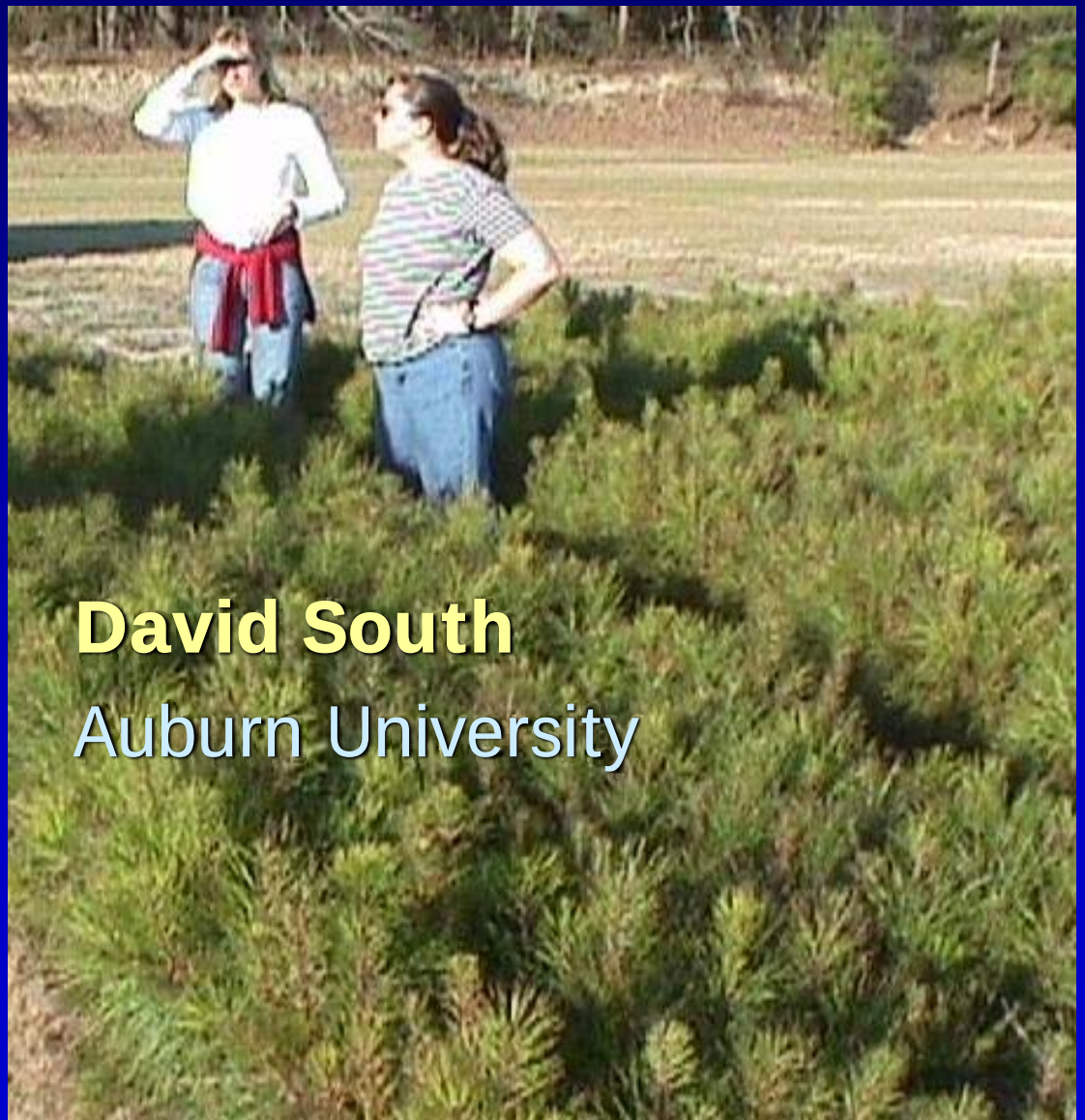
Seedling Size and Nursery Spacing



David South
Auburn University

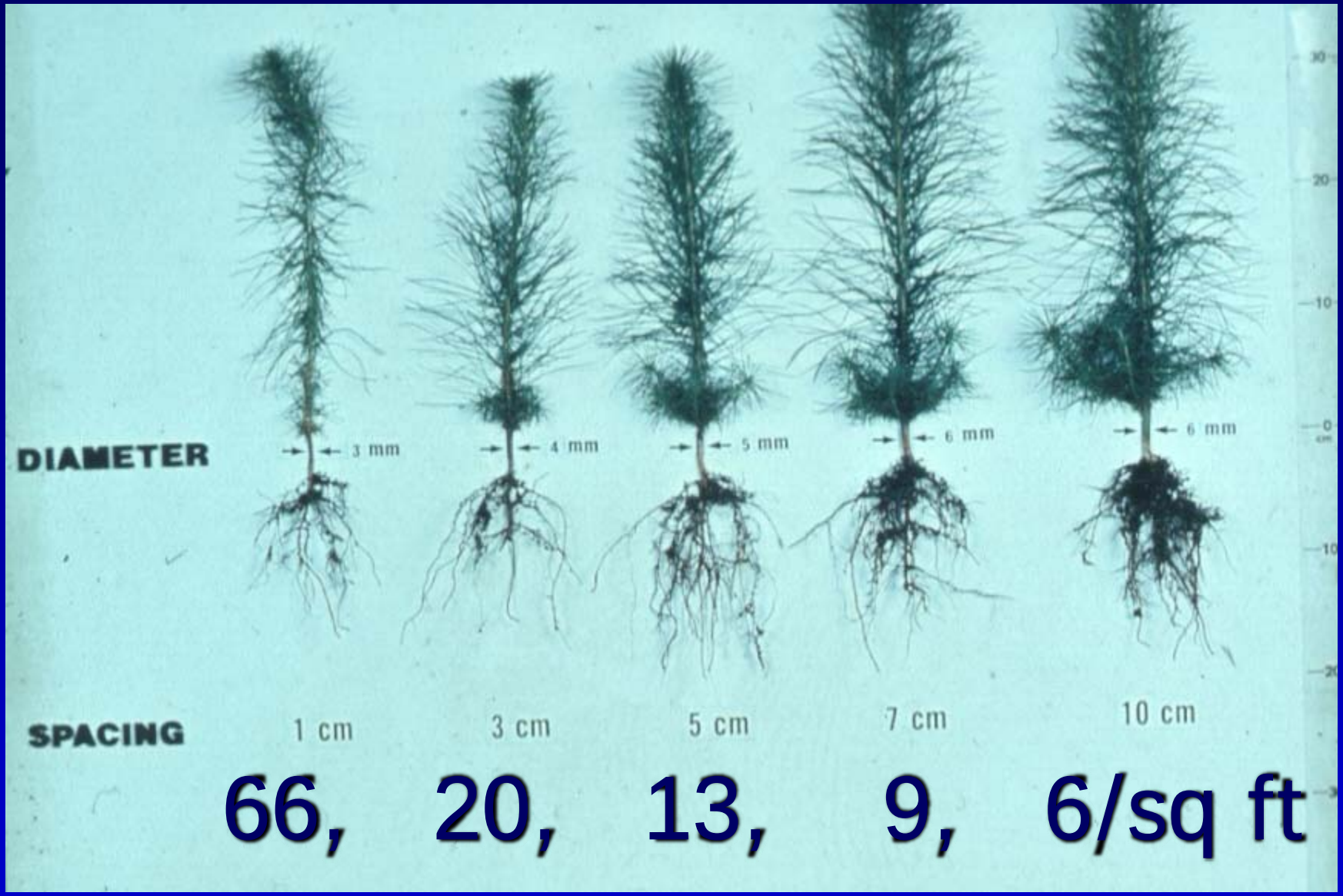
AUBURN

FORESTRY AND WILDLIFE SCIENCES

10/SQ. FT.

- Longleaf pine and many hardwood species are commonly grown at low seedbed densities in bare-root nurseries (10 seedlings per square foot or less). When these species are grown at high seedbed densities (>25 per square foot) then the field performance (survival and growth) is reduced and plantation failure is common.

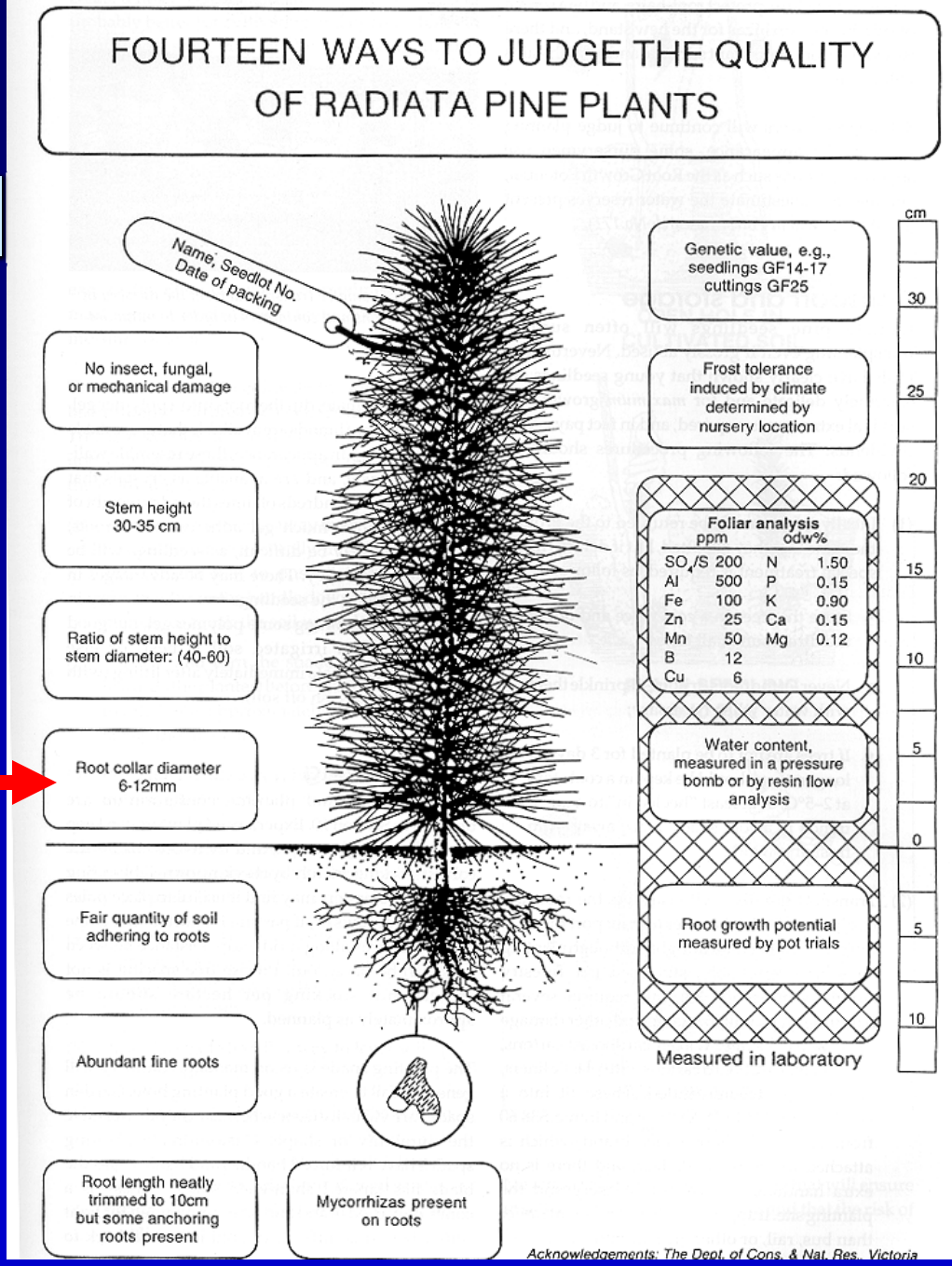
In New Zealand researchers recommend seedbed densities of 12/sq.ft on adverse site s and 15/sq.ft. on low elevation sites.


DIAMETER
3 mm
4 mm
5 mm
6 mm
6 mm
SPACING
1 cm
3 cm
5 cm
7 cm
10 cm
66, 20, 13, 9, 6/sq ft

