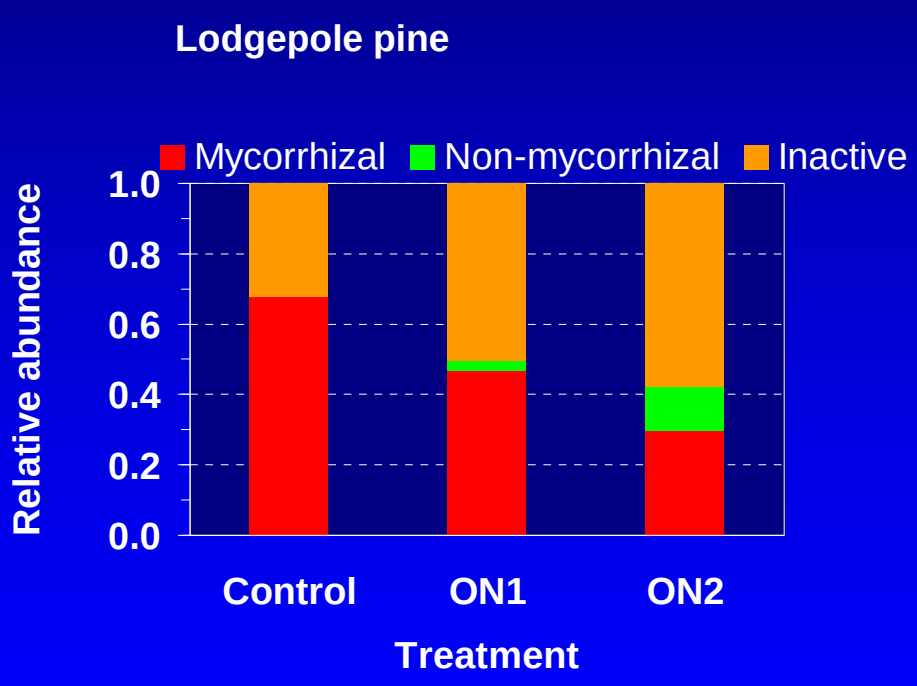


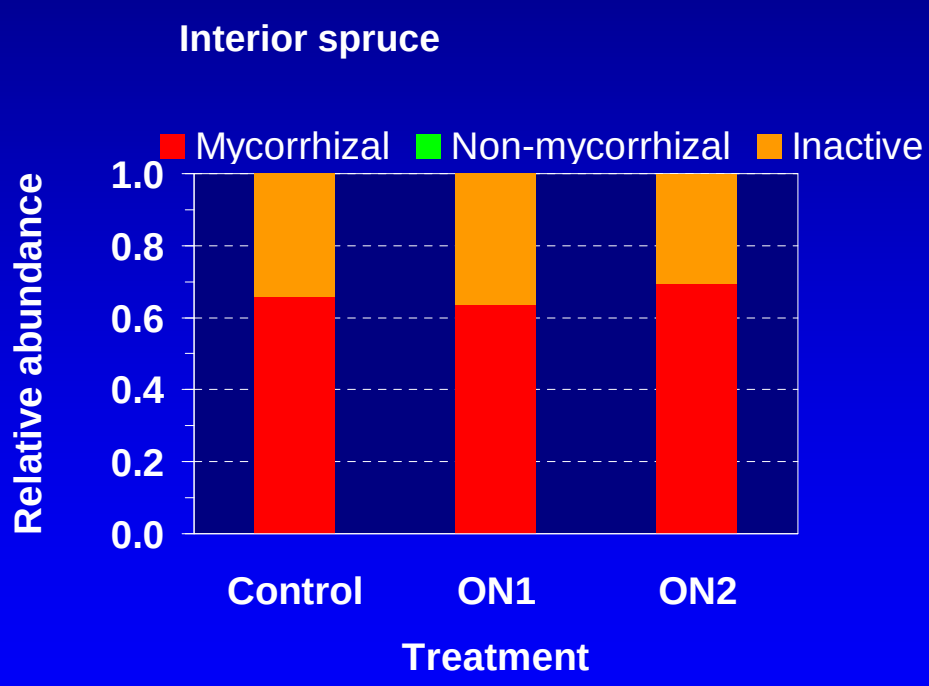
Mean fine root length by treatment

(Berch and Brockley 2008)

