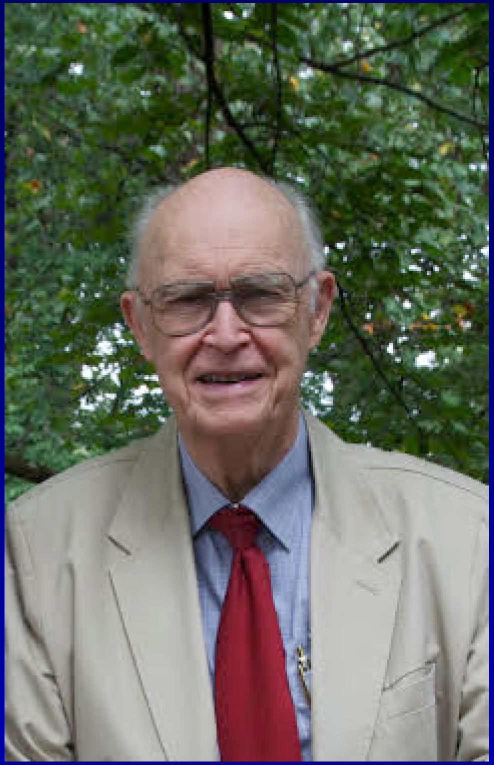
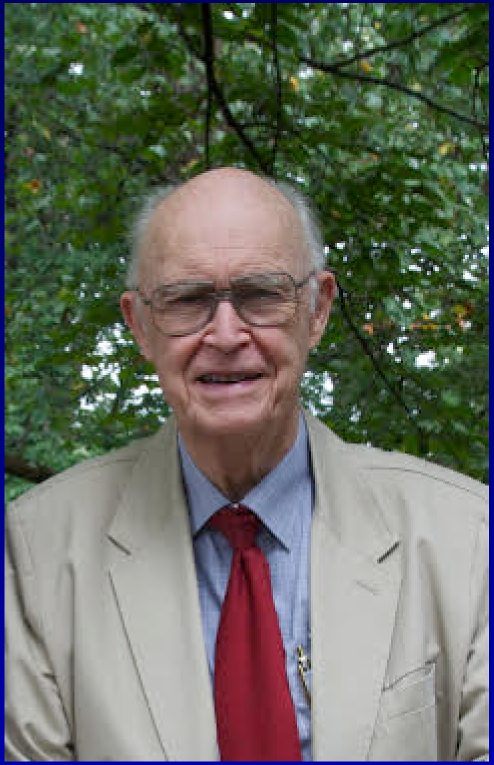


Chuck Davey

1928-2015

NC State Outstanding Professor (1968)
President of the Soil Science Society of America (1976)
SAF Barrington Moore Award (1982)
Gamma Delta Award of Merit (1983)
NC State Distinguished Graduate Professor (1989)
Fellow of the Society of American Foresters (2004)



Chuck Davey

1928-2015

Tree growth and essential nutrient elements - 14 pages

Nutrients and nutrient sources – 6 pages

Standards for soil test interpretation – 2 pages

Homework…. Read these pages.

Effects of Nursery Fertilization on Outplanting Performance

David South

AUBURN
FORESTRY AND WILDLIFE SCIENCES

Outline

- How do we define “optimum” nutrition

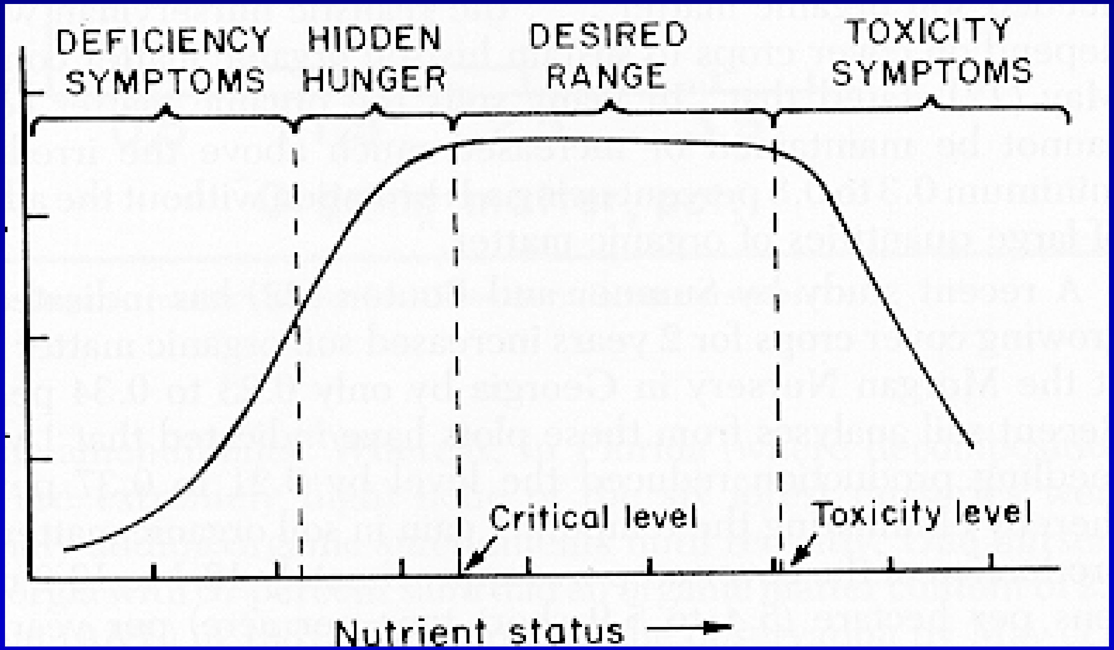
  Effects on .....
- seedling morphology
- survival
- root growth potential (RGP)
- short-term growth
- long-term growth

How do we determine the "desired range" of nutrients?

Color?
Height?

Plantable seedlings?

Field growth?



How do we determine the “desired range” of nutrients?

Color?

Table 1
Munsell color of needles of white pine and loblolly pine at the end of one year of culture for nutrient loading

Relative strength of nutrient solution	N concentration (mg L^{-1})	Color chart designation[z]	Visual color[y]
		Loblolly pine	
0.0625	13	100% 5GY 6/6	light green
0.125	26	100% 5GY 6/10	light green
0.25	51	50% 5GY 7/10	light green
		50% 5GY 6/8	light green
0.50	102	30% 5GY 7/10	light green
		70% 7.5GY 4/6	dark green
1.0	205	20% 5GY 6/10	light green
		80% 5GY 4/4	dark green
2.0	410	60% 5GY 4/4	dark green
		40% 2. 5GY 8/10	yellow green

[z]% of leaves, page, value/chroma. [y]bottom to top down the column.

How do we determine the “desired range” of nutrients?

Height?

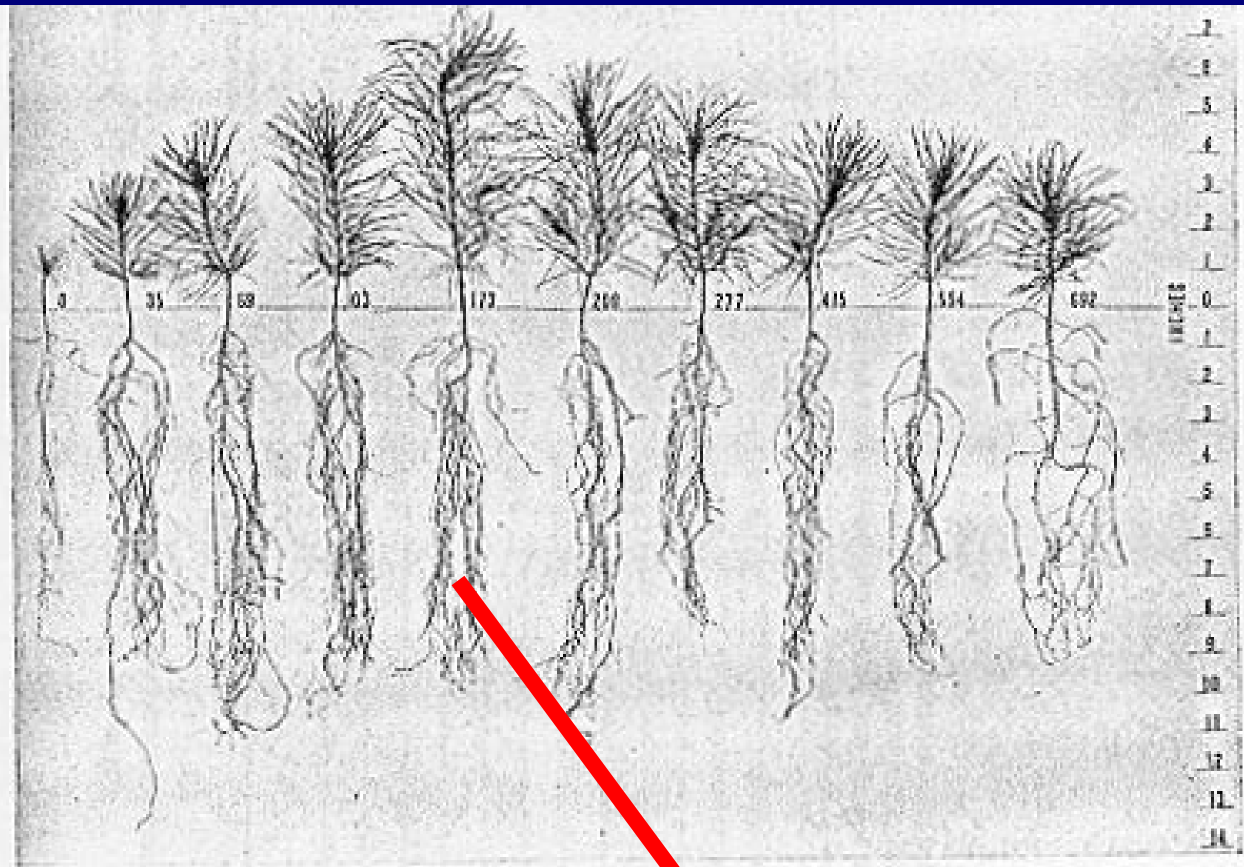
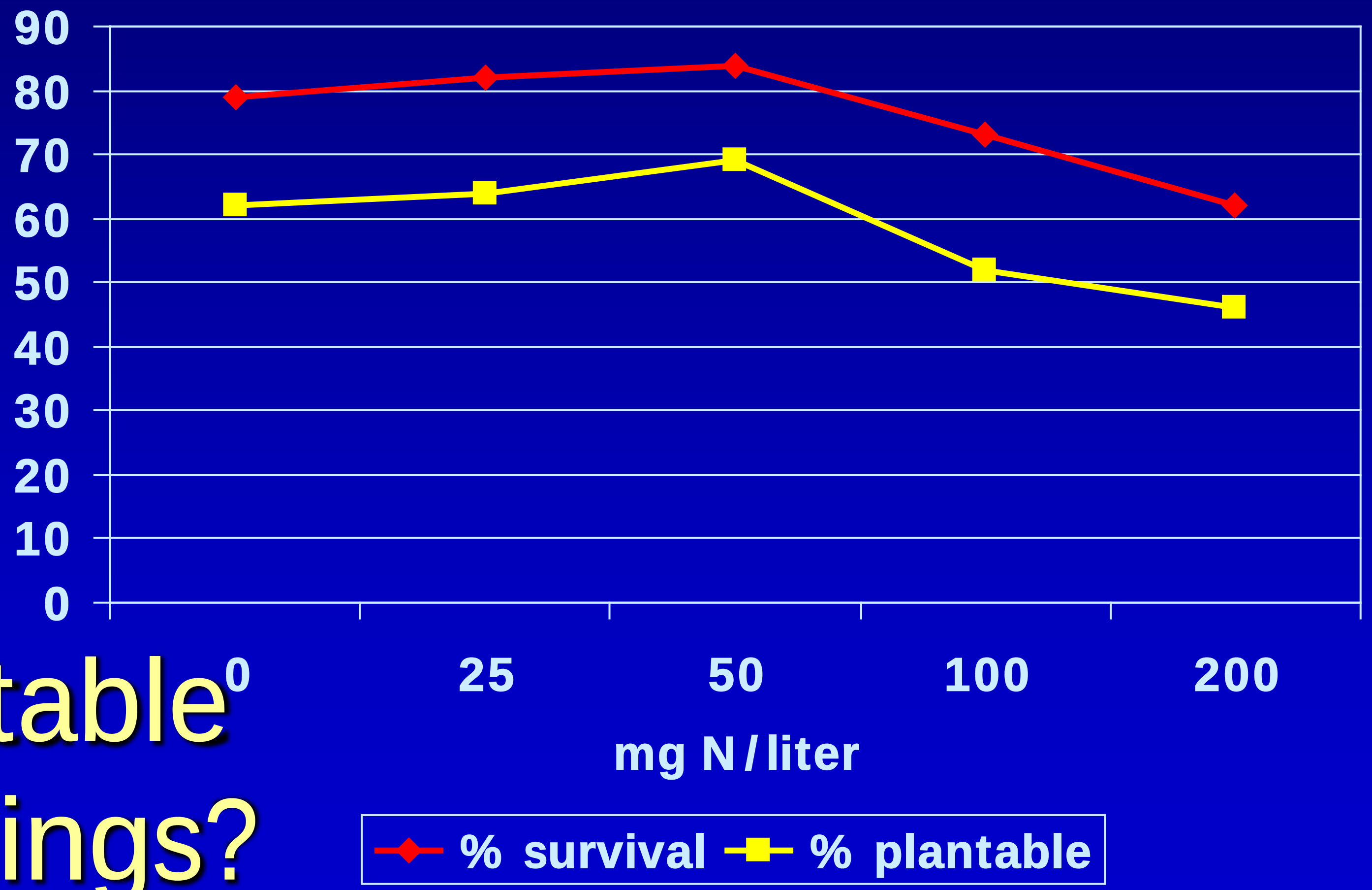


FIG. 4. Seedlings arranged according to nitrogen supplied

Code numbers on the pots and seedlings refer to the following concentrations of nitrogen in p.p.m.: 0=0; 35=48; 69=95; 103=145; 173=230; 208=275; 277=336; 415=537; 554=702; 692=855

Sweetgum Rooted Cuttings

(Rieckermann et al. 1999: New Forests)



Plantable seedlings?

Slow release fertilizer treatment on Gmelina aborea cuttings

(Redell et al. 1999: New Forests)

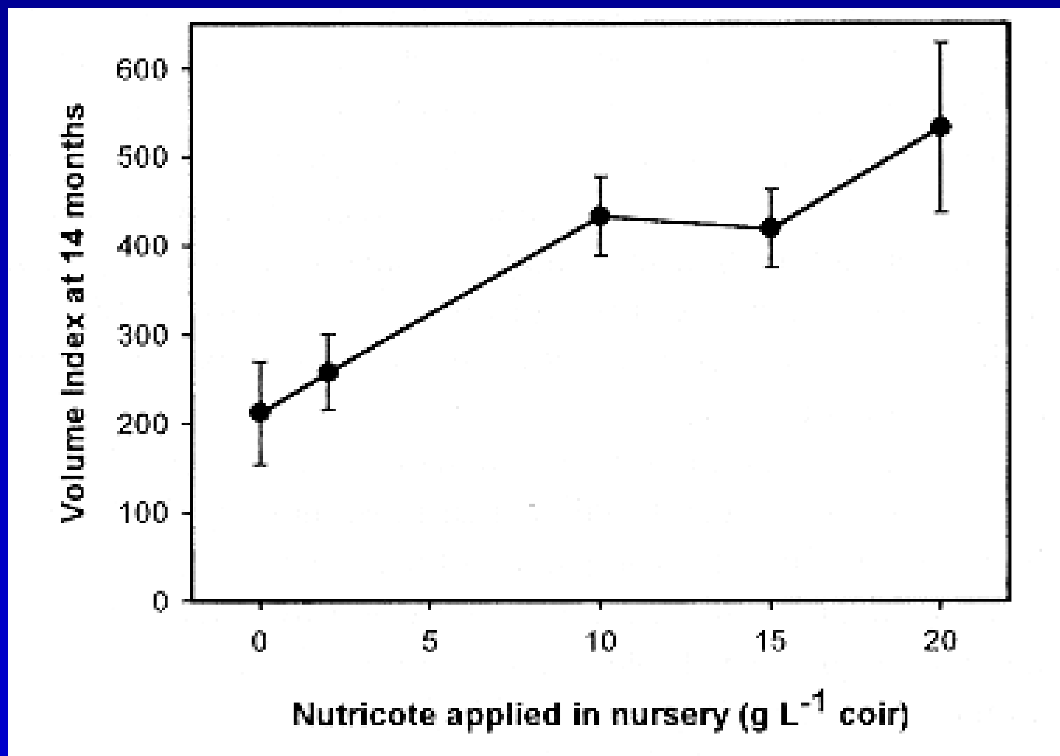
- Nutricote per liter of Coir potting medium
- 0
- 2 g
- 10 g
- 15 g
- 20 g

No effect on nursery height

No effect on field survival
avg. 94.6%

Slow release fertilizer treatment on Gmelina aborea cuttings
(Redell et al. 1999: New Forests)

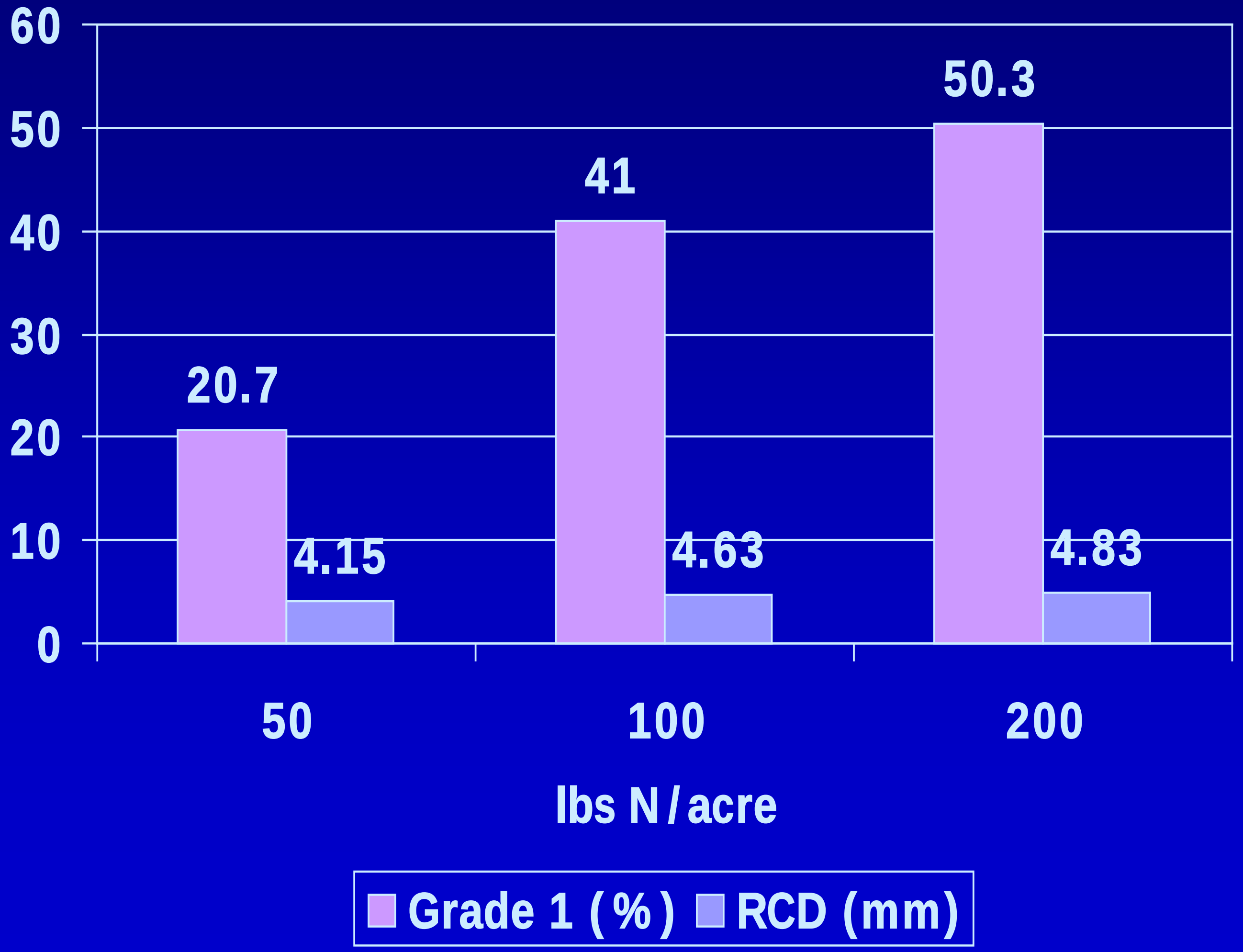
Field growth?