Radiata Pine Growers' Manual

J.P. MacLaren 1993

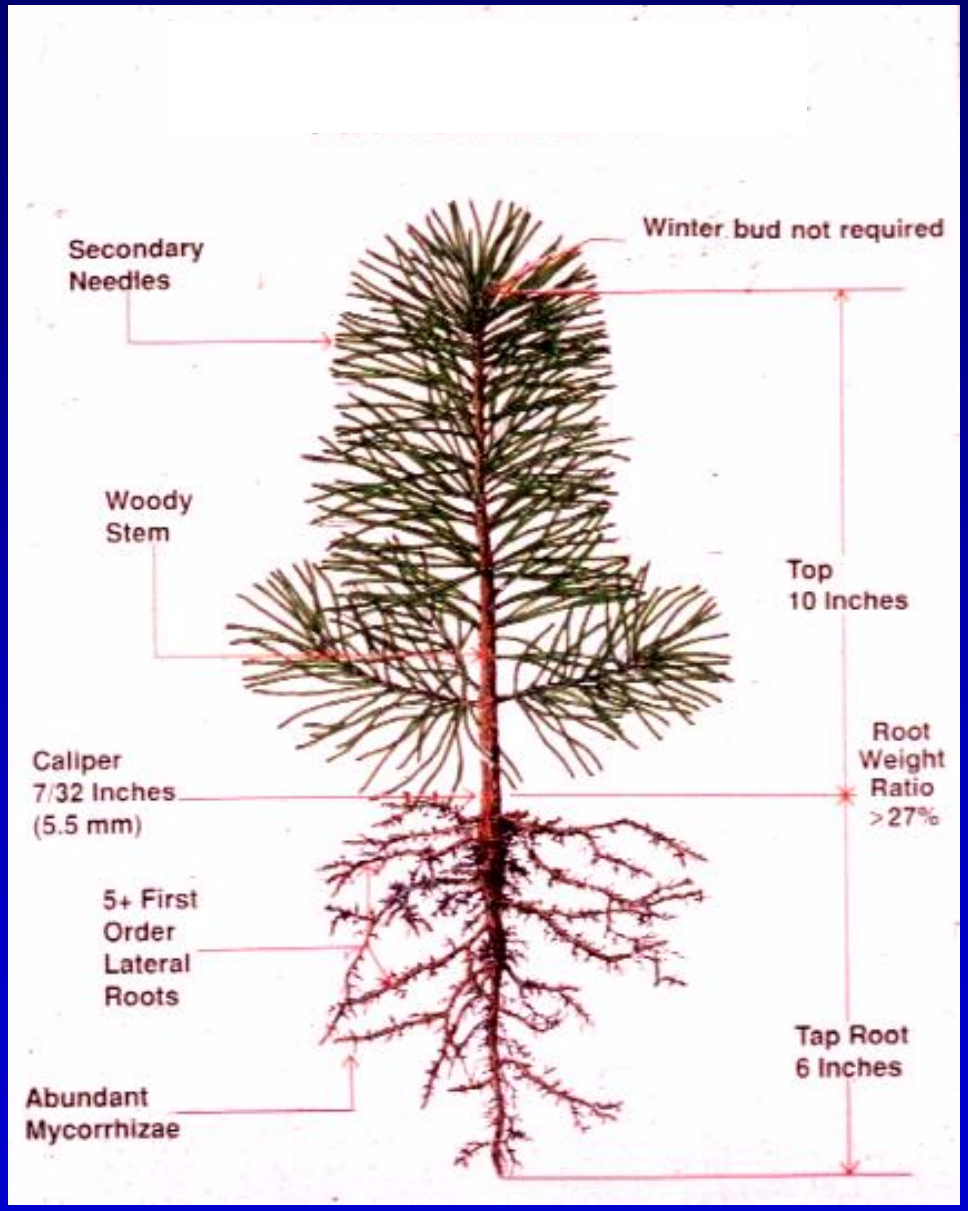
Root collar diameter 6-12 mm



Southern Pine Nursery Handbook

May 1985

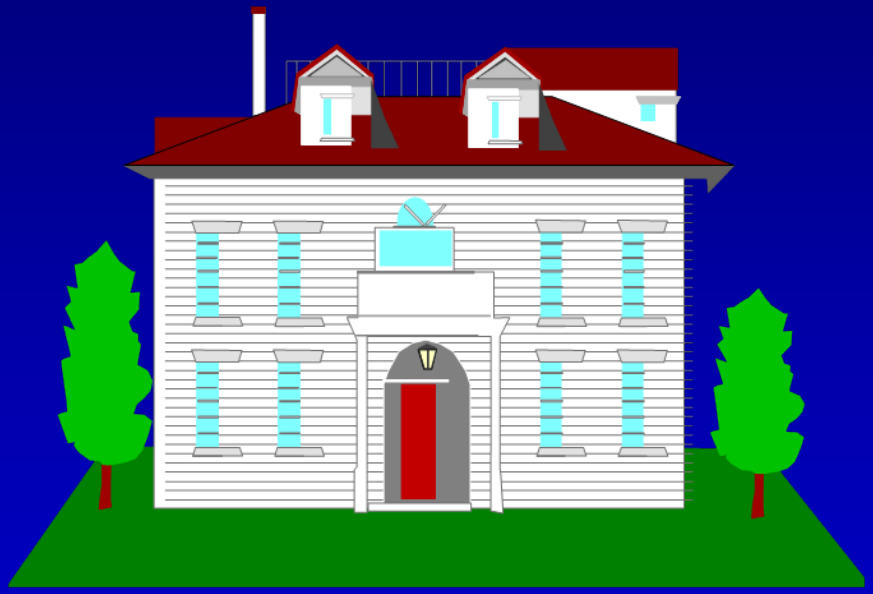
Root collar diameter
5.5 mm

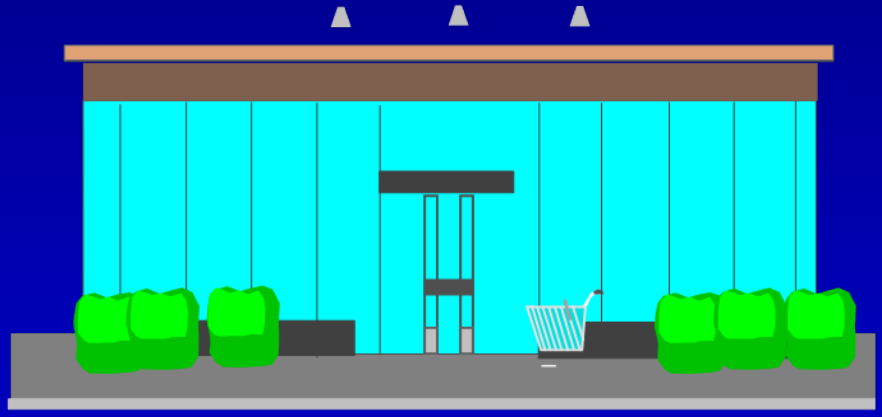


- Loblolly pine used by most researchers and landowners are commonly grown in the nursery at high seedbed densities. (more than 25 plants per square foot)

- The trend of lowering seedbed density for loblolly pine and slash pine has been slow. Many landowners have been told that seedling size is unimportant when it comes to improving survival and growth of these species. However, some companies and consultants know this is not true.

Two Schools of Thought in the South





Size makes no difference

Size matters

Three reasons not to plant low density seedlings

- Some hand planters I know told me they do not like to plant trees with big roots.
- A friend of mine works for a big paper company and he says they do not plant low density trees.
- Seedlings might cost me $5 to $7 more per acre.

Three reasons to plant low density seedlings

- Well balanced seedlings with more roots and more fibrous roots tend to survive better than smaller seedlings with small roots.
- Early growth is usually greater with low density seedlings than with regular bareroot seedlings.
- Value of extra wood harvested at age 13-15 is usually greater than extra cost of $5 to $7 per acre.

Definitions

- Cull seedling
- Plantable seedling
- Grade 2 seedling
- Grade 1 seedling
- Regular seedling
- Target seedling
- Morphologically improved seedling
- Optimum seedling

“Cull” Seedling

- A “cull” seedling is unacceptable because it does not meet a certain size standard or has a disease or has been injured.

- For loblolly pine, a cull seedling has a RCD of less than 3 mm.

“Plantable” Seedling

- A “plantable” seedling is defined as a seedling that is slightly bigger than a cull.
- For loblolly pine, a plantable seedling can have a RCD of about 3.2 mm.

“Grade 2” Seedling

- For loblolly pine, a Grade 2 seedling has a RCD between 3.2 mm and 4.7 mm.

“Grade 1” Seedling

- For loblolly pine, a Grade 1 seedling has a RCD that is greater than 4.7 mm.

“Regular” Seedling

- A “regular” loblolly pine seedling is about the size that most researchers use in their tests. Typically has a RCD of about 3.9 mm.

“Target” Seedling

- The “Target” seedling is defined as the median seedling that nursery managers try to produce the most.
- The “Target” seedling at many nurseries has a RCD less than 5 mm. However, at some nurseries it may be 7 or 8 mm.

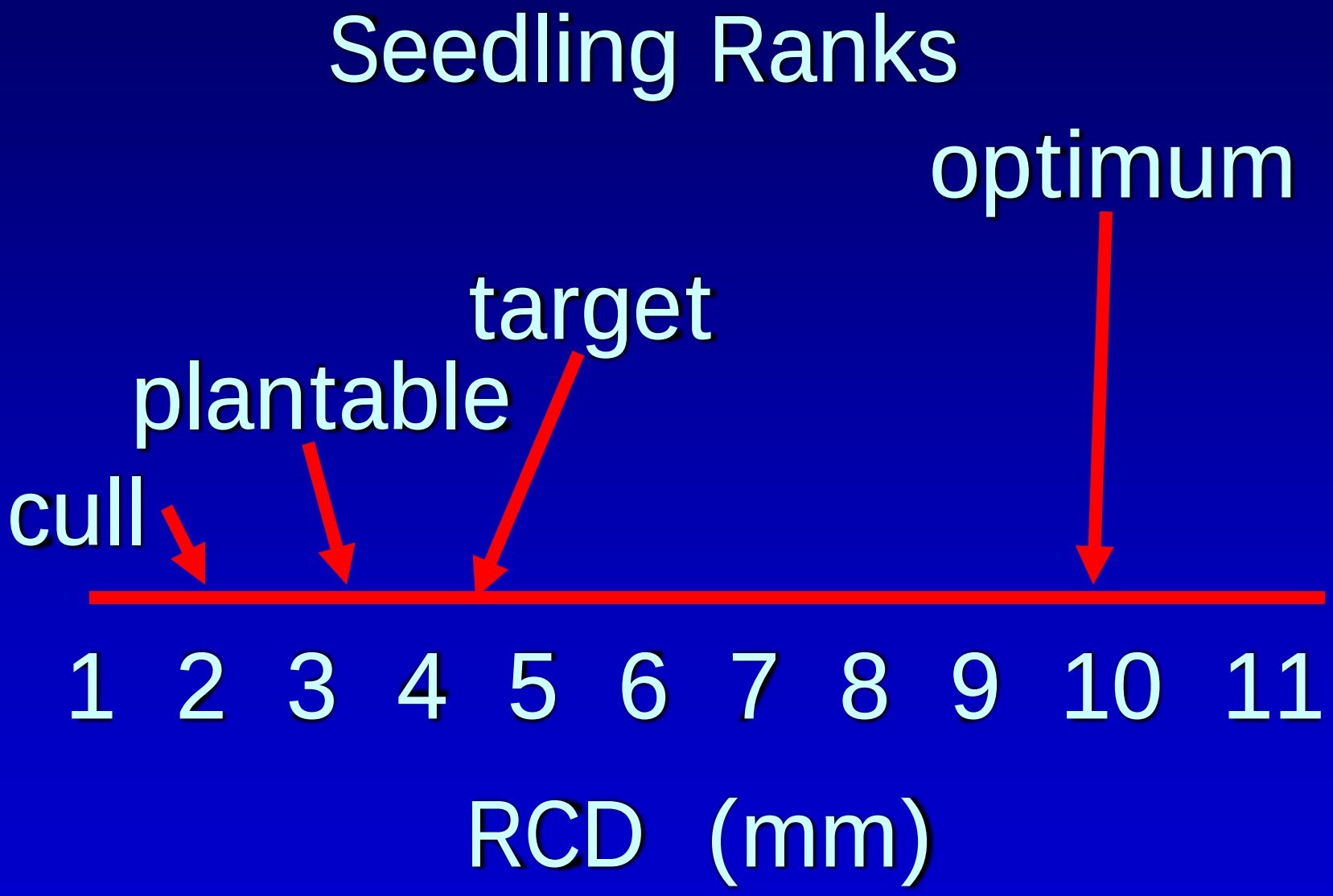
“Morphologically Improved” Seedling

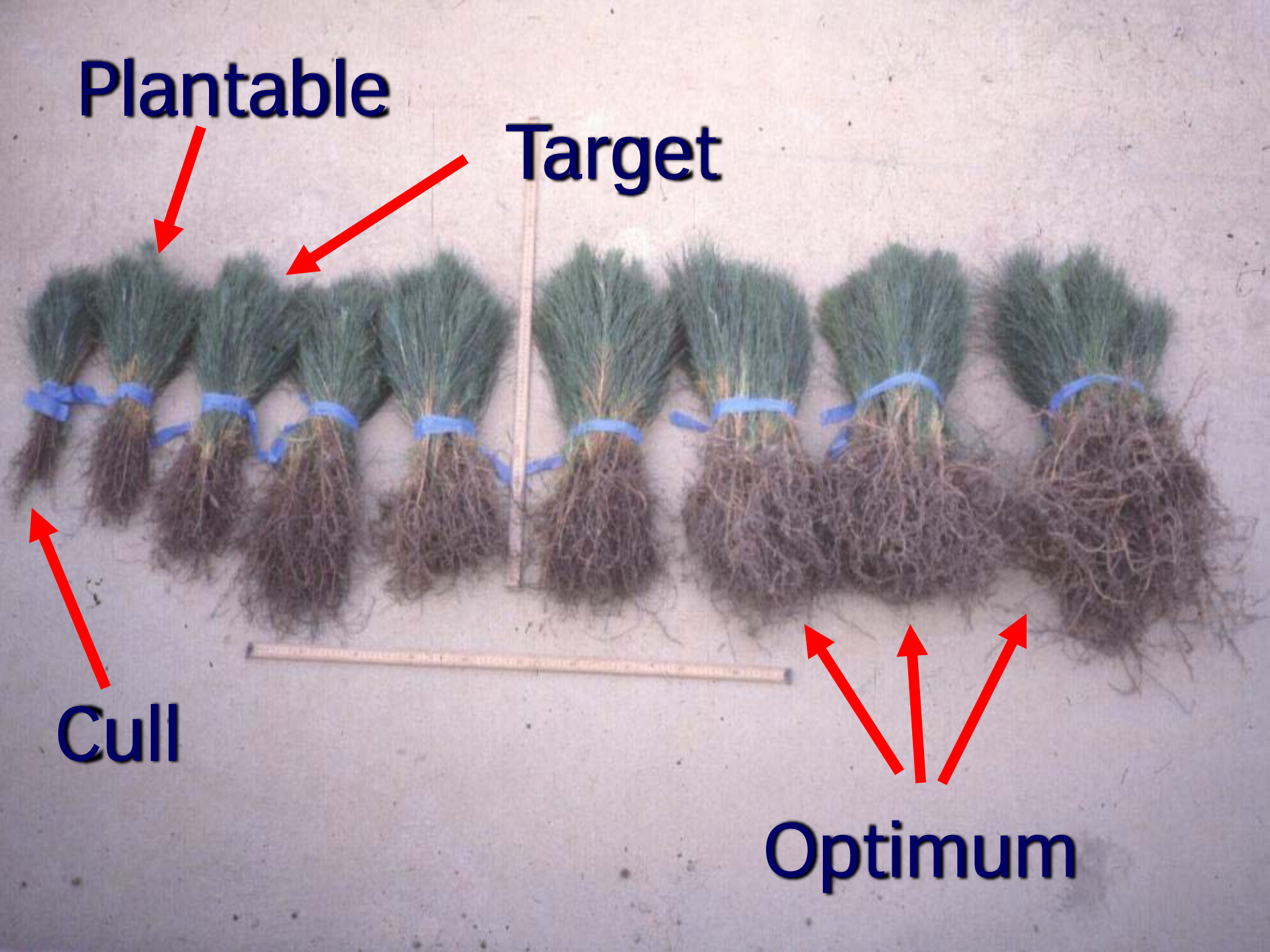
- This seedling is only grown at seedbed densities less than 20 per square foot. At least half of the seedlings have a RCD > 5 mm. This seedling has a higher root-weight ratio than “regular” seedlings and has been cultured to have more fibrous roots. It is not much taller than regular seedlings.

“Optimum” Seedling

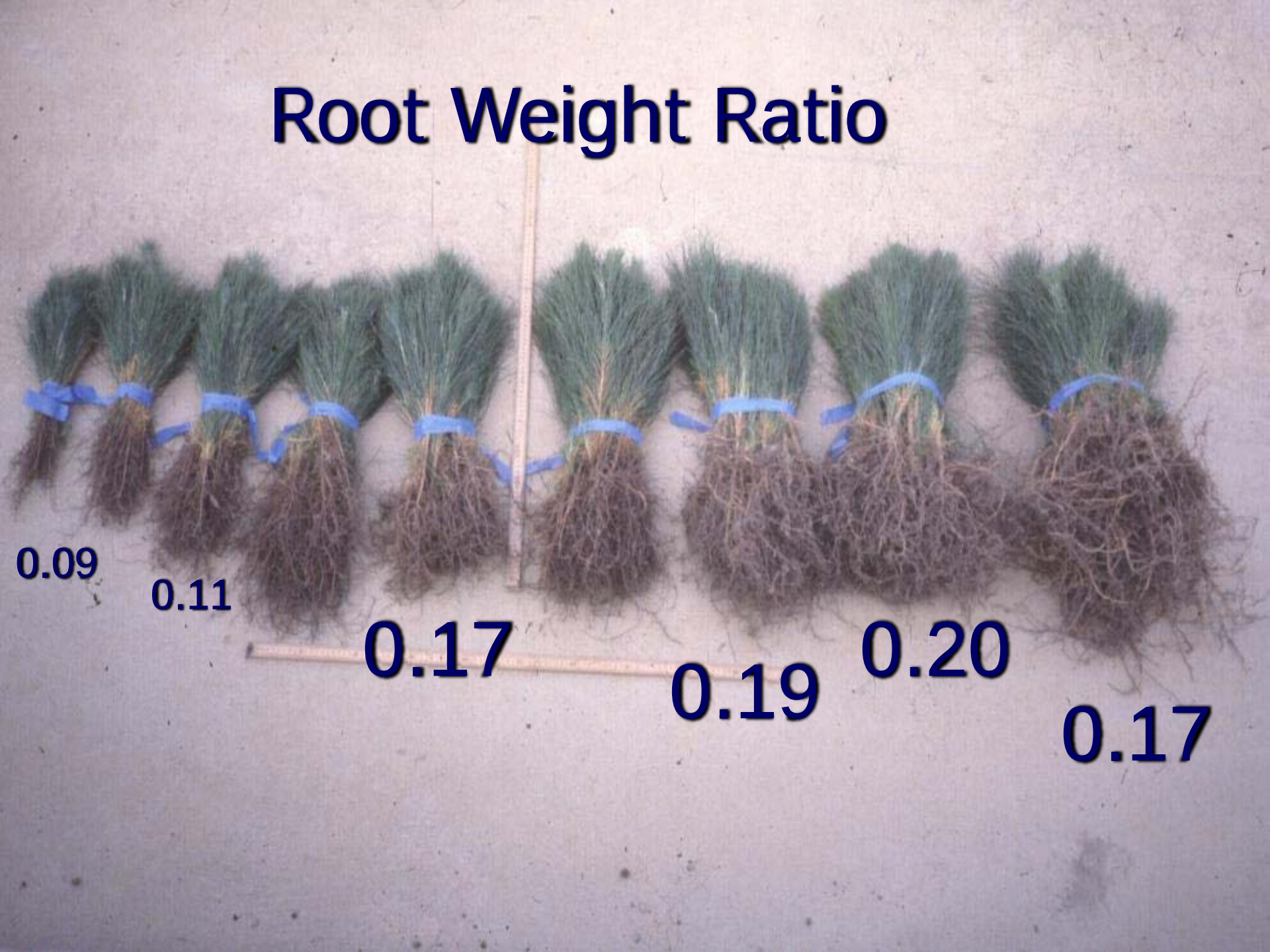
- The “optimum” seedling is defined as

  the ideotype that will minimize overall reforestation costs while achieving established goals for initial survival and growth.

