American Chestnut (*Castanea dentata*) Seedling Production: Restoring a Long-Lost Species

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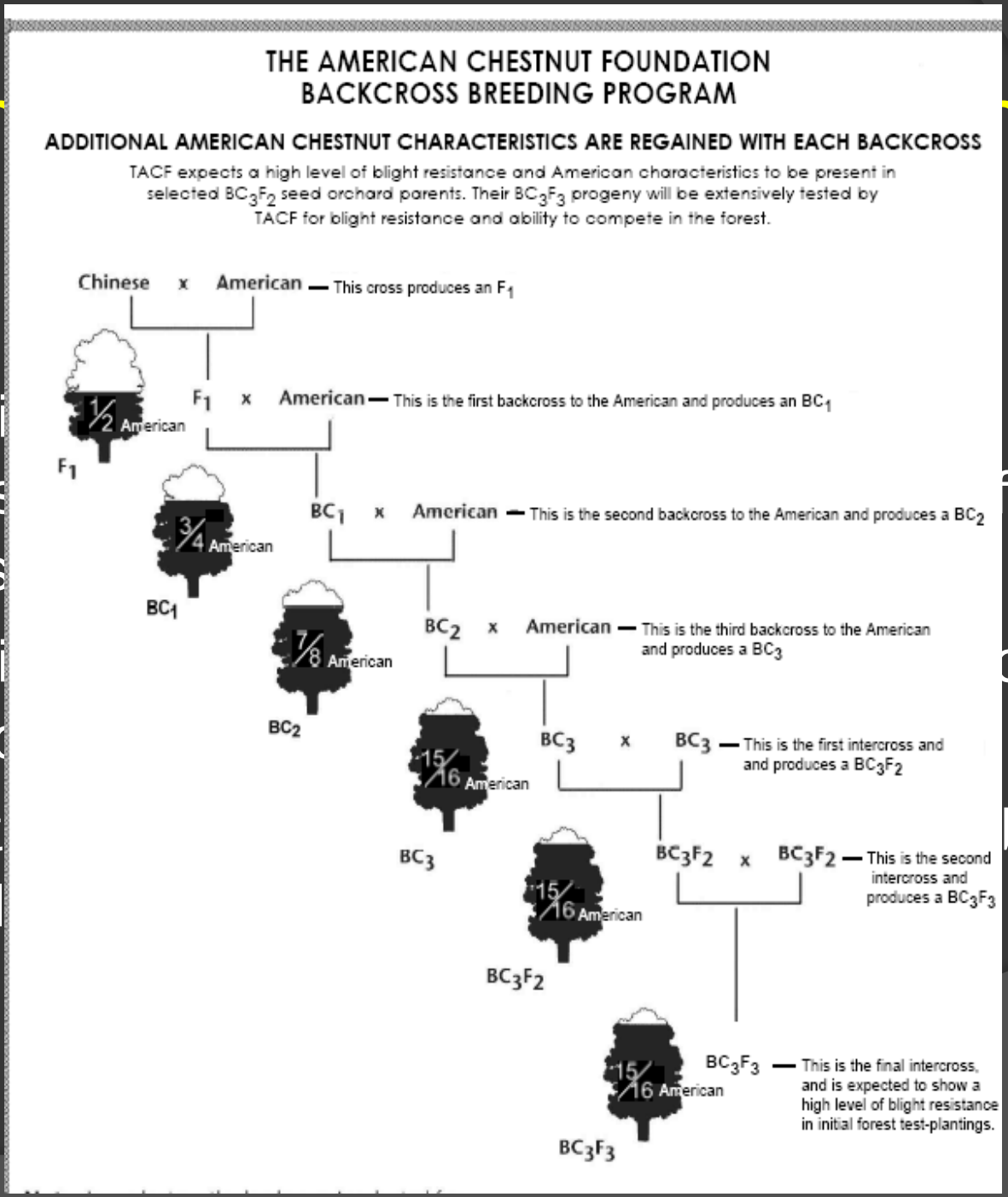
- Goal –To determine the most efficient methods to artificially regenerate oaks and American chestnut in upland hardwood forests.

Fagaceae artificial regeneration– why so hard?

- More difficult to propagate, plant, and keep in competitive position compared to pine
- Have lower heritability compared to pine
- Takes longer to mature sexually compared to pine
- Know virtually nothing about chestnut
- Nursery production/genetics is rarely discussed in literature of oak planting studies

Am ng

- Breedi for fungus ink dis
- Breedi on- Americ
- Select ber form, l



Steps for Successful Artificial Regeneration of Fagaceae Species

1. Seed collection and seed source
2. Nursery production and seedling quality
3. Planting considerations
4. Silvicultural systems
5. Seedling protection and competition control

Stacy L. Clark, Scott E. Schlarbaum, Arnold M. Saxton and Fred V. Hebard. Nursery performance of American and Chinese chestnuts and backcross generations in commercial tree nurseries. *Forestry: An International Journal of Forest Research*. 85:589-600, doi:10.1093/forestry/cps068.

Seed collection and seed source

TACF Meadowview, VA Orchard (Fred Hebard)

- **BC_3F_3 from open pollinated BC_3F_2 orchards**
- **Wild American trees from VA/TN**
- **Chinese from various sources**

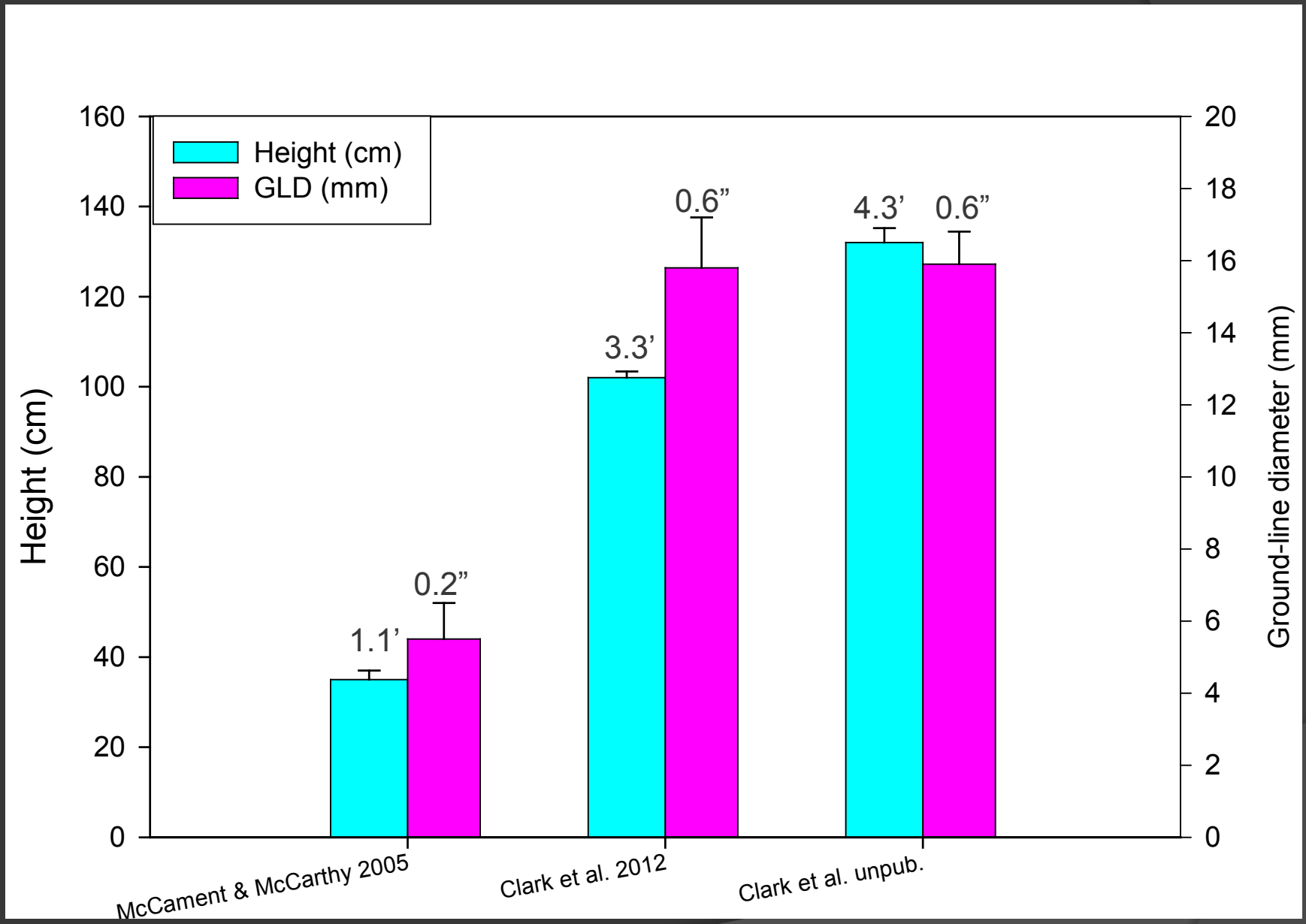
National Forest System, Southern Region (Barbara Crane, Bob Makowski)

UT-Tree Improvement Program (Scott Schlarbaum)

SRS-Stacy Clark

Justification for nursery production

- Direct seeding lowers survival
  - 50% reported after two years by McCament and McCarthy. 2005 vs. 80% for Clark et al. 2012
- Direct seeding will not produce competitive seedlings on most eastern hardwood sites
  - Might work on lowest quality sites


Height (cm)
GLD (mm)
Height (cm)
Ground-line diameter (mm)
160
140
120
100
80
60
40
20
0
20
18
16
14
12
10
8
6
4
2
0
1.1'
0.2"
3.3'
0.6"
4.3'
0.6"
McCament & McCarthy 2005
Clark et al. 2012
Clark et al. unpub.