Effect of Fertilization on seedling morphology

Slash pine - Georgia

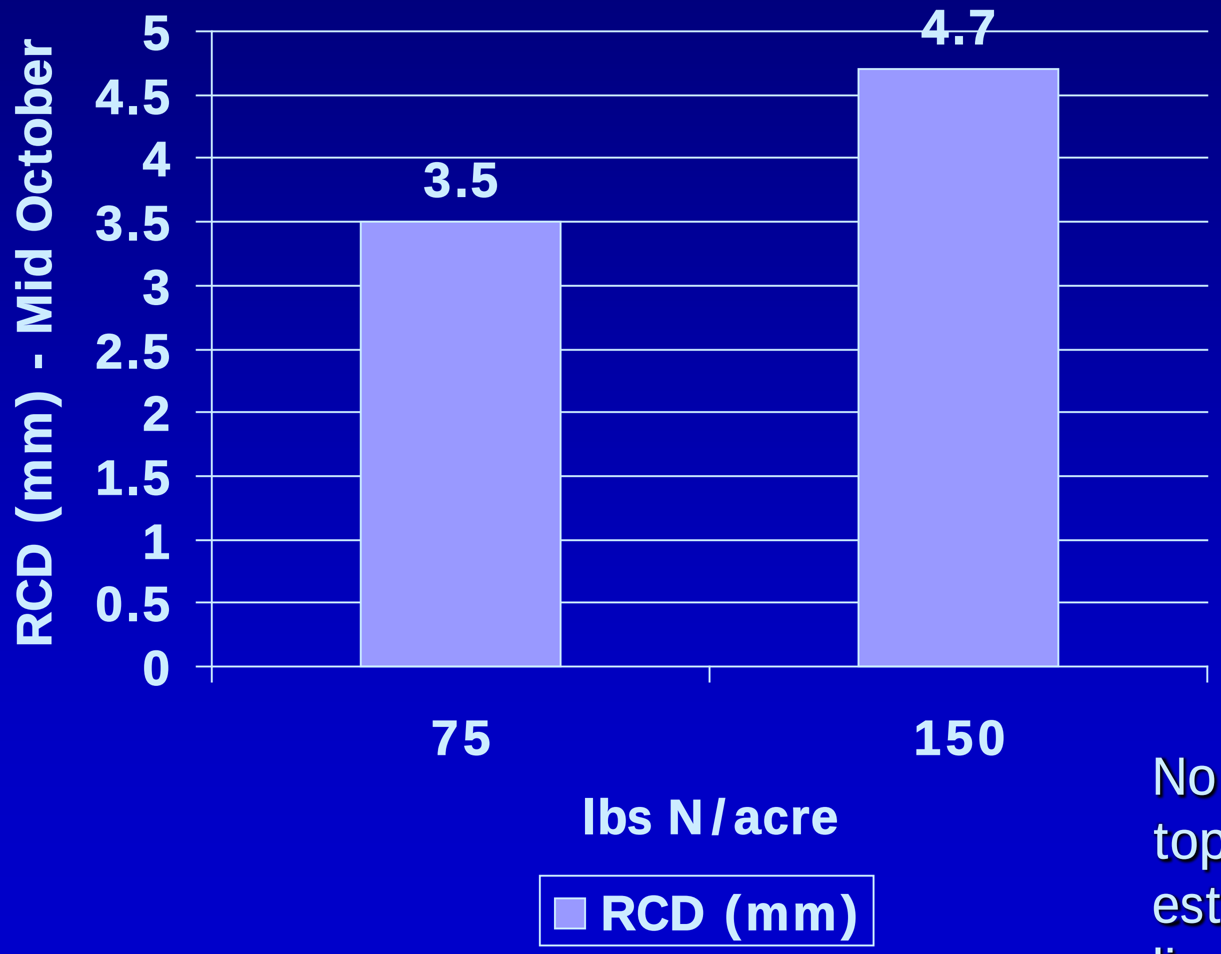
(Heser 2000: MS)



Although there is no statistical difference between 100 and 200 lbs N/acre, the trend for both diameter and grade 1 seedlings appears to be linear.

Loblolly pine - Georgia

(Kormanik et al. 1999: GTR SRS-25)



No undercutting and no top-pruning. RCD estimated from regression lines.

Loblolly - Virginia

(Dierauf 1991: VDF OR #94)

	1 X Rate	2 X Rate	Extra cost per M
1981	270 lbs N/acre	540 lbs N/acre	11 cent more
1982	270 lbs N/acre	540 lbs N/acre	11 cents more
1983	300 lbs N/acre	600 lbs N/acre	12 cents more
1984	250 lbs N/acre	500 lbs N/acre	10 cents more
1985	270 lbs N/acre	540 lbs N/acre	11 cents more

- 0.5 inch of sawdust
- 1 inch of sawdust
- 1.5 inch of sawdust

- top pruning in all years (2 times or 3 times)
- no top pruning included in 1983, 1984, 1985

Loblolly - Virginia
(Dierauf 1991: VDF OR #94)

Figure 2. Top length at lifting, 1981 study.

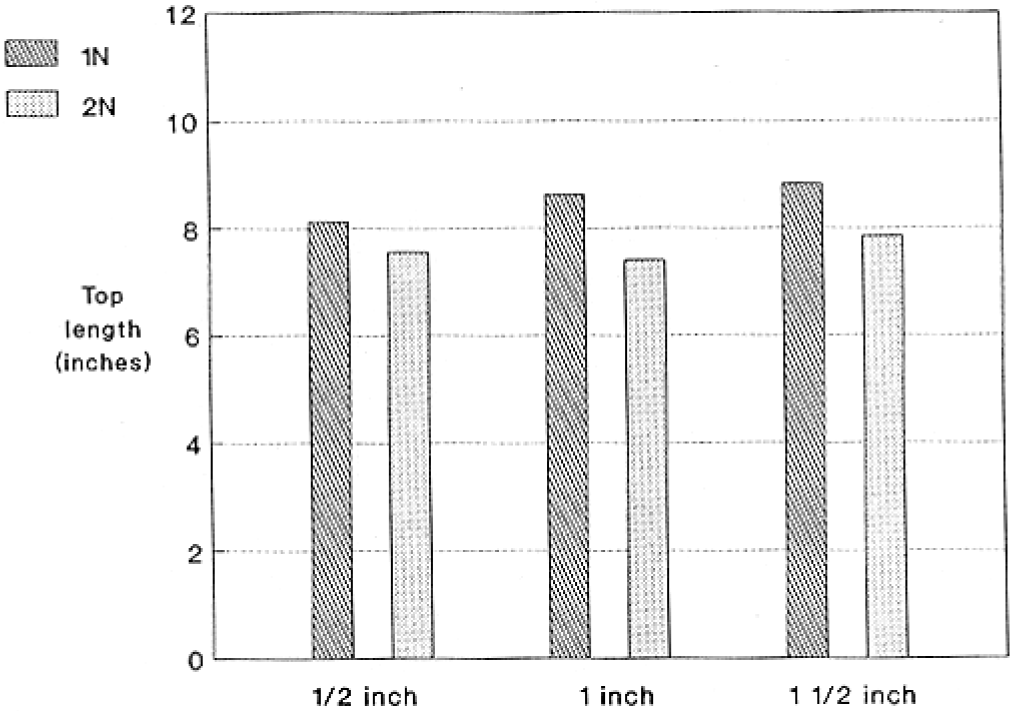
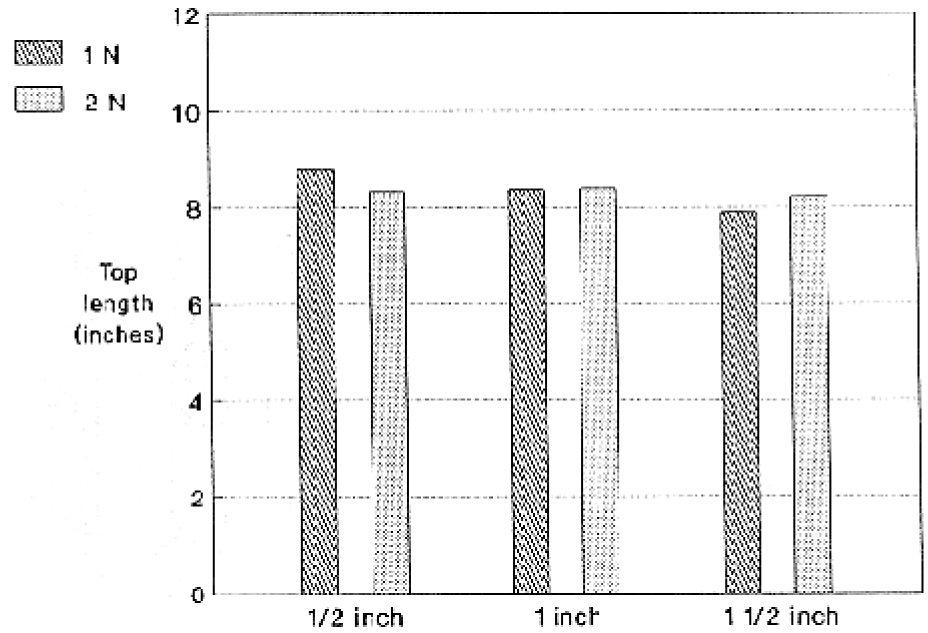
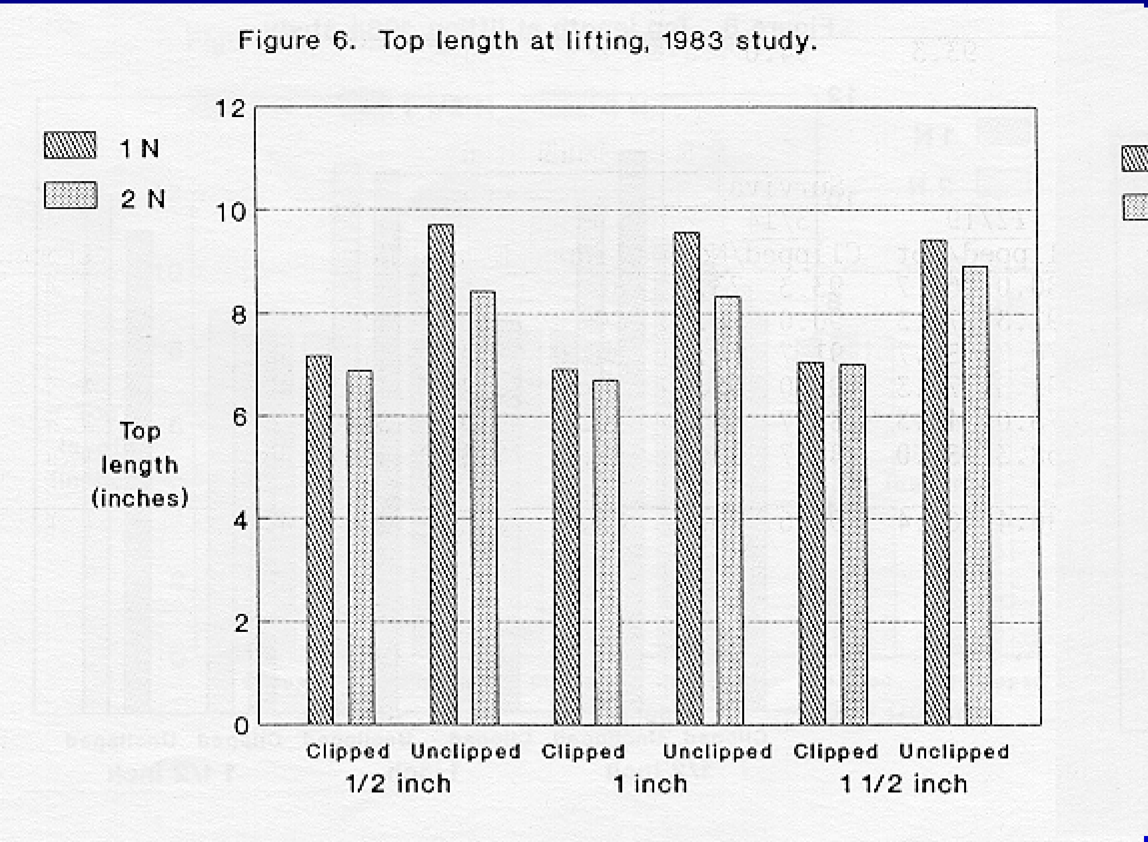


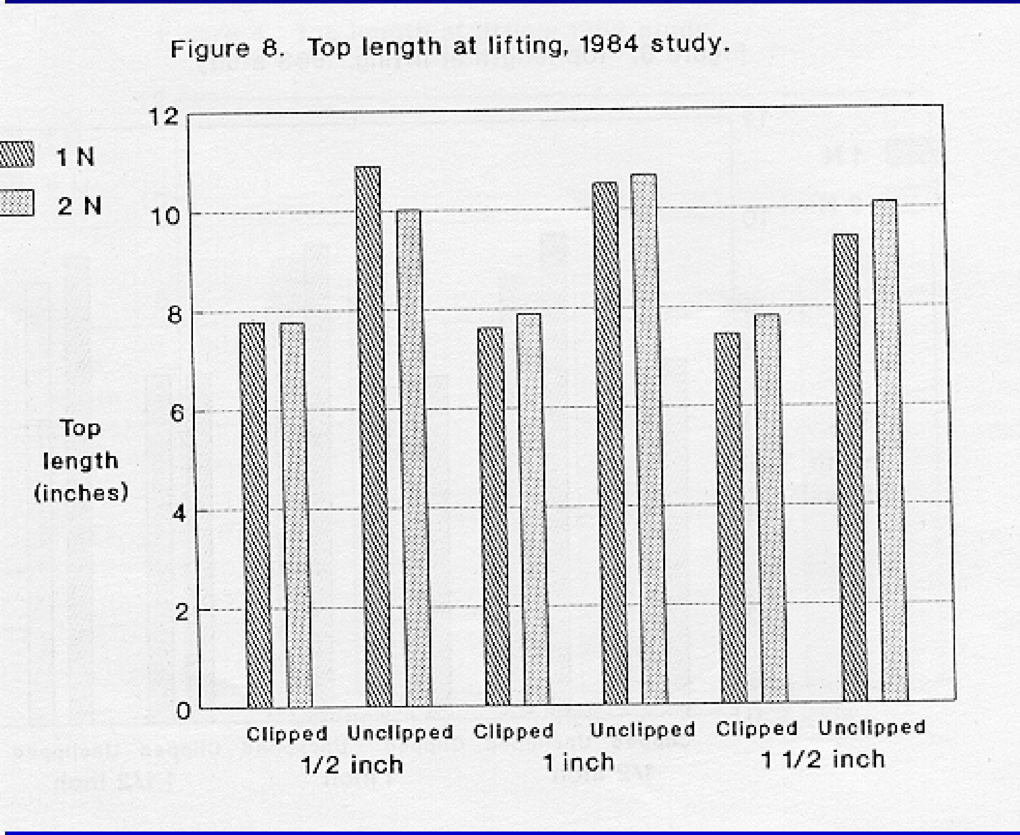
Figure 4. Top length at lifting, 1982 study.



Loblolly - Virginia

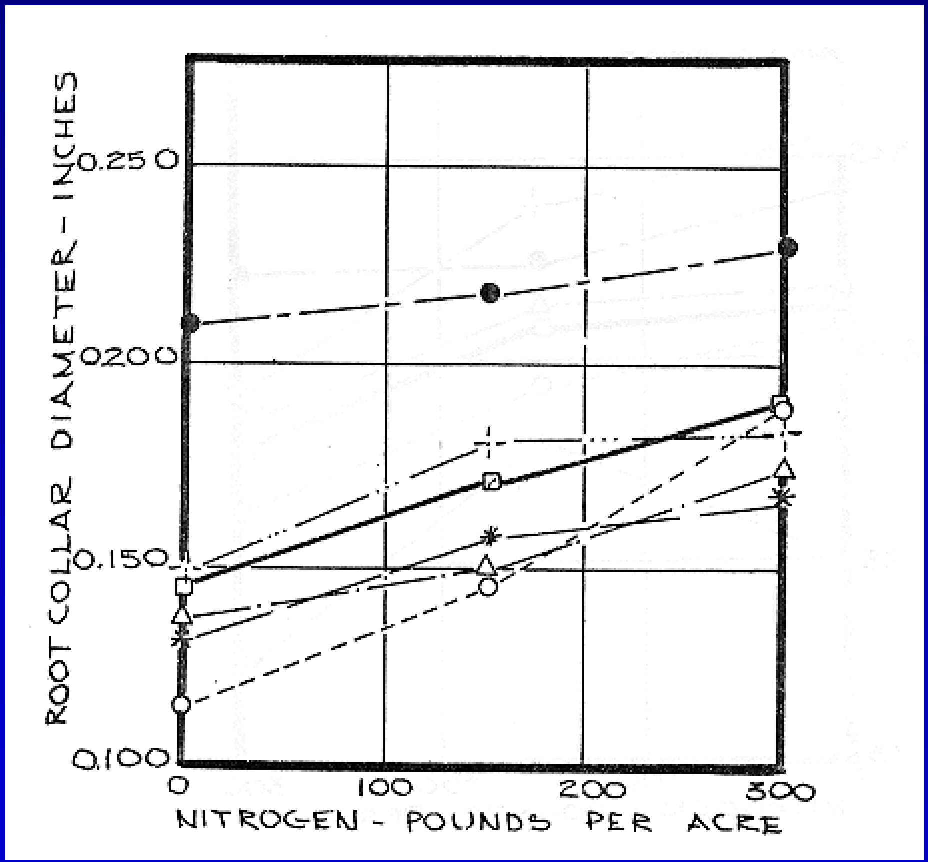
(Dierauf 1991: VDF OR #94)

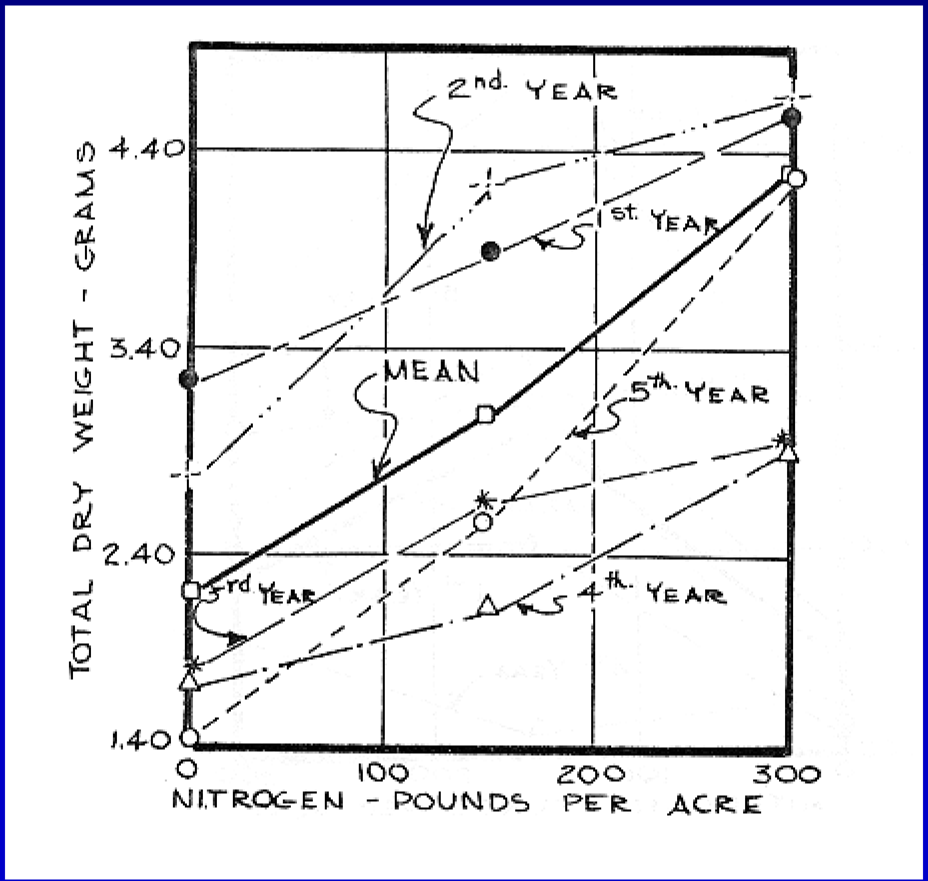




Loblolly - Mississippi

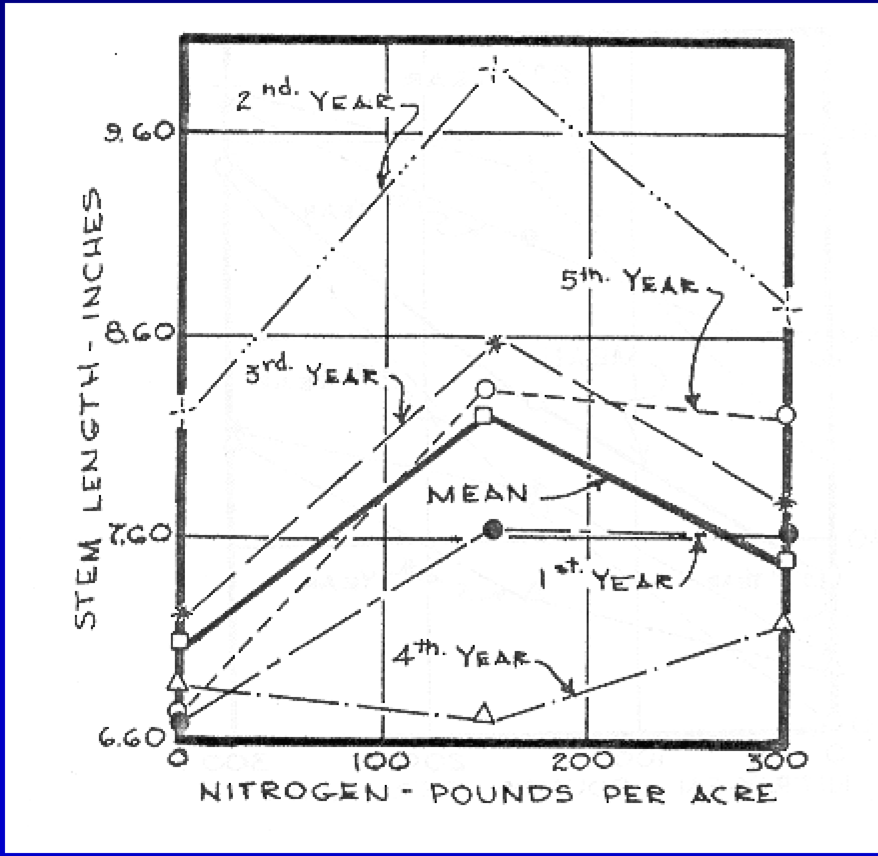
(Switzer 1962: PhD)