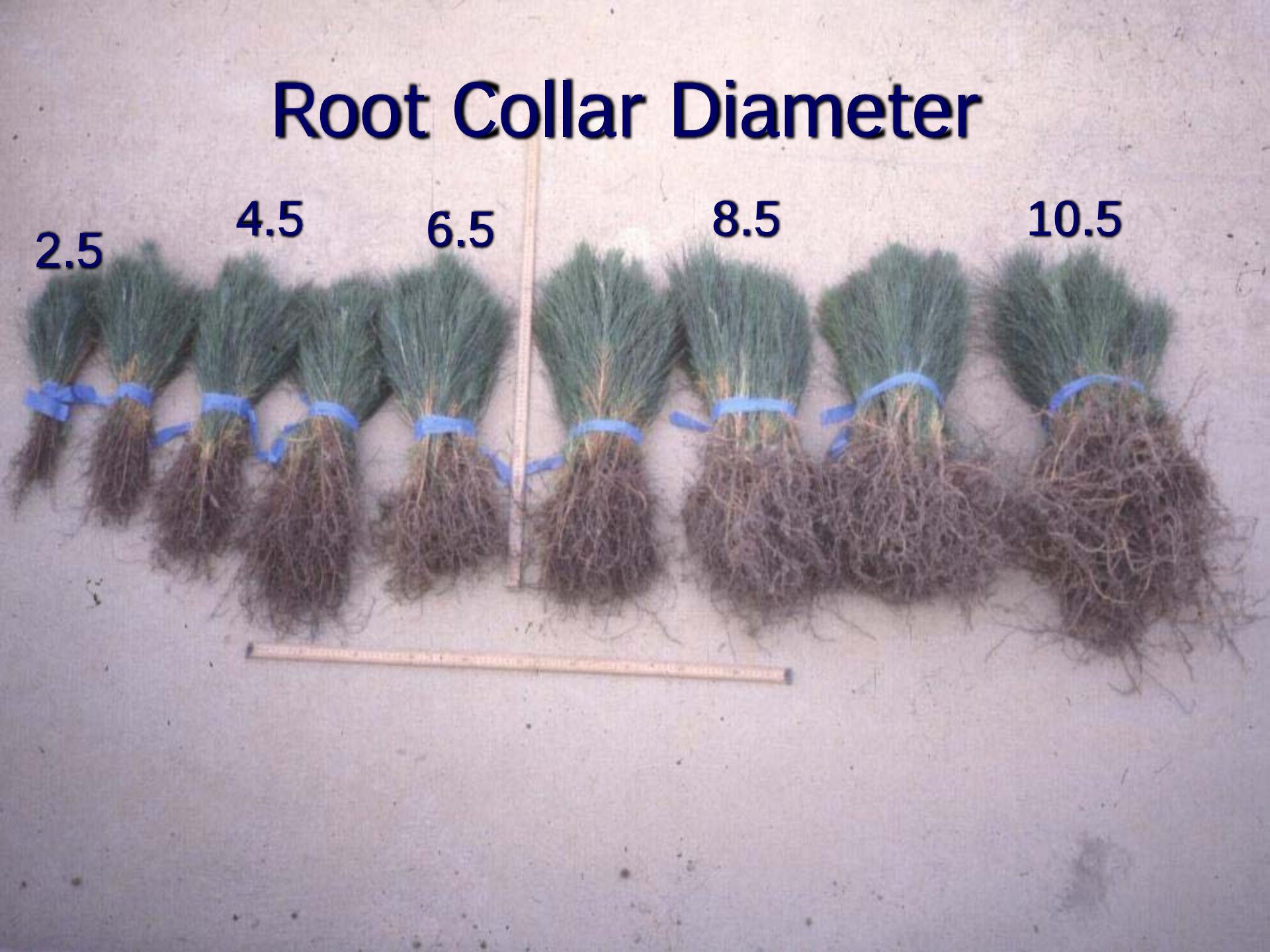

Seedling Ranks
optimum
target
plantable
cull
1 2 3 4 5 6 7 8 9 10 11
RCD (mm)


