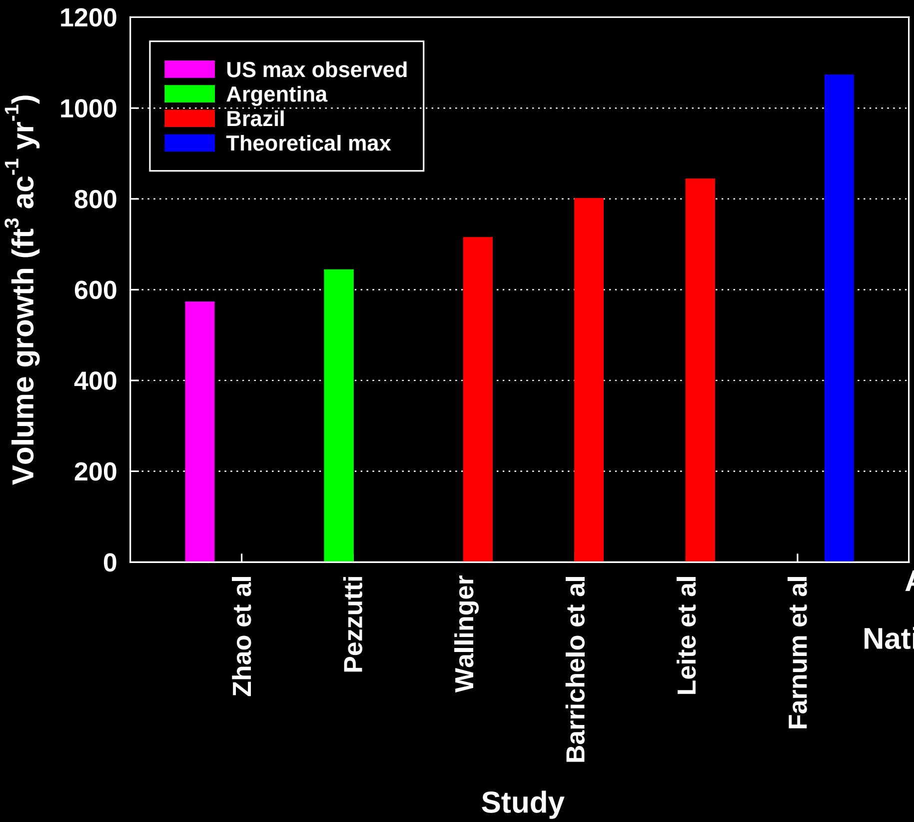
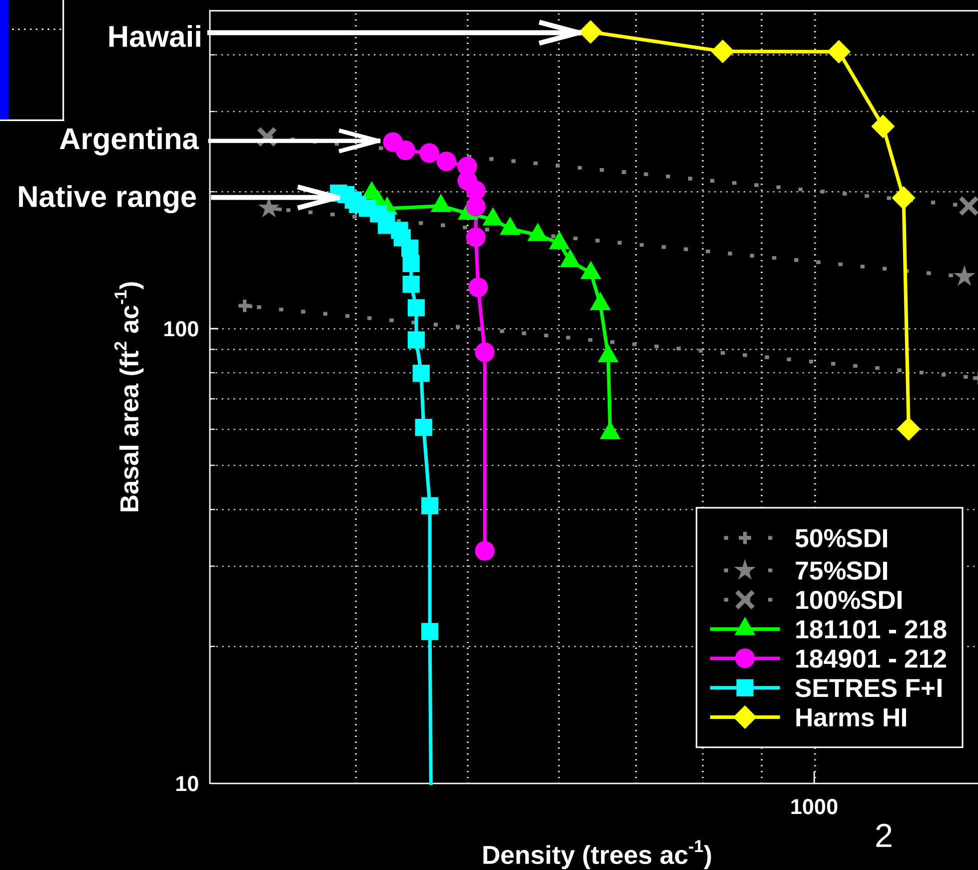
RW20: Contribution of biomass partitioning in explaining loblolly pine growth differences in the Southeast United States and Brazil

Tim Albaugh

Tom Fox, Chris Maier, Otávio Campoe, David Carter, Rachel Cook, Rafael Rubilar

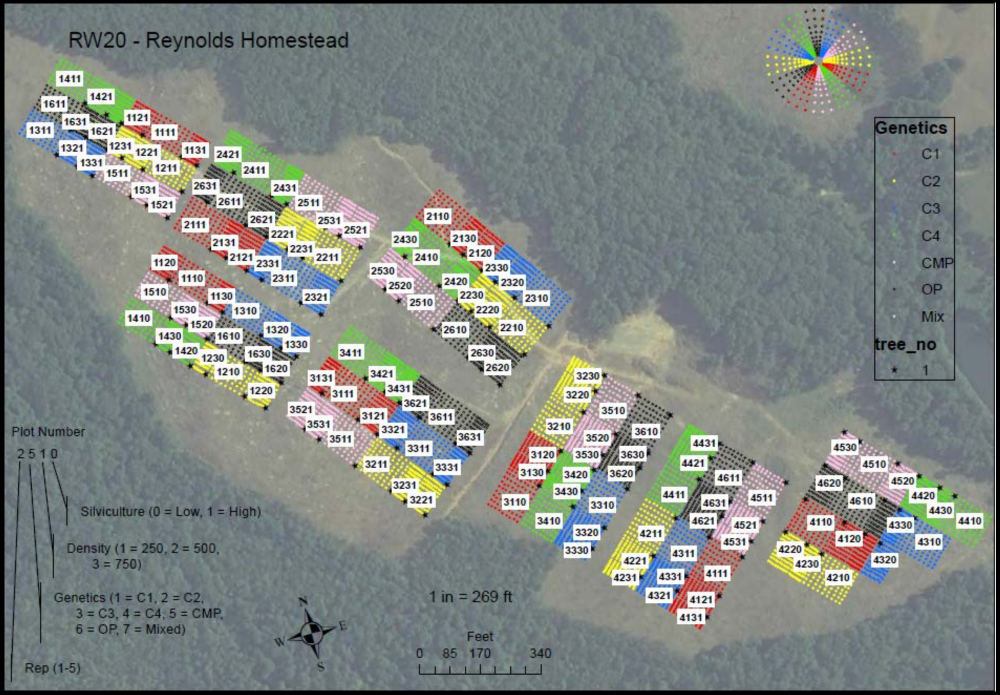
Growth and carrying capacity higher in BR and AR – why?





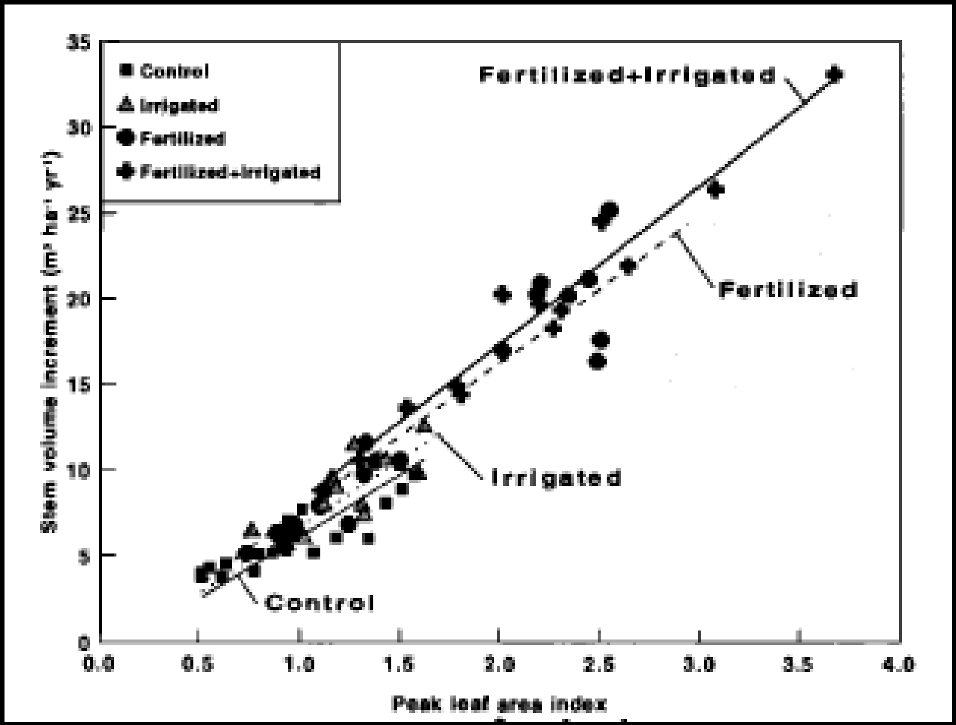
RW20: Experimental design and treatments