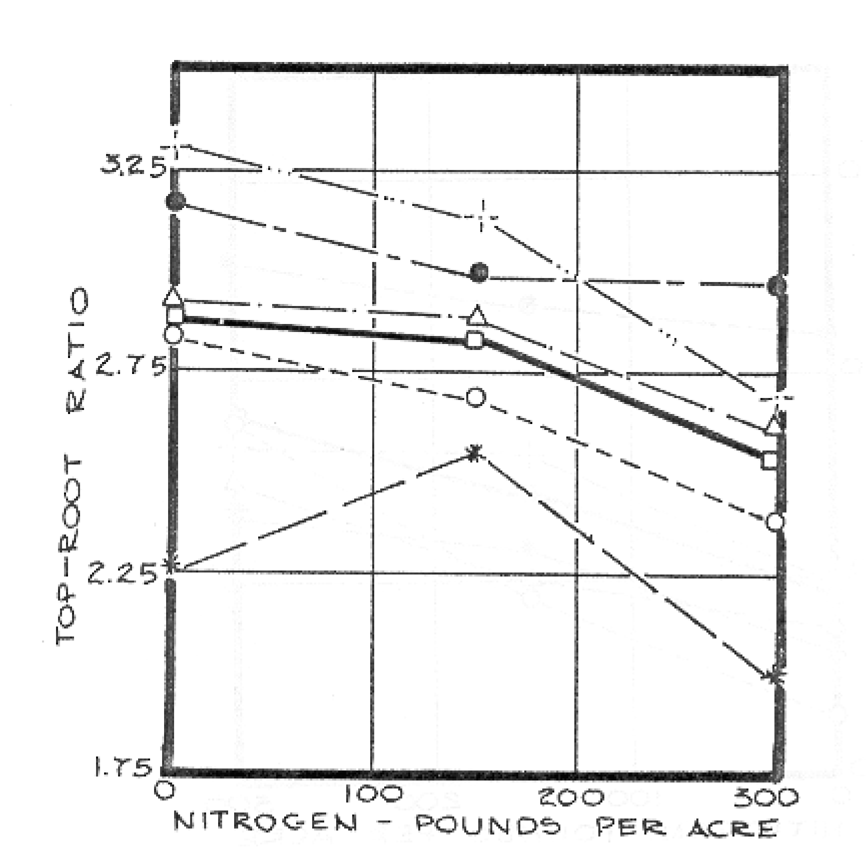




Loblolly - Mississippi

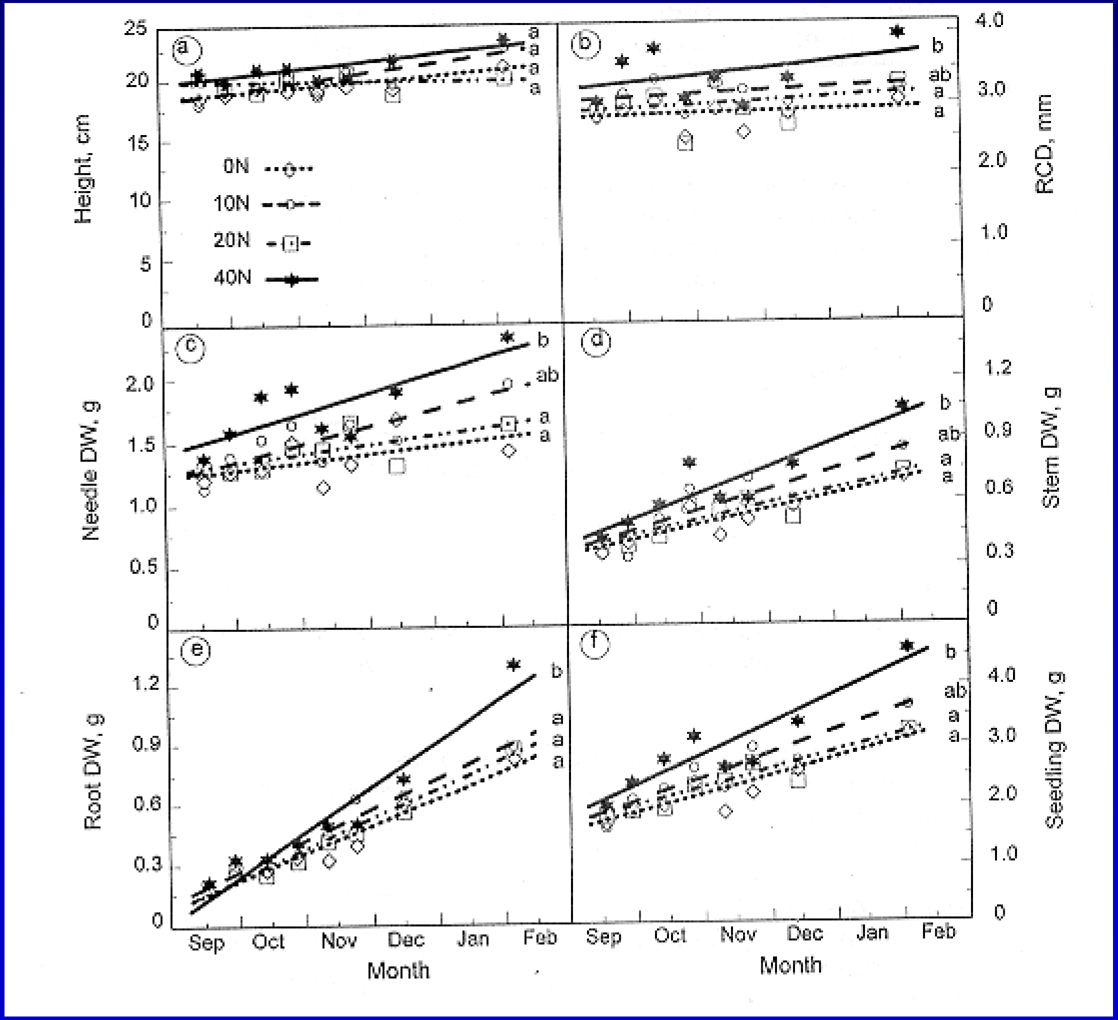
(Switzer 1962: PhD)





Loblolly - Georgia

(Sung et al. 1997: CJFR 27)



Summary

Some of the old beliefs about the
effect on N fertilization on seedling morphology were
developed under greenhouse and hydroponic systems.

The belief that extra N produces unbalanced seedlings
is not supported by data collected under nursery conditions.

In most cases with pine, top-pruning and undercutting
will alter the root/weight ratio more than extra N.

Effect of Fertilization on survival

Liquid Fertilization - 1937

(Wilde et al. 1940: JOF)

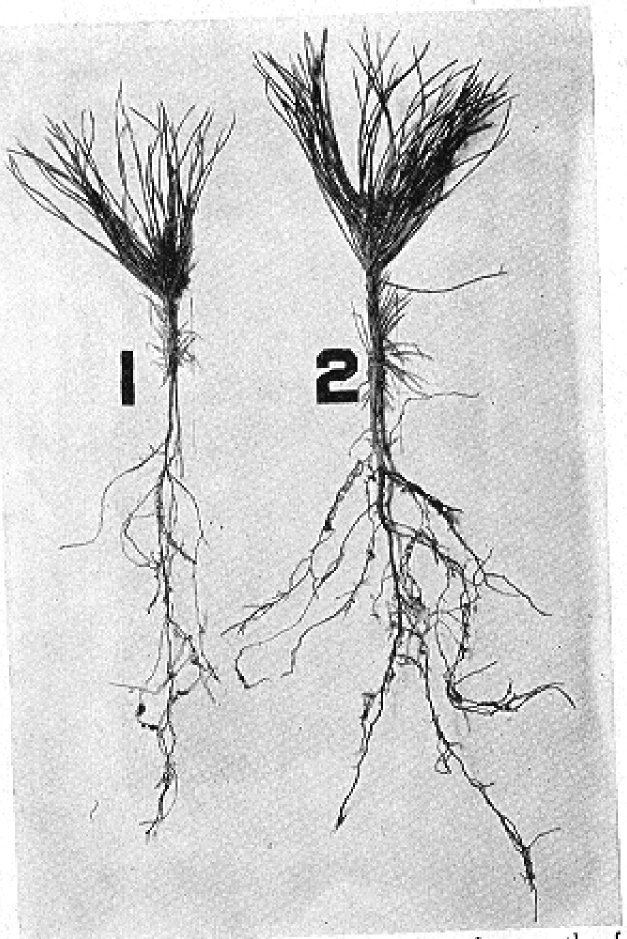


Fig. 1.—Effect of liquid fertilizer upon the growth of two-year old Scotch pine seedlings: (1) Check; (2) 600 pounds per acre of 11-48 ammonium phosphate and 13-0-44 potassium nitrate, applied in equal portions.

Liquid Fertilization - 1937

(Wilde et al. 1940: JOF)

13-0-44 11-48-0	Top inch	Root inch	Top/root	Weight (g)
Check	2.4	5.0	0.47	0.48
200 lbs	2.7	5.2	0.52	0.83
400 lbs	3.1	5.1	0.61	1.09
600 lbs	2.8	5.5	0.52	1.34

Liquid Fertilization - 1937
(Wilde et al. 1940: JOF)

Longleaf Fertilization (greenhouse)
(Allen and Maki 1954: Soil Sci.)

Longleaf - Fall Fertilization (nursery) (Hinesley and Maki 1980: SJAF)

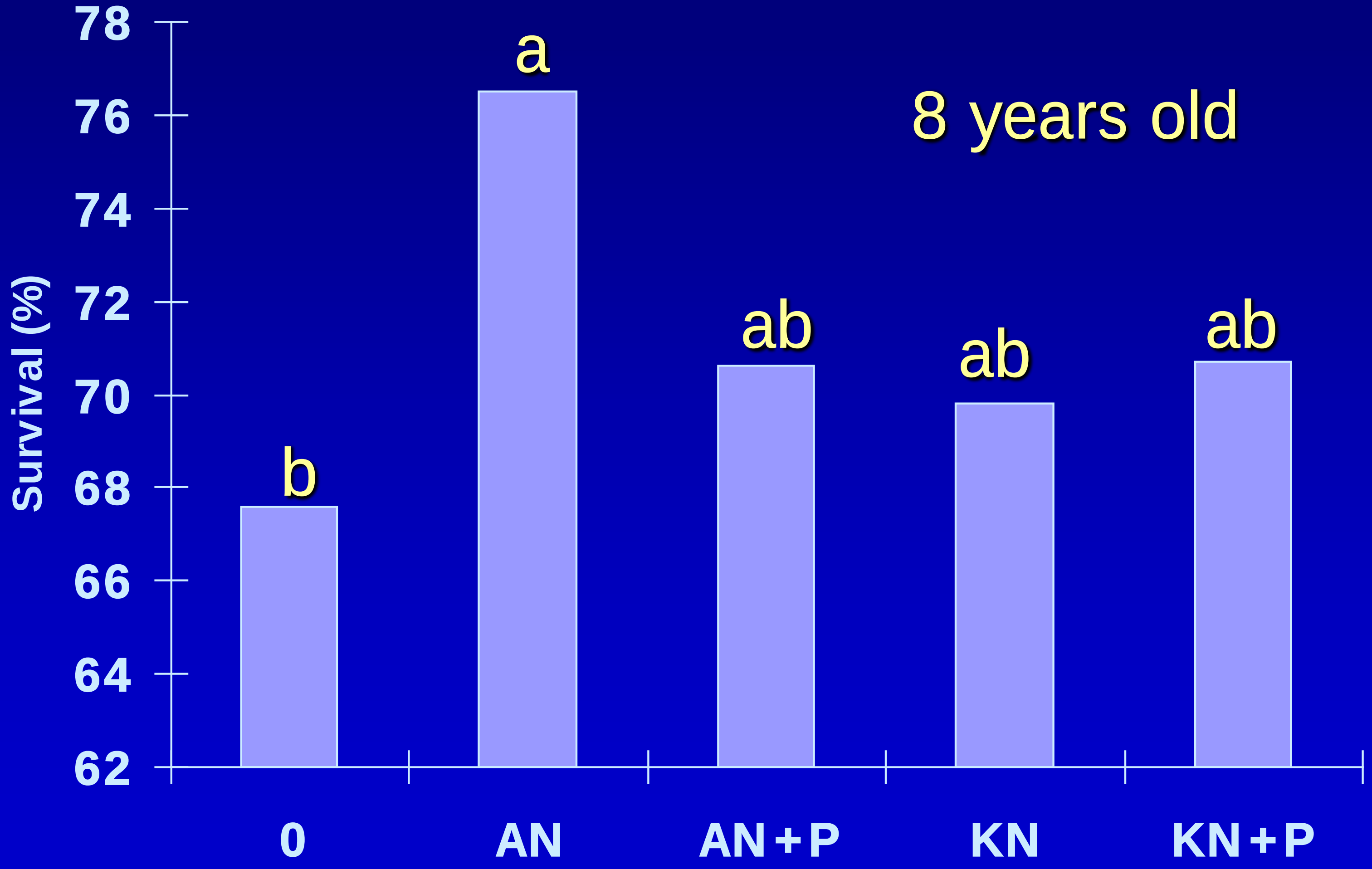
- Pre sowing
  250 lbs N
  80 lbs K
  2000 lbs of dolomitic limestone

- Ammonium nitrate 100 lbs N/acre

  350 lbs N/acre total

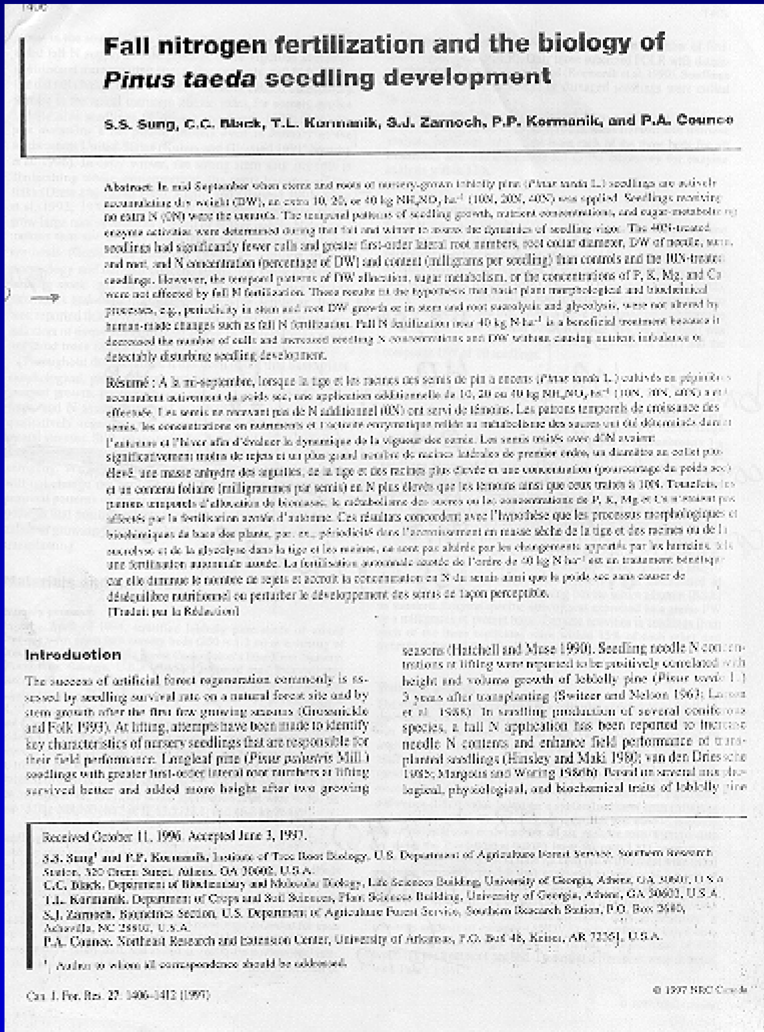
- **Fall treatments**
  150 lbs N or 300 lbs N/acre
  (AN or KNitrate) plus dolomitic limestone
  350 : 500 : 650 lbs N/acre

Longleaf - Fall Fertilization (nursery)
(Hinesley and Maki 1980: SJAF)



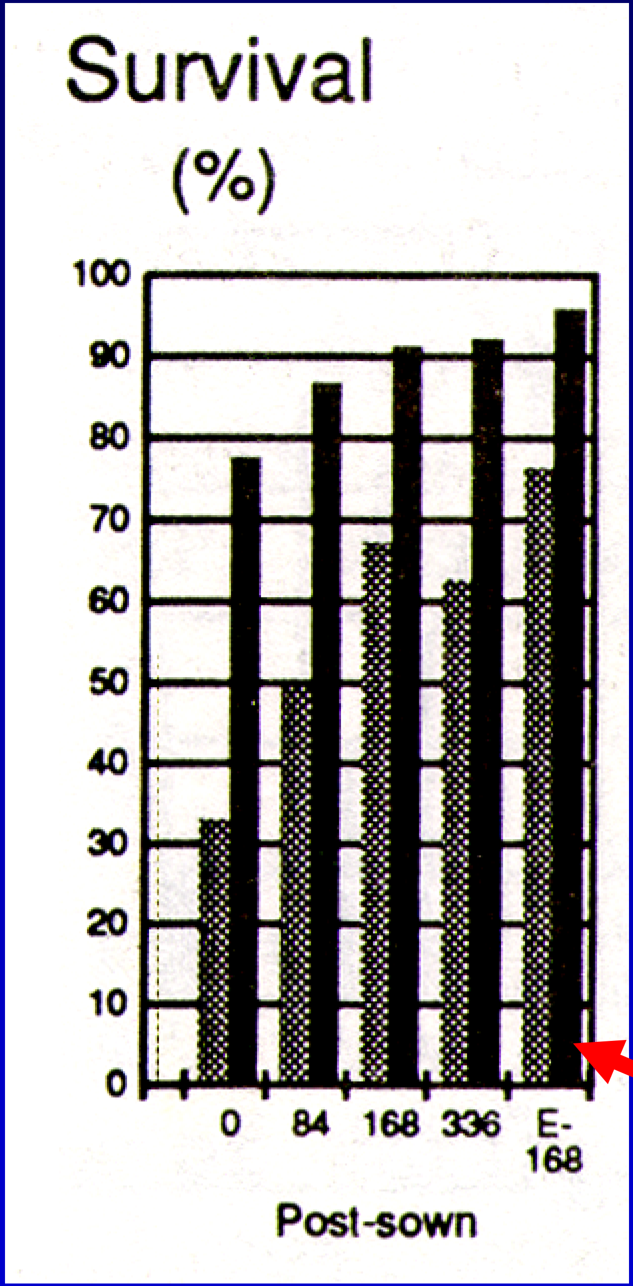
Loblolly - Georgia

(Sung et al. 1997: CJFR 27)



Although no field performance study was established, it is probable that the seedlings fertilized with 137 lbs of N/acre (May-Sept.) “will survive and grow better than the controls” that were fertilized with only 96 lbs of N/acre (May-Aug.).