Plantable
Target
Cull
Optimum

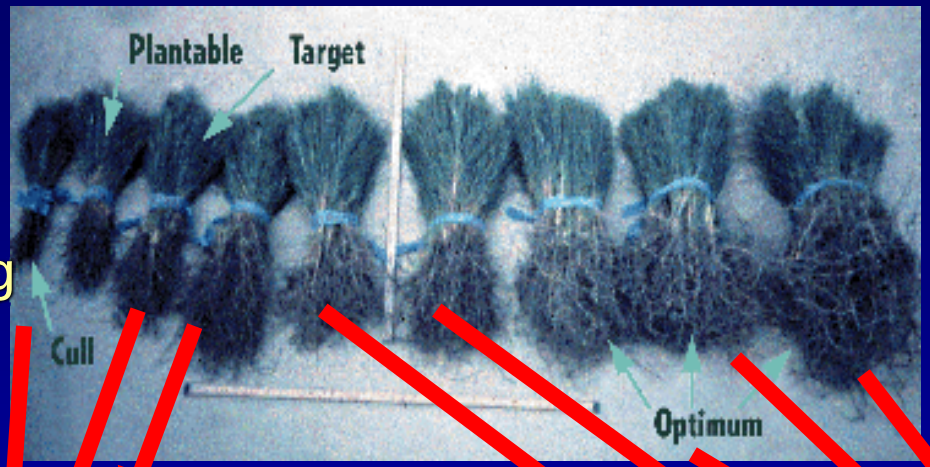
Root Weight Ratio



Root Collar Diameter

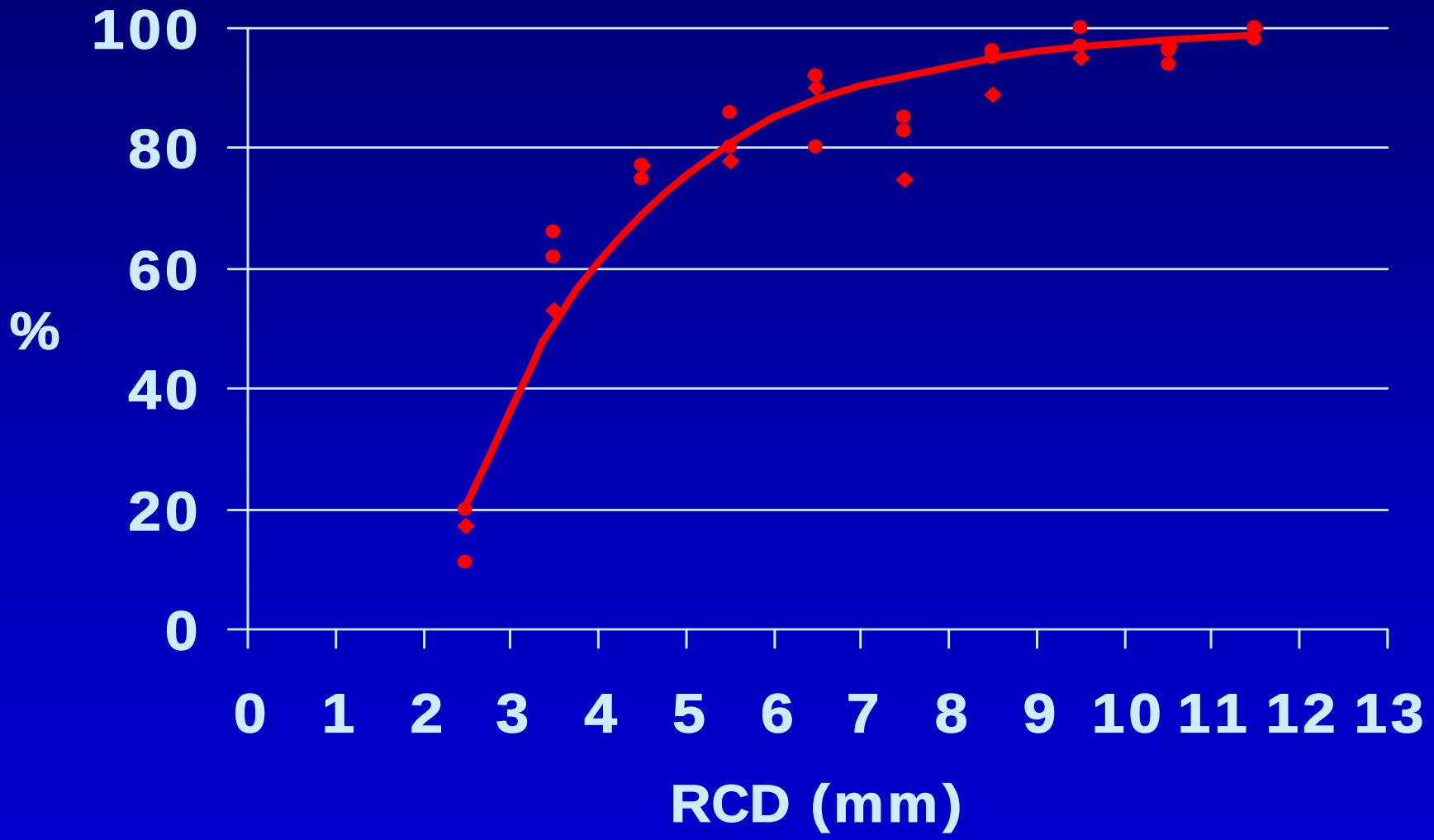


Small seedlings
for hand planting



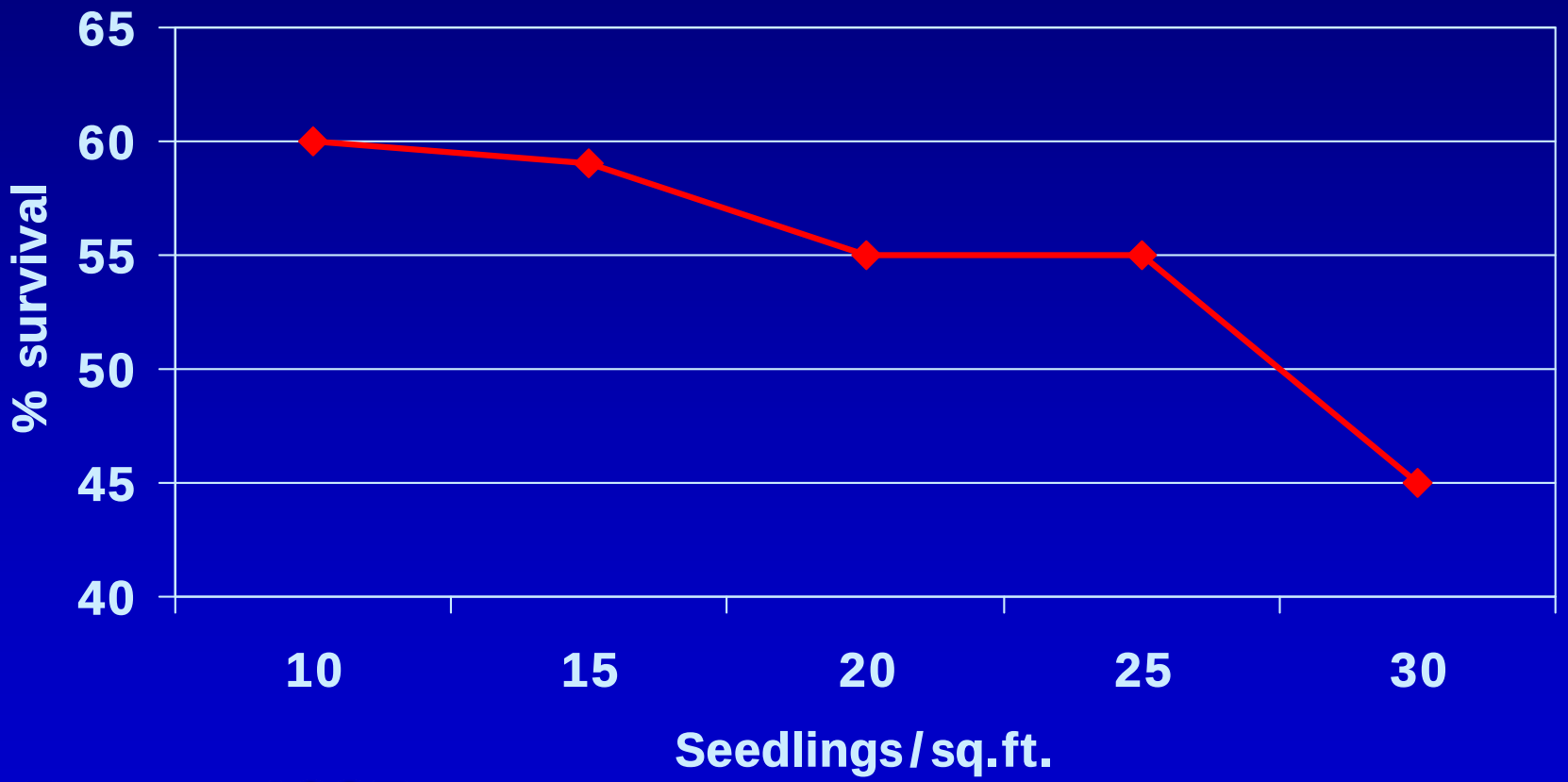
Large roots
for machine planting

Survival of slash pine planted in October



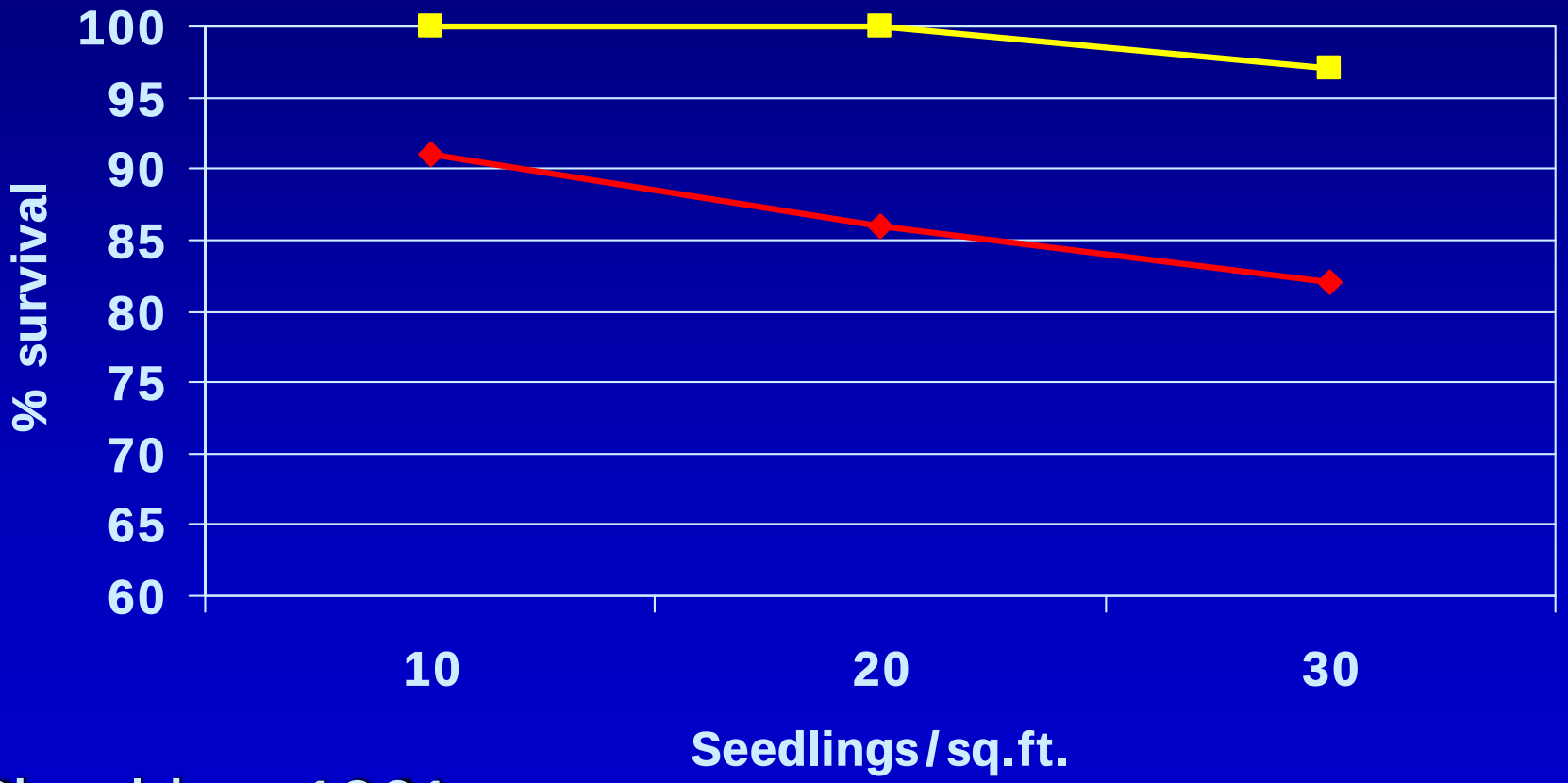
South and Mitchell 1999

Increase in Survival, Baldwin Co., Georgia



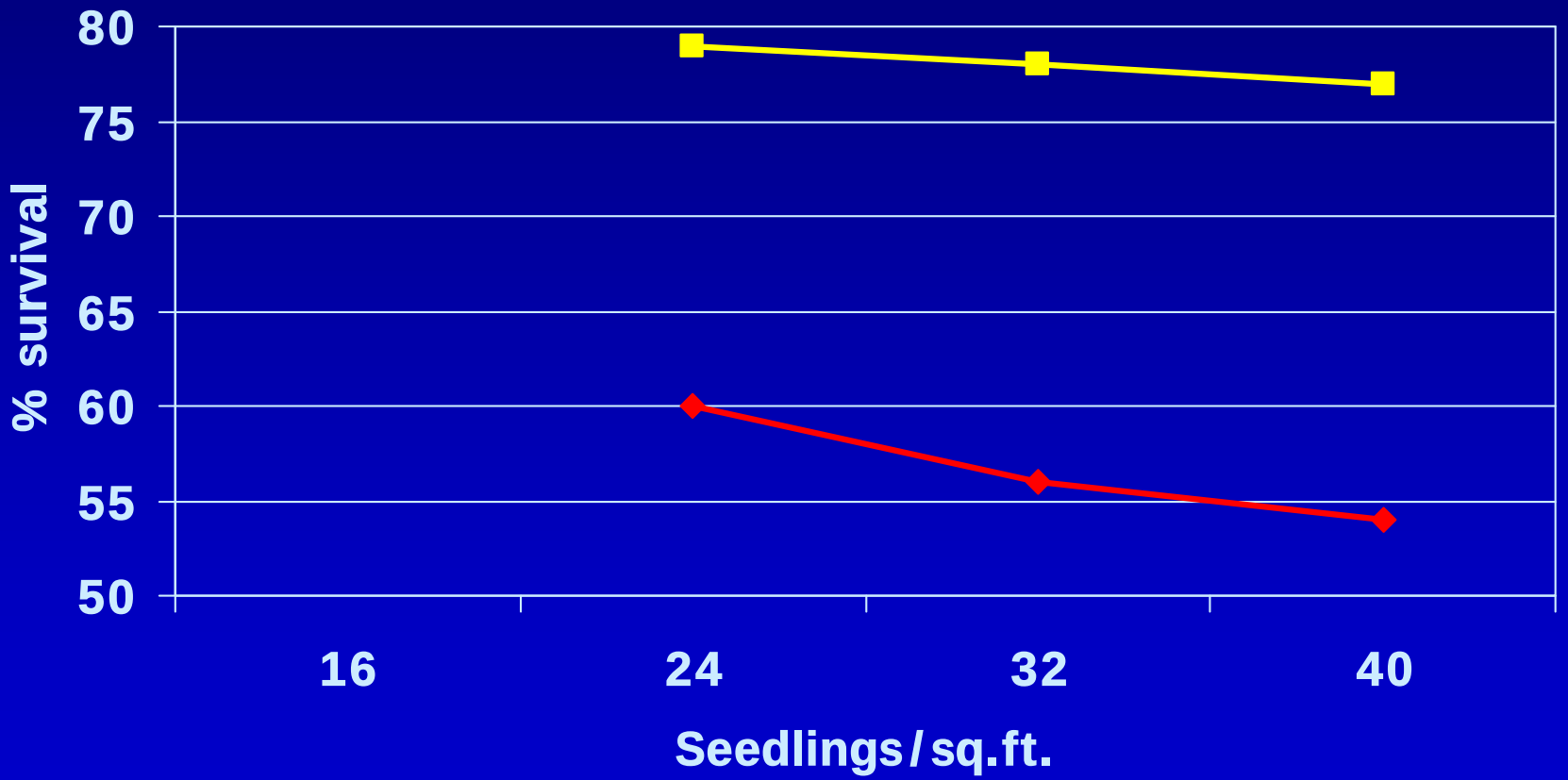
Rowan 1985

Increase in Survival Alexander State Forest, LA



Shoulders 1961

Increase in survival, Walker & Houston Co., Texas



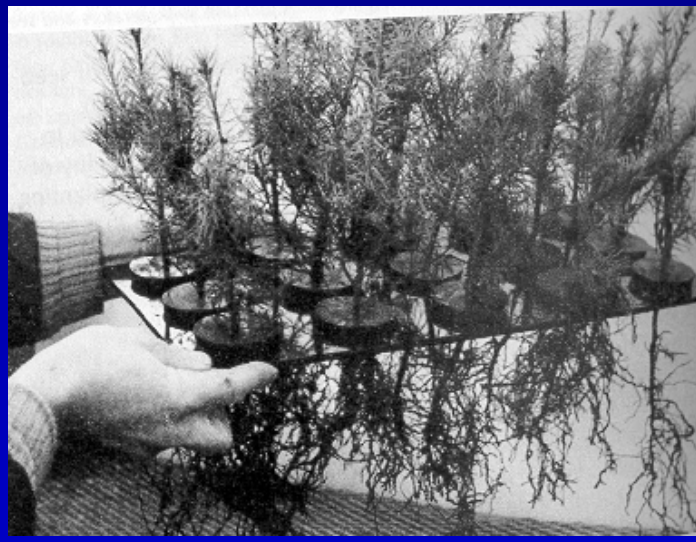
Nebgen and Meyer 1985

Increase in Survival

Study	Low density	High	% gain
Rowan - GA	15	30	14
Shoulders - LA	14	38	12
Shoulders – LA	10	30	9
Rowan – GA	15	30	8
Leach - FL	20	30	4
Shoulders - LA	13	31	3
Rowan – GA	15	30	2
Shoulders - LA	12	31	1
Shipman – SC	20	40	1
Carneiro - BR	15	26	-3

More root growth and better balance between roots and shoots

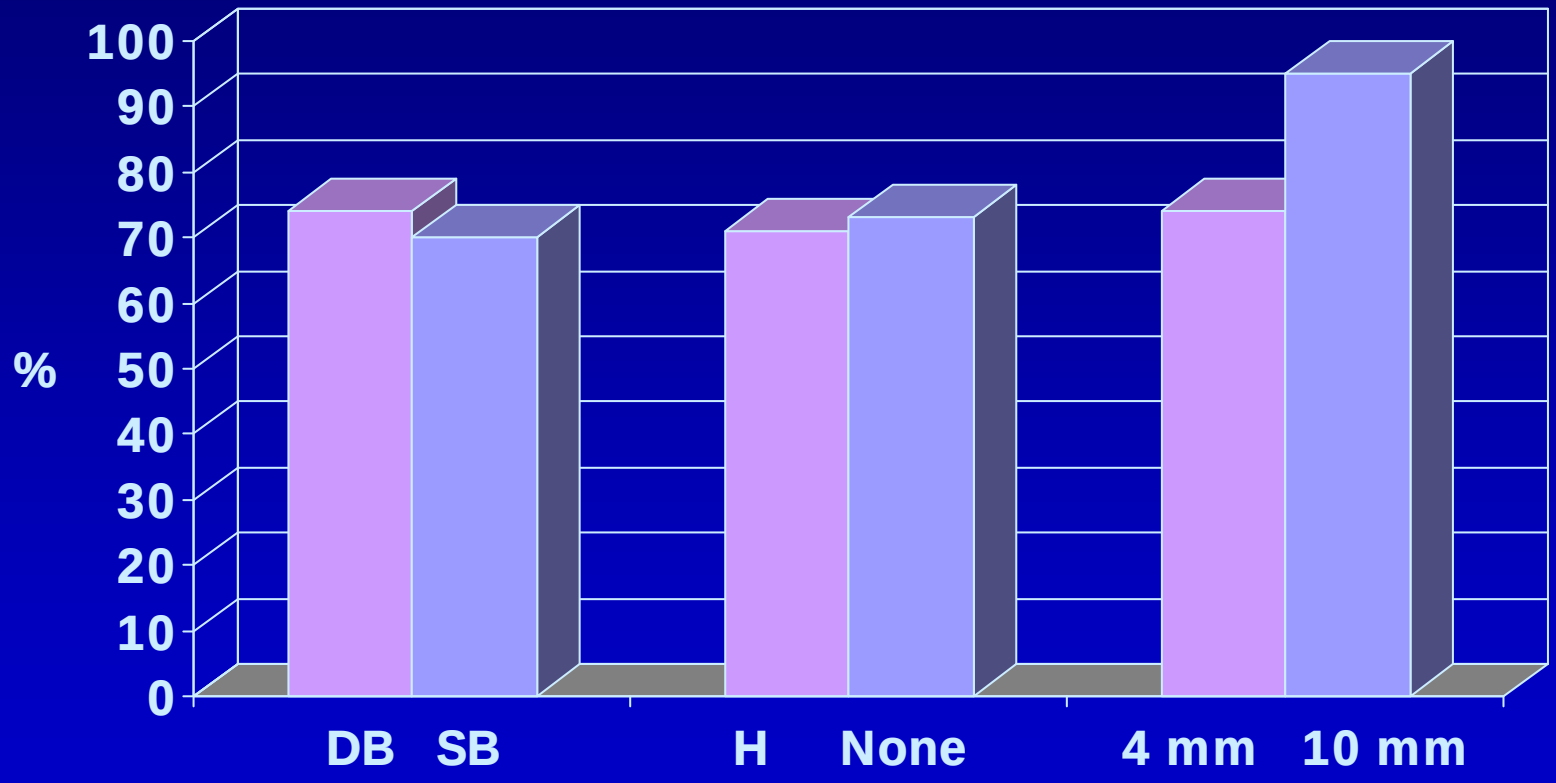
RCD (mm)	RGP (#)	RWR
3.5	6.2	0.11
5.5	21.5	0.16
8.5	57.6	0.19
10.5	61.9	0.20



Some nursery densities in 2000

Nursery	density/square foot
Atmore	19
Elberta	19
Pine Hill	17
Verbena	20

Bedding, herbicide (H) and RCD on slash pine survival



South and Mitchell 1999

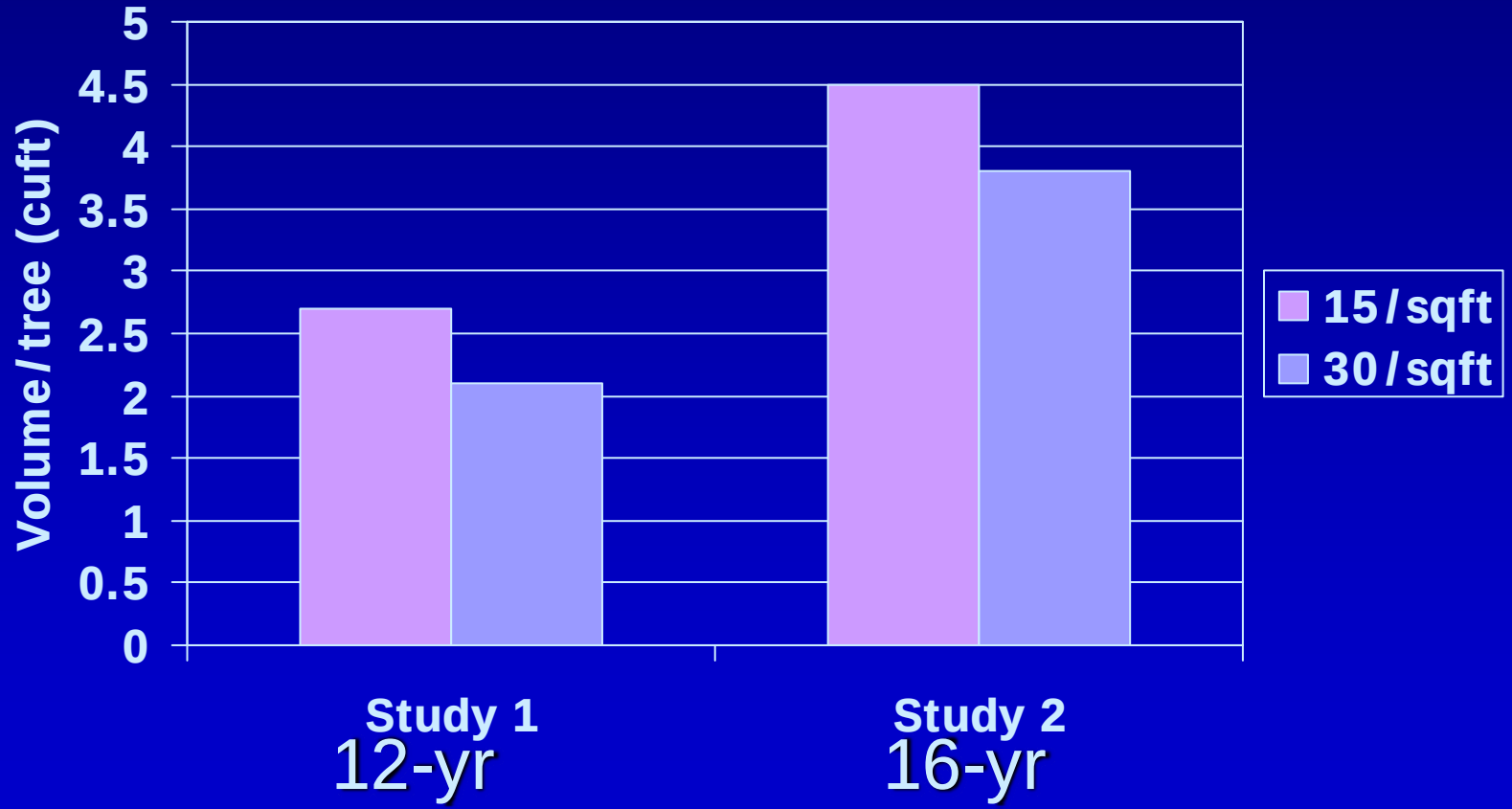
Conclusion:
Size does matter for seedling survival

On average, seedlings grown at low seedbed densities
result in about a 5%
increase in survival.