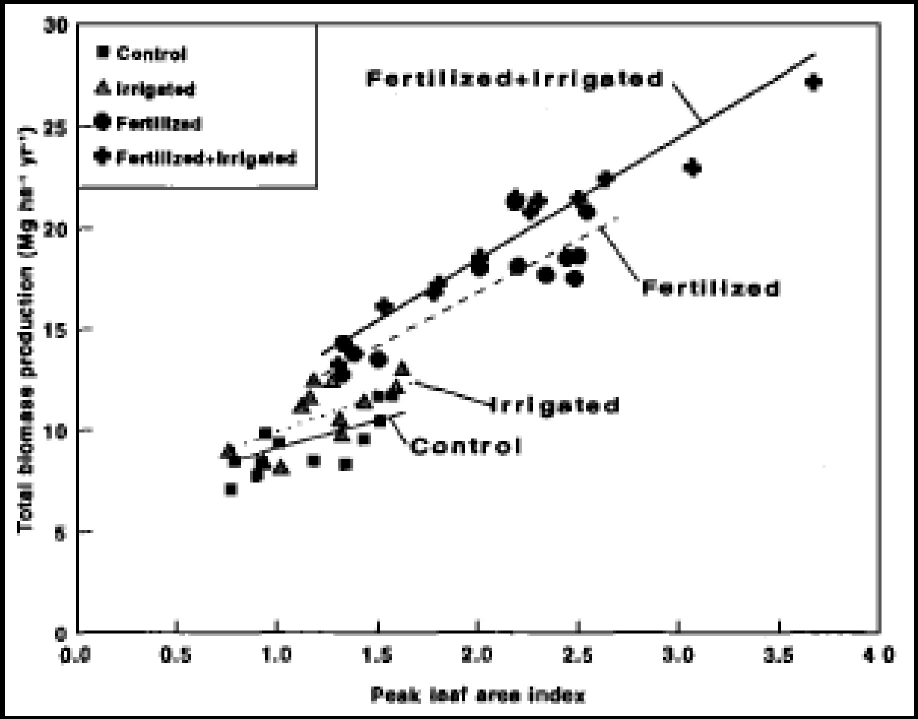
- <u>Block plots with split-split plot design</u> – replicated 3 or 4 times
  - Silviculture treatment in main plot
    - Low = typical industry operational / High = treatments to ameliorate all nutritional deficiencies
    - Low – site prep (burn, bed, chem site prep), YR1 HWC, ant control
    - High - site prep (burn, bed, chem site prep), YR1 HWC, ant control, YR1 tip moth control, YR1 NPB, YR2 VC, YR3 VC, YR5 NPB and VC, YR10 NP
  - Initial density split plot
    - 250, 500, 750 stems ac^{-1}
    - (618, 1235, 1853 stems ha^{-1})
  - Genetic entry split plot
    - 6 total: 2 moderate, 2 broad, MCP, OP
    - The same genetics at all sites!



Why examine biomass partitioning to explain US-BR growth differences

- Increased stem growth and growth efficiency (GE, more growth per unit of LAI) observed in SEUS



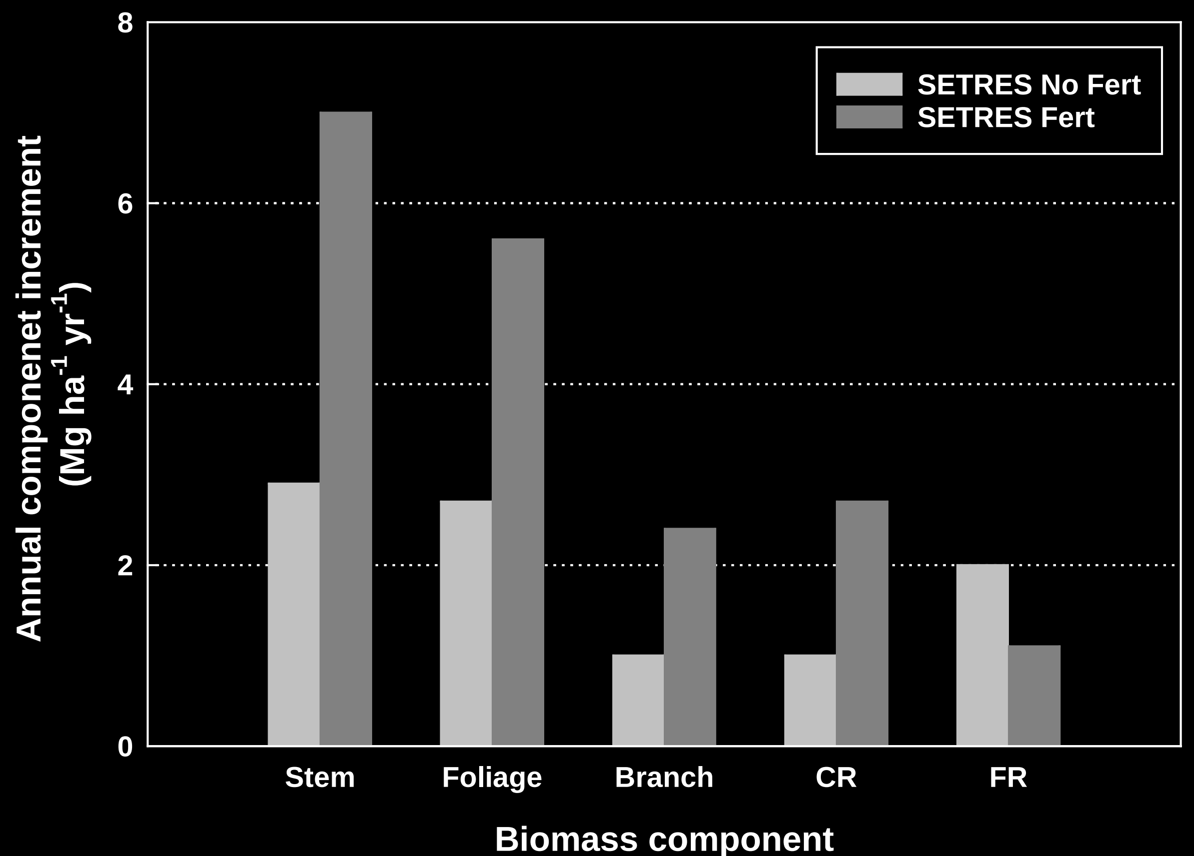


- The increase in stem growth and GE was attributed to changes in biomass partitioning with more biomass allocated below ground with poor nutrient availability.

Albaugh *et al*. 1998

Biomass partitioning shifts from FR to above ground with better resource availability

- The increase in stem growth and GE was attributed to changes in biomass partitioning with more biomass allocated below ground with poor nutrient availability.

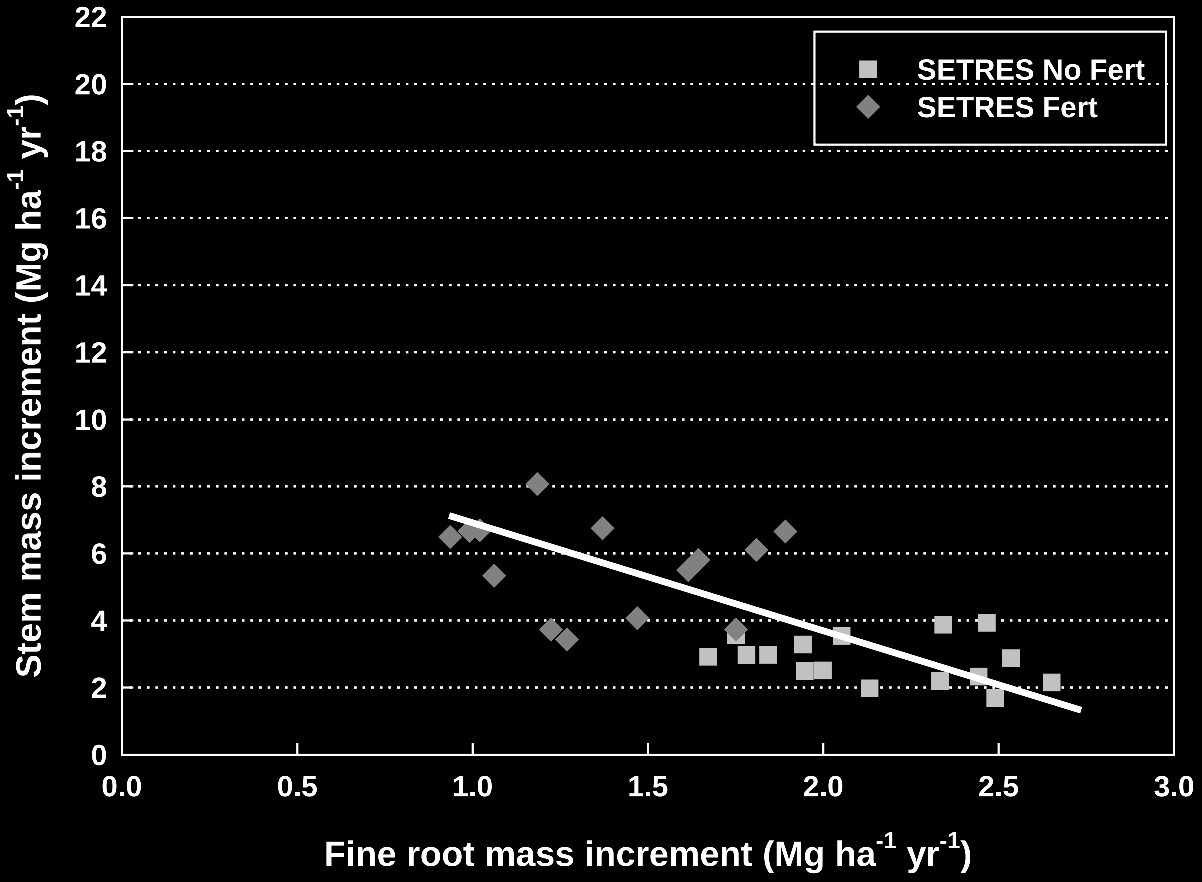


- Do we observe same things (greater GE and change in partitioning to stem) when comparing growth in SEUS and BR?