Nursery Production and Seedling Quality

- Sow at 6 per ft^2
- Use nursery with frequent fertilization regime (once every 10-14 days for NRO)
  - Villanova Nursery-Indiana State Nursery
  - East Tennessee State Nursery-TN Division of Forestry
  - Georgia State Nursery-GA Forestry Commission
  - Adjust major and minor elements prior to sowing
  - For example at ETN in 2010:
    - 135-150 lbs/acre Ammonium sulfate (35N-0P-0K) 4 applications starting May 20 ending August 3
    - Di-Ammonium Phosphate (18-46-0) once in July
    - Muriate of Potash (0-0-60) once in September
- Check soil texture for quality (sandy loam with good drainage, no hard pan)
- Cut off fertilizer/water to avoid poor root/shoot ratio

Kormanik, P.P., S.S. Sung, and T.L. Kormanik 1994. Irrigating and fertilizing to grow better nursery seedlings. P. 115-121 *in* Proc. Northeast. and Intermount. For. and Cons. Nurs. Assoc. USDA For. Serv. GTR-RM-243, Rocky Mount. Res. Sta., Fort Collins, CO.

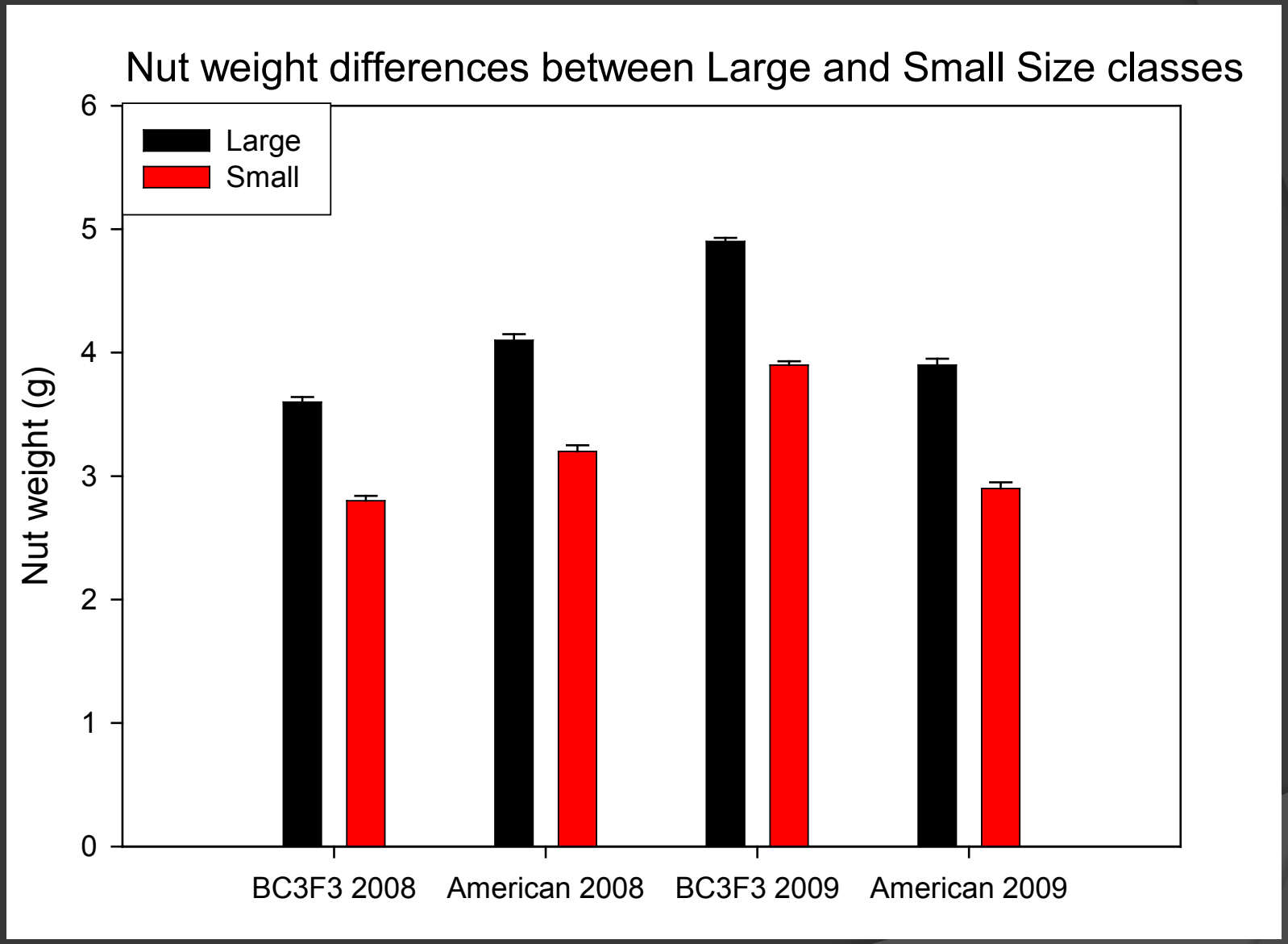
Nursery study (Clark et al. 2012)

- Determine affect of nut size on seedling quality
- Test differences among generations and parental species

Nursery study (Clark et al. 2012)

- 1789 nuts in 2007 - weighed
- 2032 nuts in 2008 - weighed
- American & Chinese (parent species)
- BC_1F_3, BC_2F_3, BC_3F_2,BC_3F_3 generations
- Split nuts into Large and Small groups within each family
- Grown in GA (2007) and TN (2008) state nurseries for 1 year

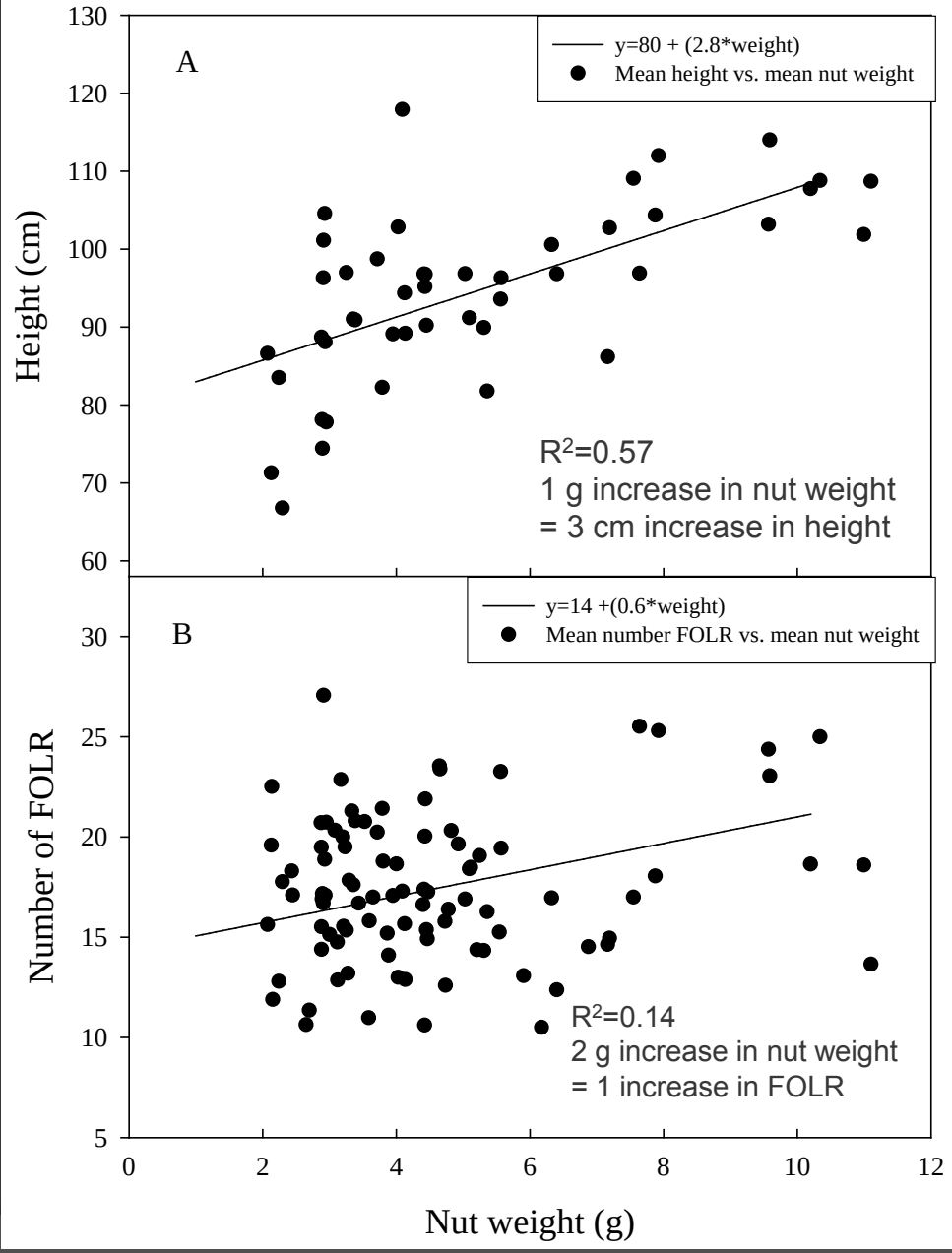
B3F3 (~94% American): Small (left), Large (right)