(assuming they are handled properly)

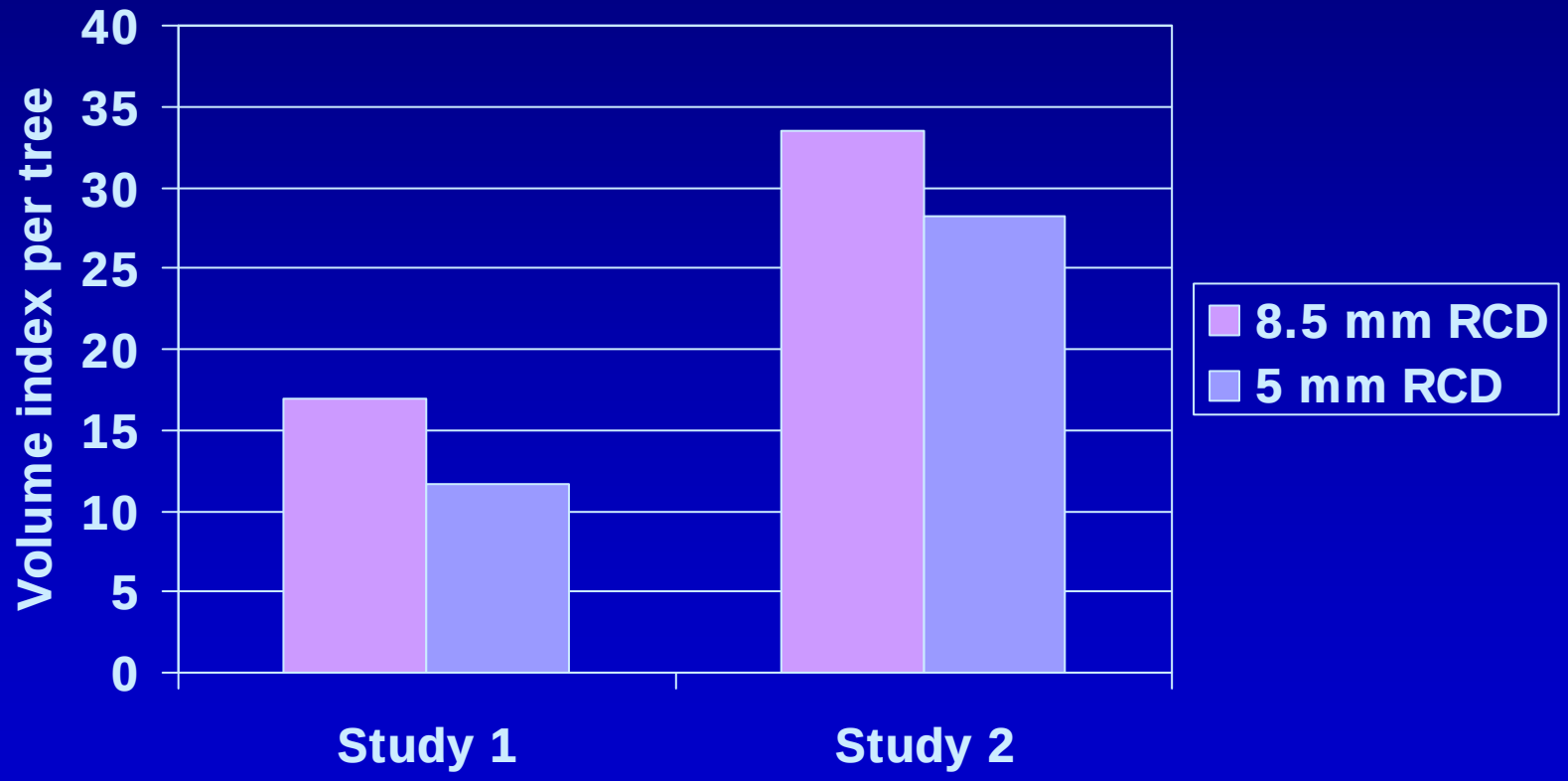
More Growth from Large-diameter seedlings

Low density trees increase growth in MS



Autry 1972

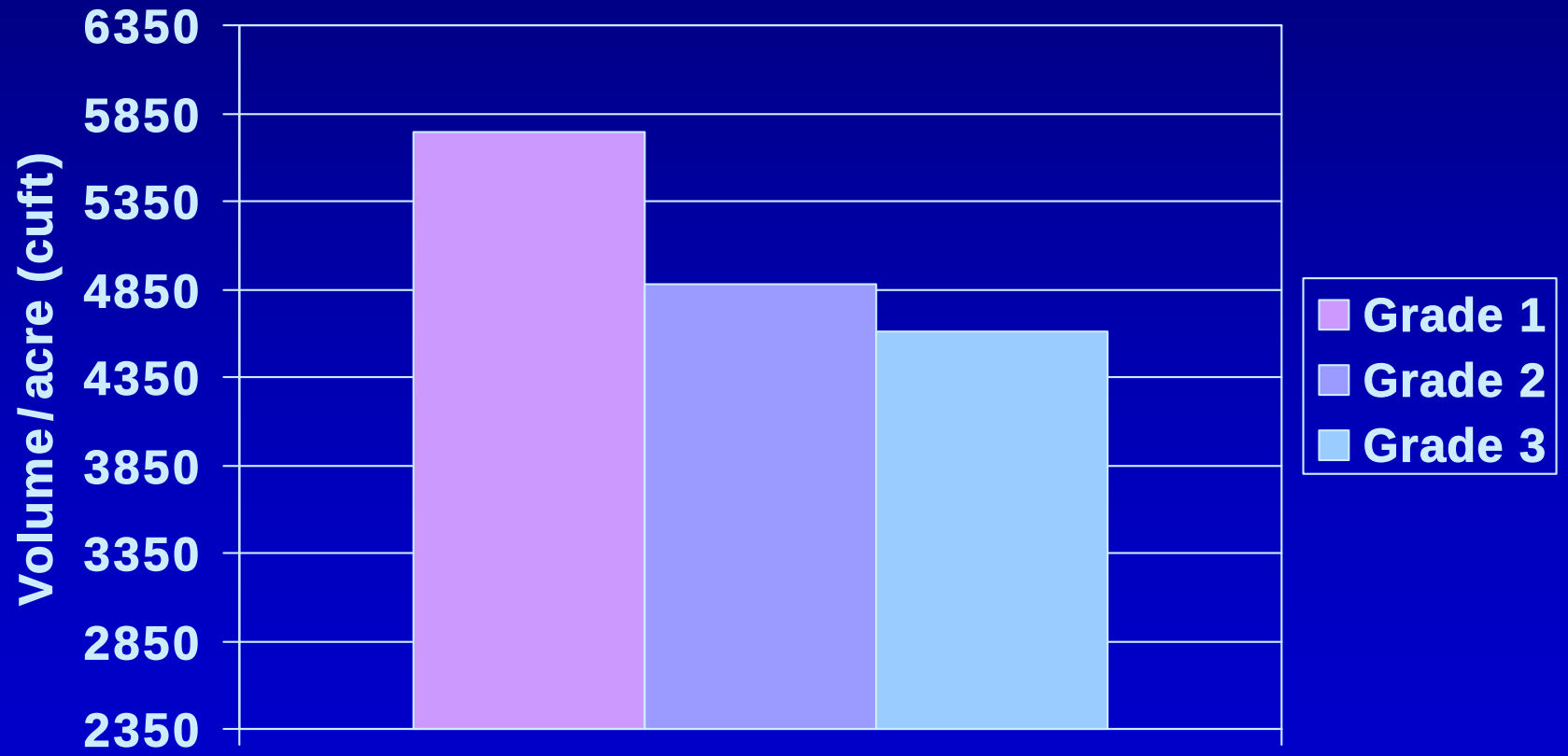
Low density trees increase growth (age 8) in GA



South, Rakestraw and Lowertz 2001

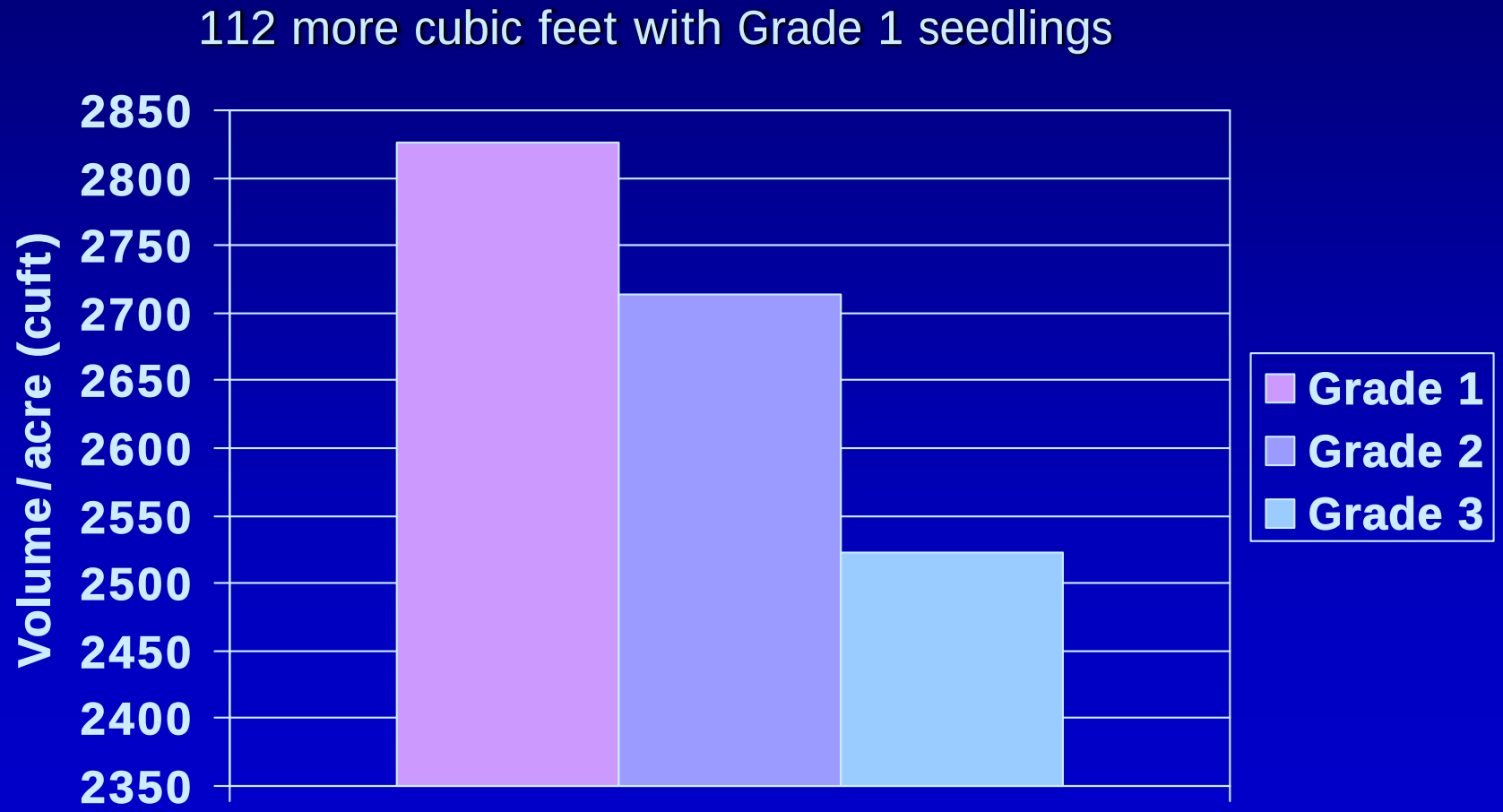
Seedling grade study at Hodge, LA (age 13)

856 more cubic feet with Grade 1 seedlings



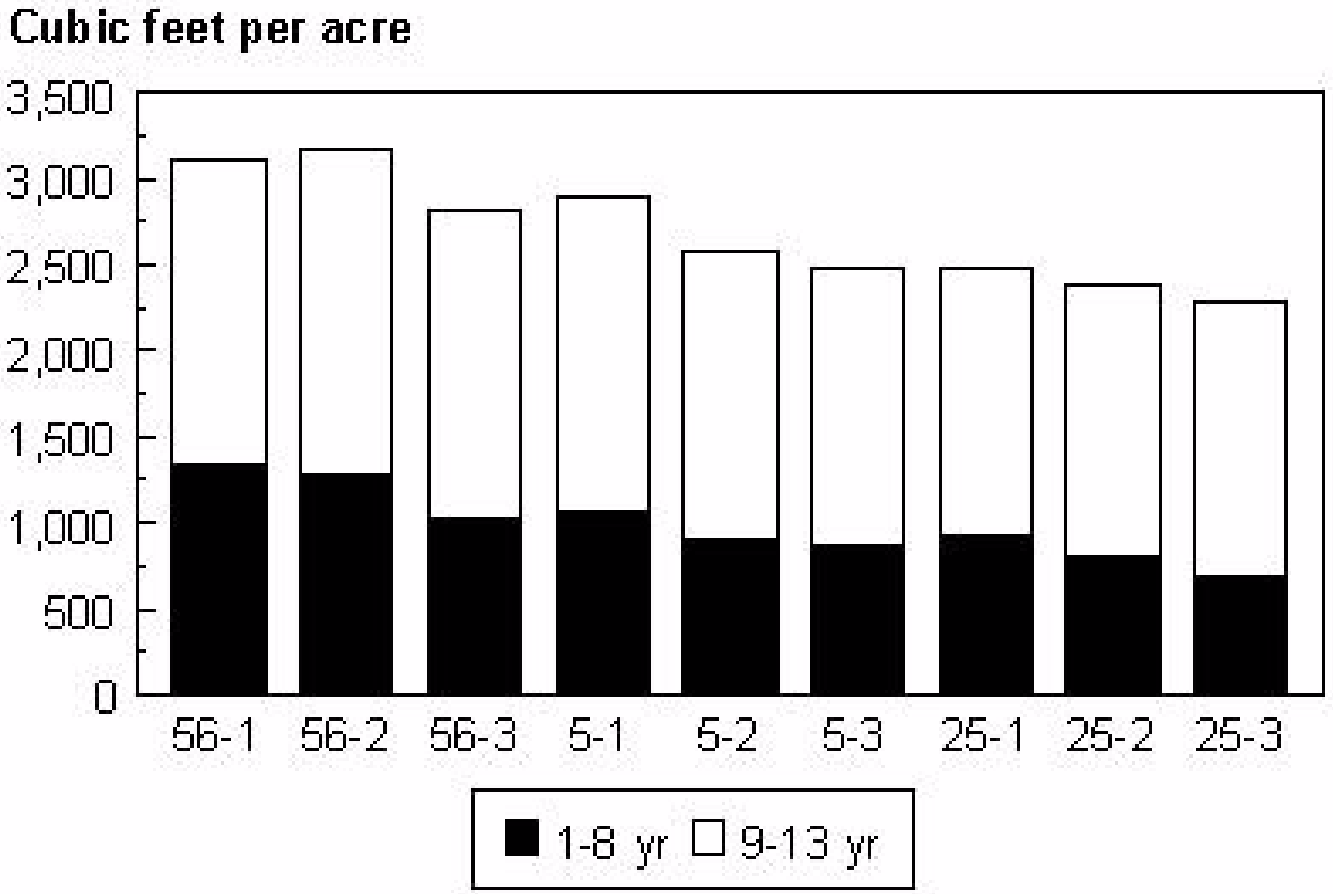
South, Boyer and Bosch 1985

Seedling grade study at Bellville, GA (age 13)



South and Rakestraw 2002

No genotype by grade interaction



South and Rakestraw 2002

Conclusion:
Size does matter for seedling growth

How much does it cost?
And can I profit from planting morphologically improved seedlings?