Albaugh *et al*. 1998

Stem mass increment decreases with increasing fine root mass increment

- SETRES individual plot data



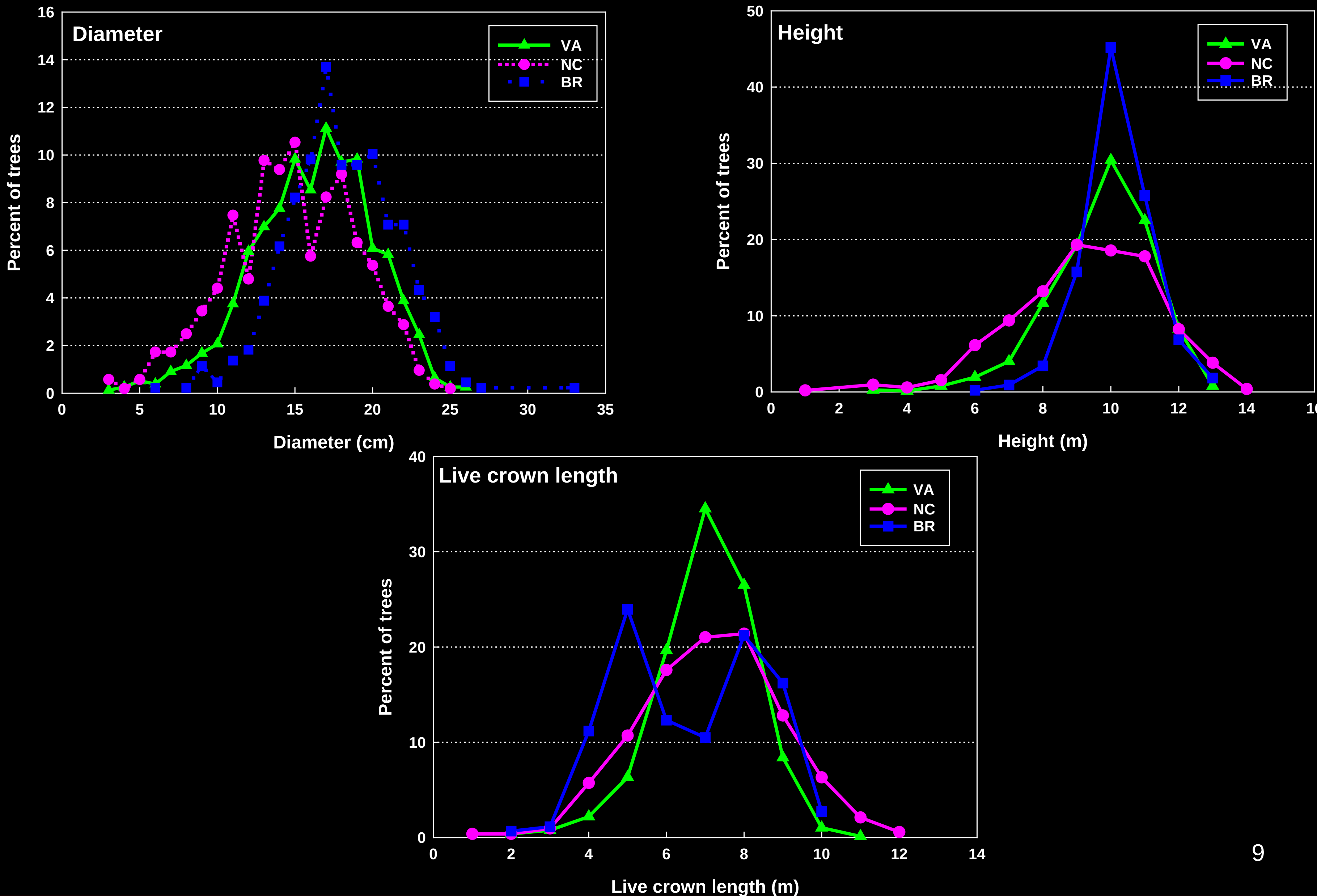
- Do we observe same this same pattern when comparing growth in SEUS and BR?

Destructive harvest 2017: detailed canopy architecture

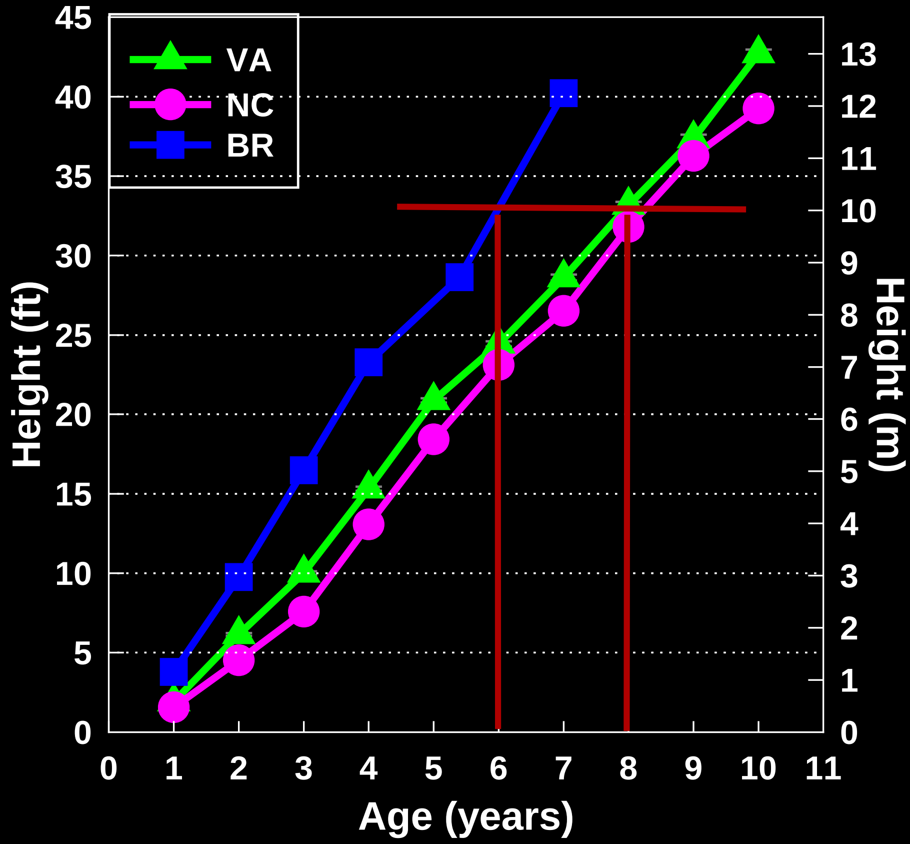
- 3 sites – VA, NC, BR
- 2 genotypes – C3, OP
- 2 densities – wide (250 tpa, 617 tph) and narrow (750 tpa, 1235 tph
- 2 silvicultures – high and low