Nut weight differences between Large and Small Size classes
Large
Small
Nut weight (g)
0
1
2
3
4
5
6
BC3F3 2008
American 2008
BC3F3 2009
American 2009

Nursery study (Clark et al. 2012)

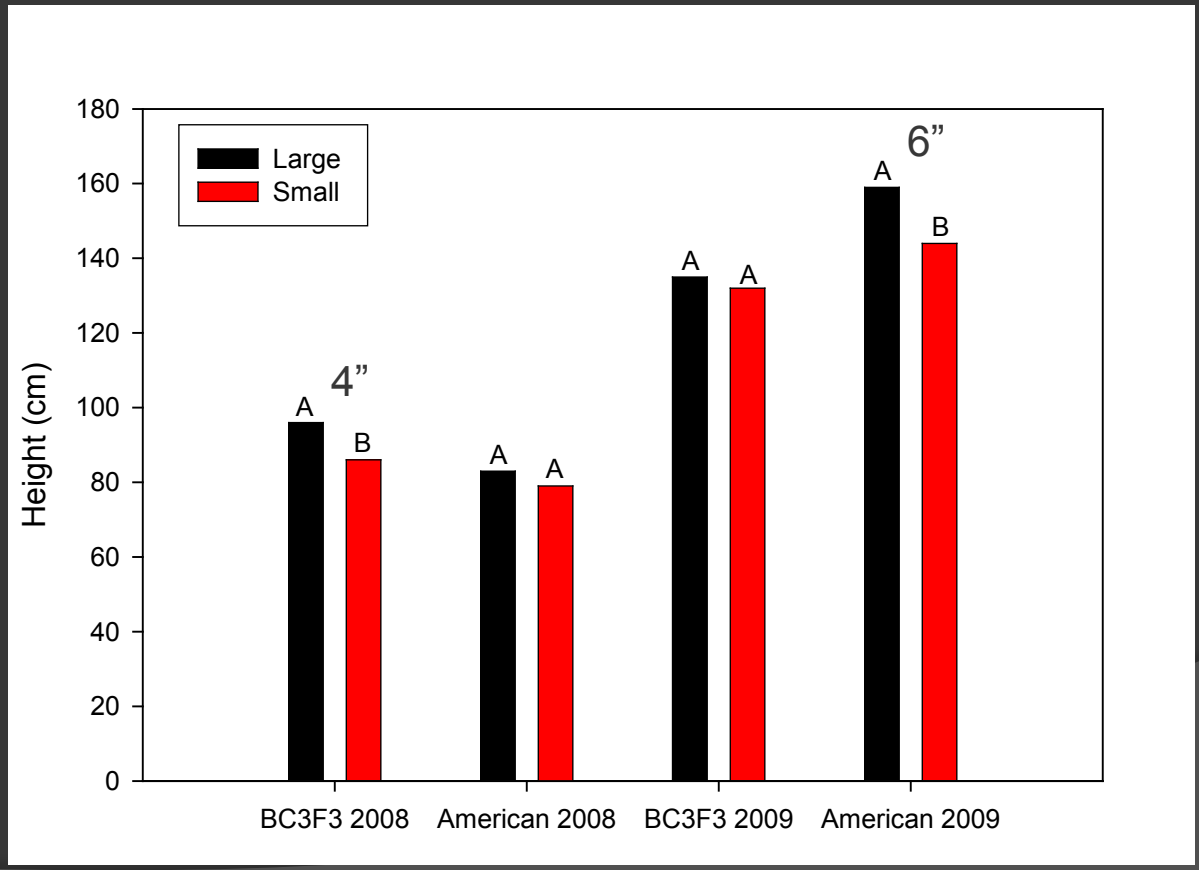
- 1-0 seedlings:
  - Height-3.2’ (2008), 4.4’ (2009); Range 0.5-8.6’
  - RCD-0.5” (2008), 0.6” (2009); Range 0.1-1.2”
  - FOLR-18 (2008), 15 (2009); Range 0-48

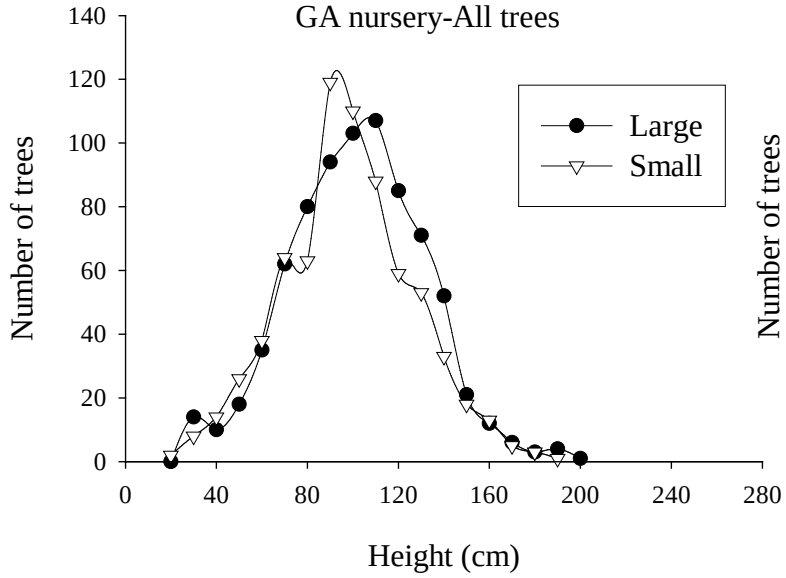
ease in nut weight
1 increase in FOLR

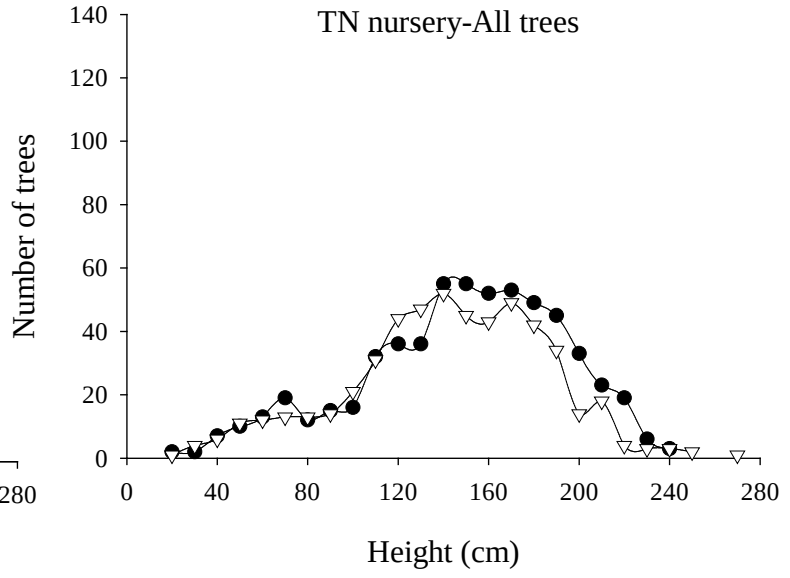

A
y=80 + (2.8*weight)
Mean height vs. mean nut weight
Height (cm)
130
120
110
100
90
80
70
60
R2=0.57
1 g increase in nut weight
= 3 cm increase in height
B
y=14 +(0.6*weight)
Mean number FOLR vs. mean nut weight
Number of FOLR
30
25
20
15
10
5
R2=0.14
2 g increase in nut weight
= 1 increase in FOLR
0
2
4
6
8
10
12
Nut weight (g)

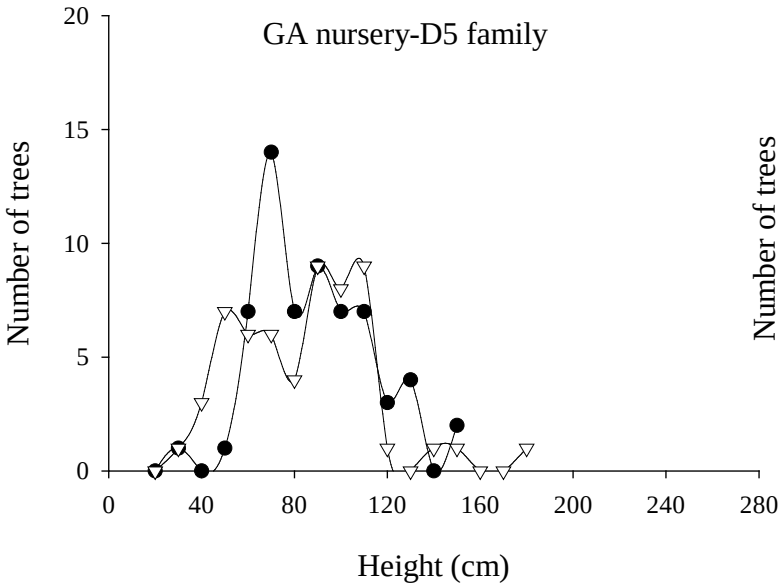
Nursery study (Clark et al. 2012)