Low density seedlings may cost $11 more per thousand seedlings

2002-03 Price List

Species	Code	Description	$ per Thousand**
Loblolly Pine	03	1.5 generation rust-resistant, Coastal	$43
Loblolly Pine	09	2.0 generation rust-resistant, Coastal	$44
Loblolly Pine	13	2.0 generation low-density, Coastal	$55

Cost/acre of low-density trees is the same when machine planting plant fewer trees

625 regular = 500 low density

544 regular = 435 low density

500 regular = 400 low density

A quick look at costs

1.1 cents more per tree

Assume machine planting

12’ x 12’ spacing = $3.33 more per acre
12’ x 10’ spacing = $4.00 more
12’ x 9’ spacing = $4.44 more
12’ x 8’ spacing = $5.00 more
12’ x 7’ spacing = $5.70 more
12’ x 6’ spacing = $6.65 more

Modeling growth
With % gain?
Or
Year gain?

Genetics (% gain)

Growth and Economic Model of SuperTree Seedlings

SuperTree Seedlings	Growth Gain	Resulting NPV*	Cost/Acre at 622 TPA
1st-generation	13%	$203	$24.26
1st-generation select	19%	$232	$26.12
1.5-generation	24%	$245	$27.37
2.0-generation	28%	$272	$29.86
Advanced-generation	28%	$272	$29.86

****NPV* (Net Present Value) is all expenses and revenues discounted back to today's money from the time of their occurrence.**

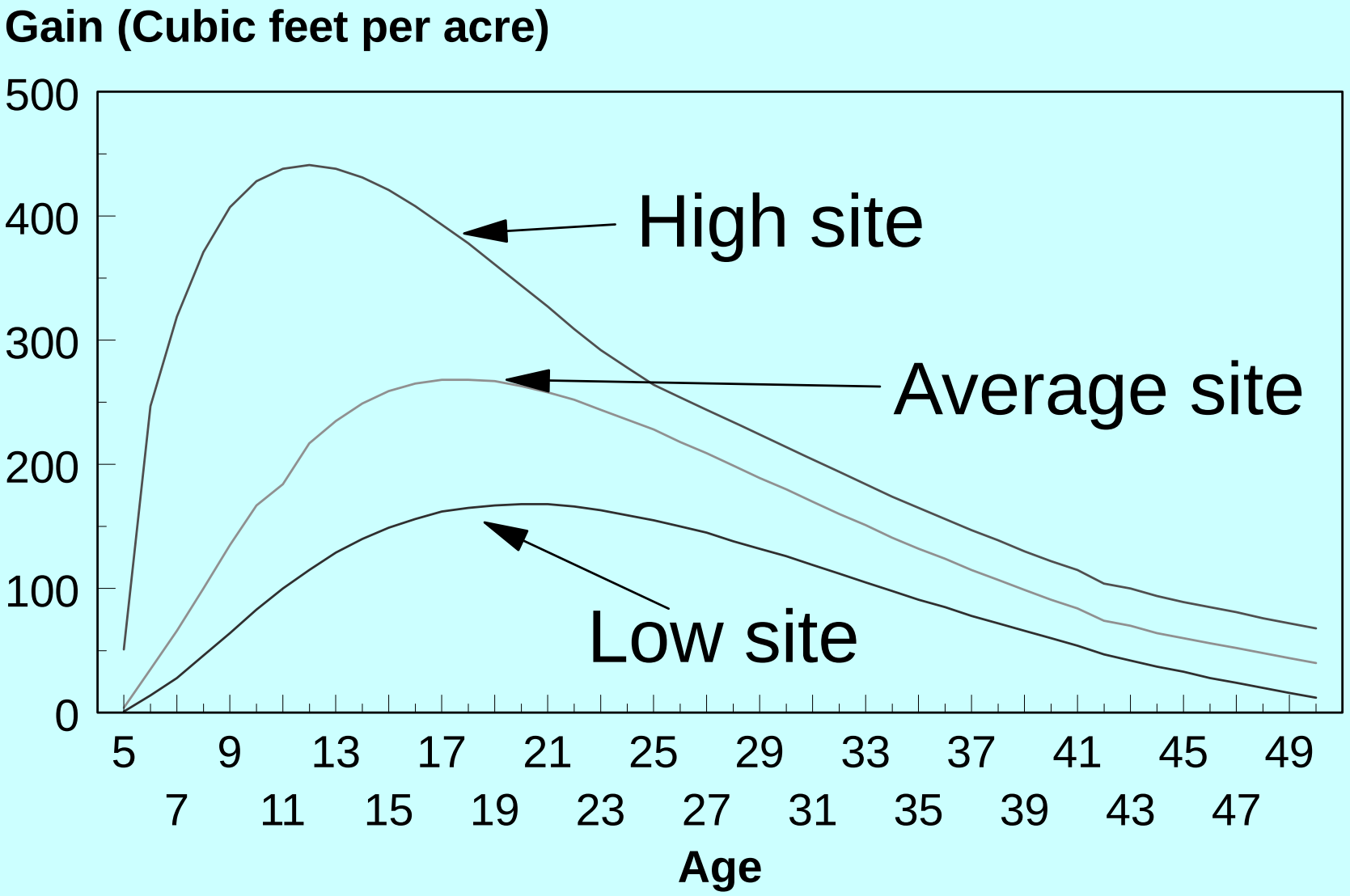
Morphologically improved seedlings Year gain

Table 5. Predicted dominant height at age 13 yr, basal area, merchantable volume and subsequent gains in present value by various time advancements in stand development.

Year gain	Dominant ht	Ave. ht	Basal area (ft^2/ac)	Vol (ft^3/ac)	Extra vol harvested (ft^3/ac)	Present value (gain/ac) ($)
	(ft)					
0	46	42	125	1,882	0	0
0.25	47	43	127	1,969	87	18
0.5	48	44	131	2,056	174	36
1	49	45	138	2,229	347	72
1.5	51	47	143	2,407	525	108

NOTE: Gains made by achieving a 0.25, 0.50, 1, or 1.5 yr advance in stand development on site index 79 (base age 25). Volume gain per ac at 13 yr calculated from the NCSU Plantation Management Simulator for upper-coastal plain sites. Assumes planting 605 trees/ac; a 6% real interest rate; an average stumpage value of \$0.60/ft^3; and a 26% tax bracket.

1-Year gain in stand establishment

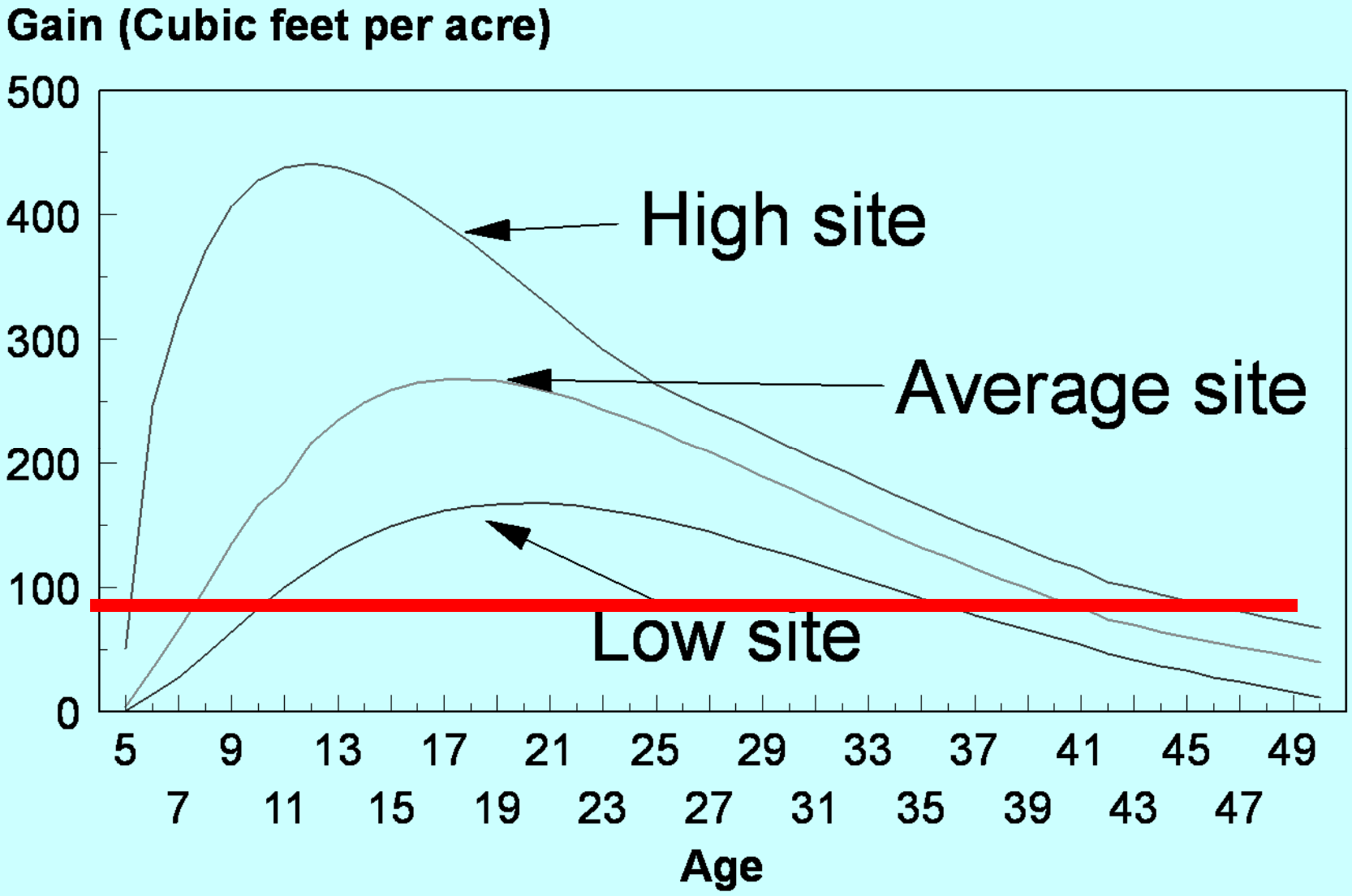


South 2000

More wood at age 13 yr

Extra cost/acre	Cubic feet/acre
$7	1.2 cords (or 86 cubic feet)

7% interest and $14/cord


Gain (Cubic feet per acre)
500
400
300
200
100
0
High site
Average site
Low site
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
Age

Realized gains

Table 4. Location, genotype, stand age, mean annual increment (MAI) and stand volumes from three block-plot studies with loblolly pine.

Location	Genotype	Years	MAI	Stand volumes (ft^3/ac)			Reference
				Grade 1	Grade 2	Difference	
Louisiana	Unimproved	13	441	5738	4882	856	South et al.1985
Georgia	Unimproved	15	138	2071*	1632	439	Sluder 1979
Georgia	Family 5	13	222	2889	2587	302	—
Georgia	Unimproved	15	151	1962*	1726	236	Sluder 1979
Georgia	Family 25	13	191	2484	2388	96	—
Georgia	Family 56	13	239	3105	3168	-63	—

* It is assumed that "select" seedlings would be classified as Grade 1 seedlings based on RCD.

$7/acre ..... 86 cubic feet/acre

Conclusion:
Planting morphologically improved seedlings can be cost effective

Can we reduce establishment costs when using “optimum” seedlings?

Site location

- Loblolly pine, Hamilton Ridge site in South Carolina

Hamilton Ridge in SC

Ideotype B seedlings

- Seedbed density 26/ft^2
- Nitrogen 300 lbs/a
- Avg RCD = 5 mm
- Avg ht = 17 in
- 80 % grade 1 seedlings

Ideotype A seedlings

- Seedbed density 19/ft^2
- Nitrogen 375 lb/a
- Avg RCD = 8.5 mm
- Avg ht = 19 in
- 100 % grade 1 seedlings

- Standard silviculture
- Ideotype B seedlings

- Standard silviculture
- Ideotype A seedlings

- Intensive silviculture
- Ideotype B seedlings

- Intensive silviculture
- Ideotype A seedlings

Standard

- Shear-rake-pile bed
- DAP at planting
- Velpar and Oust at planting
- ($202/acre)

Intensive

- Shear-rake-pile bed
- DAP at planting
- Velpar and Oust at planting
- 2 insecticide - yr 1
- Arsenal + Escort -yr 1
- Arsenal + Escort - yr 2
- 2 insecticide - yr 2
- KCl + DAP - yr 3
- ($386/acre

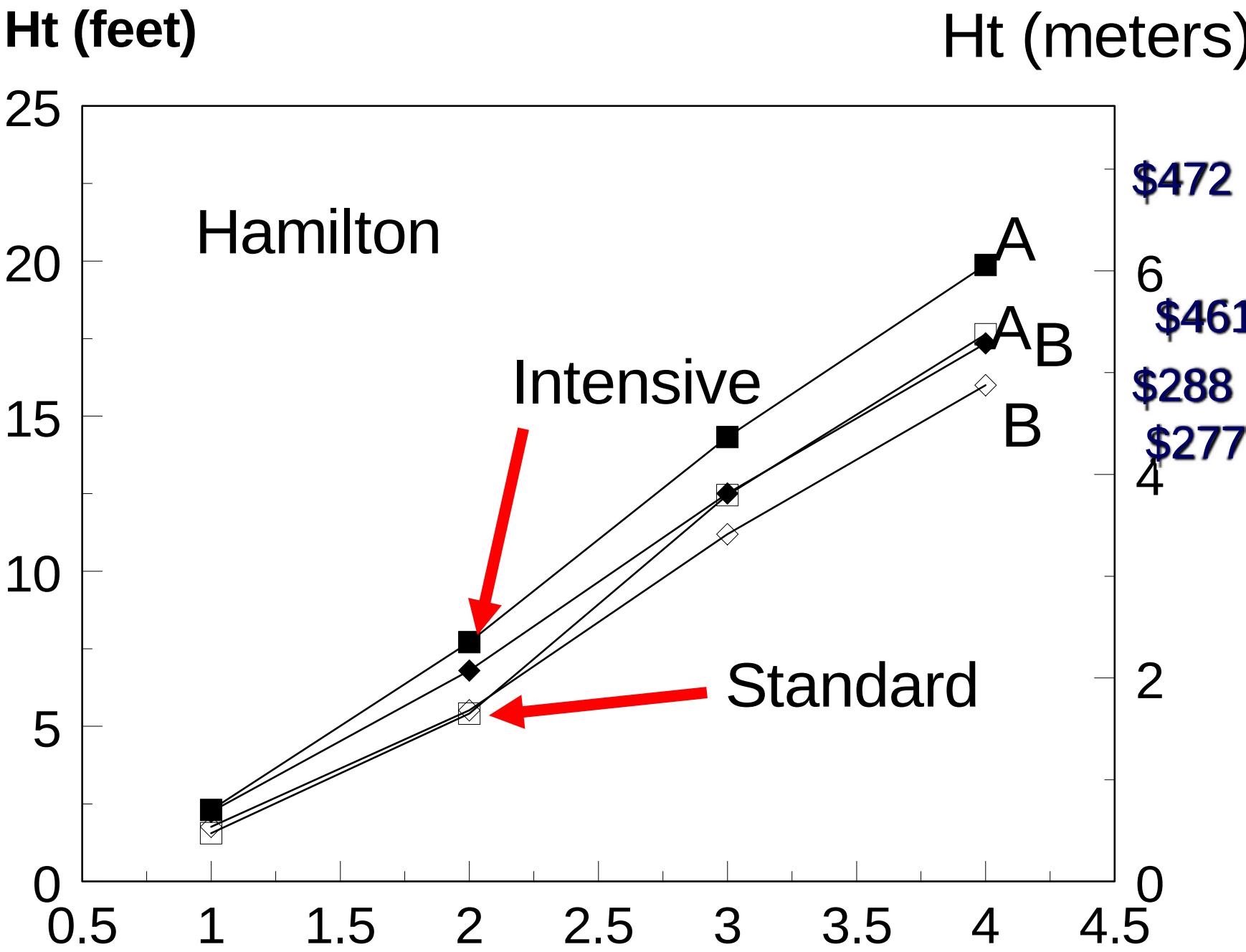
Establishment costs per acre

Shear-rake-pile-bed	$140
Machine planting	$50
DAP at planting	$32
Herbicides	$30/application
Insecticide	$18/application
KCl + DAP	$52