Mean relative abundance of mycorrhizal, non-mycorrhizal, and inactive fine roots by treatment

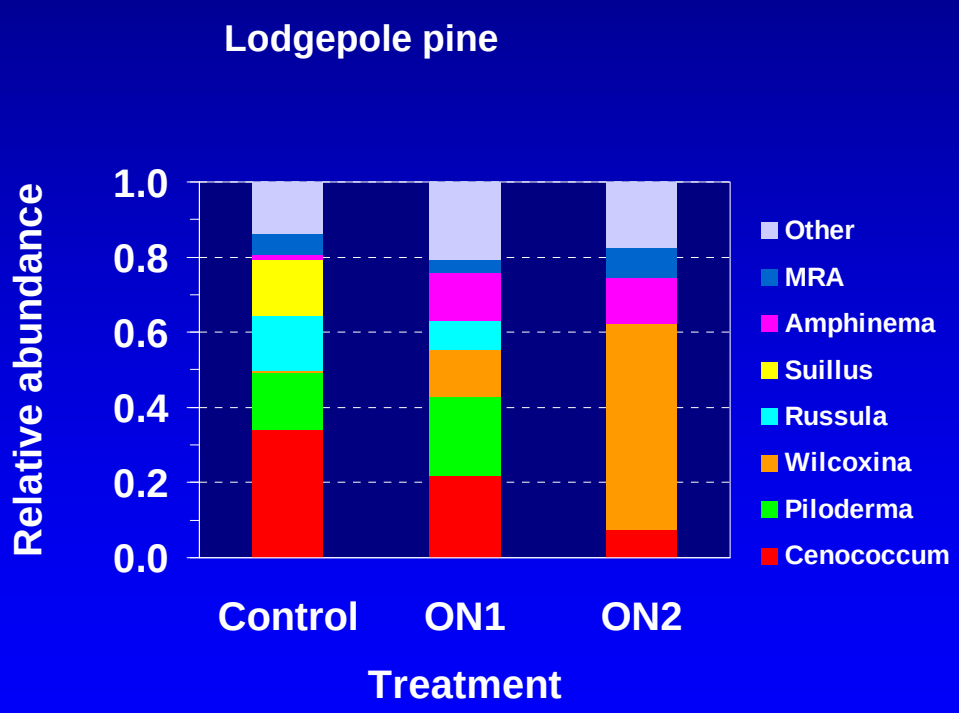
Berch and Brockley (2008)