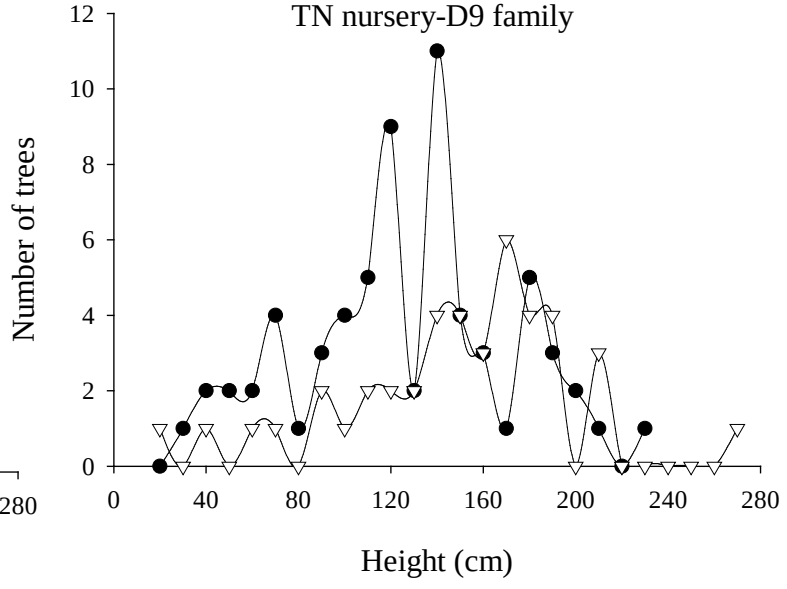
- Nut size class did not affect number of FOLR or RCD, but did affect height at lifting



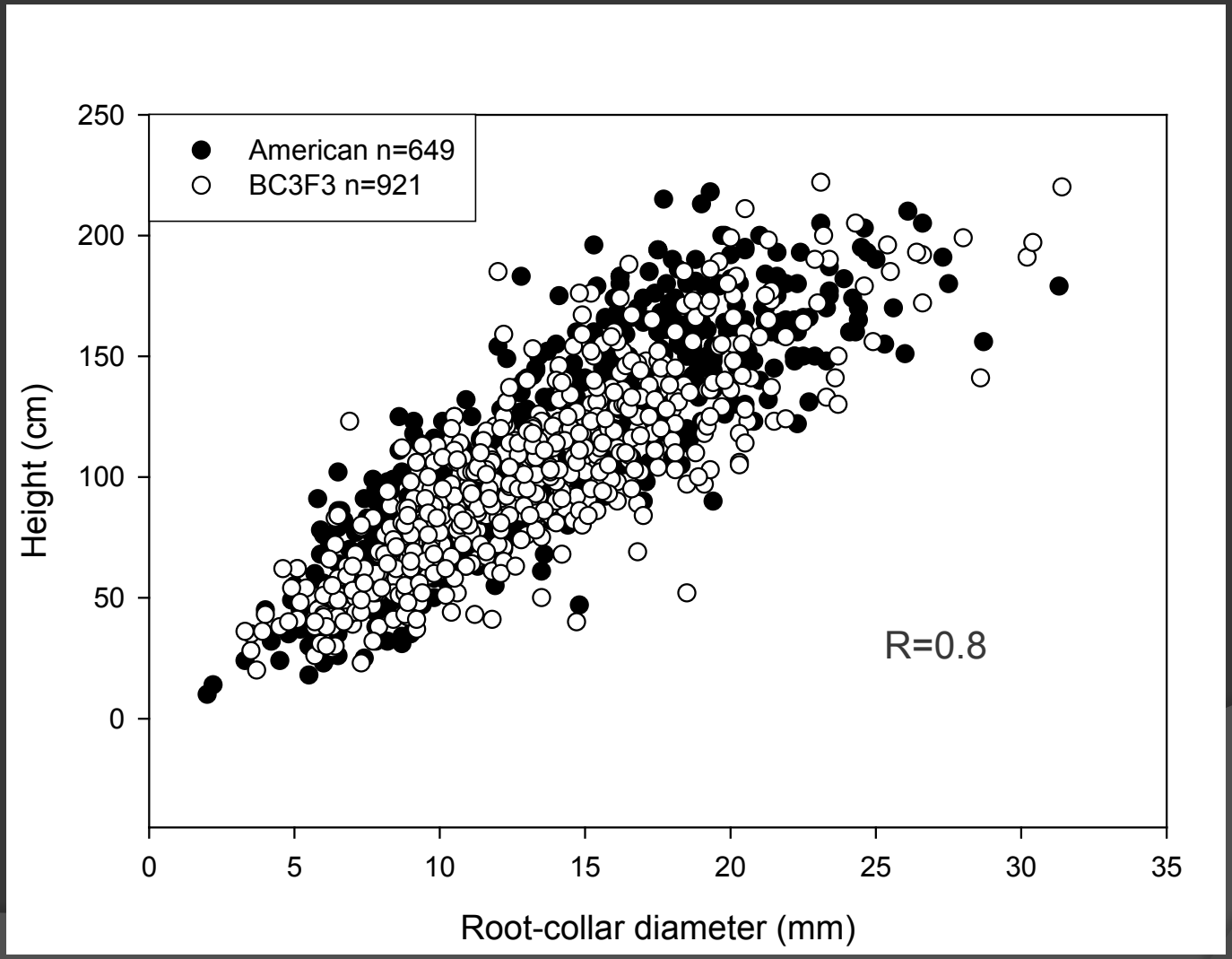

GA nursery-All trees
Large
Small
Number of trees
Height (cm)
0
20
40
60
80
100
120
140
0
40
80
120
160
200
240
280

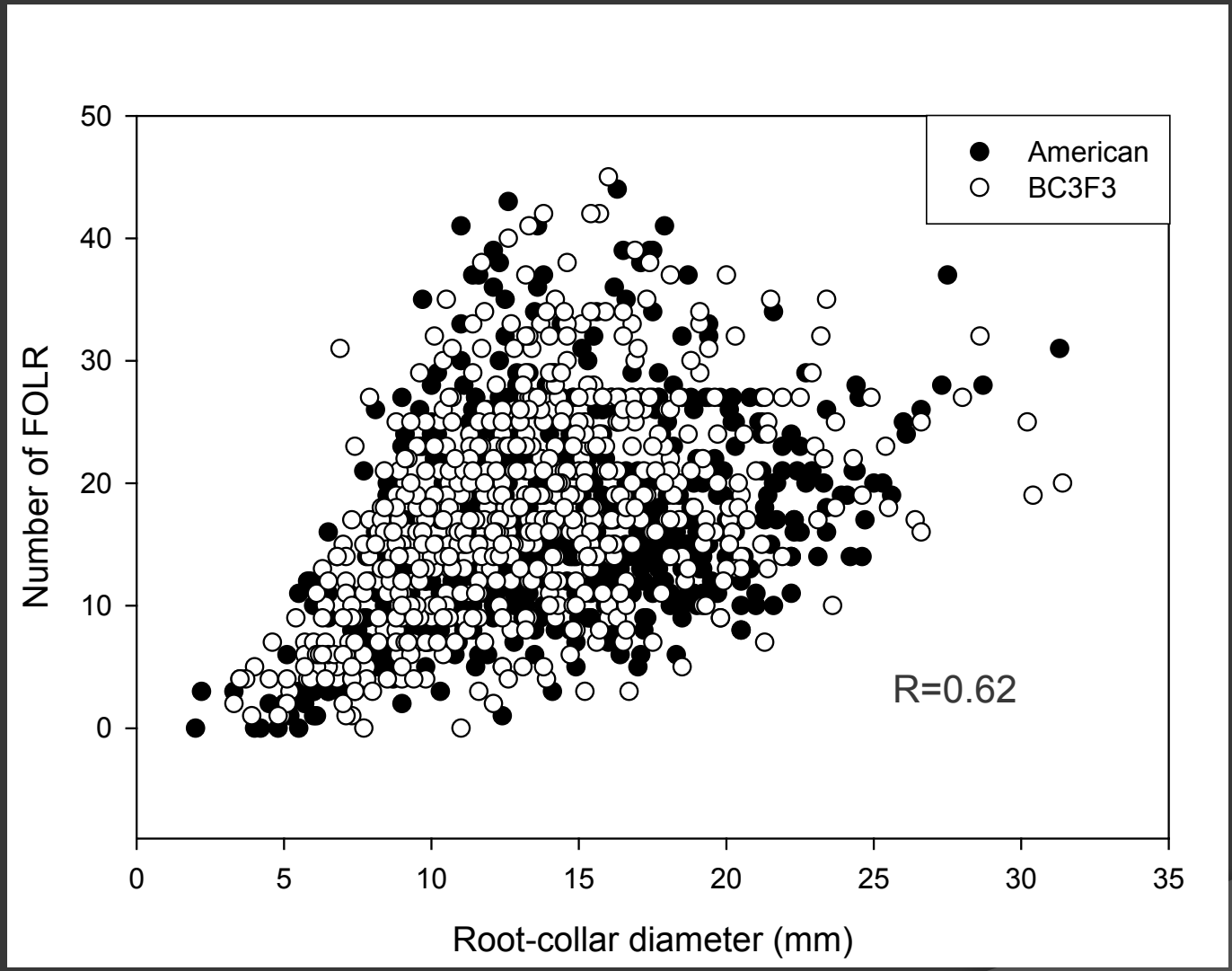

TN nursery-All trees
Number of trees
Height (cm)
0
20
40
60
80
100
120
140
0
40
80
120
160
200
240
280