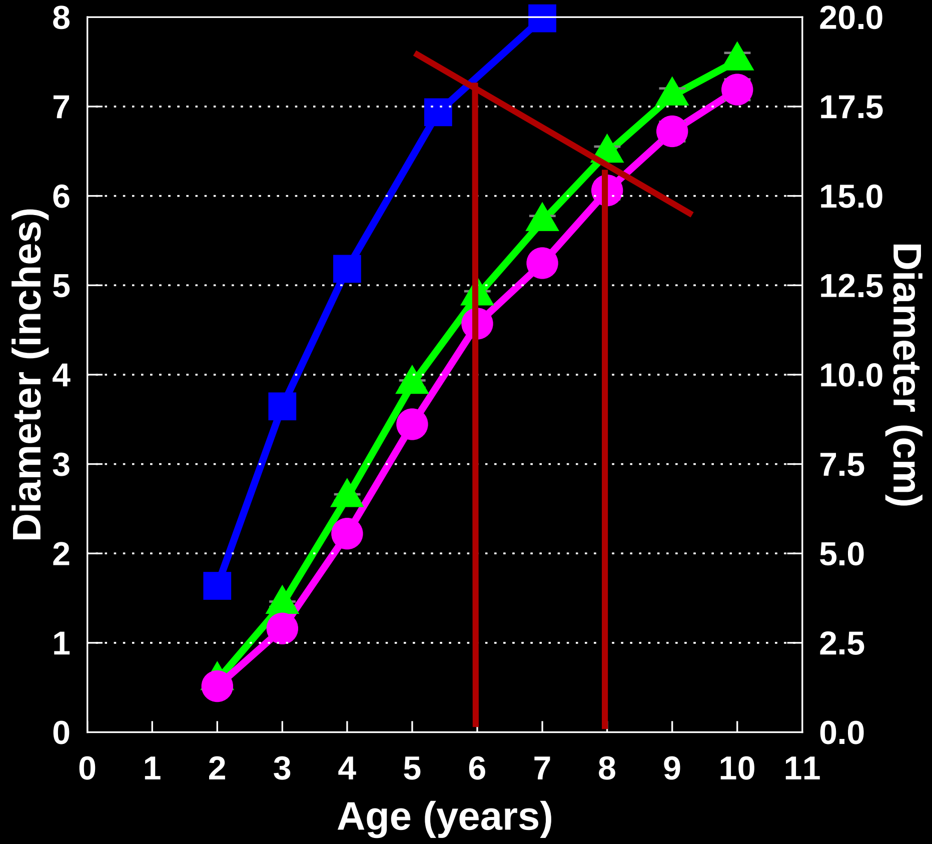
Destructive harvest 2017: above and below ground

RW20: Tree size distributions similar (but with interesting differences)

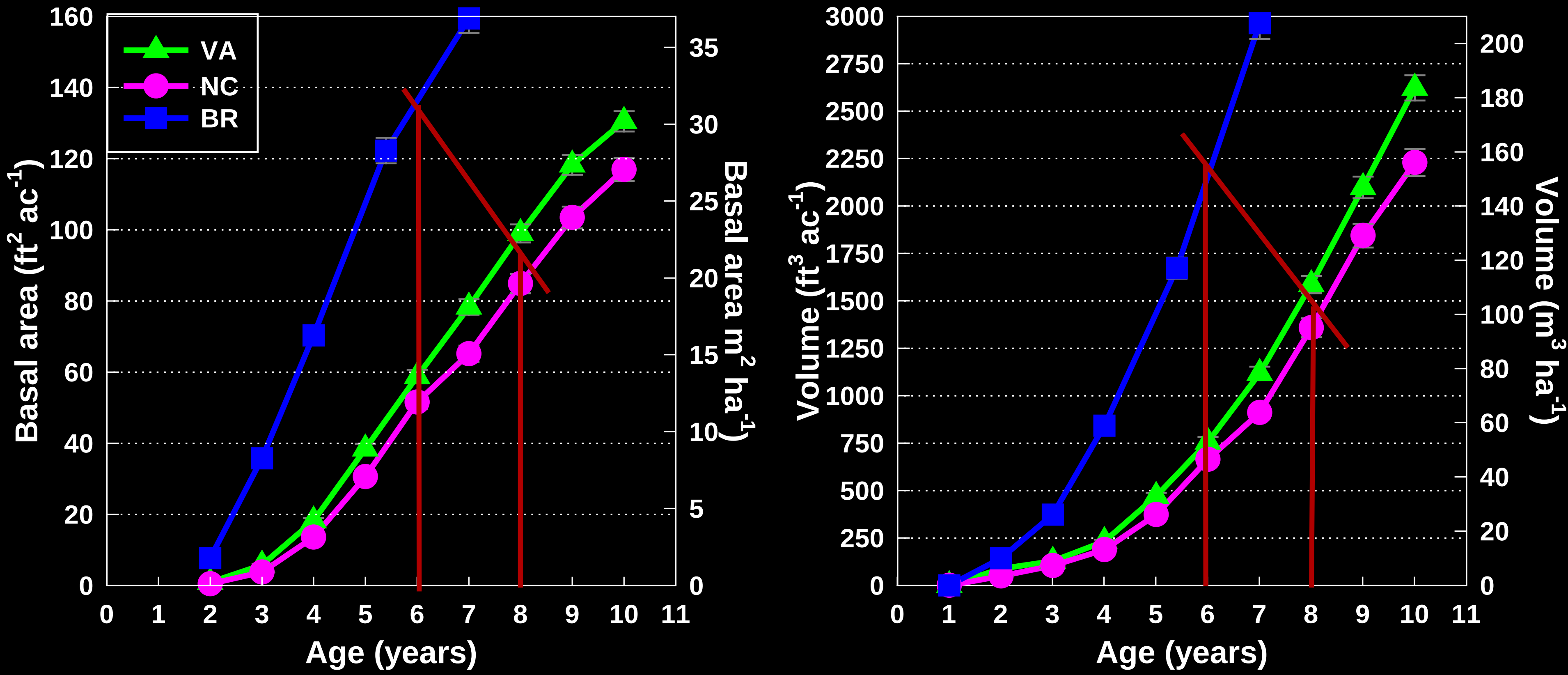


Trees in VA and NC at age 8 and BR age 6 about the same height

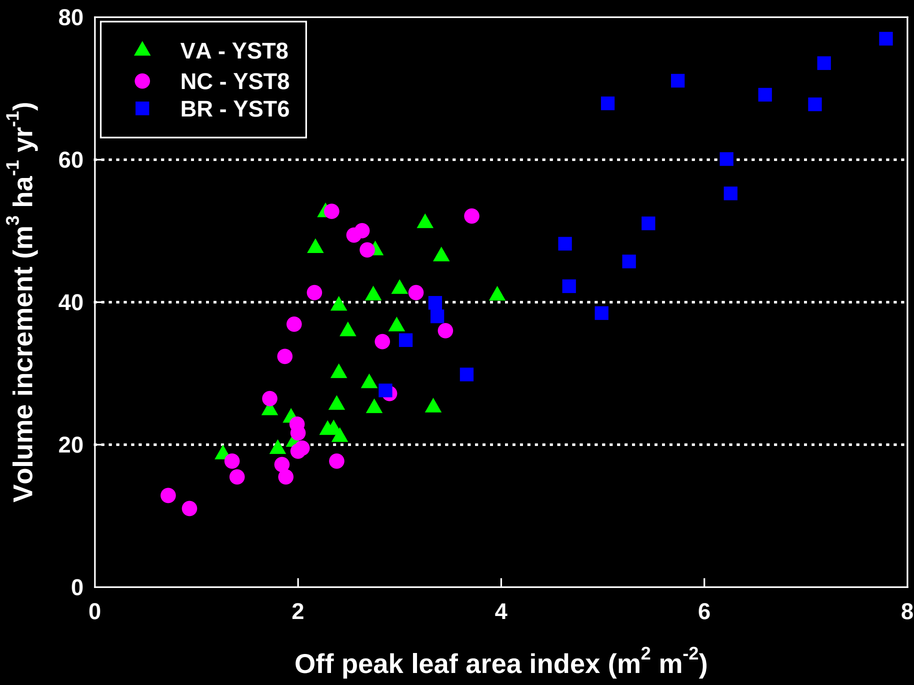




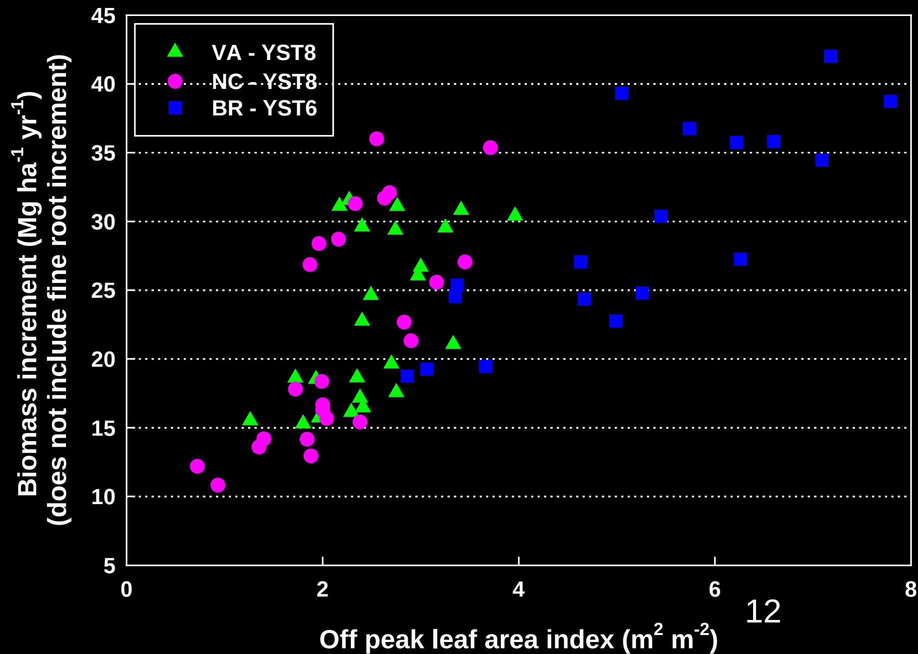
Small differences in diameter result in larger differences at stand scale