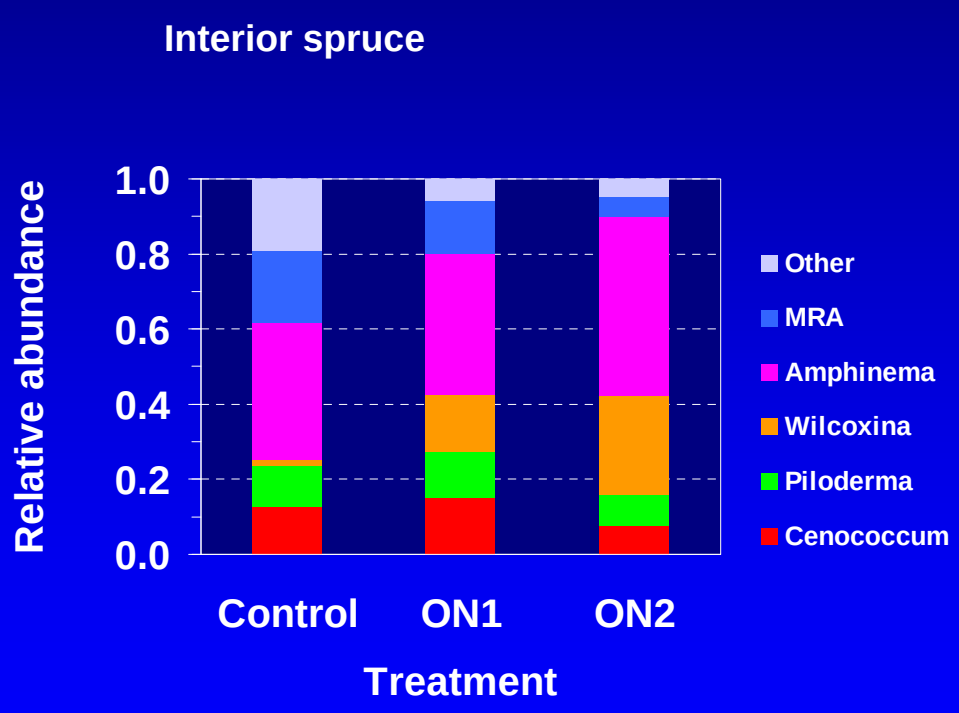




Mean relative abundance of ectomycorrhizal types by treatment

Berch and Brockley (2008)

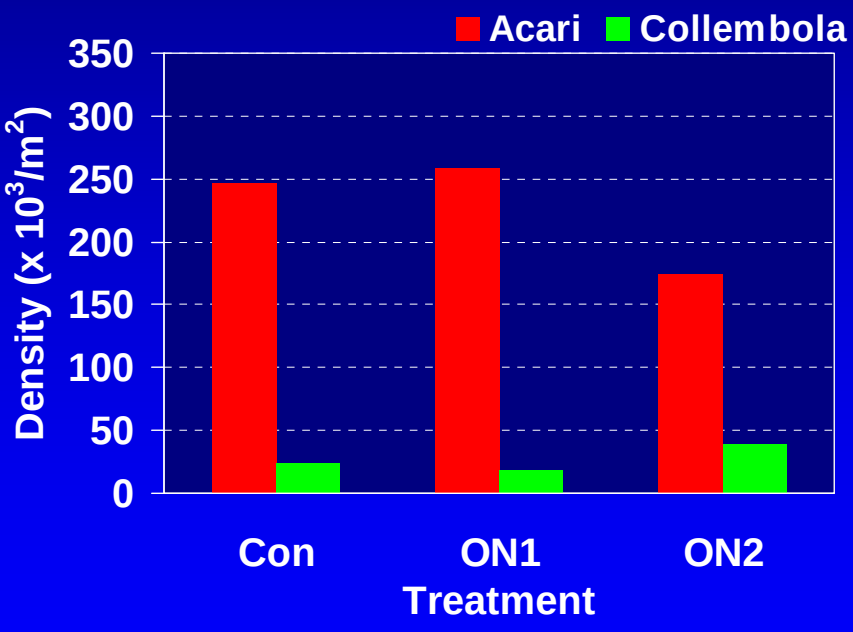




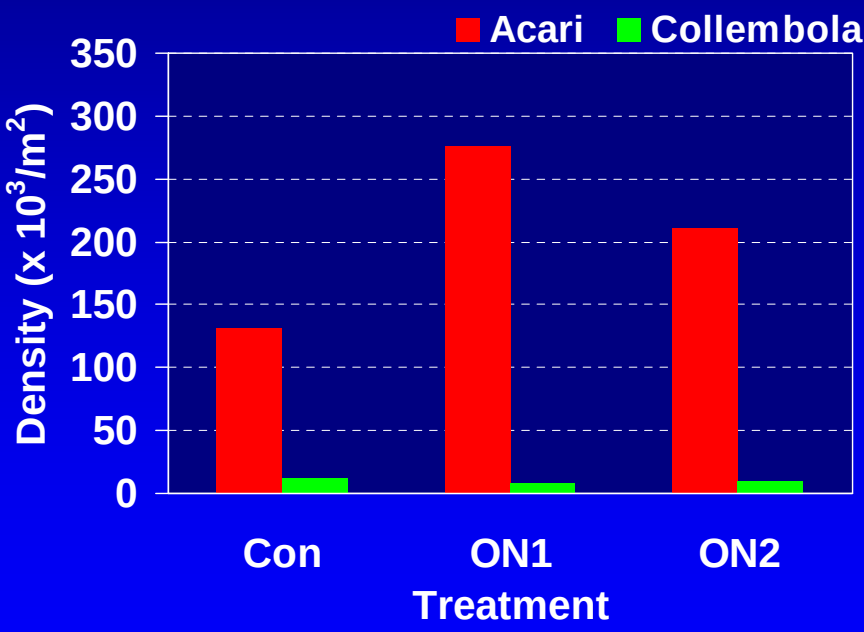
Mean mesofauna density in forest floor

Berch and Brockley (2008)