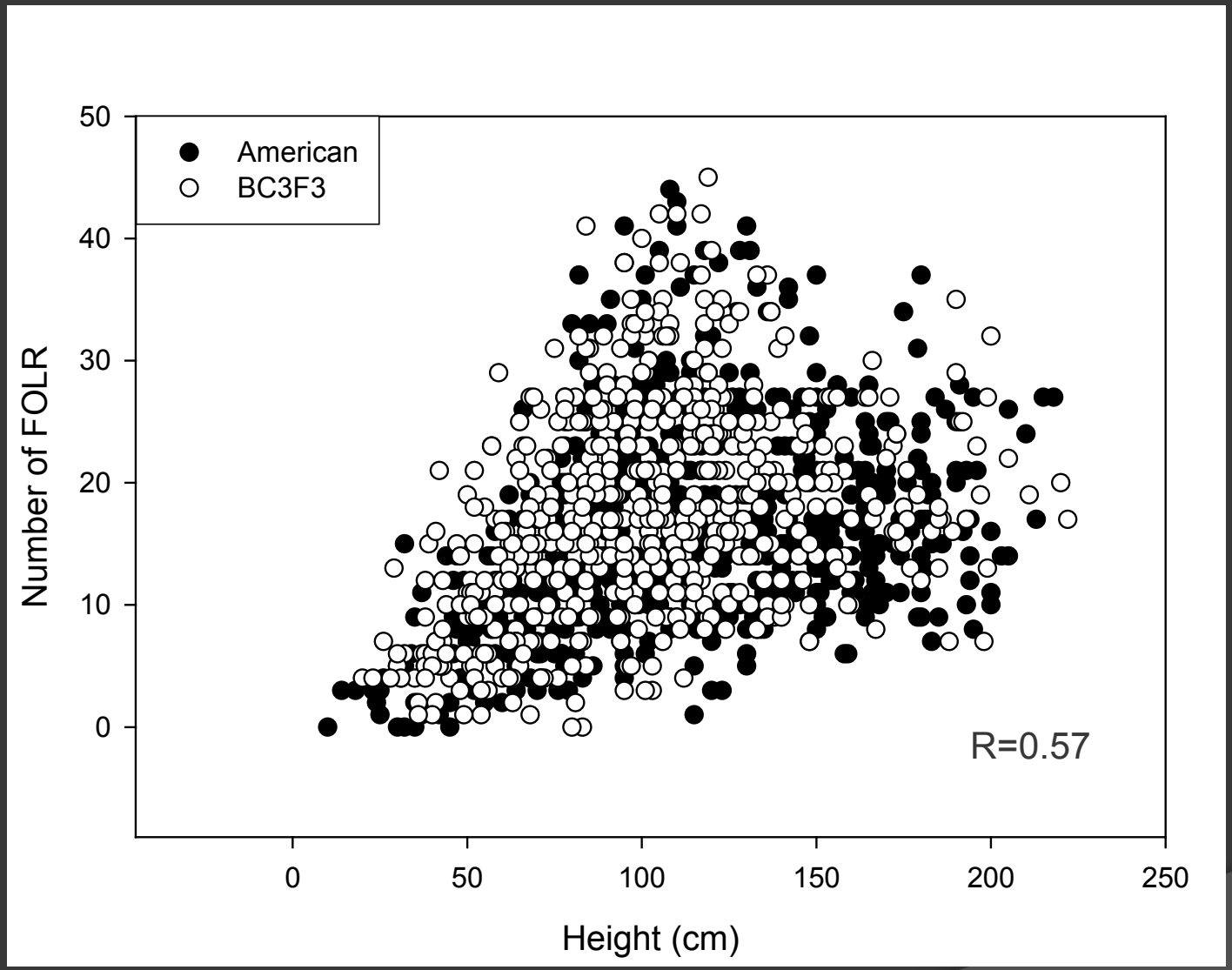

GA nursery-D5 family
Number of trees
Height (cm)
0
5
10
15
20
0
40
80
120
160
200
240
280


TN nursery-D9 family
Number of trees
Height (cm)
0
2
4
6
8
10
12
0
40
80
120
160
200
240
280

- Root-collar diameter most highly correlated to above and below ground variables




American
BC3F3
R=0.62
Number of FOLR
Root-collar diameter (mm)
0
10
20
30
40
50
0
5
10
15
20
25
30
35


American
BC3F3
Number of FOLR
Height (cm)
R=0.57
0
10
20
30
40
50
0
50
100
150
200
250

Summary of Nursery study (Clark et al. 2012)

- Nut size did affect height growth, was slightly correlated to root growth, and was not correlated to RCD growth
- Seedlings were highly variable in growth regardless of size class
- RCD should be primary grading criteria
- BC_3F_3 were more similar to Americans than to Chinese

Nursery Production and Seedling Quality

- Similar approach as oak (Paul Kormanik's work)
- Can differentiate seedling size classes for planting
- Averaged 3.2' for 2009 plantings; 4.4' for 2010 and 2011 plantings
- Root-collar diameter is most highly correlated with height and number of roots
- *Phytophthora* is going to be a major problem with American chestnut nursery propagation

Nursery Production and Seedling Quality

- Seedling grades:
- Premium - Highest quality
  - Plant on highest quality sites
  - Top 10-25% of trees from nursery
  - Plant where you want fast seed/growth production
  - RCD $\geq$ 0.5”; Height $\geq$ 4’
  - Given average site conditions, will require lowest maintenance costs

Nursery Production and Seedling Quality

- Minimum - Average in quality
  - Plant on medium to high quality sites
  - Top 40-50% trees from nursery
  - Will require some maintenance
  - RCD 0.3”; Height 2.5-4’
- Cull - Poorest in quality
  - Do not plant
  - Given average site conditions, will require abundant maintenance
  - RCD<0.3” ;Height < 2.5’


Nursery-run NRO seedlings


Cull NRO seedlings

Planting considerations

- Match planting tool with size of seedling
  - Auger (6-8”) or shovel for very large seedlings
  - KBC bar (modified to increase bar width) to plant quality-grown seedlings
  - Dibble-bar will not work
- Trim lateral roots to planting width
  - Don’t let planting crew trim roots
- Don’t leave air pockets in planting hole
- Don’t think “pine” mentality
  - Increase pay to planting crew
  - Increase spacing for larger seedlings
  - Be more targeted with planting locations within the stand

Modified KBC bar

Silvicultural Systems

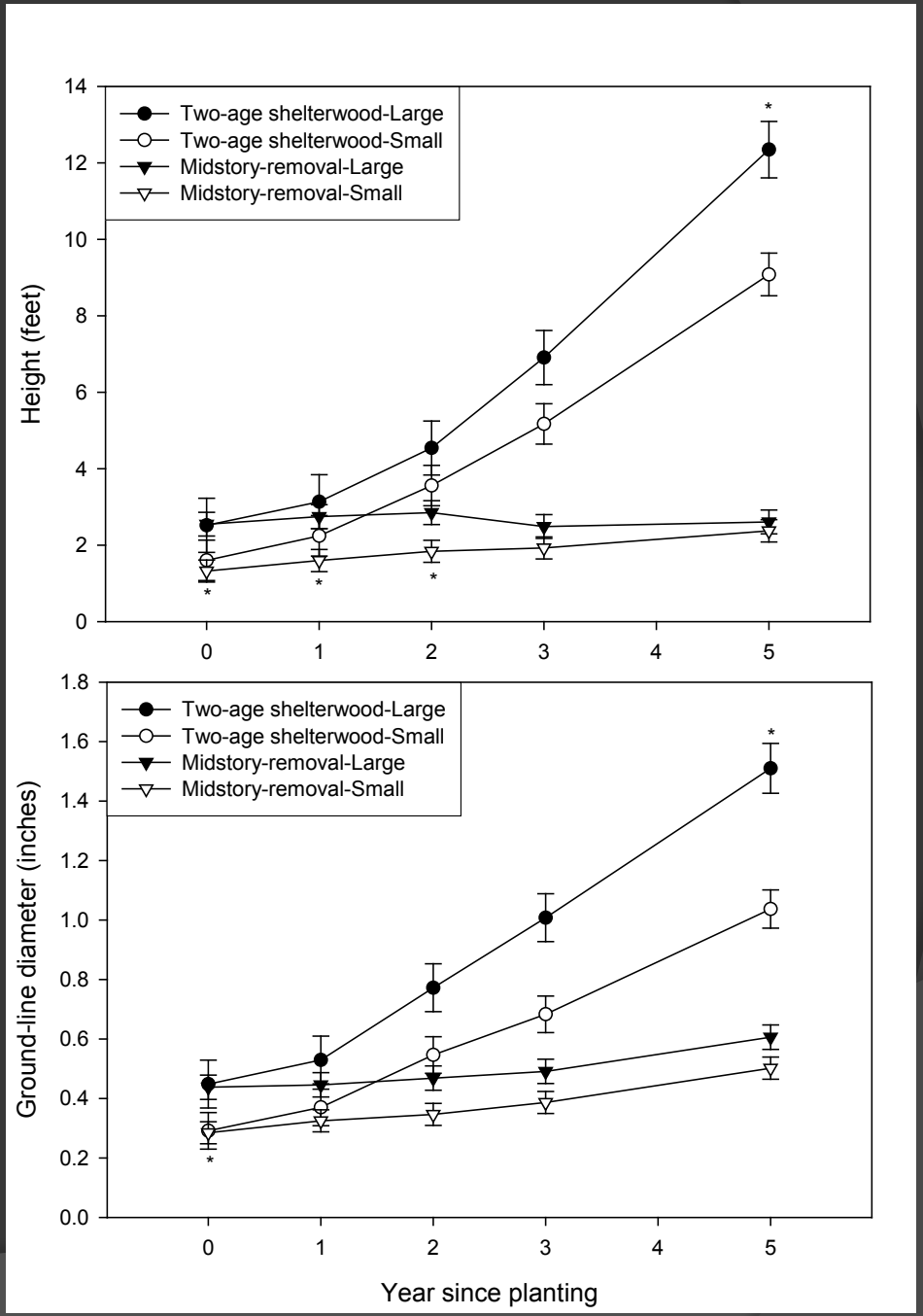
- Regeneration harvests:
  - Commercial shelterwood harvests
    - 30-50% canopy cover (residual stocking ~40-60%)
    - To reduce competition, the amount of overstory retention should increase with increasing site quality, depending on competition control and other restrictions
    - Remove overwood when trees are well established or leave as two-aged