Poor site



Loblolly - Texas

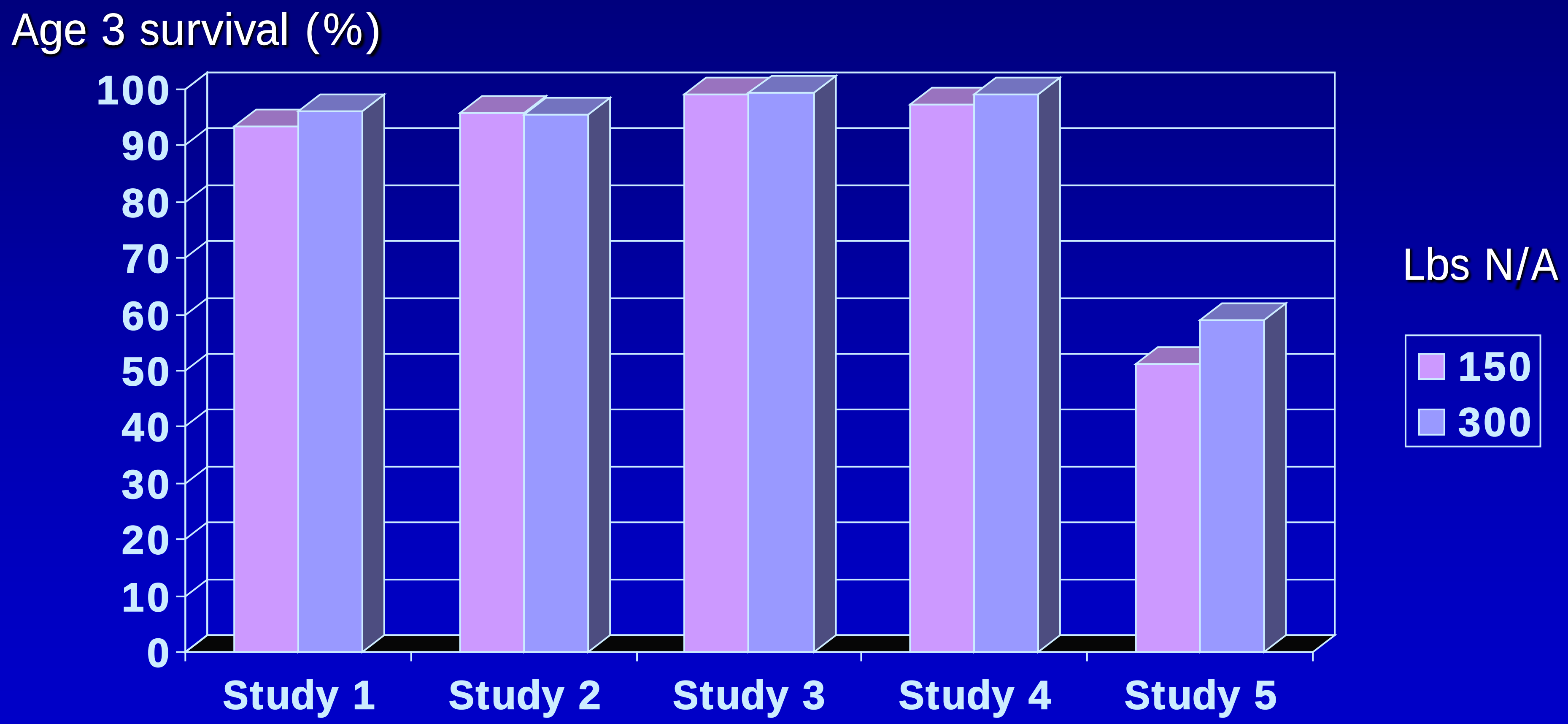
(Barber et al. 1991: BSSRC)

Post-sowing fertilization significantly increased survival on the poor site but had no effect on the good site. Pre-sowing fertilization had little effect on survival at both sites.

Weed control

Loblolly - Mississippi

(Switzer 1962: Phd)



Loblolly - Virginia
(Dierauf 1991: VDF OR #94)

		1 X Rate	2 X Rate	Extra cost per M
■	1981	270 lbs N/acre	540 lbs N/acre	11 cent more
■	1982	270 lbs N/acre	540 lbs N/acre	11 cents more
■	1983	300 lbs N/acre	600 lbs N/acre	12 cents more
■	1984	250 lbs N/acre	500 lbs N/acre	10 cents more
■	1985	270 lbs N/acre	540 lbs N/acre	11 cents more

- 0.5 inch of sawdust
- 1 inch of sawdust
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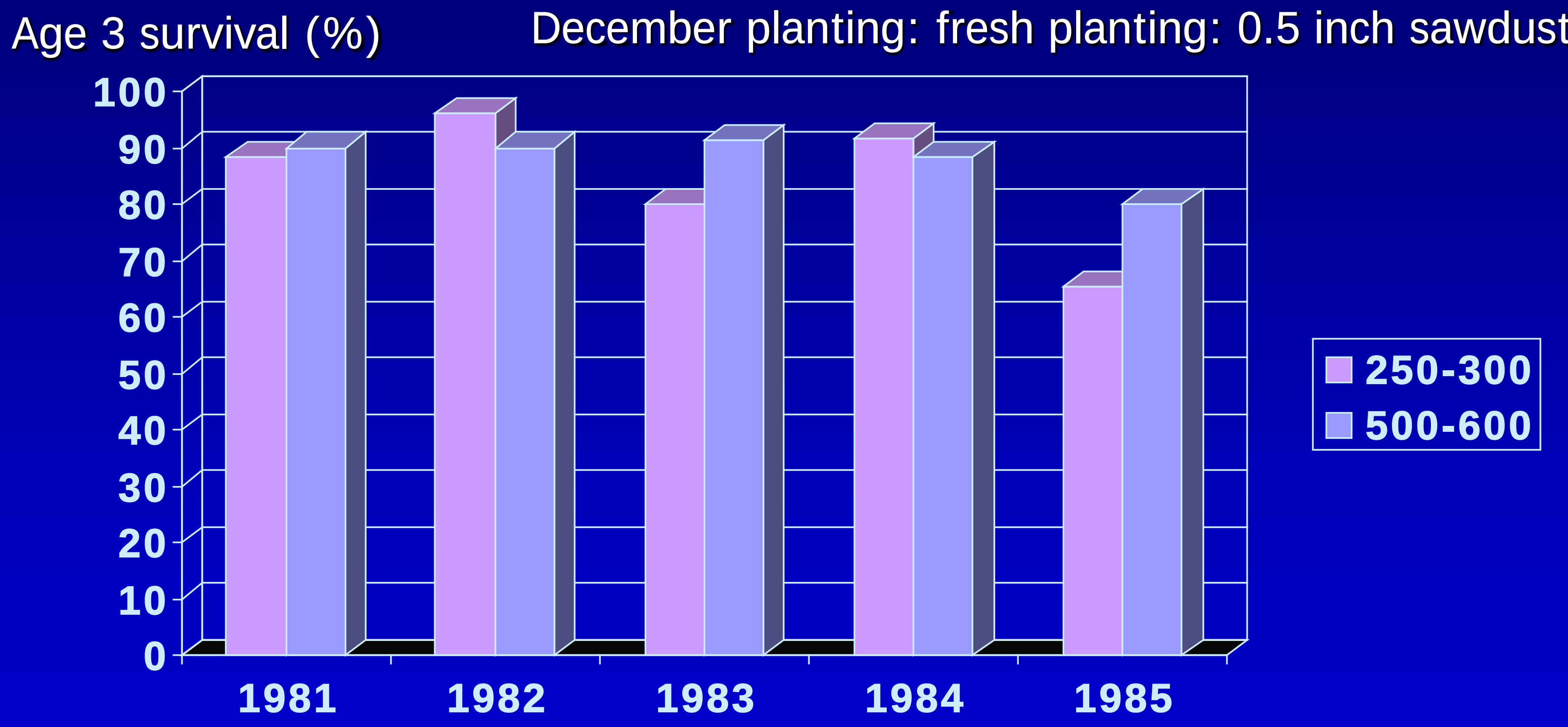
- top pruning in all years (2 times or 3 times)
- no top pruning included as a treatment in 1983, 1984, 1985

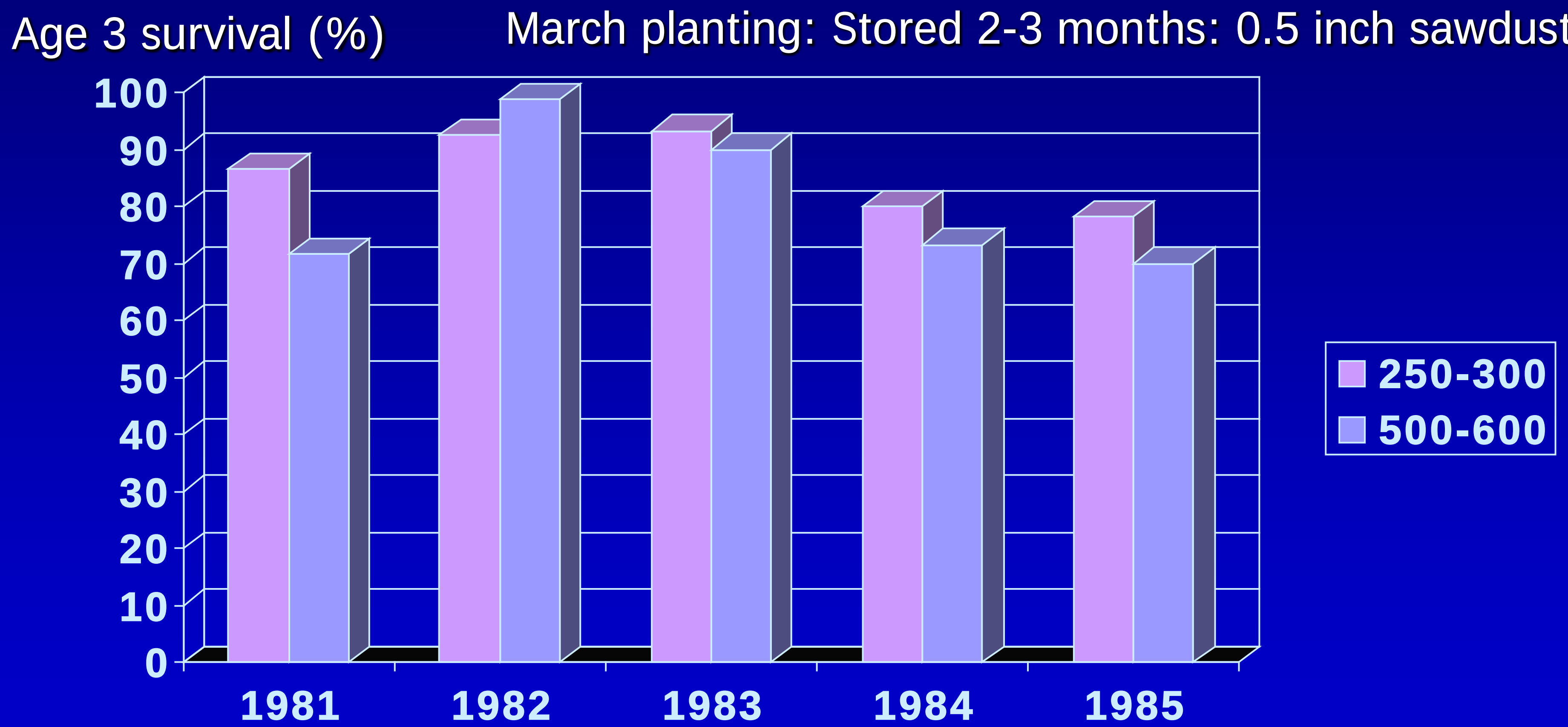
Loblolly - Virginia

(Dierauf 1991: VDF OR #94)



Loblolly - Virginia

(Dierauf 1991: VDF OR #94)



Fall applied nitrogen and slash pine

(Irwin et al. 1998: SJAF)

- Fall treatments
- Control
- 150 lbs ammonium nitrate - Nov 15 — 50 lbs N/acre
- 150 lbs ammonium nitrate - Nov 15 — 150 lbs N/acre
  150 lbs ammonium nitrate - Nov 29
  150 lbs ammonium nitrate - Dec 13

Fall applied nitrogen and slash pine

(Irwin et al. 1998: SJAF)

	Nitrogen per acre		
Variable	181 lbs	231 lbs	331 lbs
RCD	5.1	4.9	5.2
Ht	27	26	26
Shoot wt	4.5	3.9	4.4
Root wt	1.6	1.4	1.5

Fall applied nitrogen and slash pine
(Irwin et al. 1998: SJAF)

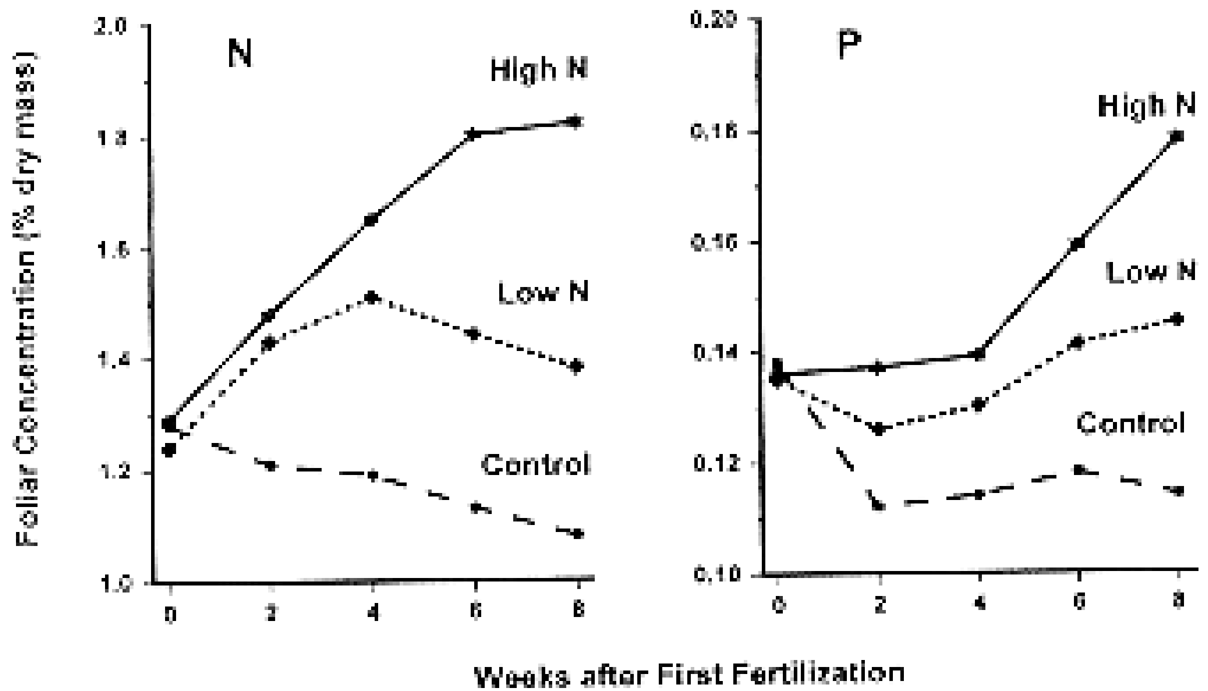


Figure 1. Foliar N and P concentrations during the 8 wk sampling period as affected by soil application of N only: low N—one application 57 kg N/ha on November 15, 1989; high N—three applications at 57 kg N/ha on November 15 and 29, and December 13.

Fall applied nitrogen and slash pine
(Irwin et al. 1998: SJAF)

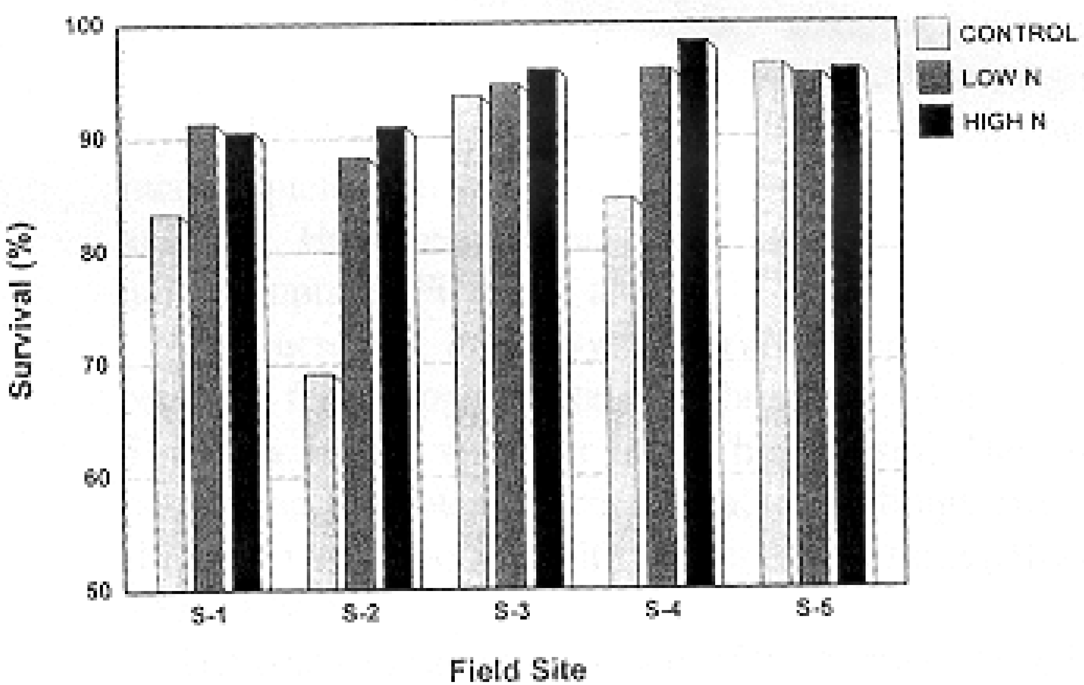
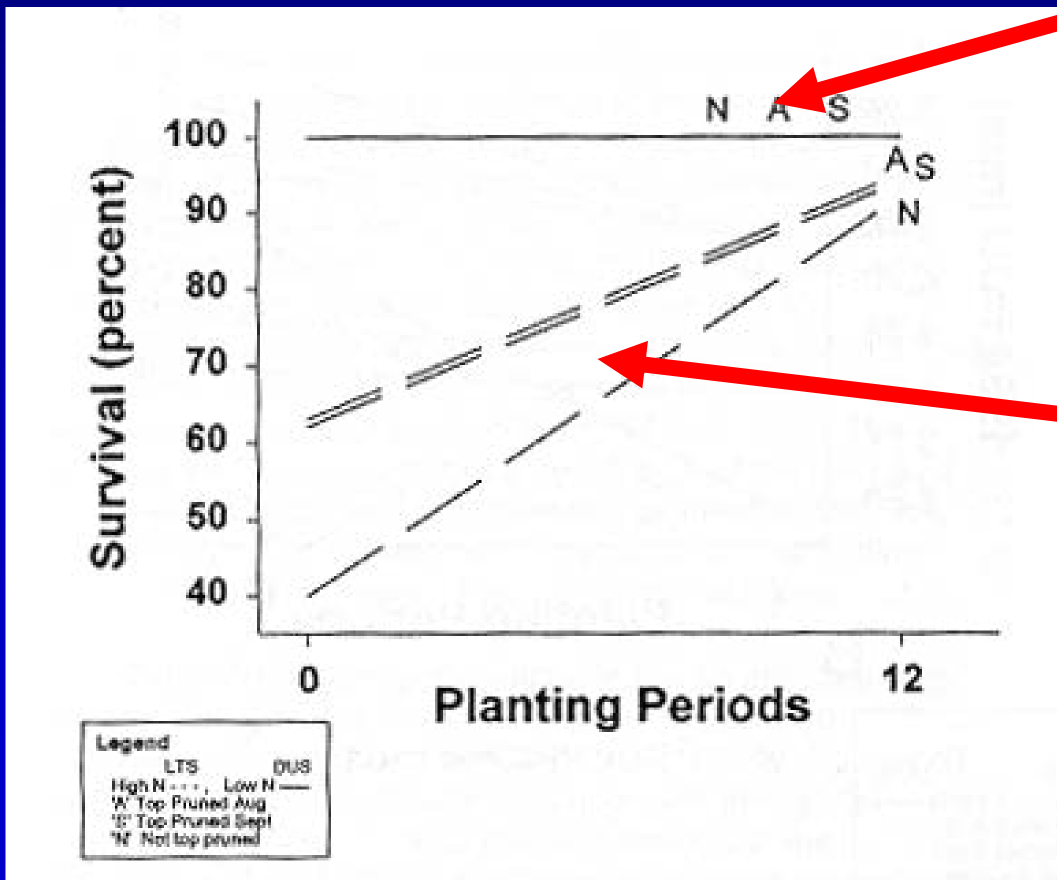


Figure 4. First-year survival of fertilized and unfertilized slash pine seedlings. Mean contrasts among treatments showed that survival of the N-fertilized seedlings, excluding site 5, was significantly higher than unfertilized ($P < 0.0001$).