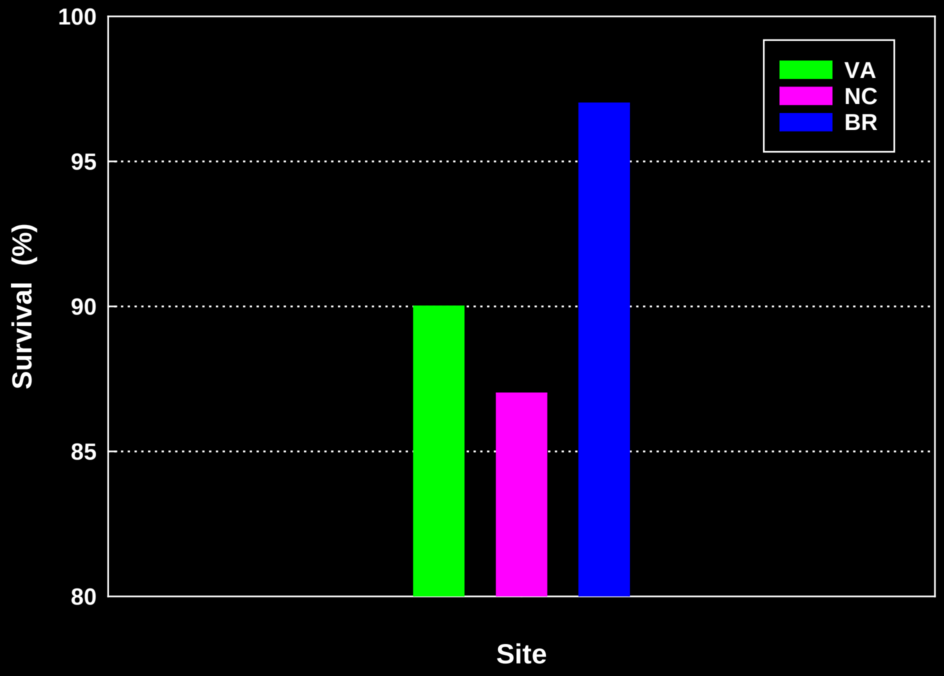
RW20: No apparent site effects on GE for volume or total biomass



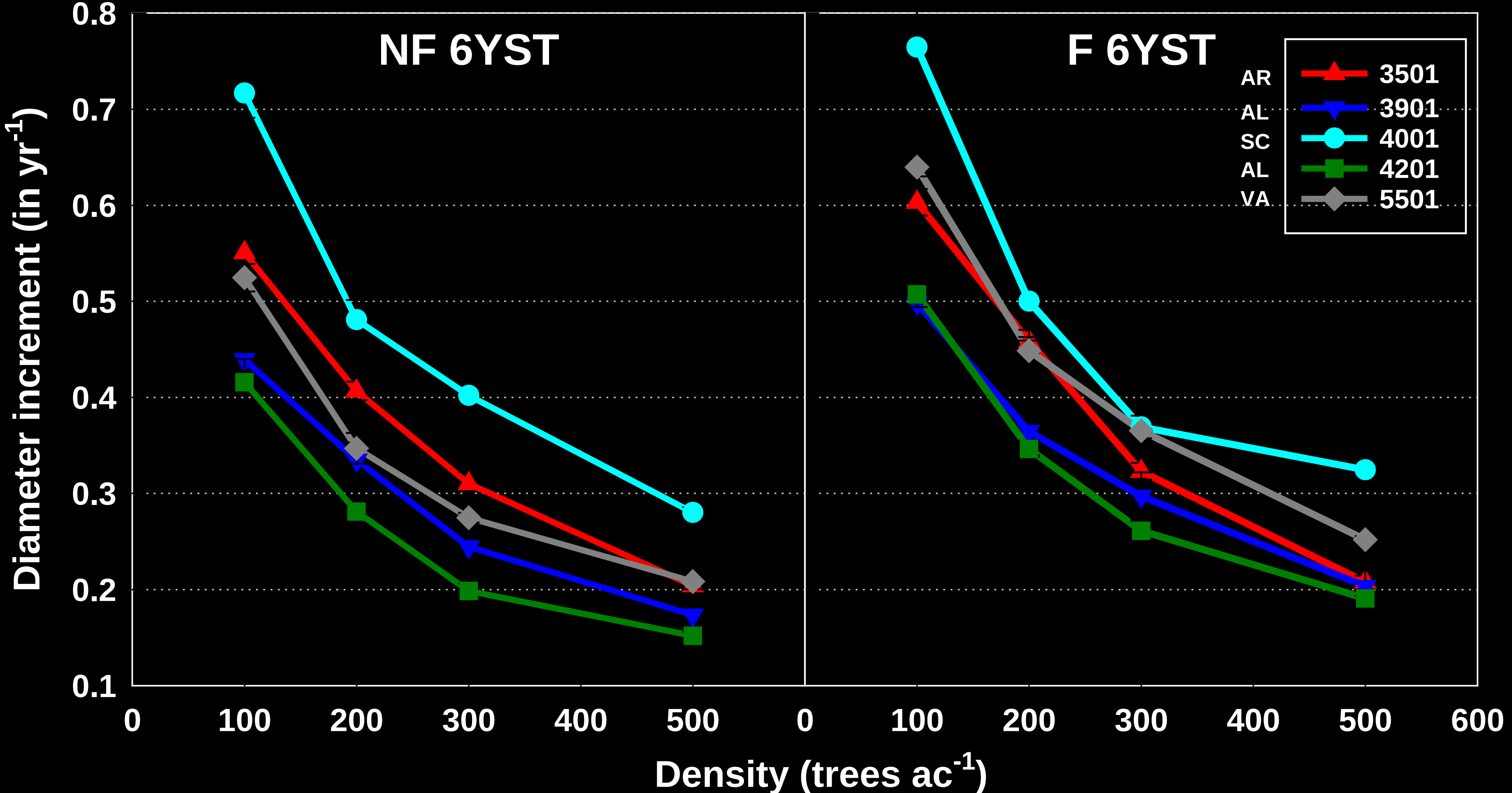
- Albaugh *et al*. 2018 – no site effects no light use efficiency but there were density and genotype
- Similar results here – no site effects on GE, but stem growth (volume) and total biomass increment greater in BR
- This is different from the increased GE at SETRES with better nutrition



RW20: Biomass analysis affected by survival differences – OP at VA and NC bare root

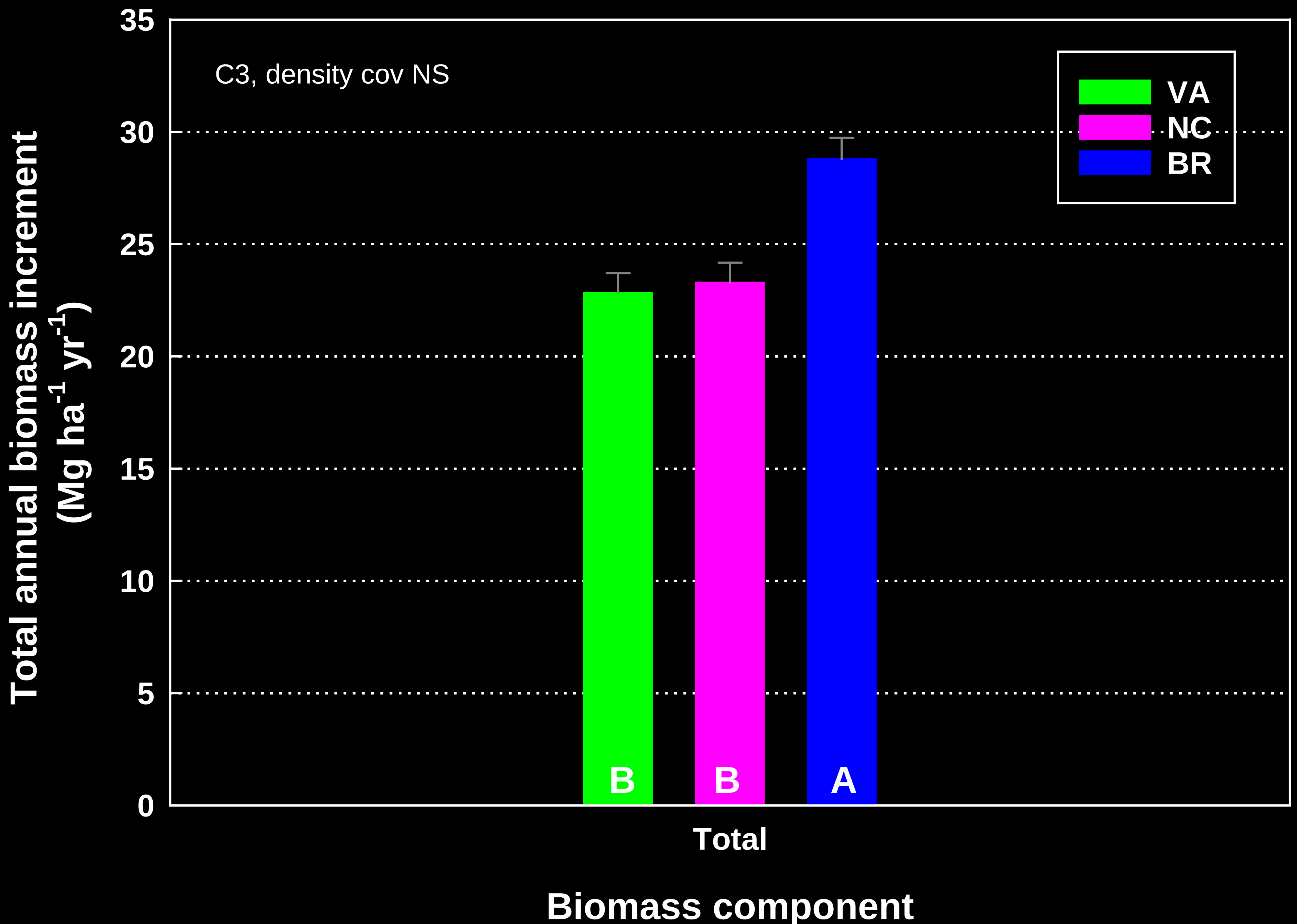


Remember RW19 greater diameter increment with lower density -OP trees in low survival plots are 'bigger than they should be'