Silvicultural Systems

- Non-commercial shelterwood treatment (e.g., oak shelterwood or Loftis shelterwood)
  - Seedlings may survive, but will not grow well until overwood removed (light compensation point is 2-5%; light saturation will occur at 30-50% full sunlight)
  - Preliminary results indicate high-quality seedling die after 1-2 years in this system
  - When overstory is removed, seedlings will probably need competition control depending on site quality

Silvicultural Systems

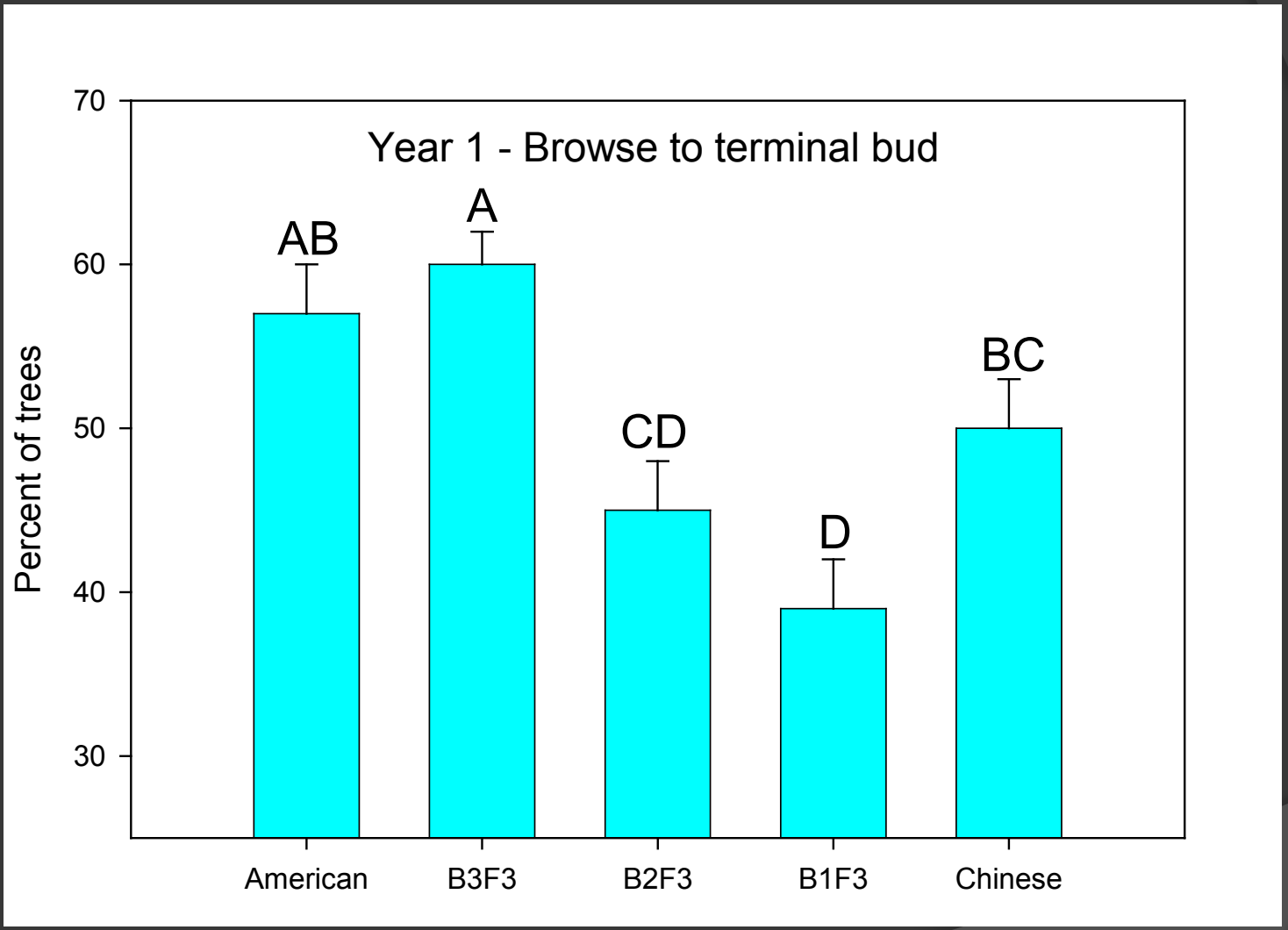
Clark, S.L. Henry McNab, David Loftis, Stan Zarnoch. 2012. American chestnut growth and survival five years after planting in two silvicultural treatments in the southern Appalachians, USA. Forests 3:1017-1033; doi: 10.3390/f3041017



Seedling protection

- A 20” tree at planting was 5 times more likely to be browsed than a 60” tree
- Small seedlings more likely to be browsed by deer (55%) compared to Large seedlings (48%)
- Shelters are effective, but expensive
  - ($1-5/tree)
  - Bears can destroy them
- Fence if money is available
- Commercial repellents
  - Require frequent application (monthly)
  - Rain can increase application frequency
  - $1.40 per year per tree
  - A lot cheaper than shelters! ($3-6 per tree)
- Medium to high-quality seedlings won’t get damaged by rabbits

Deer browse on planted chestnut seedling

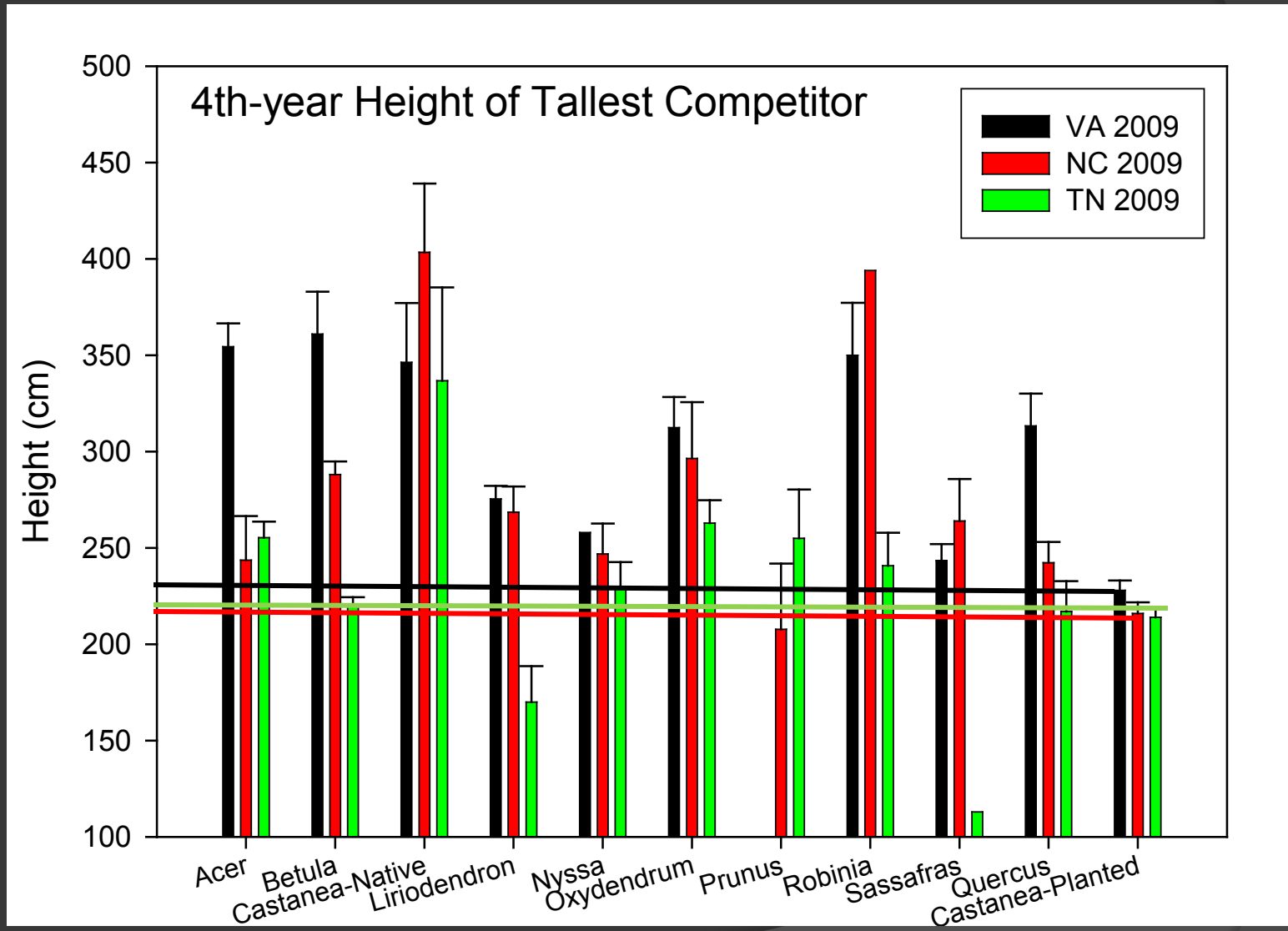

Year 1 - Browse to terminal bud
Percent of trees
70
60
50
40
30
AB
A
CD
D
BC
American
B3F3
B2F3
B1F3
Chinese

Competition Control

- Competition control in regeneration harvests:
  - Treat stumps and stems of undesirables 1-6” dbh on higher quality sites (SI>70)
    - Garlon 3A (cut stump or preharvest hack and squirt)
  - Treat sprouts of undesirables after harvest
    - Garlon 4 (streamline spray)
- More competition control will be needed on higher quality sites and where residual basal area is low

Johnson, P.S. et al. 1986. Planting northern red oak in the Missouri Ozarks: A prescription. Northern Journal of Applied Forestry 3:66-68.