Loblolly pine - Georgia

(Kormanik et al. 1999: GTR SRS-25)

Block 1: 75 Lb N/acre
No undercutting
Easy to plant due to small roots.
"well balanced" seedlings



Seedlings grown in raised beds at Athens, GA.

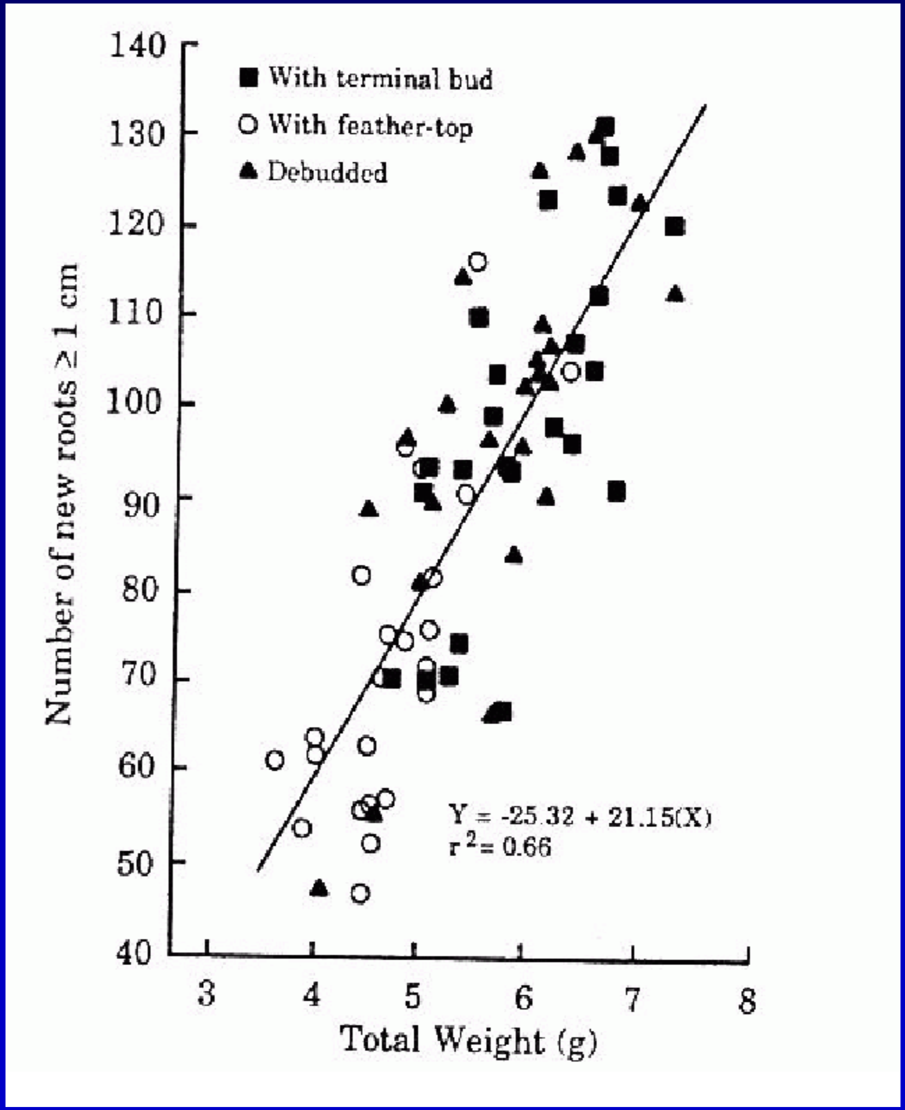
Block 2: 150 Lb N/acre
No undercutting
Difficult to hand plant properly due to large lateral roots. Seedlings were poorly balanced.
They were not "morphologically improved" due to high seedbed density (24-26/sq ft)

Summary

When seedling survival is high, there will be little or no fertilizer effect.

However, when grown at operational nurseries and planted on adverse sites, extra N in the nursery can sometimes increase survival by producing seedlings that are no taller but have larger root systems than N deficient seedlings.

Effect of N Fertilization on RGP



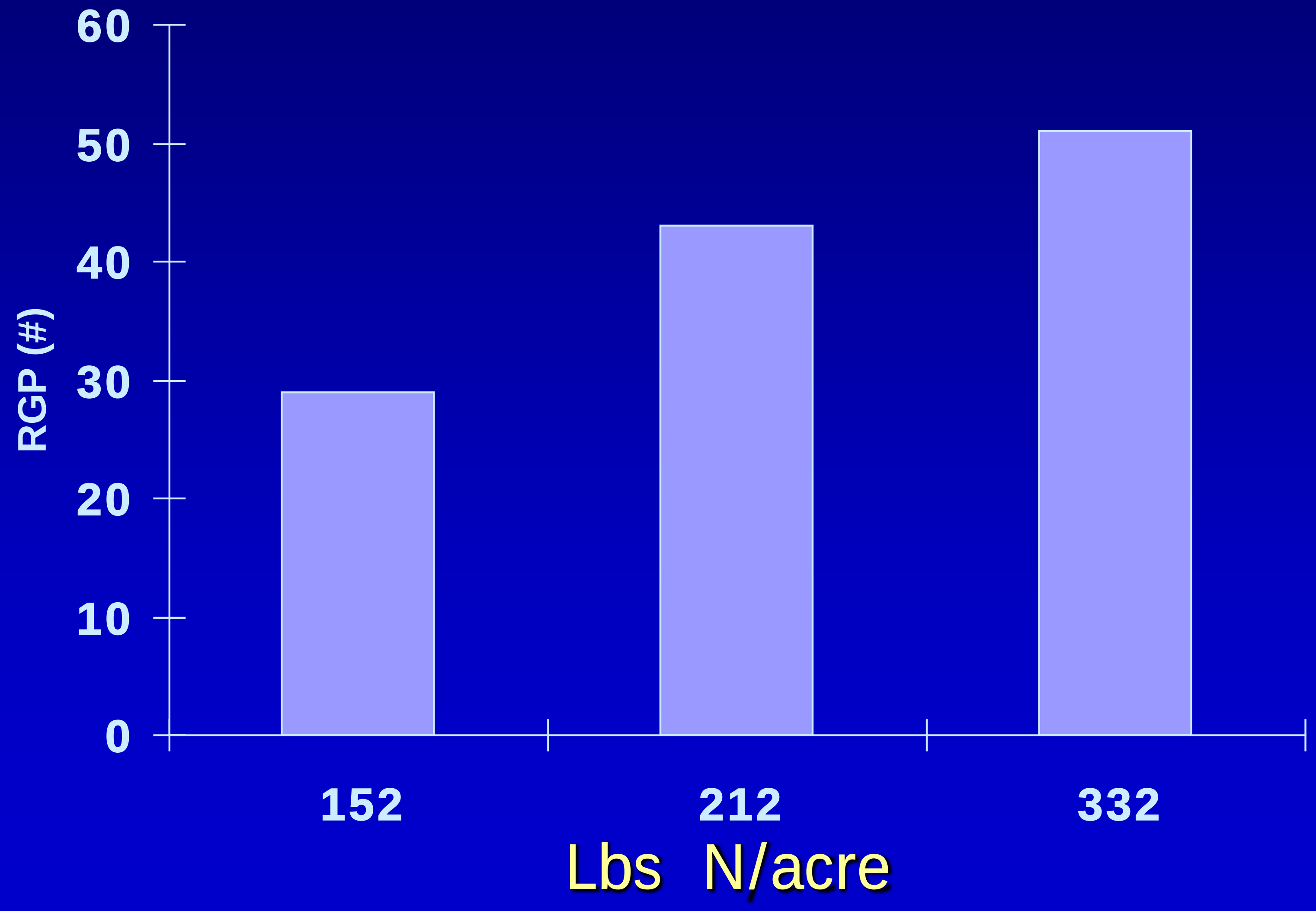
Williams, South and Glover 1988 CJFR

Loblolly pine - Fall Fertilization (containers)
(Williams and South 1994: 8th BSSRC)

- Growing season N
  152 lbs N/acre 20-20-20 and 15-30-15

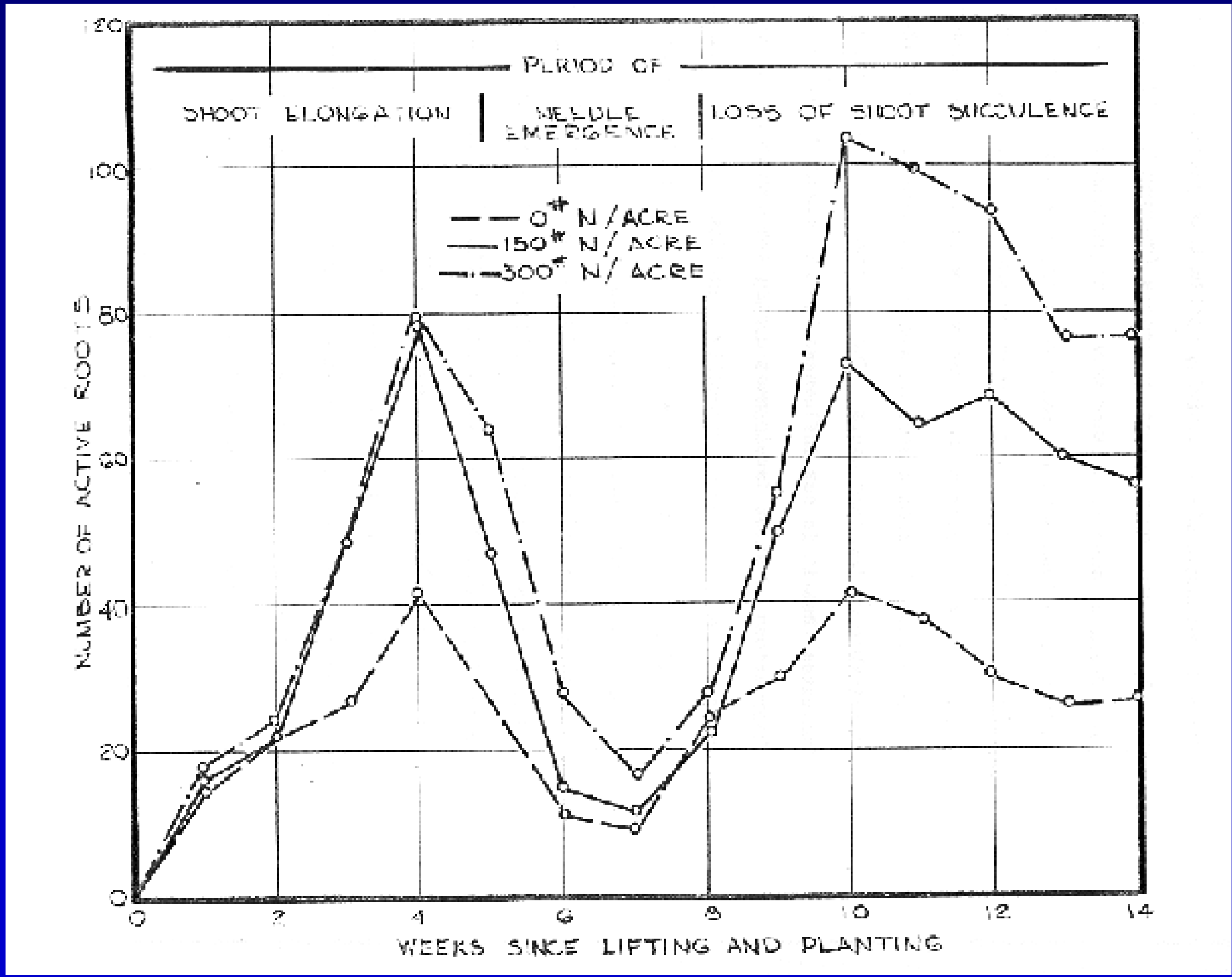
- Fall treatments
  control
  60 lbs N/acre (DAP)
  180 lbs N/acre (DAP)

Loblolly pine - Fall Fertilization (containers)
(Williams and South 1994: 8th BSSRC)



Loblolly - Mississippi

(Switzer 1962: Phd)



Summary

If the environmental conditions are good and seedling survival is high, then there will be little or no differences in survival among fertilizer treatments.

However, when conditions are stressful and seedling mortality is moderate, those seedlings that have higher root-growth will likely survive better than seedlings that are deficient in N at time of outplanting. In some cases "deficient" means levels below 1.4% N in December.

Effect of Fertilization on short-term growth

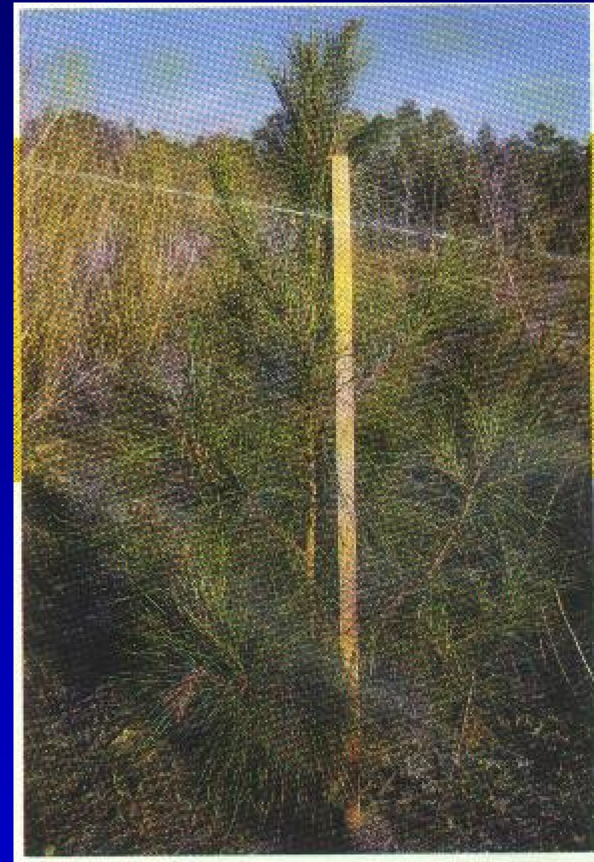


FIG. 3. First-year height of a seedling from the high nitrogen fertilization regime, approximately 6.5 mm in root collar diameter, and planted on a site receiving herbaceous weed control. The measurement standard is 3.2 ft.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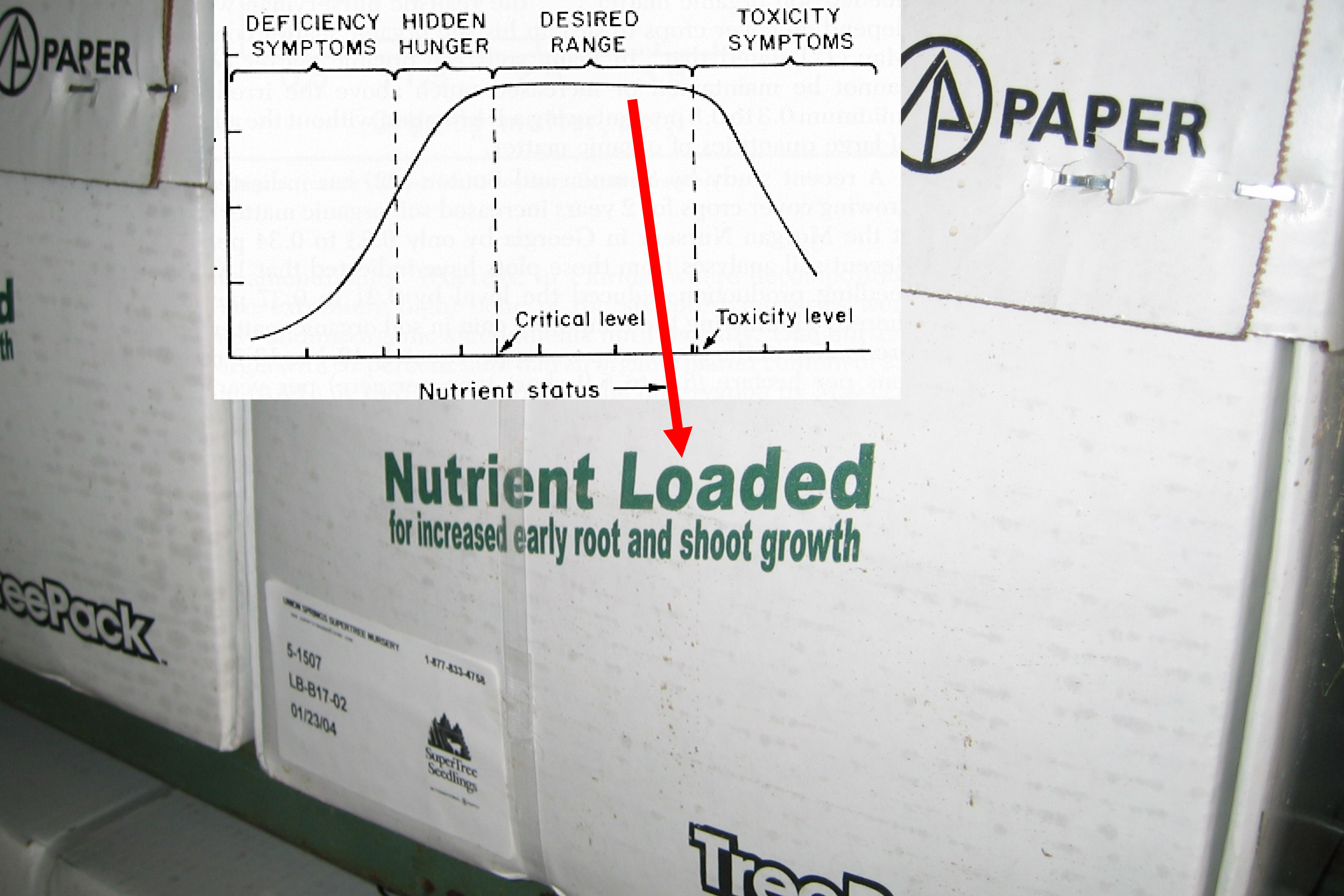
DEFICIENCY SYMPTOMS
HIDDEN HUNGER
DESIRED RANGE
TOXICITY SYMPTOMS
Critical level
Toxicity level
Nutrient status
PAPER
PAPER
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for increased early root and shoot growth
UNION SPRINGS SUPERTREE NURSERY
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LB-B17-02
01/23/04
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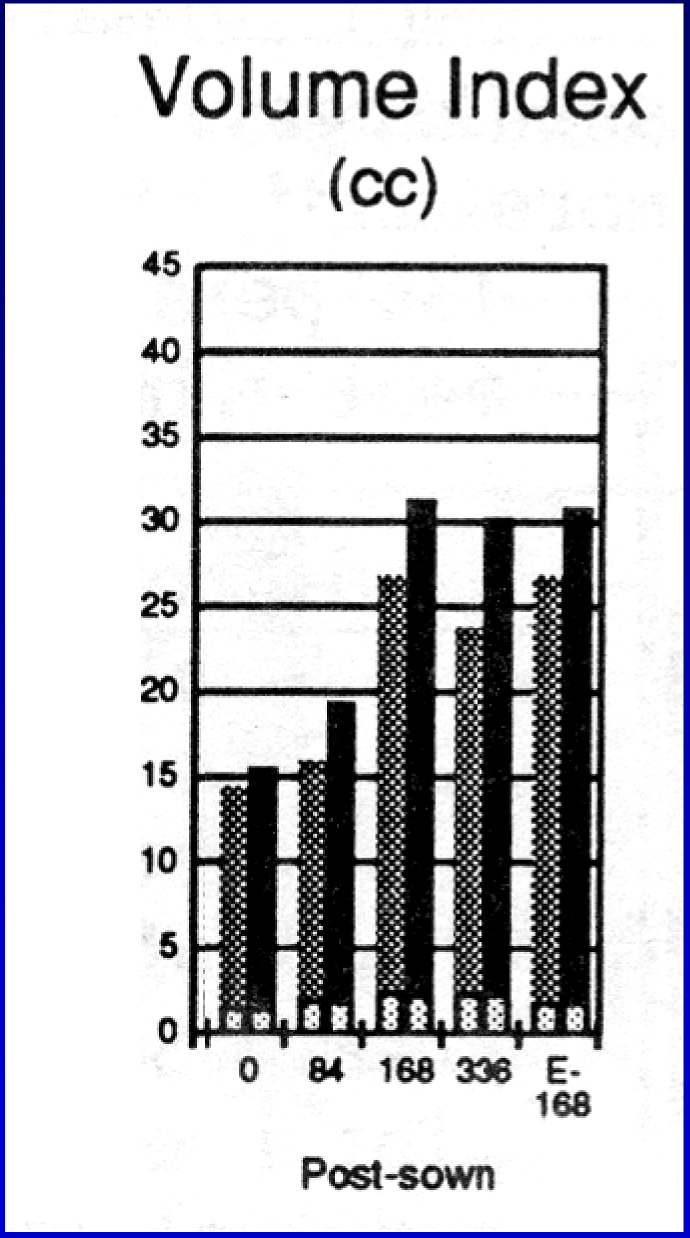


Loblolly - Texas

(Barber et al. 1991: BSSRC)

Post-sowing fertilization had a positive impact on first-year size of the seedlings: however, use of initial seedling size as a covariate reduced statistical significance in most cases.