Lodgepole pine



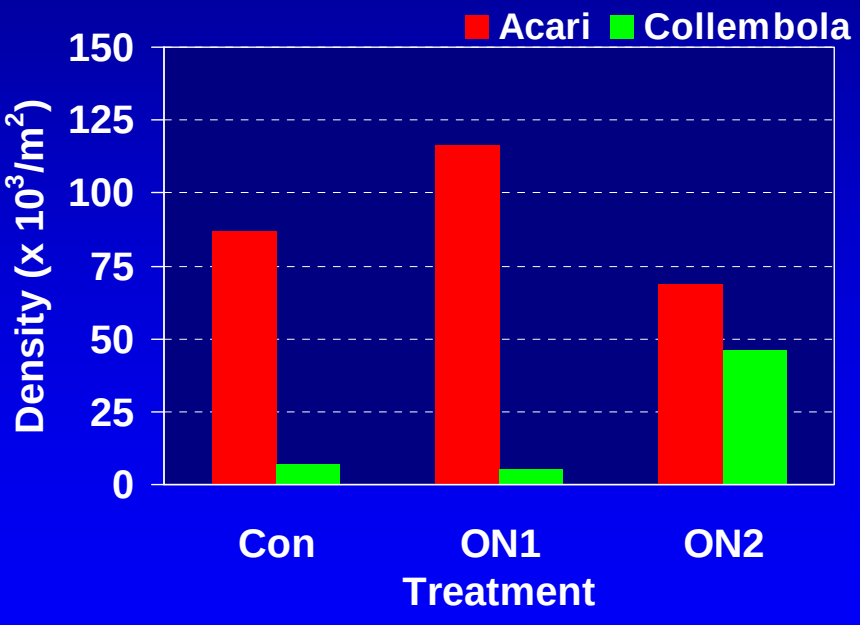
Interior spruce



Mean mesofauna density in mineral soil

Berch and Brockley (2008)