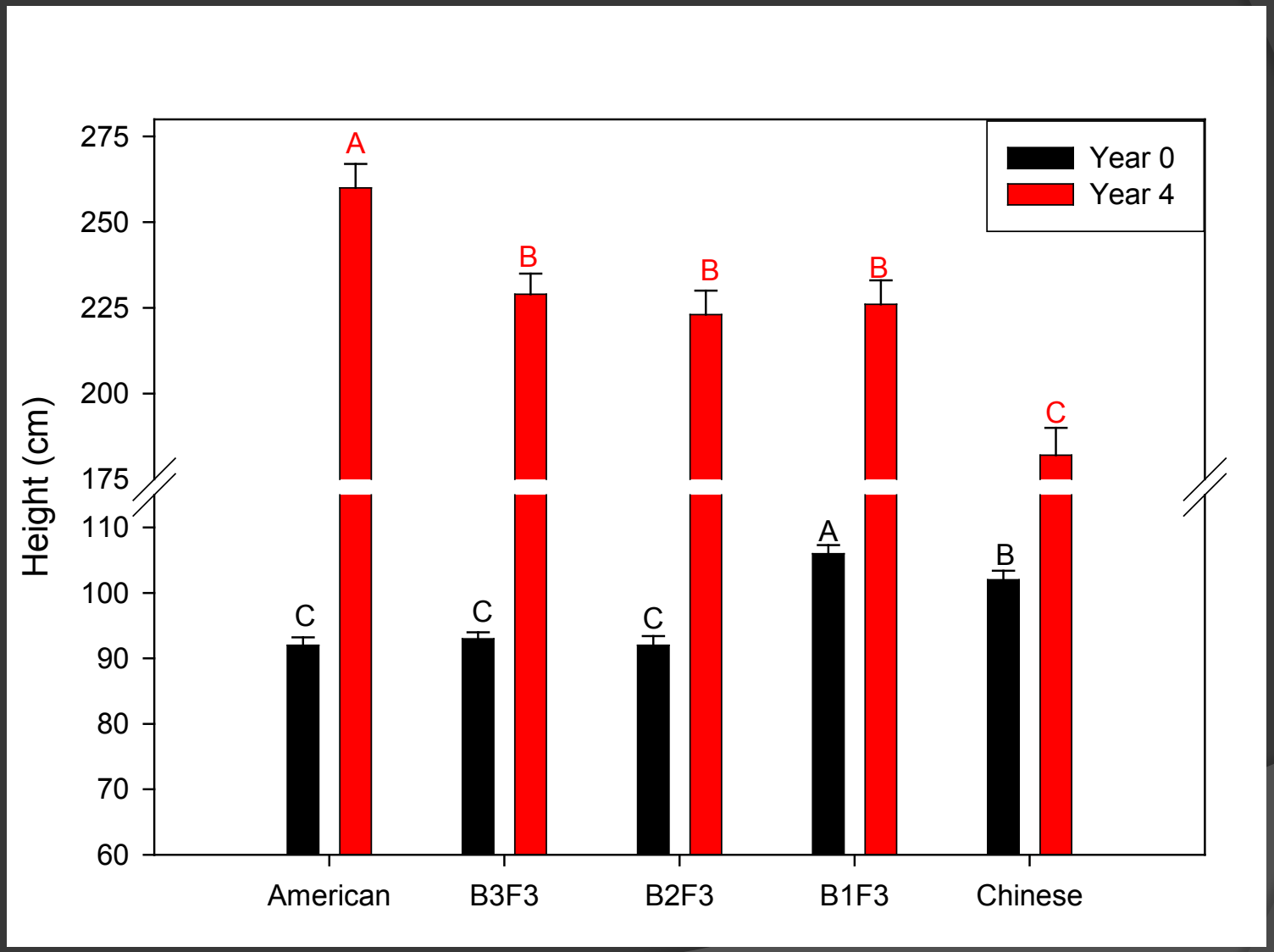
Spetich, M.A., et al., 2002. Competitive capacity of Quercus rubra L. planted in Arkansas’ Boston Mountains. Forest Science 48:504-517.


4th-year Height of Tallest Competitor
VA 2009
NC 2009
TN 2009
Height (cm)
500
450
400
350
300
250
200
150
100
Acer
Betula
Castanea-Native
Liriodendron
Nyssa
Oxydendrum
Prunus
Robinia
Sassafras
Quercus
Castanea-Planted

Overview of American chestnut field performance 2009 plantings

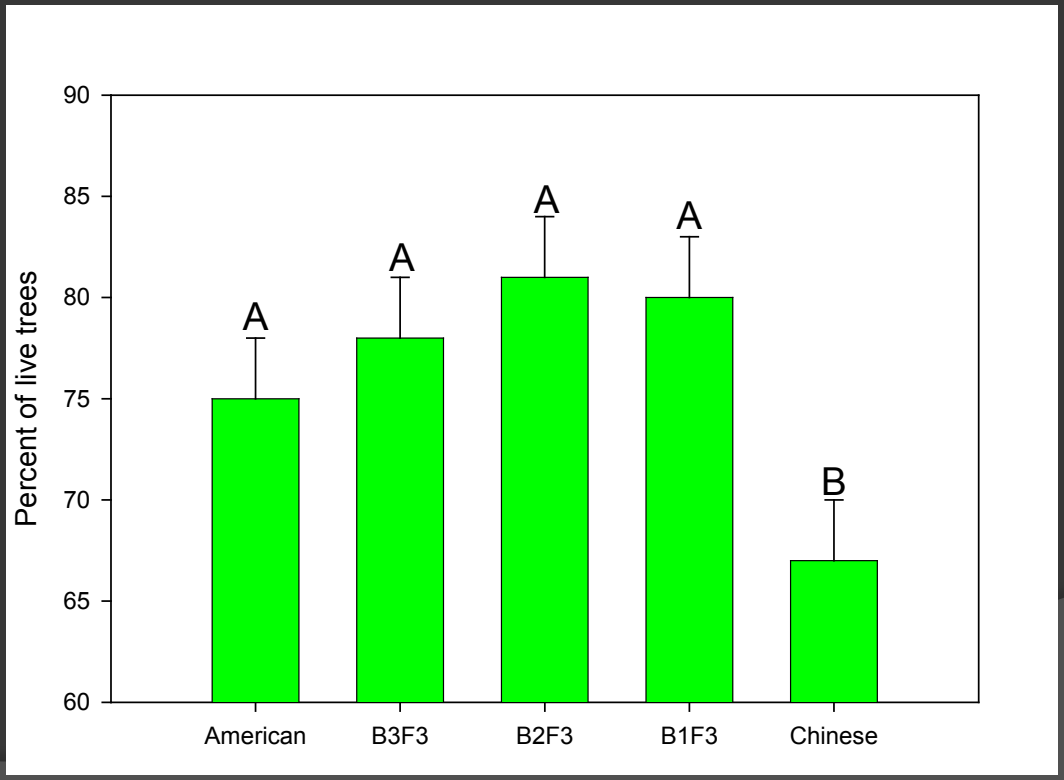
Height

- Year 0: Generation, Size, Family effects significant
  - All Size Interactions significant
  - Mean=3.2’
  - Large=3.7’ vs. Small 2.6’
- Year 4: Location, Size, Generation, Family effects significant, (no interactions)
  - Mean=7.4’ (0.5-17.5’)
  - Large = 8’vs. Small=7’


Height (cm)
275
250
225
200
175
110
100
90
80
70
60
Year 0
Year 4
A
B
B
B
C
C
C
C
A
B
American
B3F3
B2F3
B1F3
Chinese