Extra Nursery study - Loblolly

(Blake and South 1990: Highlights)

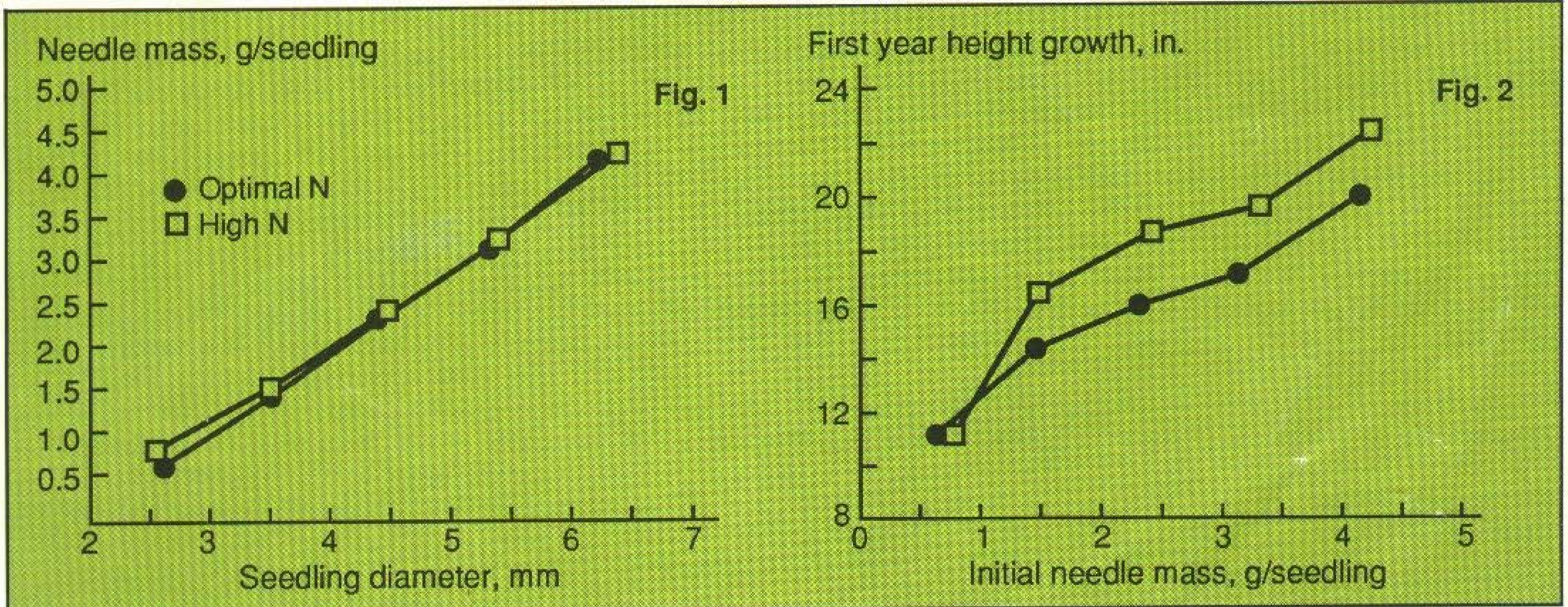


FIG. 1. Average relationships between needle mass of weight and seedling diameter at outplanting for two nursery nitrogen regimes: a nitrogen fertilization rate adequate for seedling development (Optimal N) and a rate 50% greater than needed for best nursery growth (High N).
FIG. 2. Average relationship among first-year growth after planting in the field, needle mass or weight, and previous nursery N regime.

Fall applied nitrogen and slash pine

(Irwin et al. 1998: SJAF)

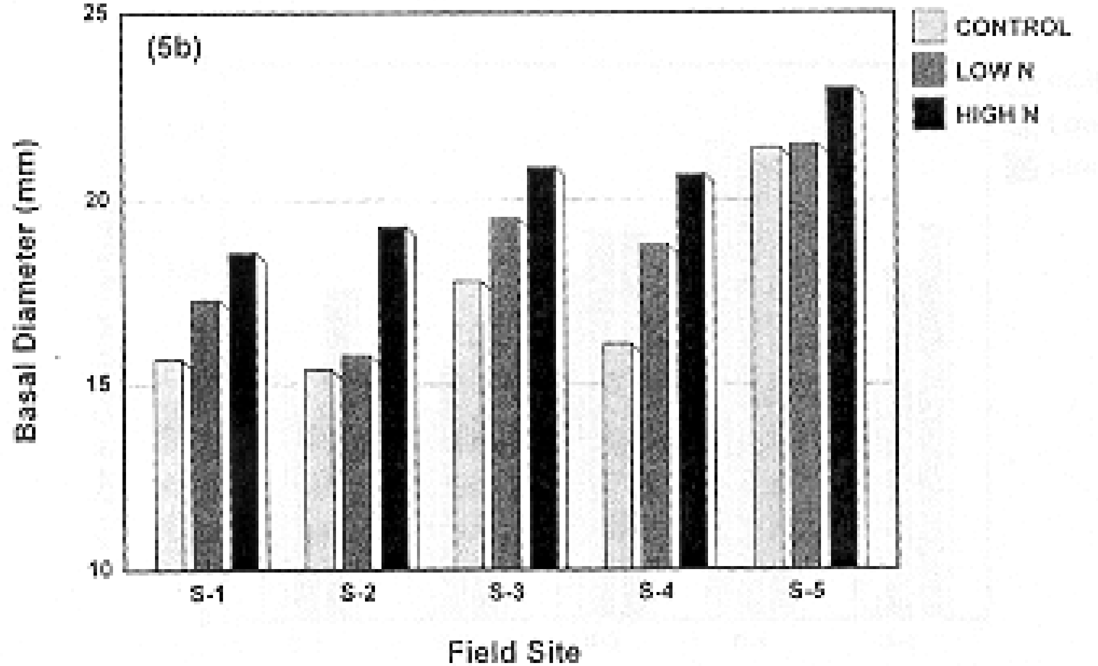


Figure 5. Total height (a) and stem diameter (b) of late N-fertilized and unfertilized slash pine seedlings 1 yr after planting. Mean contrasts for both height and diameter, showed N-fertilized seedlings were significantly higher than unfertilized ($P < 0.0001$).

20 Nursery study - Loblolly
(Larsen et al. 1988: SJAF)

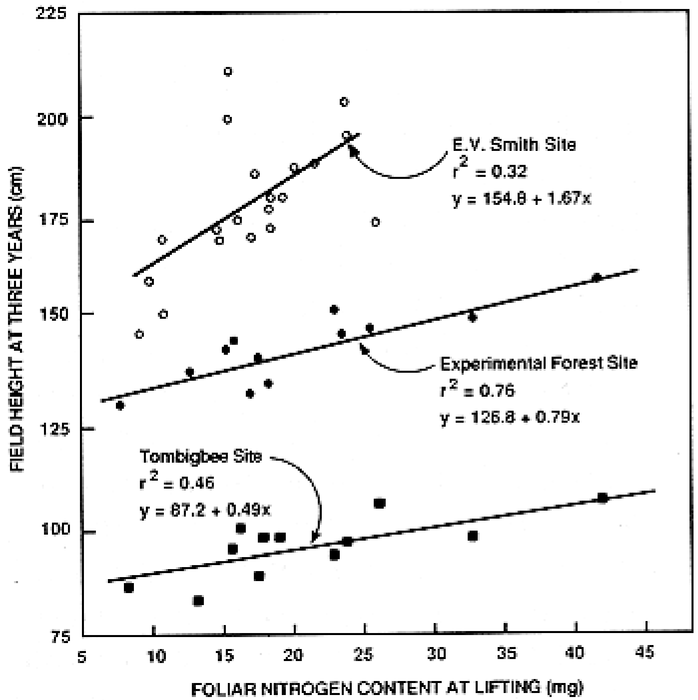


Figure 1. The relationship between third-year field height and foliar nitrogen content (mg/seedling) at lifting for the E. V. Smith Research Center site in Macon County, AL, the Experimental Forest site in Oktibbeha County, MS, and the Tombigbee site in Lowndes County, MS. (Solid symbols from 1957 outplantings by Switzer and Nelson 1963.)

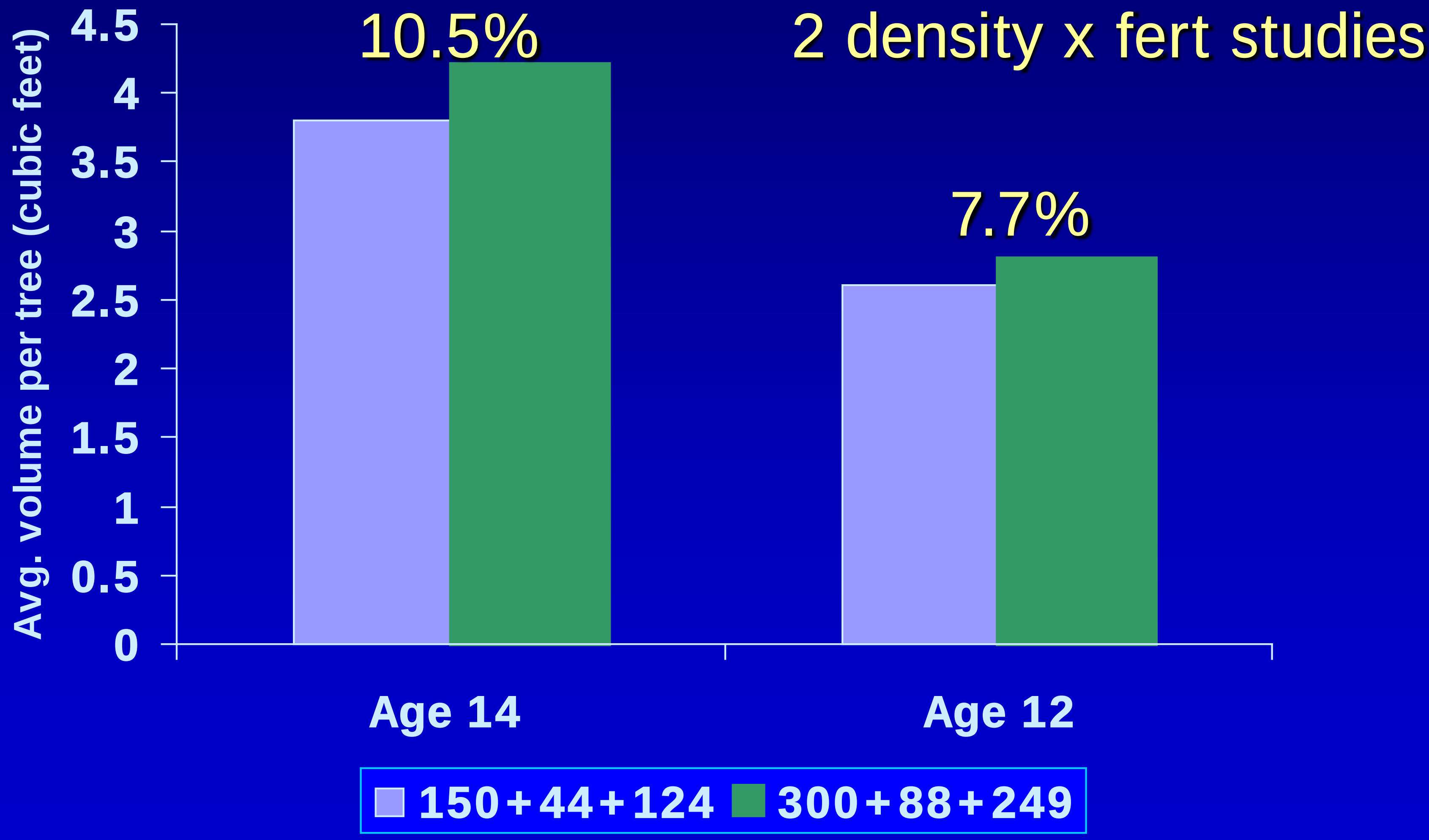
Summary

Applying extra N in the nursery in the nursery can increase early growth on some sites. This early growth can sometimes be attributed to simply producing seedlings with larger RCD, larger roots and more foliage. Dr. Lee Allen says “Resources grow leaves…. Leaves grow trees.”

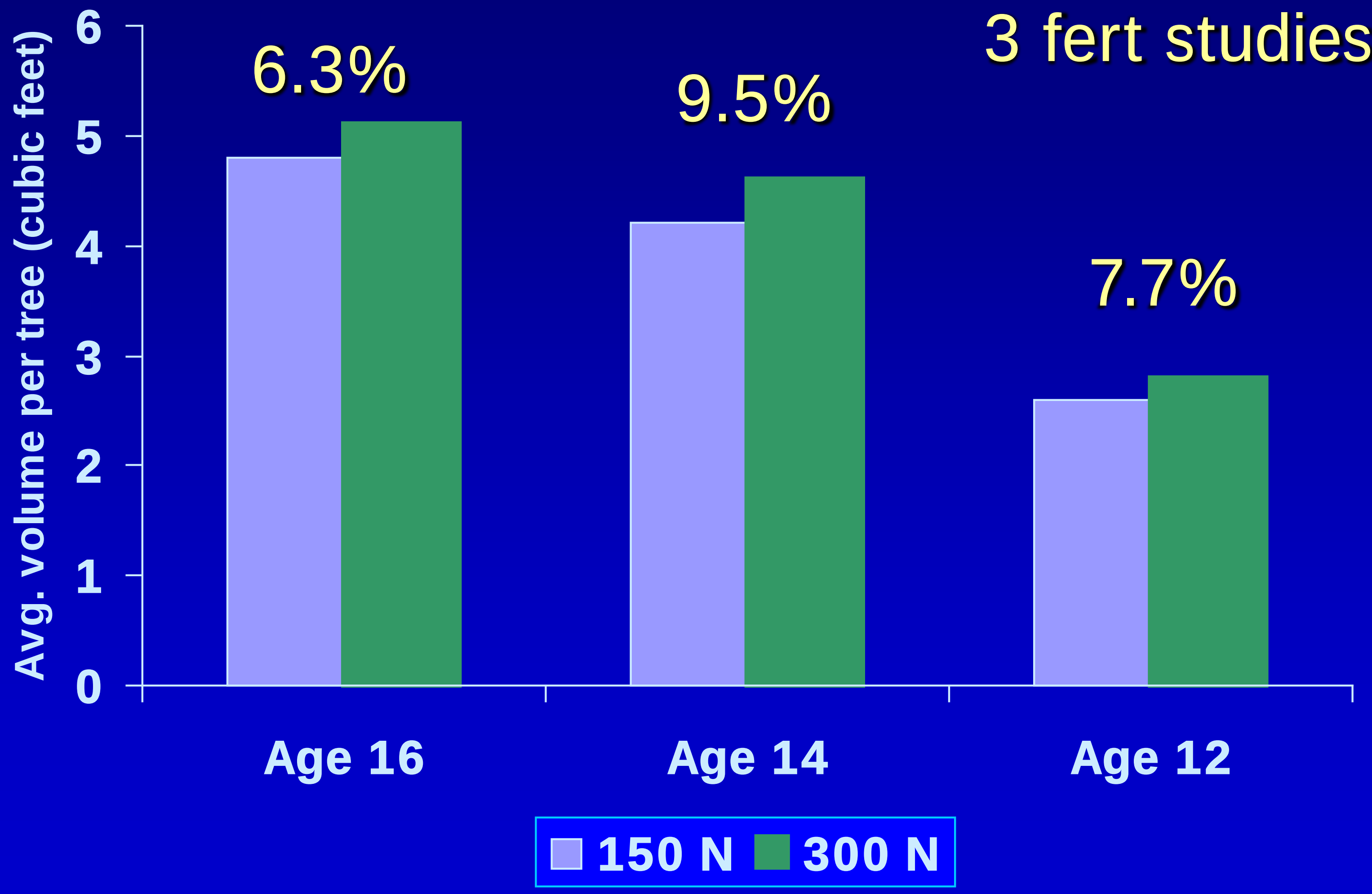
However, in some cases, extra growth appears to be related just to increases in nitrogen concentrations in the foliage. This suggests that early growth may be a function of both more leaves and higher foliar N.