Lodgepole pine



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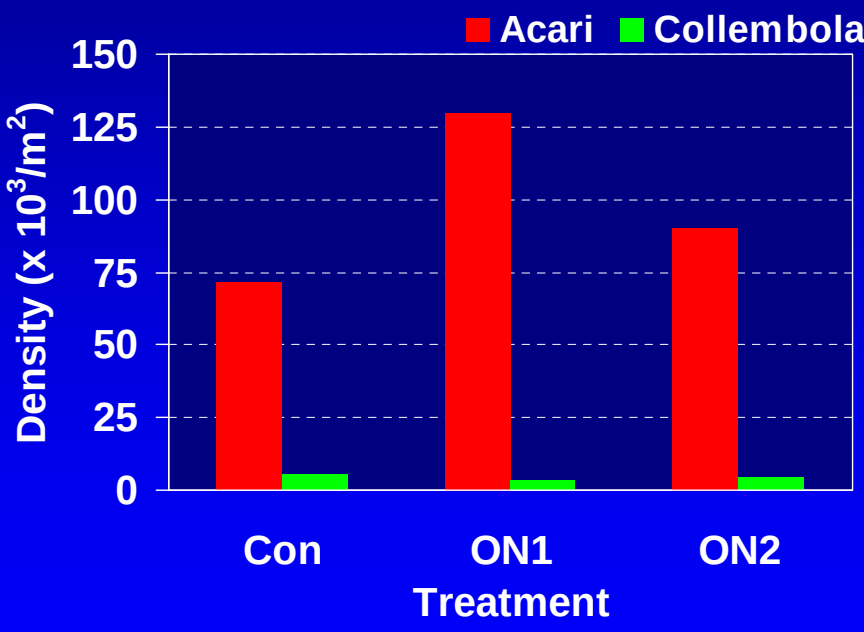
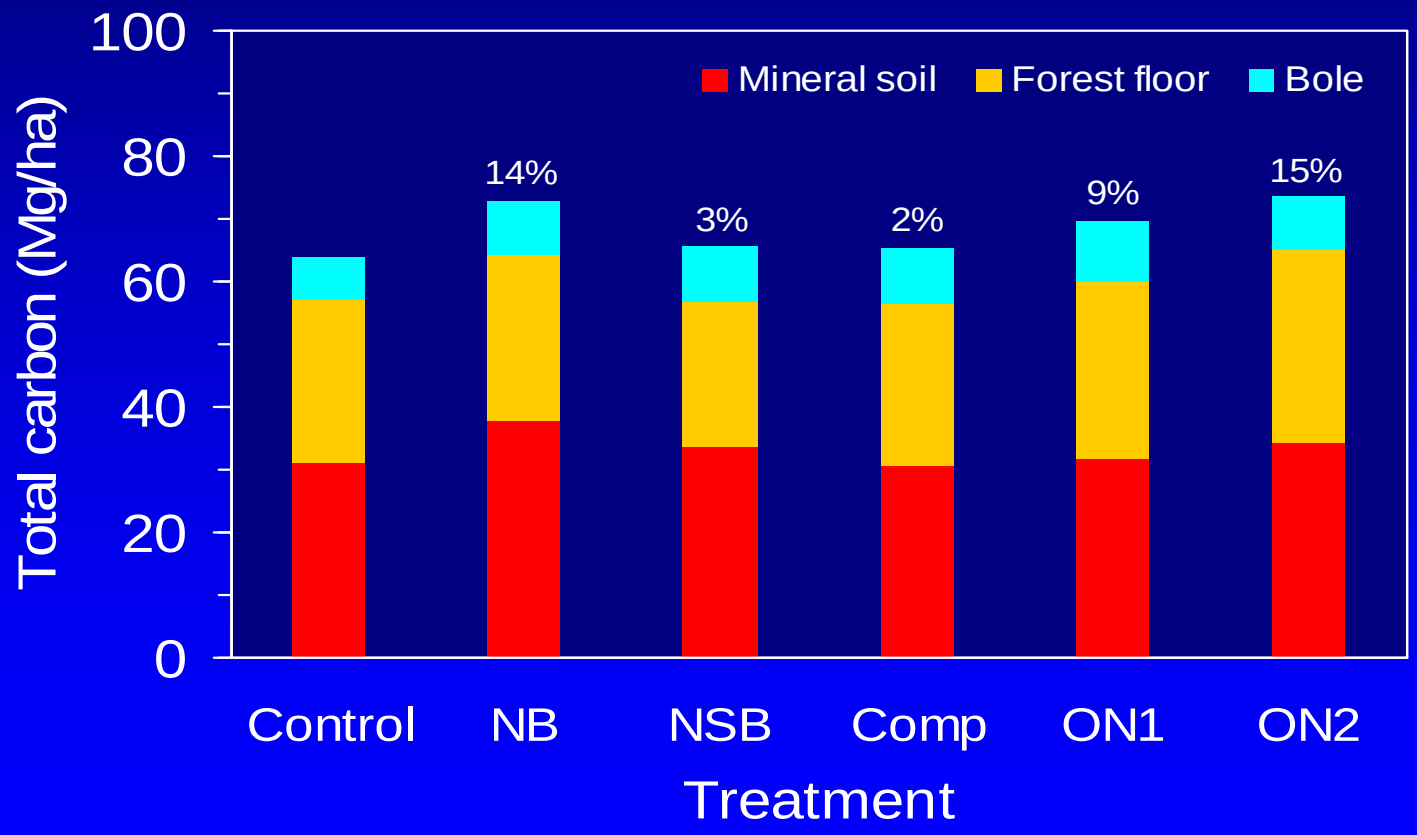


Can repeated fertilization increase above- and below-ground C sequestration?

Soil and bole carbon sequestration at year 12

Lodgepole pine (Brockley 2007, 2009)