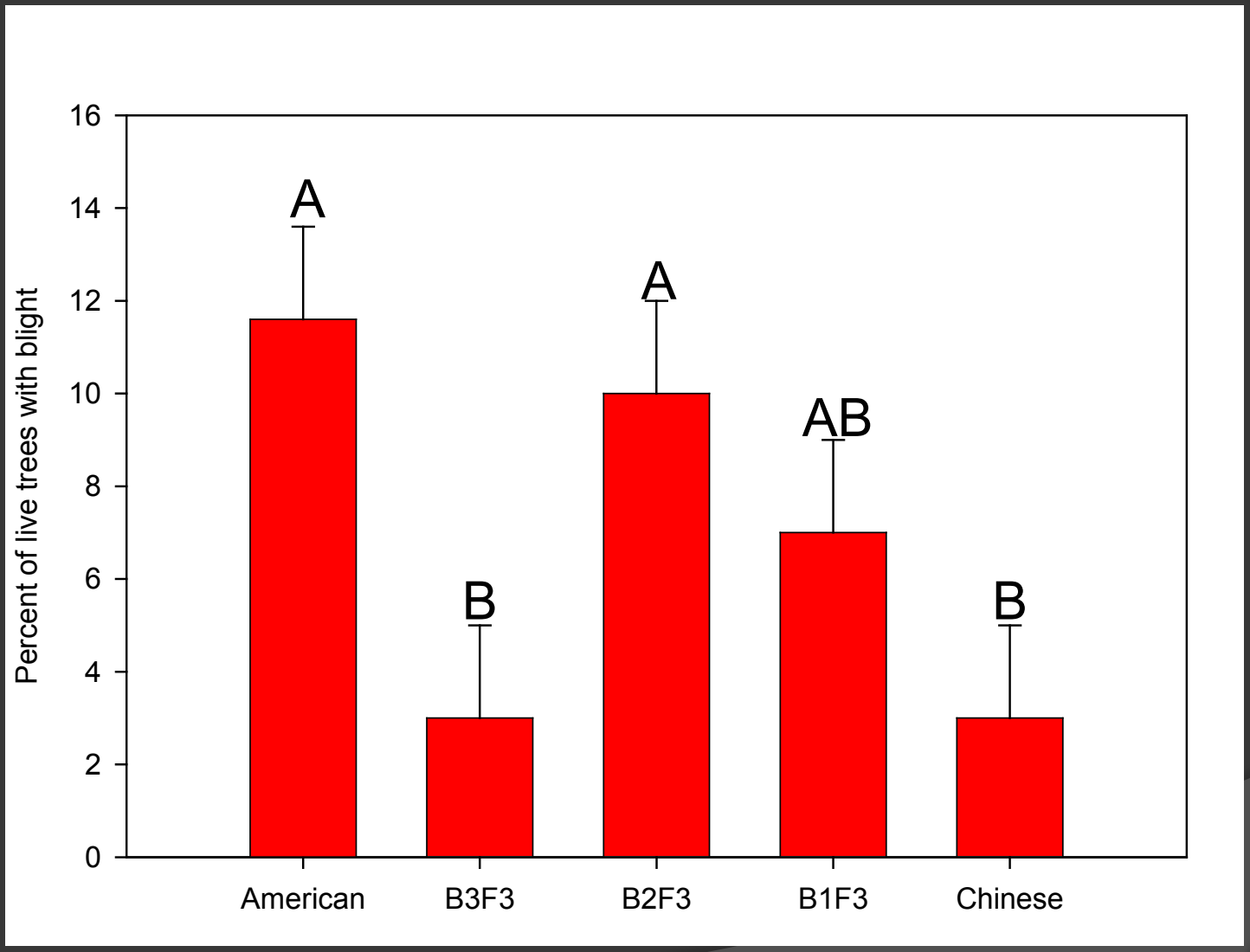
Survival

- Year 4: Generation, Size and interaction effects significant
  - Mean=77%
  - Large=73% vs. Small=80%



Blight

- Year 4: Generation, Family effects significant (no interactions); size not significant
  - Mean=7%
  - All BC_3F_3 families are the same and equal to Chinese

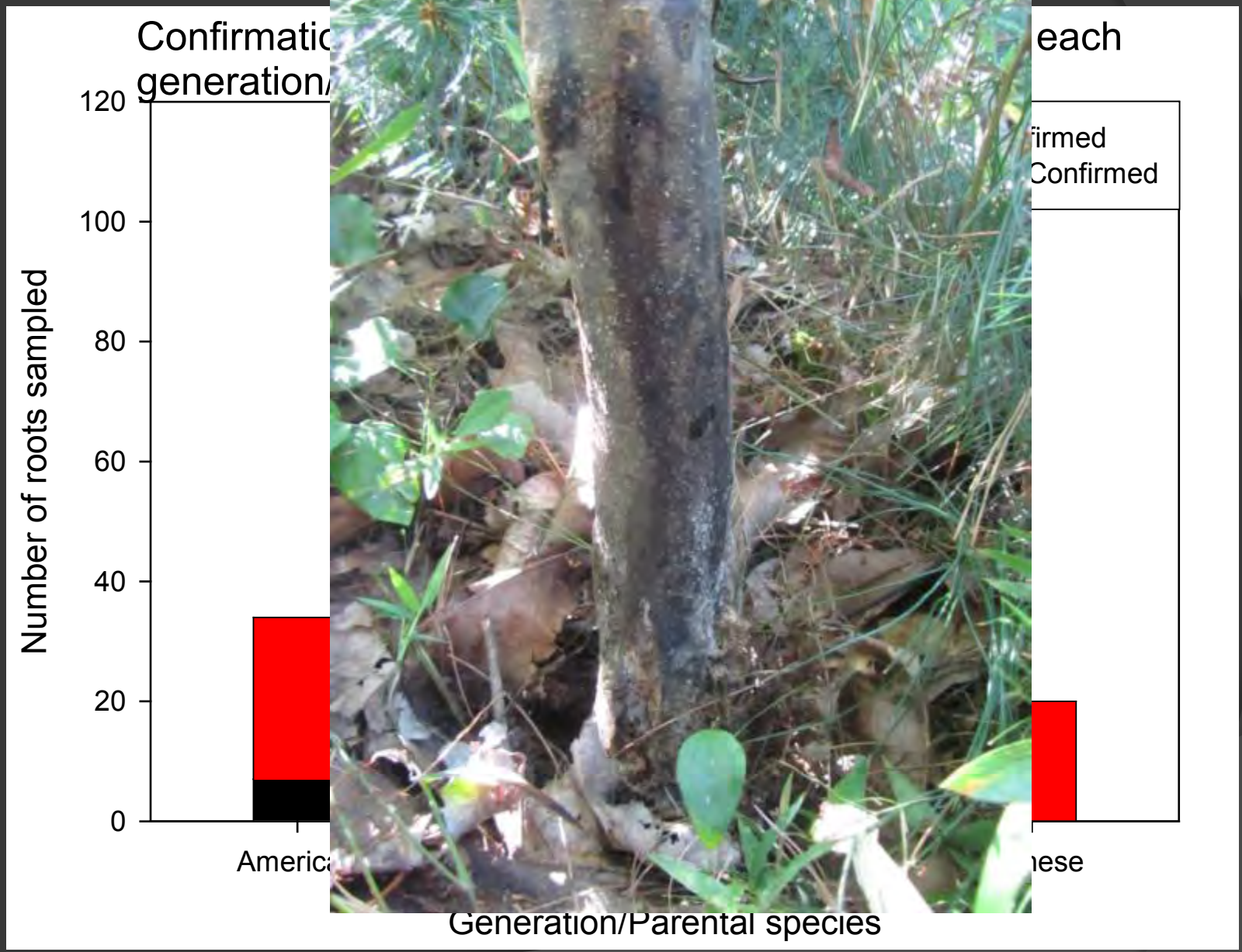

Percent of live trees with blight
16
14
12
10
8
6
4
2
0
A
B
A
AB
B
American
B3F3
B2F3
B1F3
Chinese

2011 Plantings: Growth and Survival

- These plantings are compromised by root rot caused by *Phytophthora cinnamomi*
- Overall survival ranged from 51 to 83% after one year and is dropping fast
- Growth was negative due to dieback

Phytophthora cinnamomi: What is it?

- Exotic fungal pathogen that came into US in 1870s
- Attacks American chestnut, shortleaf pine, and Frasier fir
- Is most virulent in clayey, compacted, or poorly drained soils
- Chestnuts show little resistance
- No chemical treatment is effective
- We hypothesize that it comes from commercial nursery soils and is transplanted through bare-root nursery seedlings
- Does not grow in northern latitudes (above ~40°)


Confirmatic
generation/
each
120
100
80
60
40
20
0
Number of roots sampled
firmed
Confirmed
Americ
nese
Generation/Parental species

The Future:

- Biological Barriers:
  - Deer
  - *Phytophthora*
  - Will blight resistance break down?
  - Other exotic and native pests (Chestnut gall wasp, Asiatic oak weevil, Ambrosia beetle)

Barriers: *Phytophthora*?

- Use containerized seedlings
  - Increased costs (5-10x of bare-root)
  - RPM™ (Root Pruning Method) is most advanced technology (Forrest Keeling nursery)
- Grow seedlings in northern nursery
  - Increased costs
  - Smaller seedlings (~18”)
  - Logistics difficult

Conclusions

- Chestnut will require more resources to plant compared to oak
  - *Phytophthora* in southern nurseries
- Nut size is probably not an important consideration for today
- Seedling size grading does improve overall growth, but may lower survival
- Deer appear to prefer chestnuts with more native DNA and smaller trees

Acknowledgements

- Forest Service, Region 8: Barbara Crane, the late Don Tomczak (retired), Sandy Henning, Roger Williams (retired), Jim Stelick and staff, John Blanton (retired), Russ MacFarlane and staff, Jason Rodrigue and staff
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- Steve Jeffers and Inga Meadows, Clemson University
- Gary Griffin, Virginia Tech University (Emeritus)
- Forest Service, State and Private Forestry, Forest Health Protection

Websites

- Stacy Clark's research page:
  - http://www.srs.fs.usda.gov/uplandhardwood/americanchestnut.html
- Region 8 page:
  - http://www.fs.fed.us/r8/chestnut/
- TACF:
  - www.acf.org – Main Page
  - http://www.acf.org/Tree_ID/5species.php - Page on chestnut ID
- MOU between USDA Forest Service and TACF:
  - http://fsweb.wo.fs.fed.us/aqm/grants/static/servicewide_agreements/american_chestnut_foundation/10-MU-11132425-123.pdf