Effect of Fertilization on Long-term growth

Loblolly - Fertilization (nursery)
(Autry 1972: MS thesis)



Loblolly - Fertilization (nursery)
(Autry 1972: MS thesis)



Loblolly - Fertilization (nursery)
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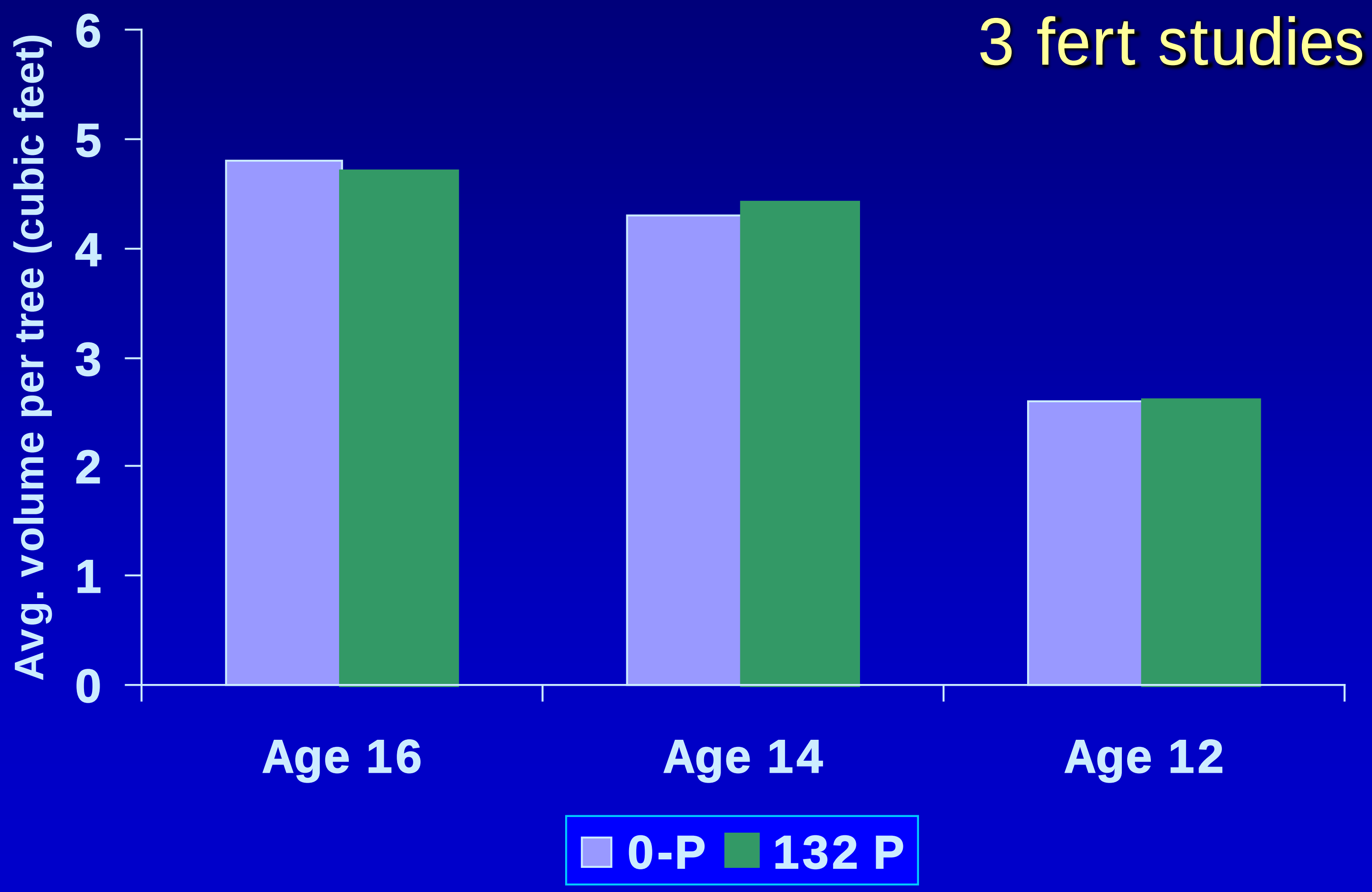
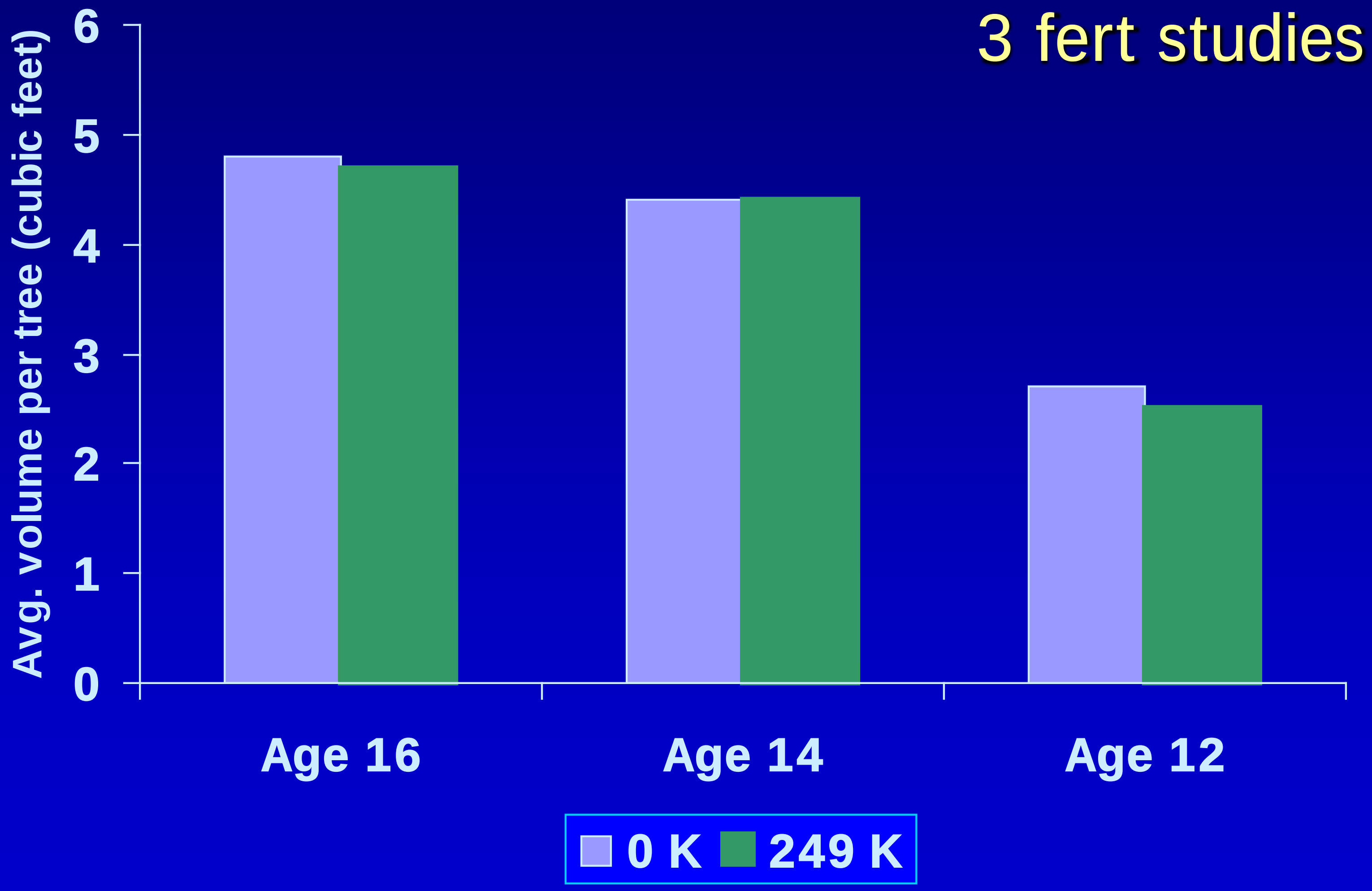


Loblolly - Fertilization (nursery)
(Autry 1972: MS thesis)



Loblolly - Fertilization (nursery)
(Autry 1972: MS thesis)

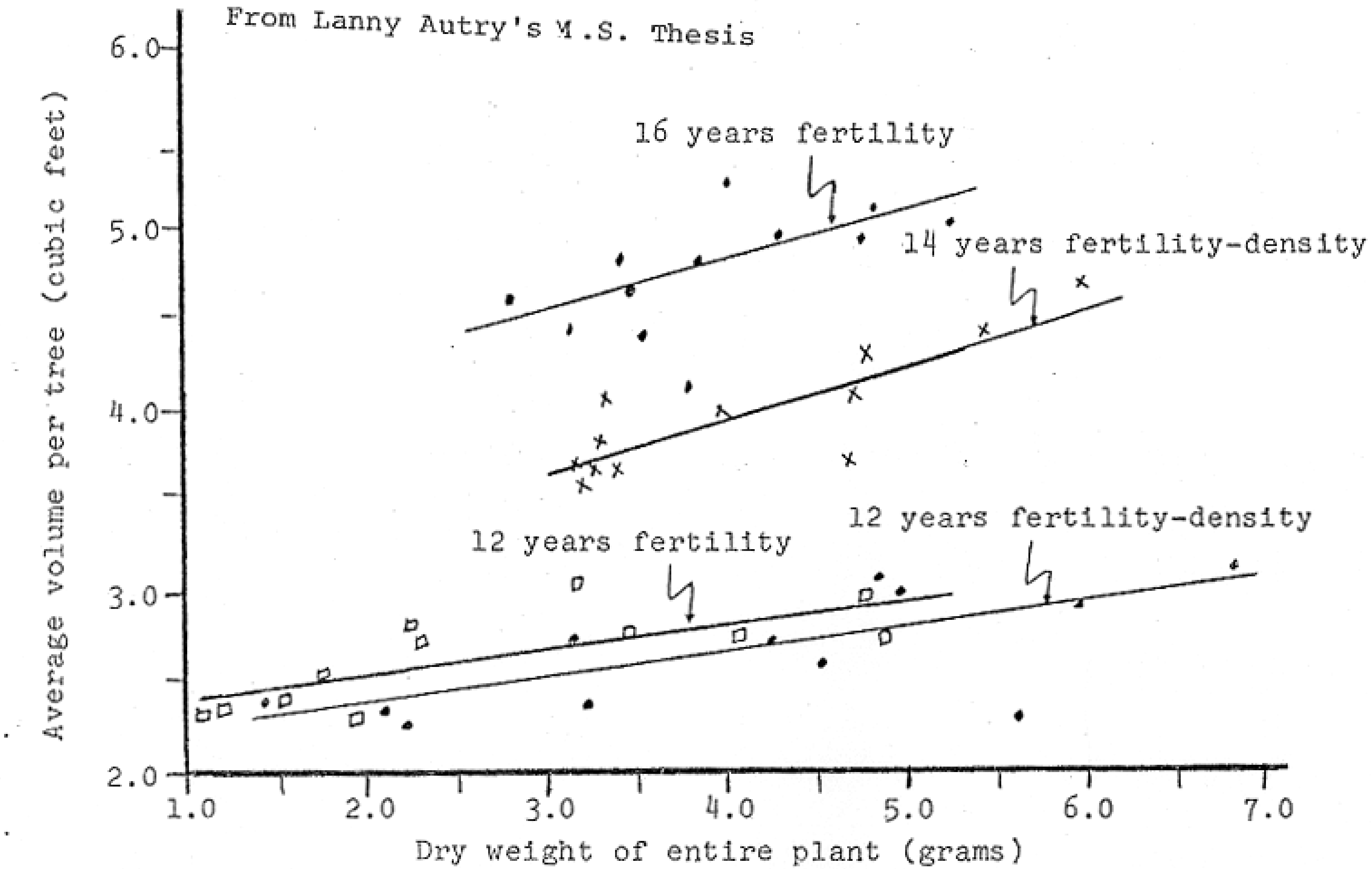
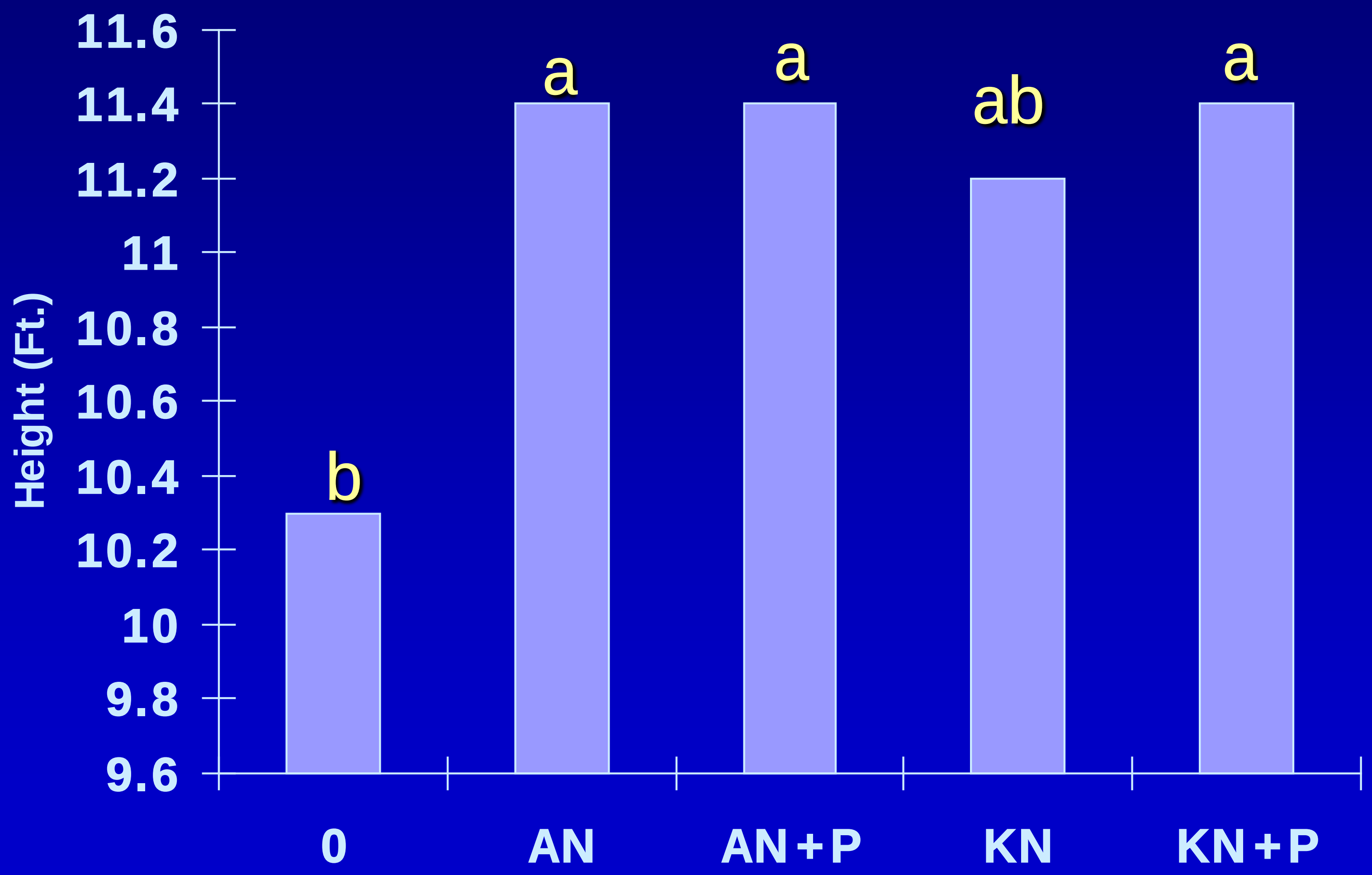


Figure 4. The relation of total dry weight of the seedlings at lifting to average volume per tree at the end of the indicated field seasons.

Longleaf - Fall Fertilization (nursery)
(Hinesley and Maki 1980: SJAF)

8 years old



Loblolly - Virginia

(Dierauf and Chandler 1995: VDF OR #121)

	RCD	Top	Density
	mm	Inch	#/sq ft
150 lbs	5.1	9.8	18.4
300 lbs	5.3	10.1	18.8
450 lbs	5.1	8.9	18.6

Loblolly - Virginia

(Dierauf and Chandler 1995: VDF OR #121)

Age 7 data N.S.

N rate	Survival	DBH	HT	D*D*Ht	
	%	Inch	Ft		
150 lbs	88.8	3.8	20.2	2.025	
300 lbs	85.6	3.9	20.7	2.186	7.9%
450 lbs	90.6	4.0	20.8	2.197	8.5%

Summary

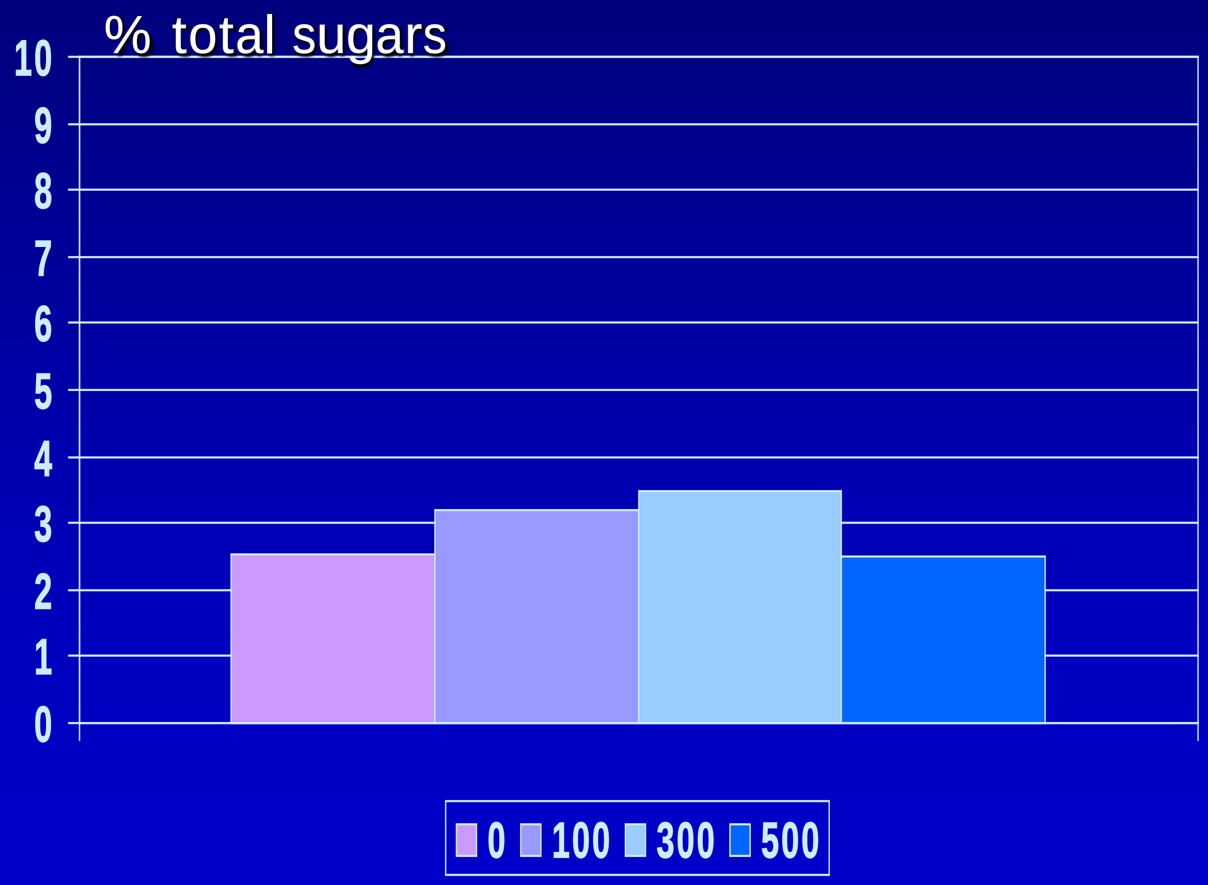
On some sites, extra N in the nursery can increase tree volume 7 to 16 years after planting. This long-term effect is likely not due to a persistent "treatment effect" but due instead to simply getting the trees "up and going" sooner.

No long-term benefit should be expected in situations where extra N (applied in the nursery) does not improve early growth in the field.

Extra K Fertilization in the nursery has little benefit for Survival and Early Growth

White spruce - Wisconsin

(Kopitke 1941: JOF)



Lbs K_2O/A
(as KCl in August)

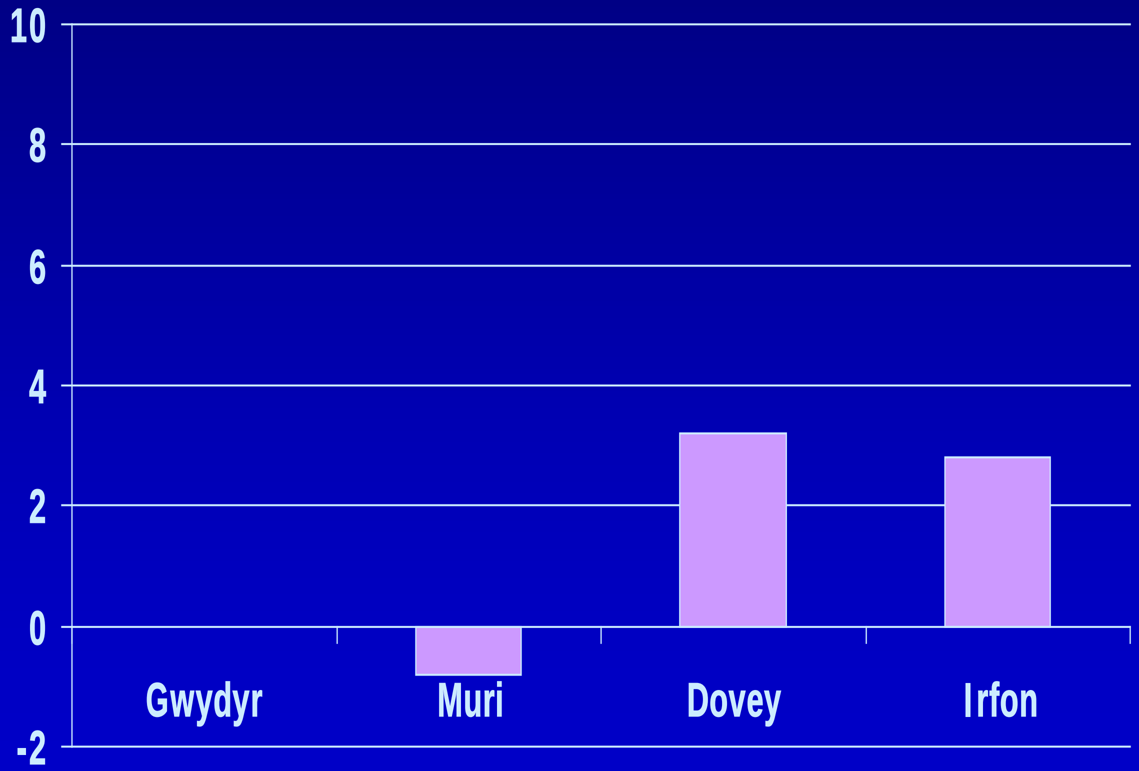
"Timely correction of potash deficiency are recommended as a prerequisite for production of frost resistant nursery stock."