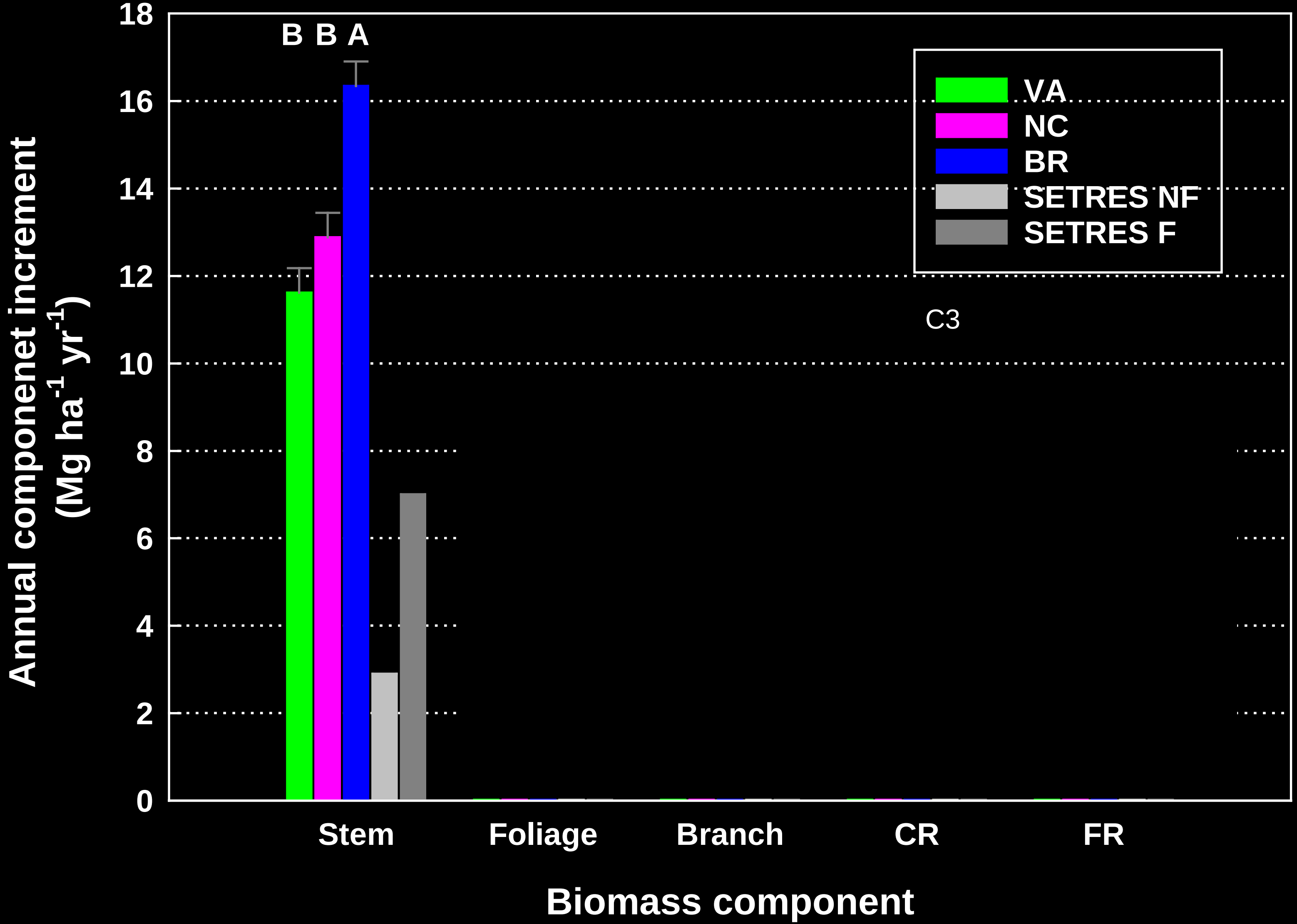
Using density as a covariate over corrects and inflates biomass
Working on better covariate but for now no genotype (OP-C3) comparison possible
Site, density and silviculture tests are possible using only C3

Site: BR>NC=VA in total biomass

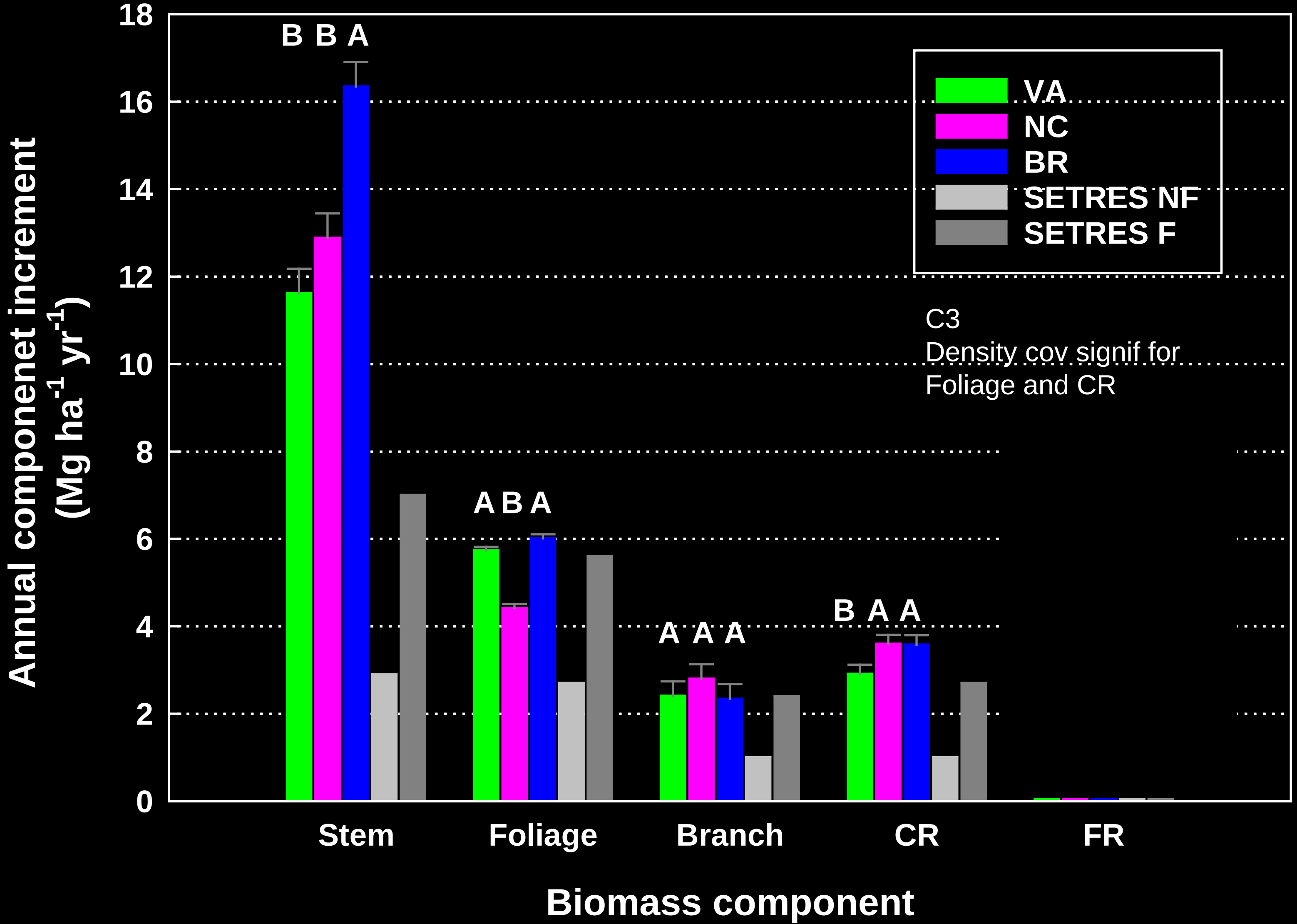


‘Total’ includes stem, branches, foliage and coarse roots but excludes fine roots (<2mm diameter)