Establishment costs

Intensity	*Stock*	*Plant*	*Treat*	*$/Ac*
Reg	B -$25	$50	$202	$277
Reg	A -$36	$50	$202	$288
Intensive	B -$25	$50	$386	$461
Intensive	A-$36	$50	$386	$472

($461 - $288 = $173)

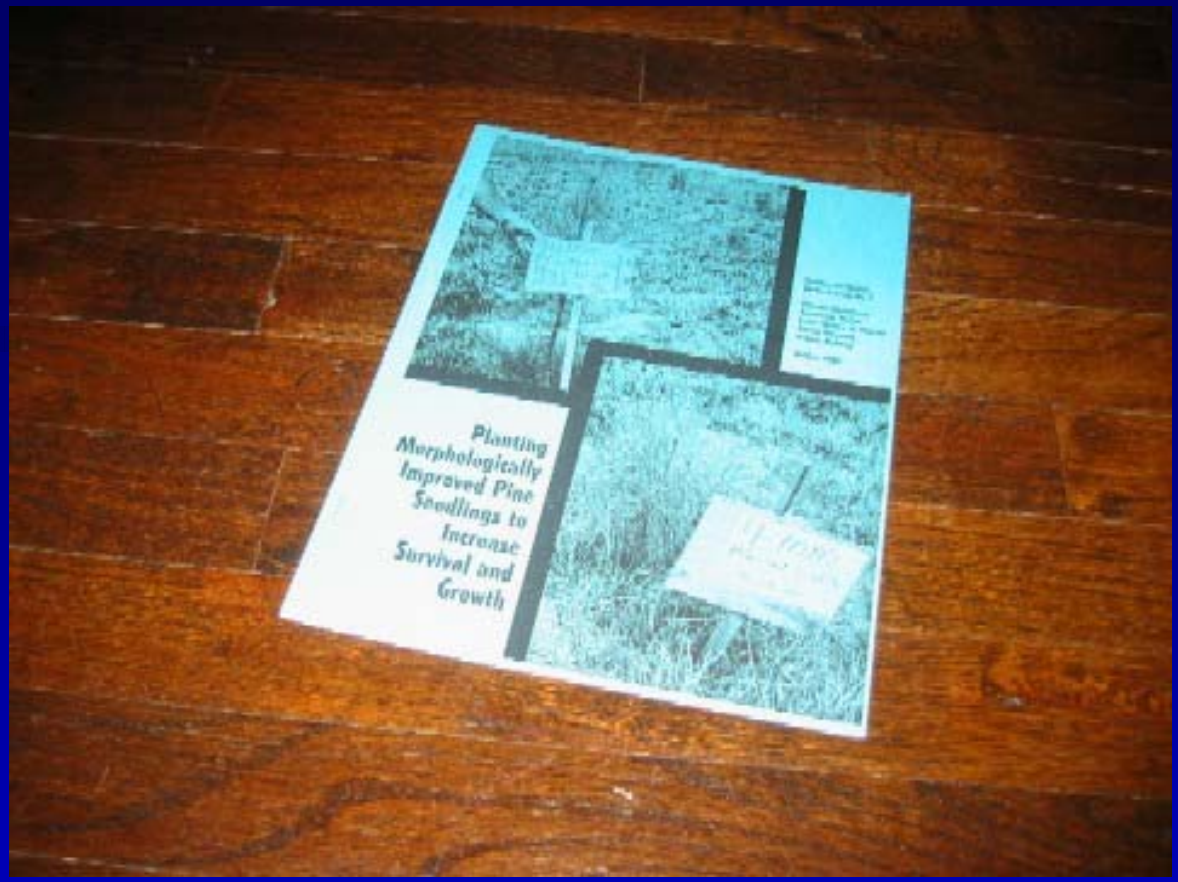

Ht (feet)
Ht (meters)
25
20
15
10
5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
6
4
2
0
$472
$461
$288
$277
Hamilton
Intensive
Standard
A
A
B
B

Hamilton Ridge site

- Survival was high 93.5% for both ideotypes.
- When comparing alternative methods of establishment, planting low-density seedlings (in this case) can achieve the same response as planting 5 mm seedlings and investing $173/acre in intensive management.

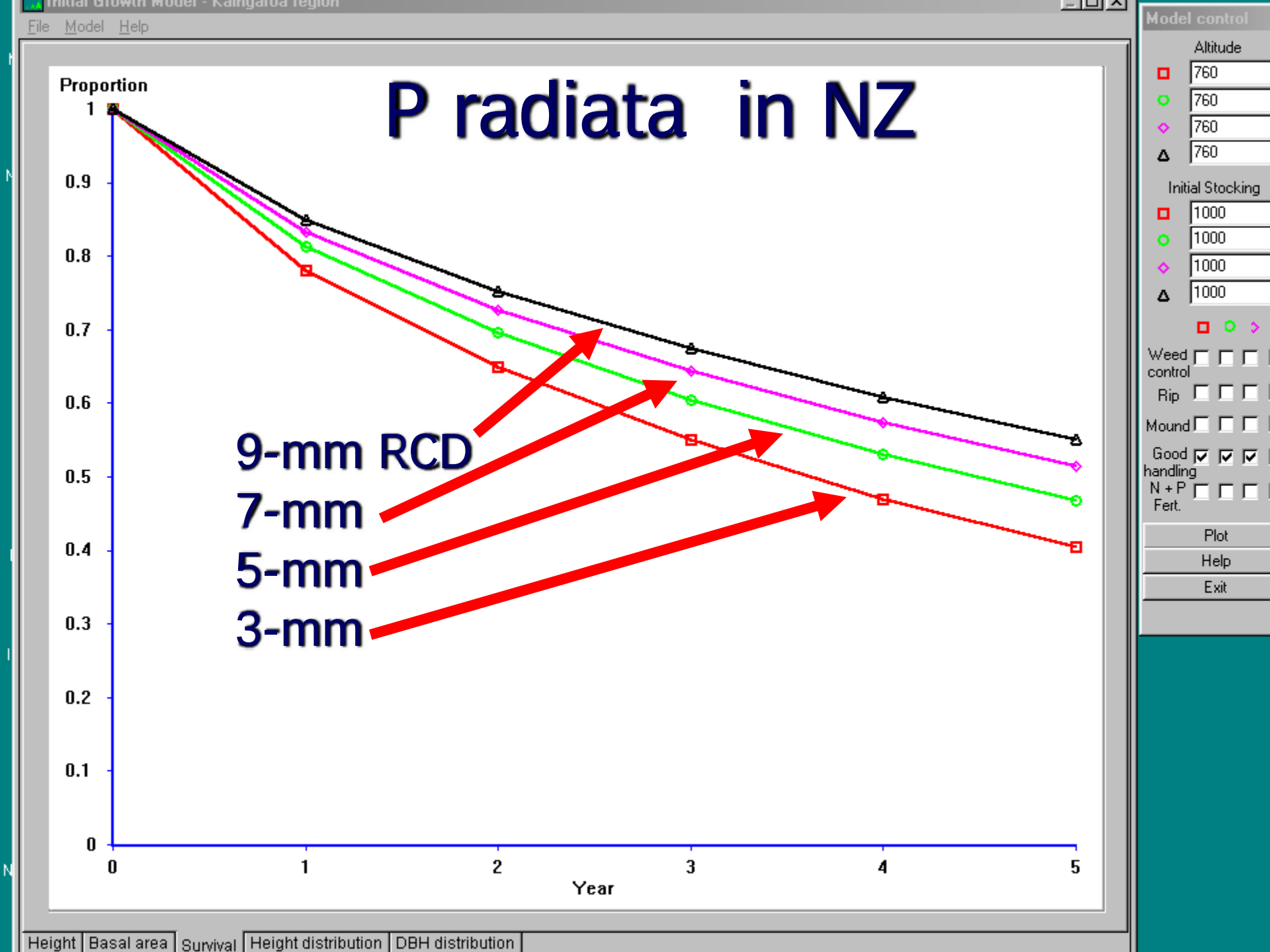
Conclusions

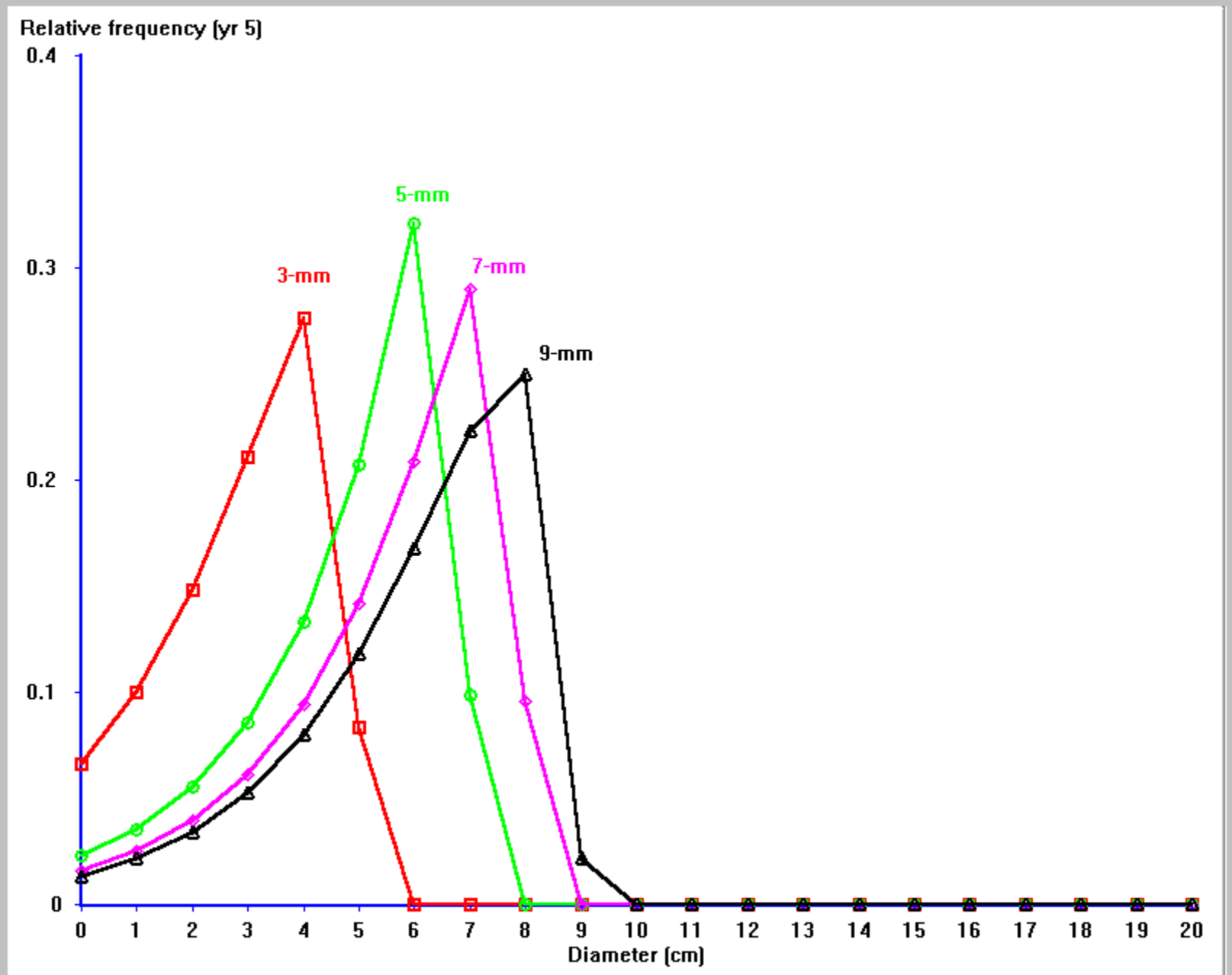
- Gains in survival and growth can be achieved by planting low-density seedlings (machine planting recommended)
- Per seedling costs are higher for low-density seedlings than for regular seedlings but the benefit/cost ratio can be substantial



www.forestry.auburn.edu/sfnmc/morphology.pdf

QUESTIONS???


Initial Growth Model - Kaingaroa region
File Model Help
P radiata in NZ
Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
Year
9-mm RCD
7-mm
5-mm
3-mm
Model control
Altitude
760
760
760
760
Initial Stocking
1000
1000
1000
1000
Weed control
Rip
Mound
Good handling
N + P Fert.
Plot
Help
Exit
Height
Basal area
Survival
Height distribution
DBH distribution



Altitude

□	760
○	760
◇	760
△	760

Initial Stocking

□	1000
○	1000
◇	1000
△	1000

	□	○	◇	△
Weed control	☐	☐	☐	☐
Rip	☐	☐	☐	☐
Mound	☐	☐	☐	☐
Good handling	☑	☑	☑	☑
N + P Fert.	☐	☐	☐	☐

Plot
Help
Exit

eight | Basal area | Survival | Height distribution | DBH distribution

A quick look at costs

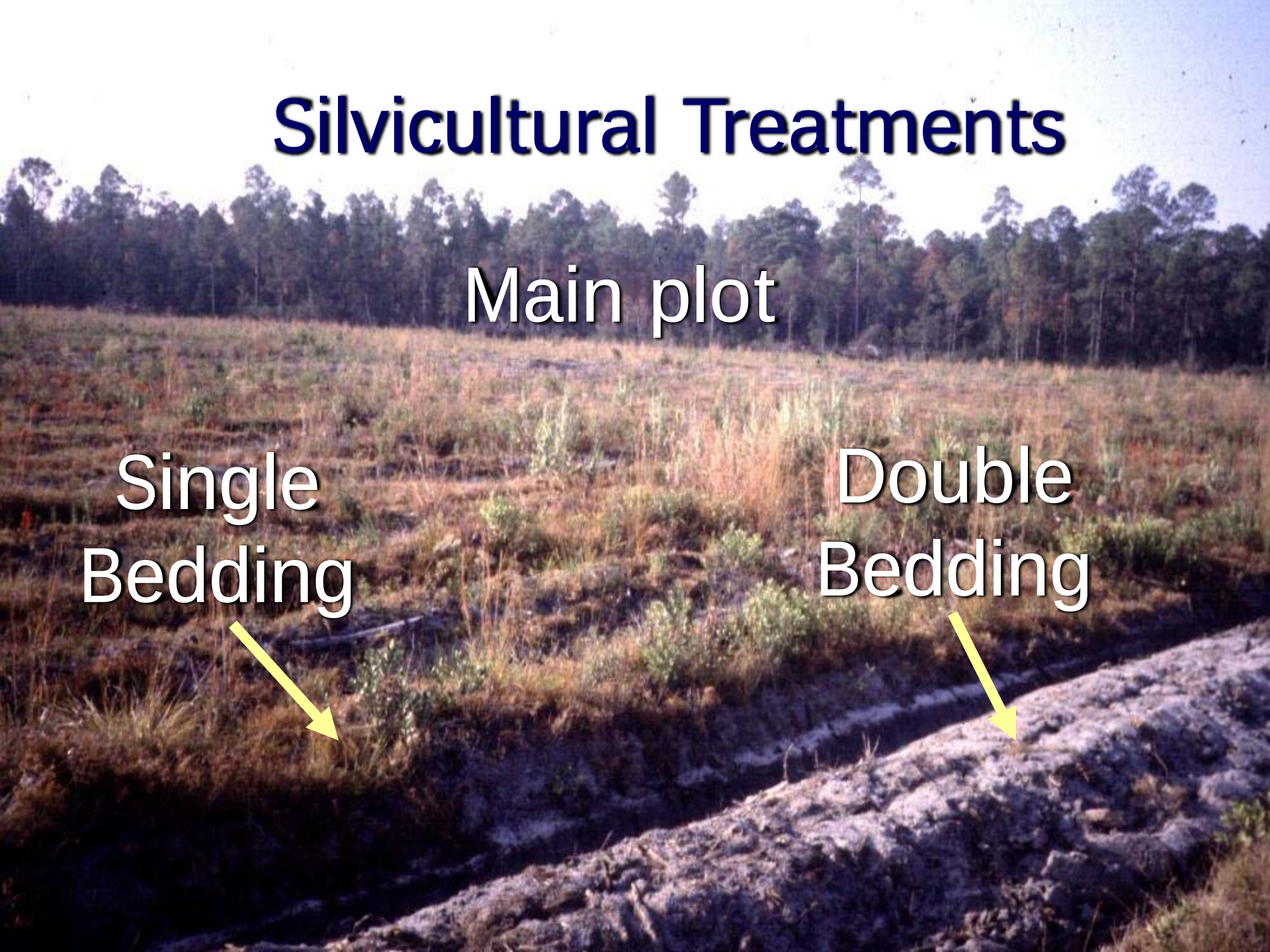
2.9 cents more per tree

Assume machine planting

Assume 60% landowner assistance

10’ x 11’ spacing = $4.59 more per acre
10’ x 10’ spacing = $5.04 more
10’ x 9’ spacing = $5.62 more
10’ x 8’ spacing = $6.32 more
10’ x 7’ spacing = $7.22 more