(no freeze tests conducted on whole seedlings)

Sitka spruce - UK

(Benzian 1974: Forestry)

Increase in 1st yr growth (cm)

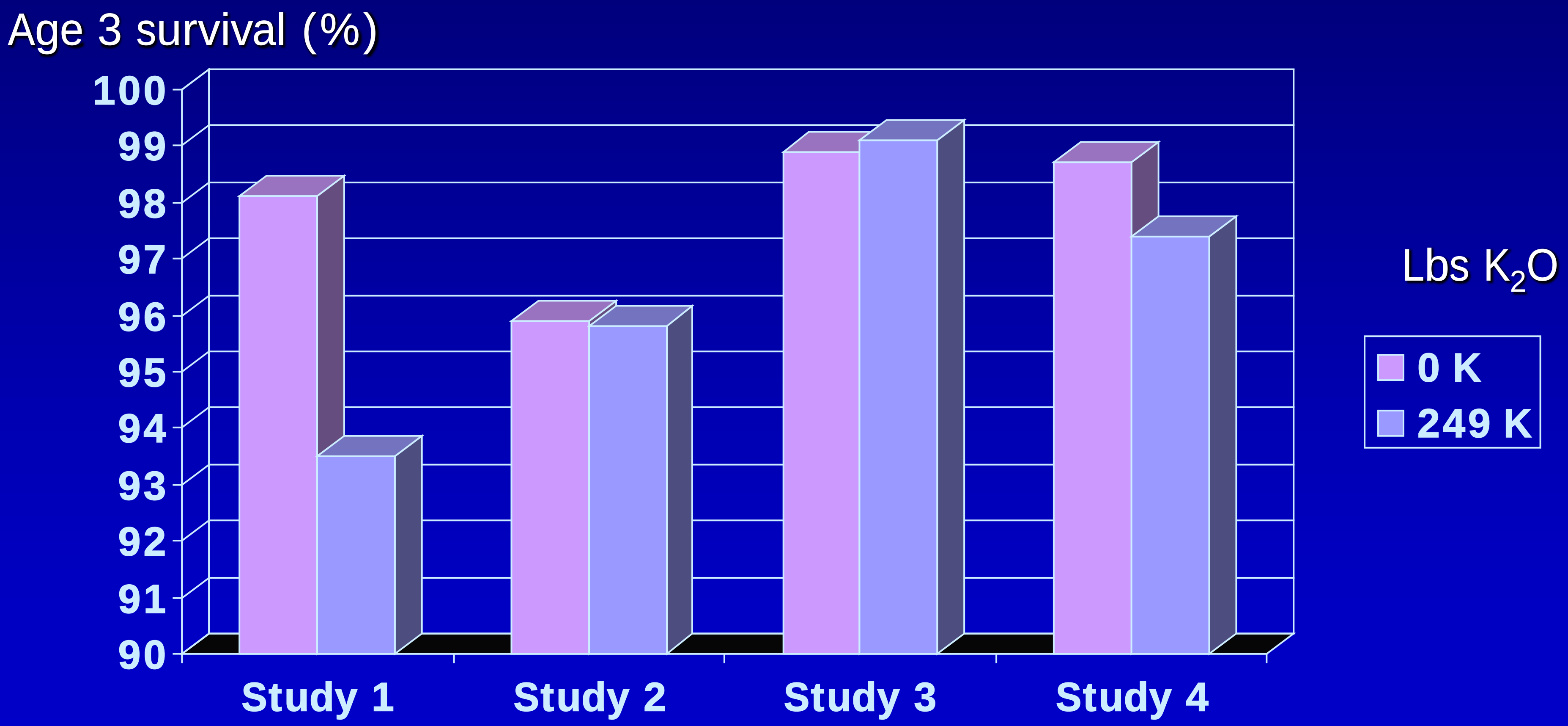


125 Lbs K/A (as KsSO4 in September)

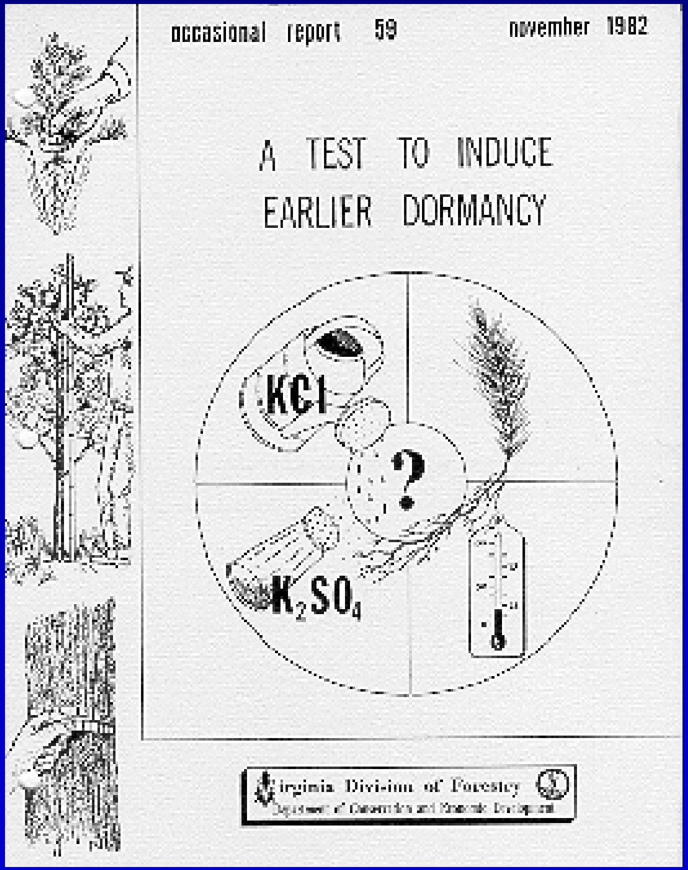
"In the few experiments which tested late-season potassium in the nursery, K concentrations were increased from deficiency to barely sufficiency level: growth in the forest was increased in 2 of the 4 experiments. The extra K had no effect on frost damage."

Loblolly - Mississippi

(Switzer 1962: Phd)



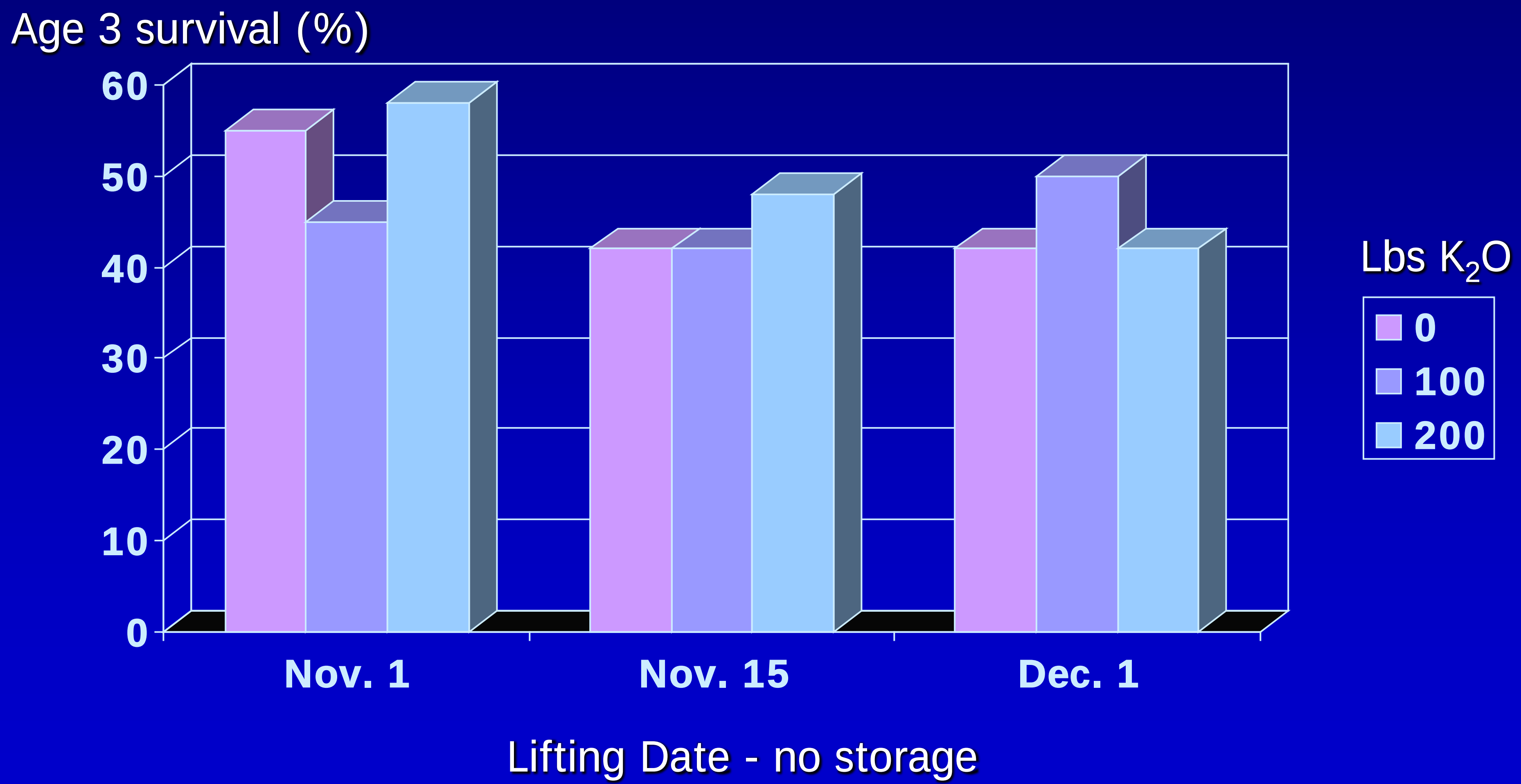
Loblolly - Virginia
(Dierauf 1982: VDF OR #59)



Potassium fertilizer applied in mid-September had the reverse effect of what we expected. But we were only looking at one aspect: whether potash would cause seedlings to become dormant earlier in the fall

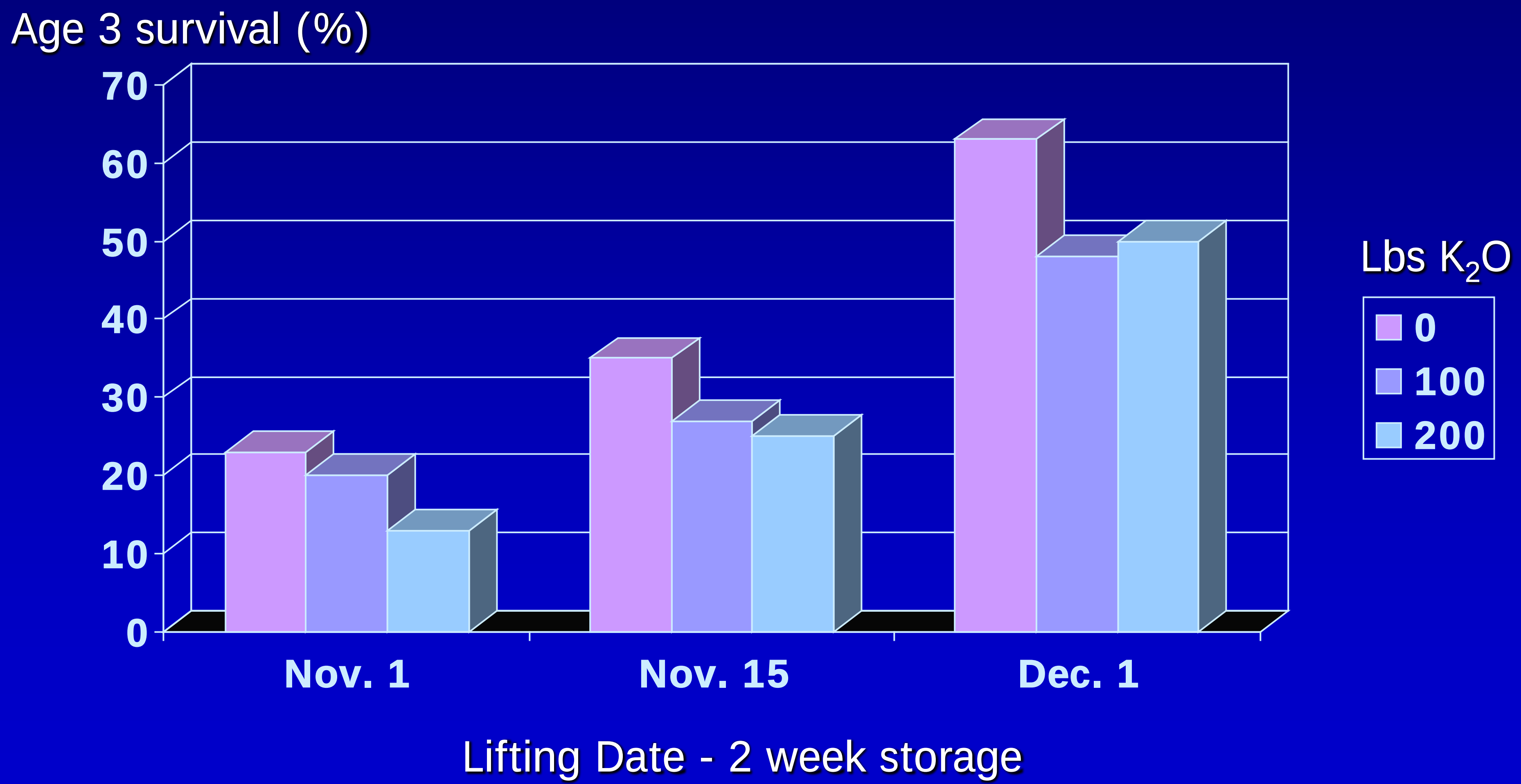
Loblolly - Virginia

(Dierauf 1982: VDF OR #59)

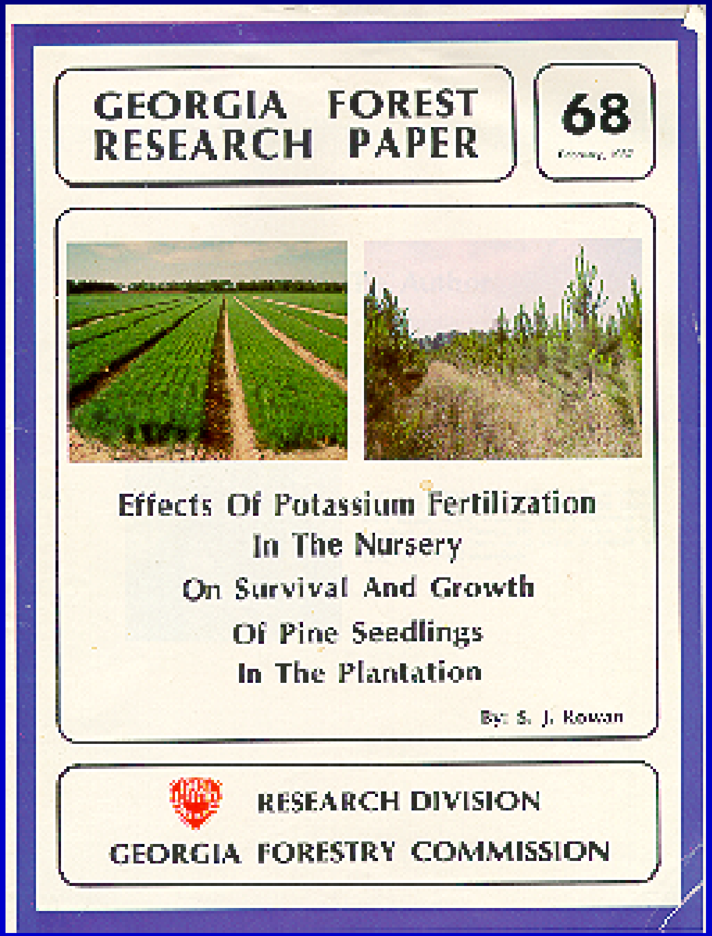


Loblolly - Virginia

(Dierauf 1982: VDF OR #59)



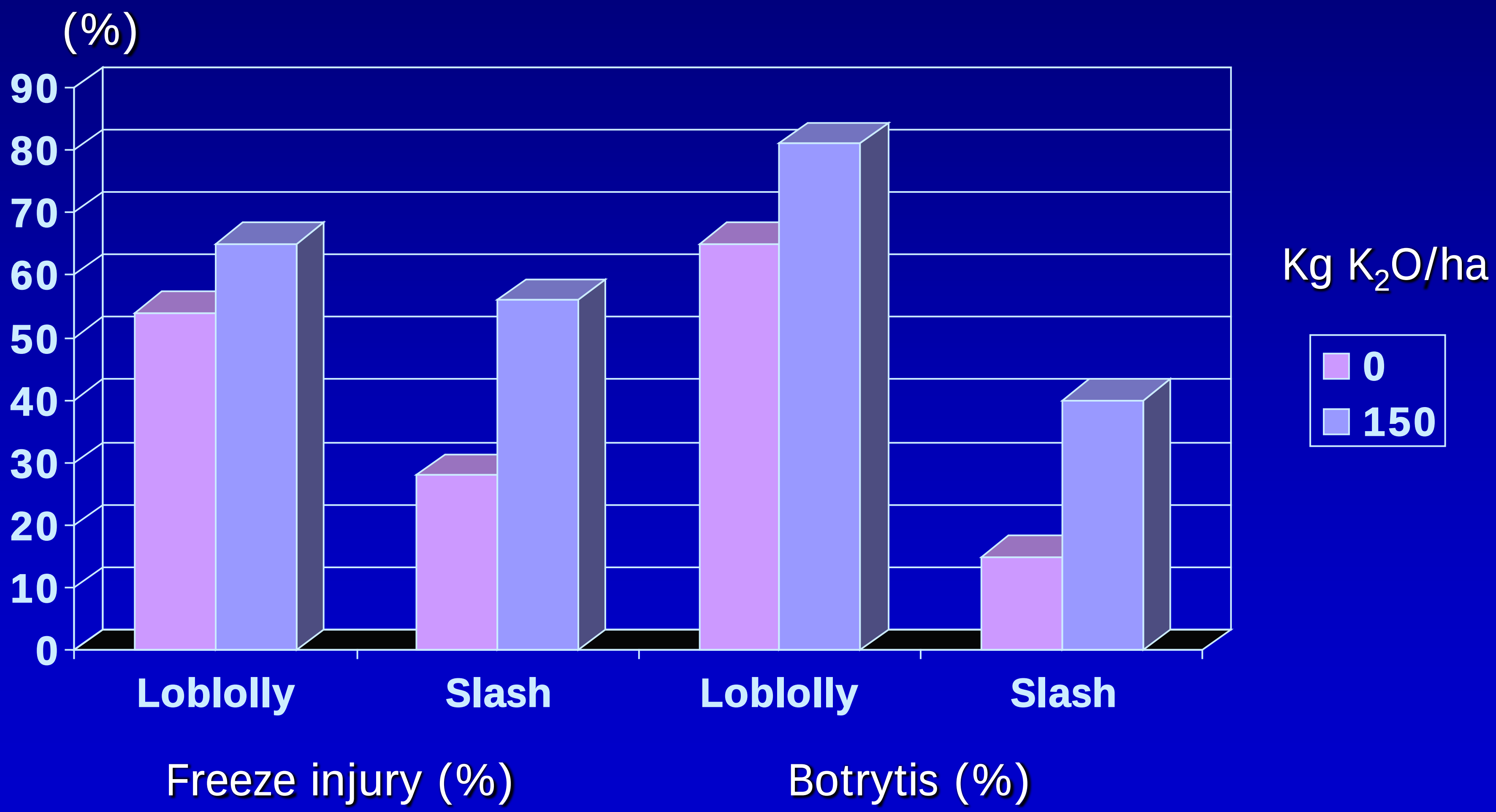
Loblolly - Georgia
(Rowan 1987: GFC #68)



Potassium source, rate, frequency, nor date of application affected winter bud formation, resistance to artificial freezing temperatures, or seedling size in the nursery. Seedling growth, survival and disease in outplantings were not affected

Loblolly - Slash - Alabama

(South et al. 1993: SAFJ#166)



Summary

K should be applied to avoid a deficiency. However, for the southern pines, there is no evidence that providing extra K to seedlings increases freeze resistance or promotes the formation of terminal buds.

Predictions for the Future

Regeneration foresters will become increasingly interested in improving early field growth by planting seedlings that are not deficient in N

A very cheep investment in improving seedling quality

- When managers apply 300 lbs of N per acre/yr (operational now at some nurseries), the extra cost of fertilizers will amount to only 4 cents per outplanted acre!!!!!!!