Site: BR partitions more C to stem, VA and NC >>SETRES Fert

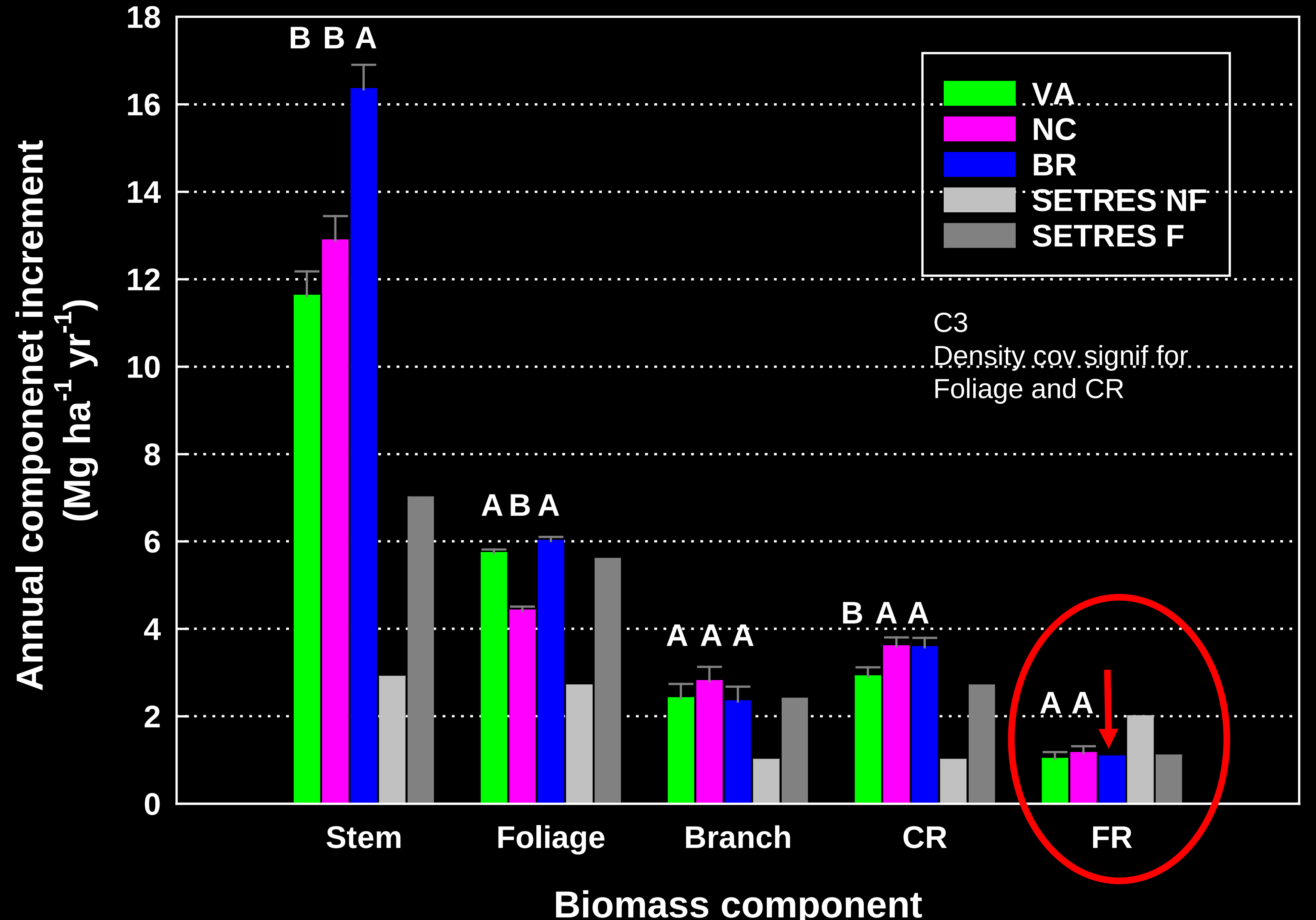


Site: BR ~ VA and NC for foliage, branch, CR and similar to SETRES Fert

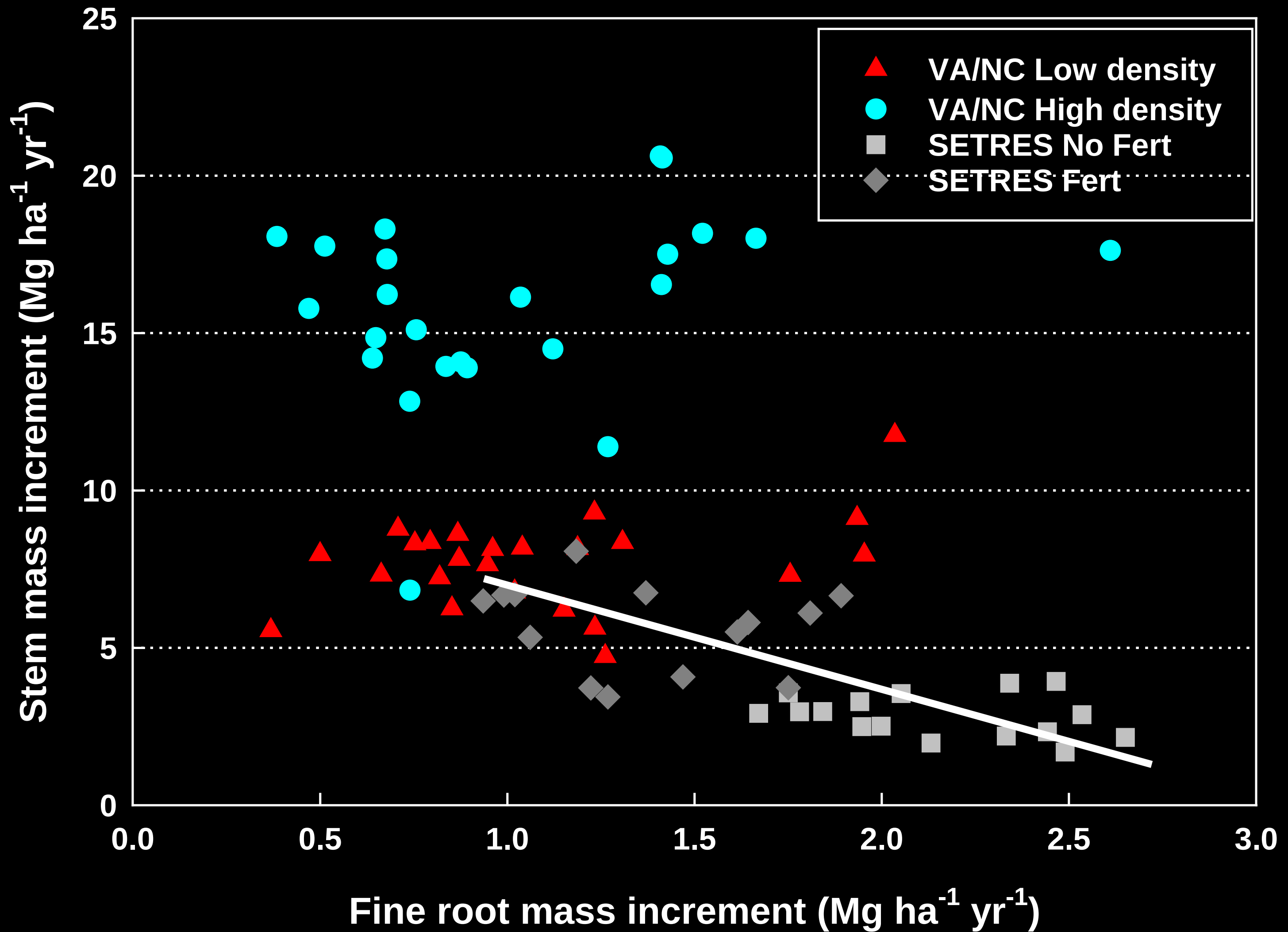


It appears the trees need to produce a certain amount of foliage, branch and coarse root and then partition available C to stem