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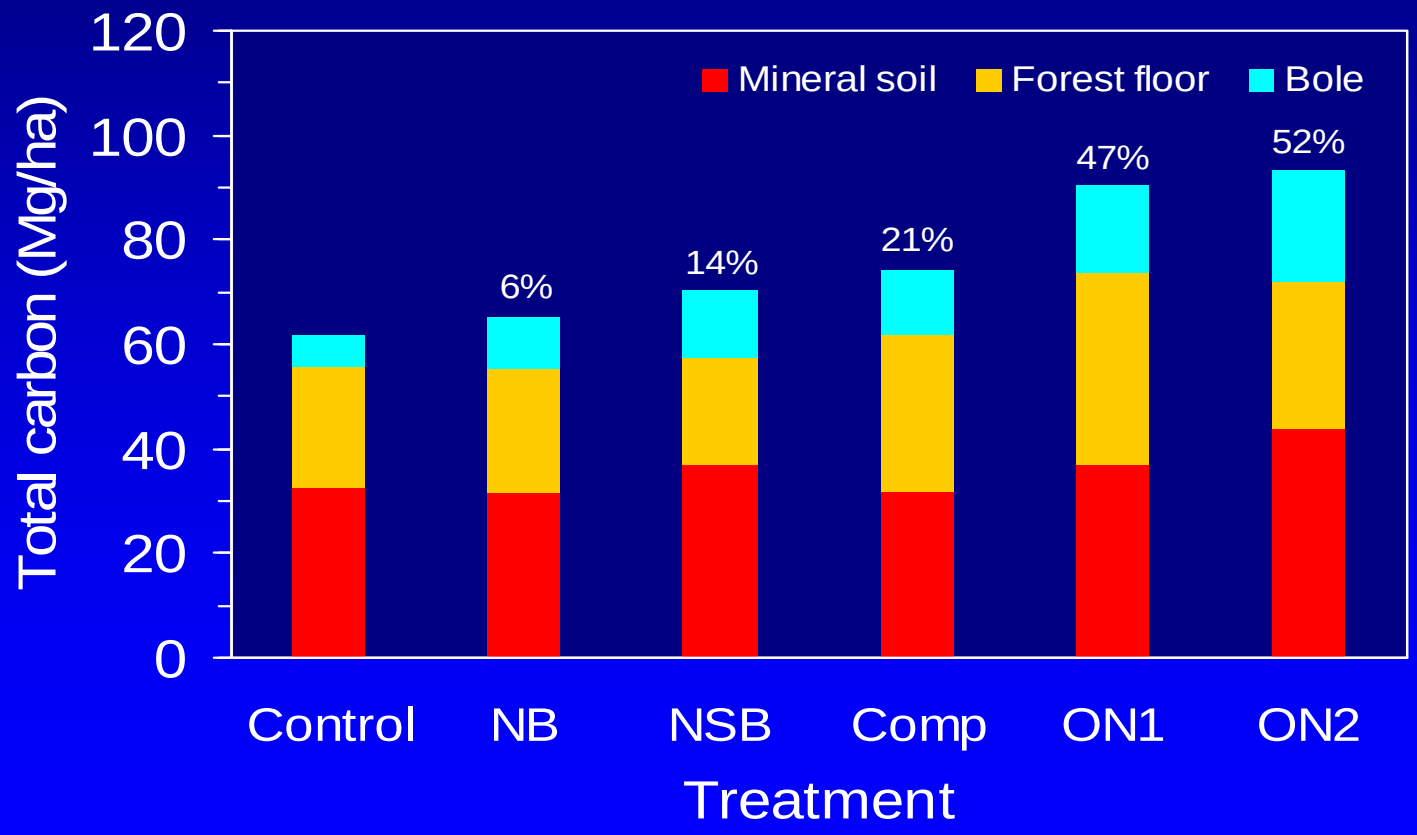

Summary

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- N deficiencies are widespread and serious

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Summary

Lodgepole pine

- N deficiencies are widespread and serious
- Growth response following N fertilization is variable
- Combined application of N and S often improves growth response
- Other deficiencies (e.g., B) may be induced by N fertilization
- Available foliar diagnostic criteria and predictive tools reduce uncertainty regarding fertilizer operations
- Large and frequent nutrient additions are apparently relatively ineffective and inefficient in stimulating growth of young stands

Summary

Interior spruce

- N deficiencies are widespread, especially on broadcast burned sites

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- Best responses are associated with low foliar N (< 1.0%)
- N fertilization may induce a short-term S deficiency, but stand growth is often not improved when S is included in fertilizer prescriptions
- B deficiencies may limit growth on some sites
- Repeated fertilization may offer an excellent opportunity to increase fiber yield, reduce rotation length, and sequester above- and below-ground C

Contact me

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More information and publications

www.for.gov.bc.ca/hre/standman/trtfert.htm