Silvicultural Treatments



Silvicultural Treatments

Seedling diameter Class

Split-split plot

10 diameter classes

Survival

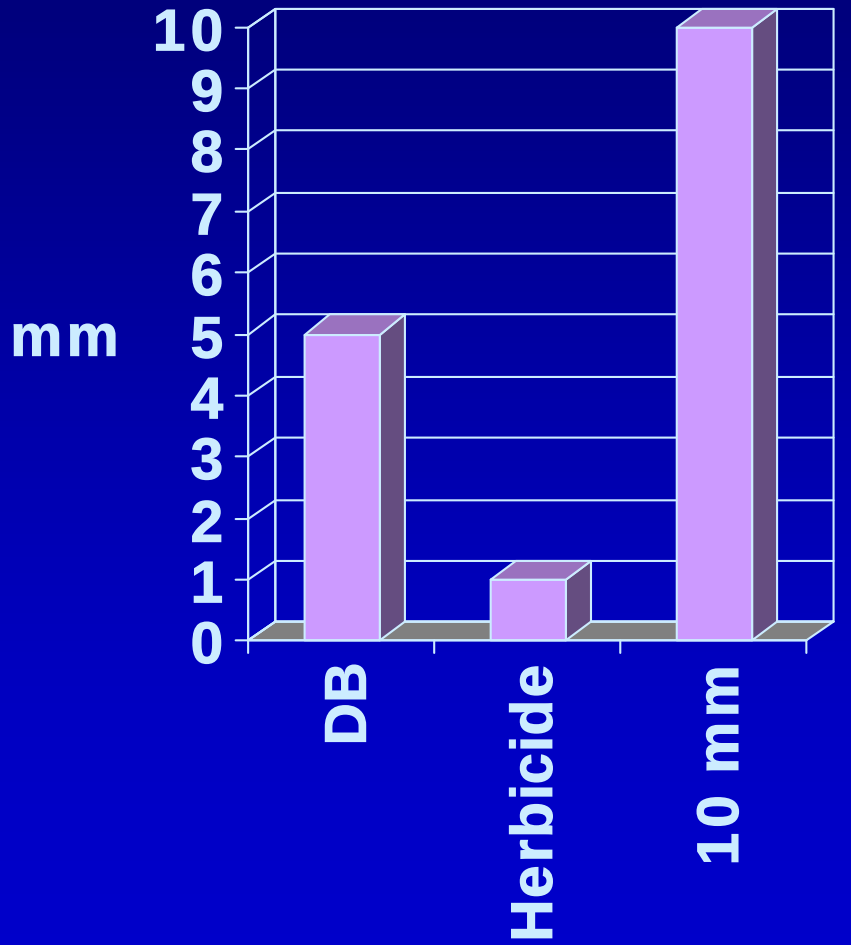
- Double-bedding did not increase survival ($p=0.36$).
- A single application of imazapyr did not increase survival ($p=0.45$).
- Seedling class had a strong effect on survival ($p=0.0001$)

4th-yr DBH

- Double-bedding increase DBH slightly ($p=0.074$).
- A single application of Arsenal did not increase DBH ($p=0.72$).
- Seedling class had a strong effect on DBH ($p=0.0001$)

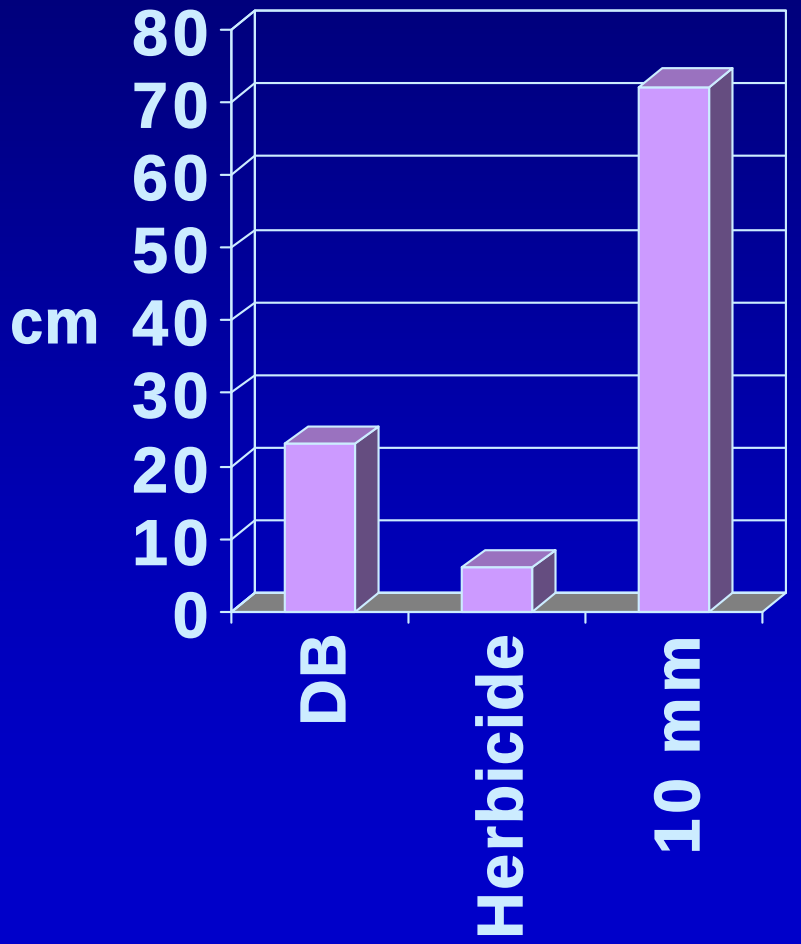
Increase in DBH

- In comparison to 4 mm seedlings, 10 mm seedlings increased 4-yr DBH by 10 mm



Increase in Height

- In comparison to 4 mm seedlings, 10 mm seedlings increased 4-yr heights by 72 cm



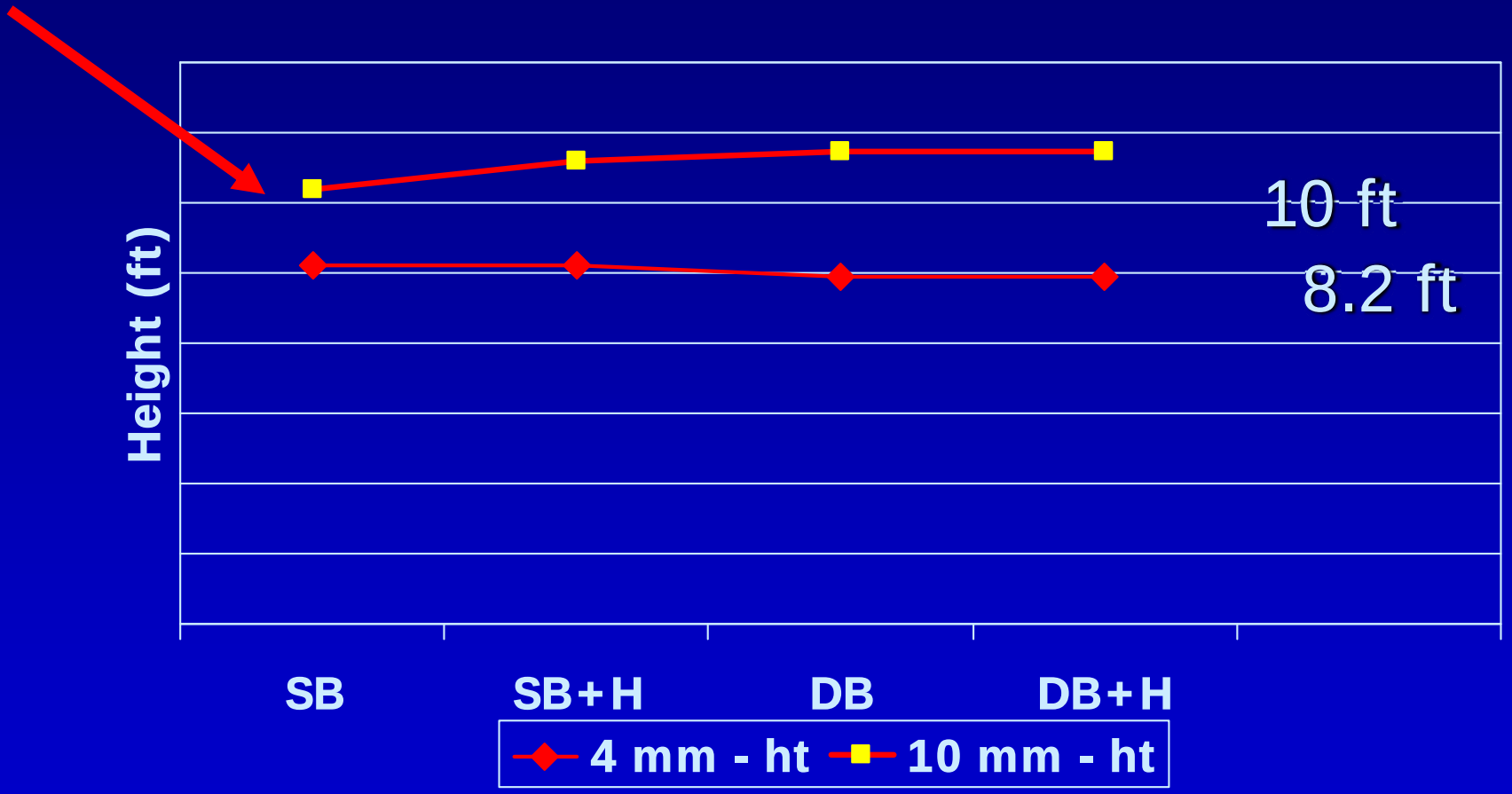
Establishment targets

- Survival > 90%
- Height at age 4 > 10 feet

Establishment costs / Acre

- Machine planting = $48
- Double bed = $65
- Single bed = $36
- Herbicide = $40
- 4 mm seedlings = $14
- 10 mm seedlings = $34

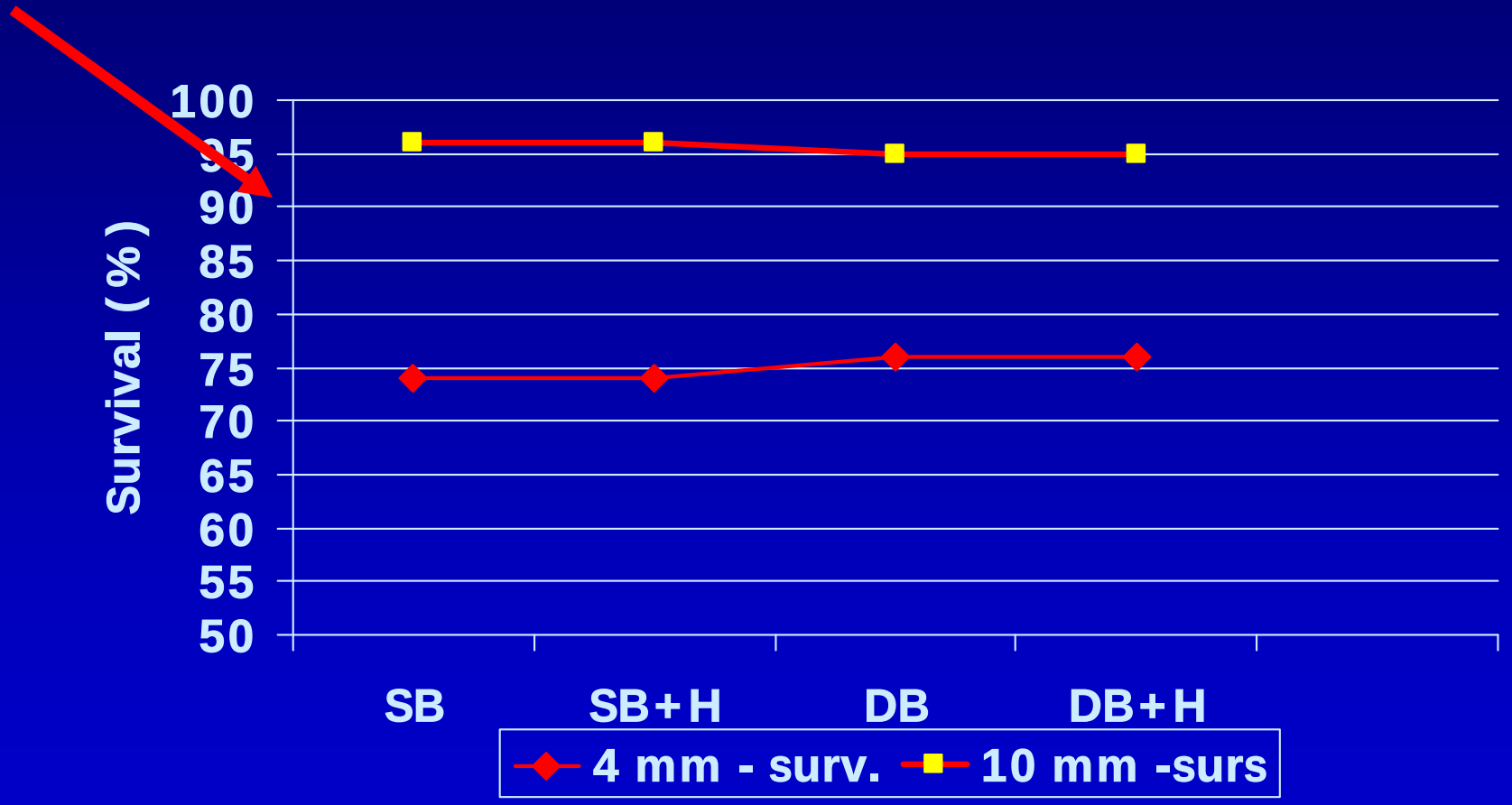
Performance targets



Site locations

- Loblolly pine, Hamilton Ridge site in South Carolina
- Slash pine, at Homerville, Georgia

Performance targets



Establishment costs

Bed	*Herb*	*RCD*	*Target*	*$/Ac*
Single	-	4	No	98
Single	-	10	Yes	118
Double	-	4	no	127
Single	+	4	no	139
Double	+	4	no	167
Double	+	10	yes	187

Slash pine site

- Survival is positively related to RCD.
- For one site in Georgia, the “optimum” seedling has a RCD of about 9-10 mm.
- When comparing alternative methods of establishment, planting large-diameter seedlings can (in some cases) reduce overall establishment costs by $49/acre.

Results - Height - Yr 4

- Hamilton ridge
  - Intensity (P = 0.048)
  - Ideotype (P = 0.011)