Site: No BR FR data (estimated) – VA=NC=SETRES Fert

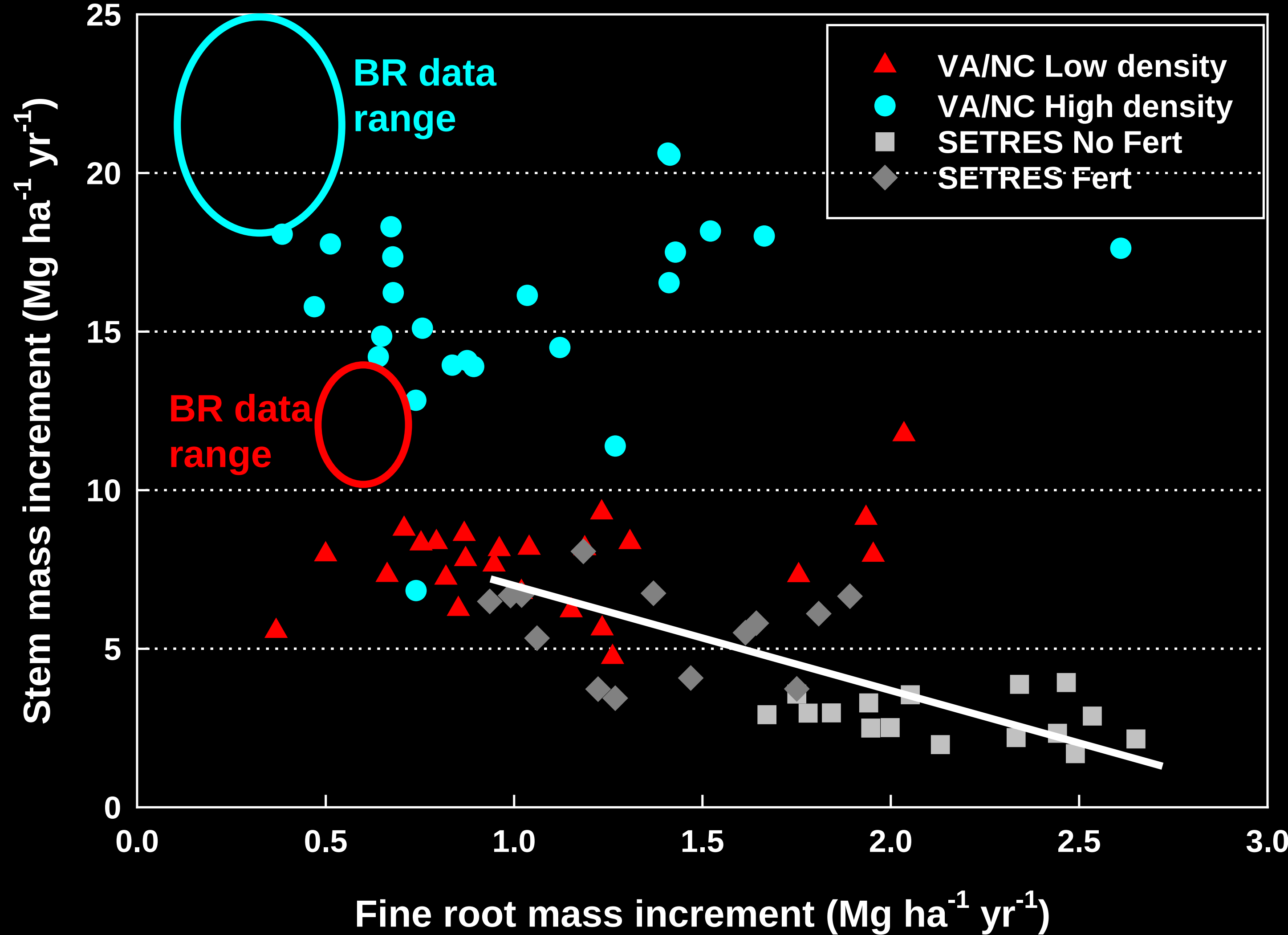


Fine root production supports wide range of stem production



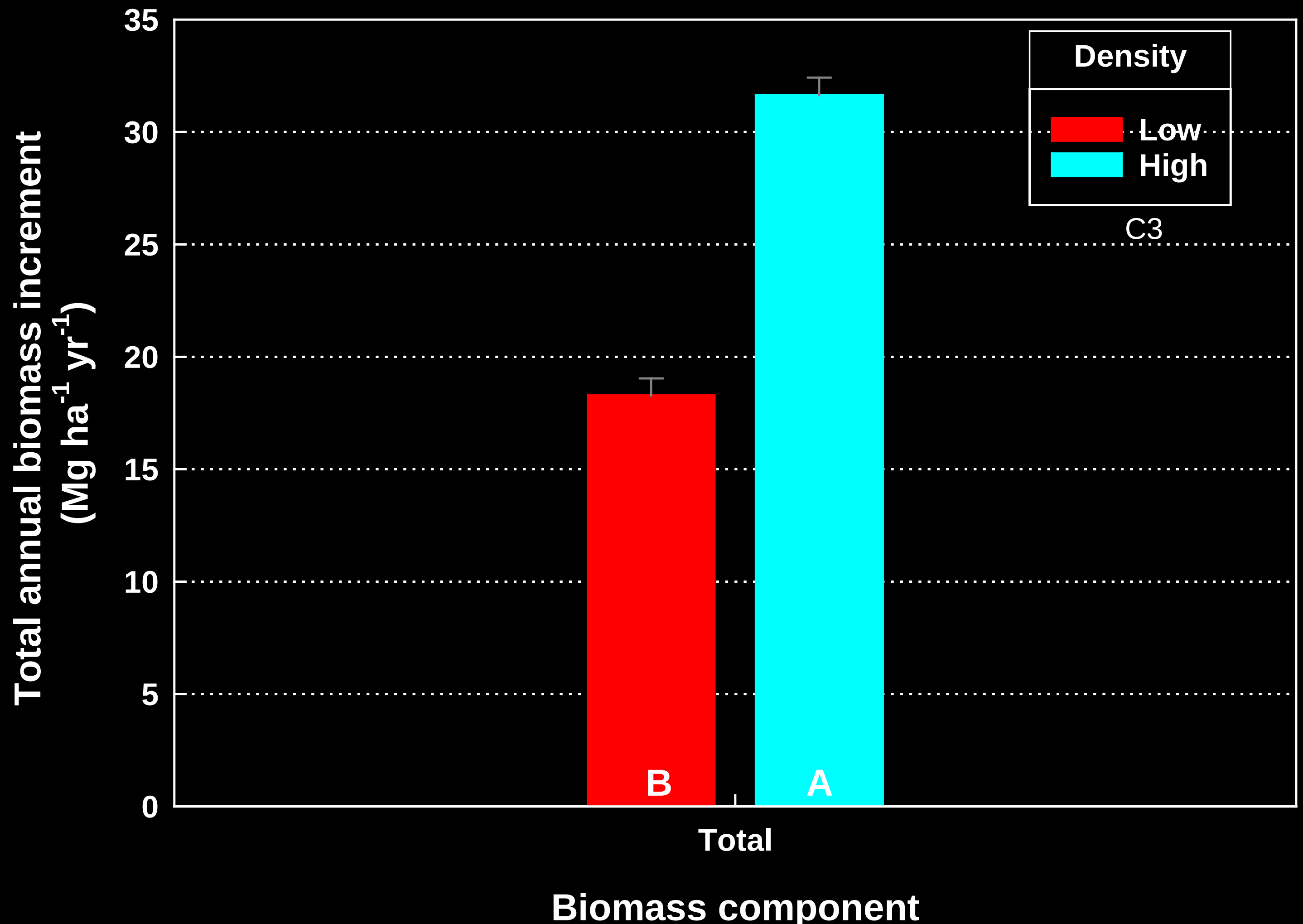
At VA and NC no relationship between FR increment and stem increment for a given level of density

Not much room for BR site to produce less FR (<0.5 mg/ha/yr)



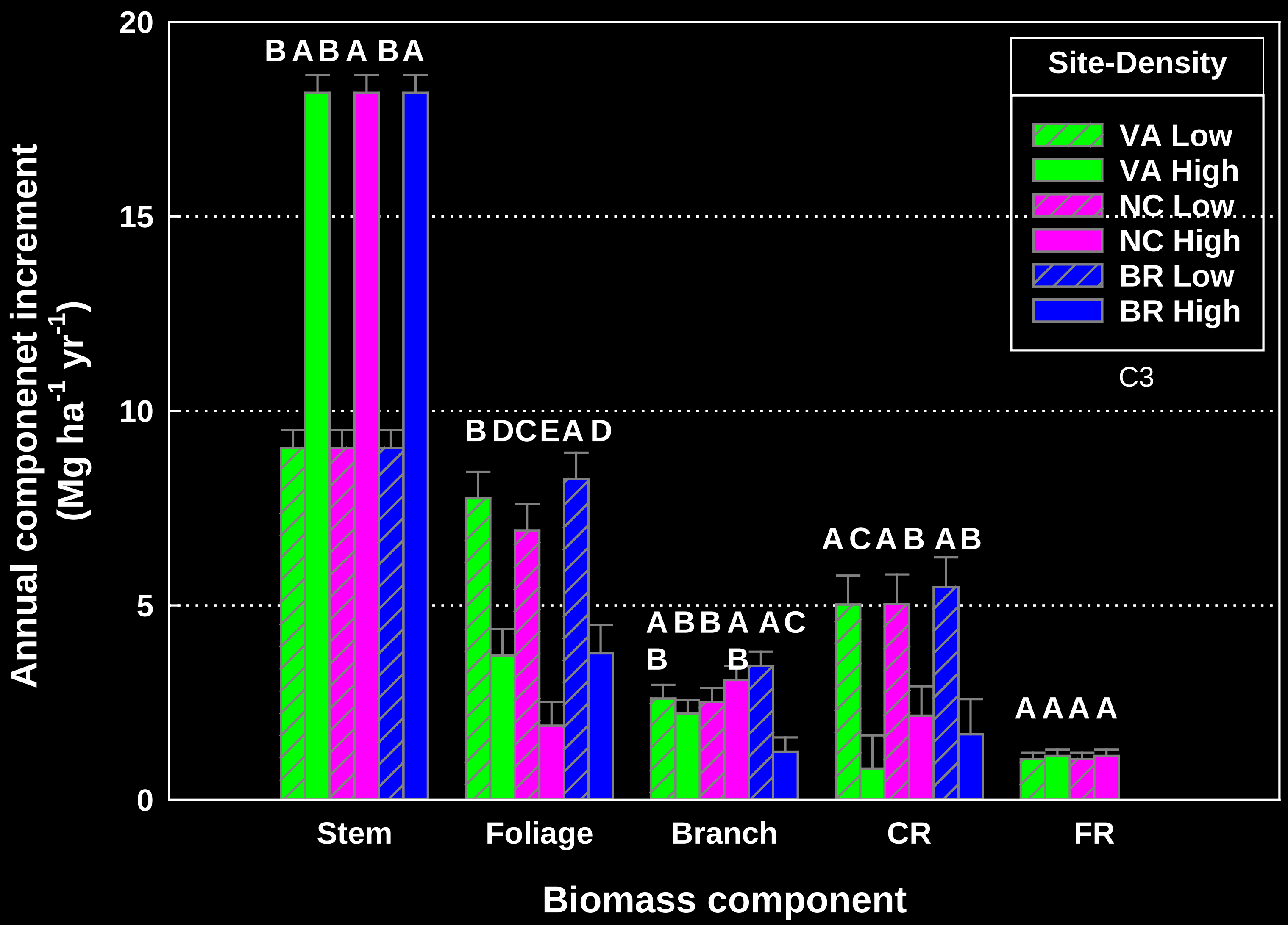
Supports that partitioning to fine root is probably NOT driving productivity differences between US and BR

Density: 200% increase in trees → 72% increase in total biomass
-site x density not significant



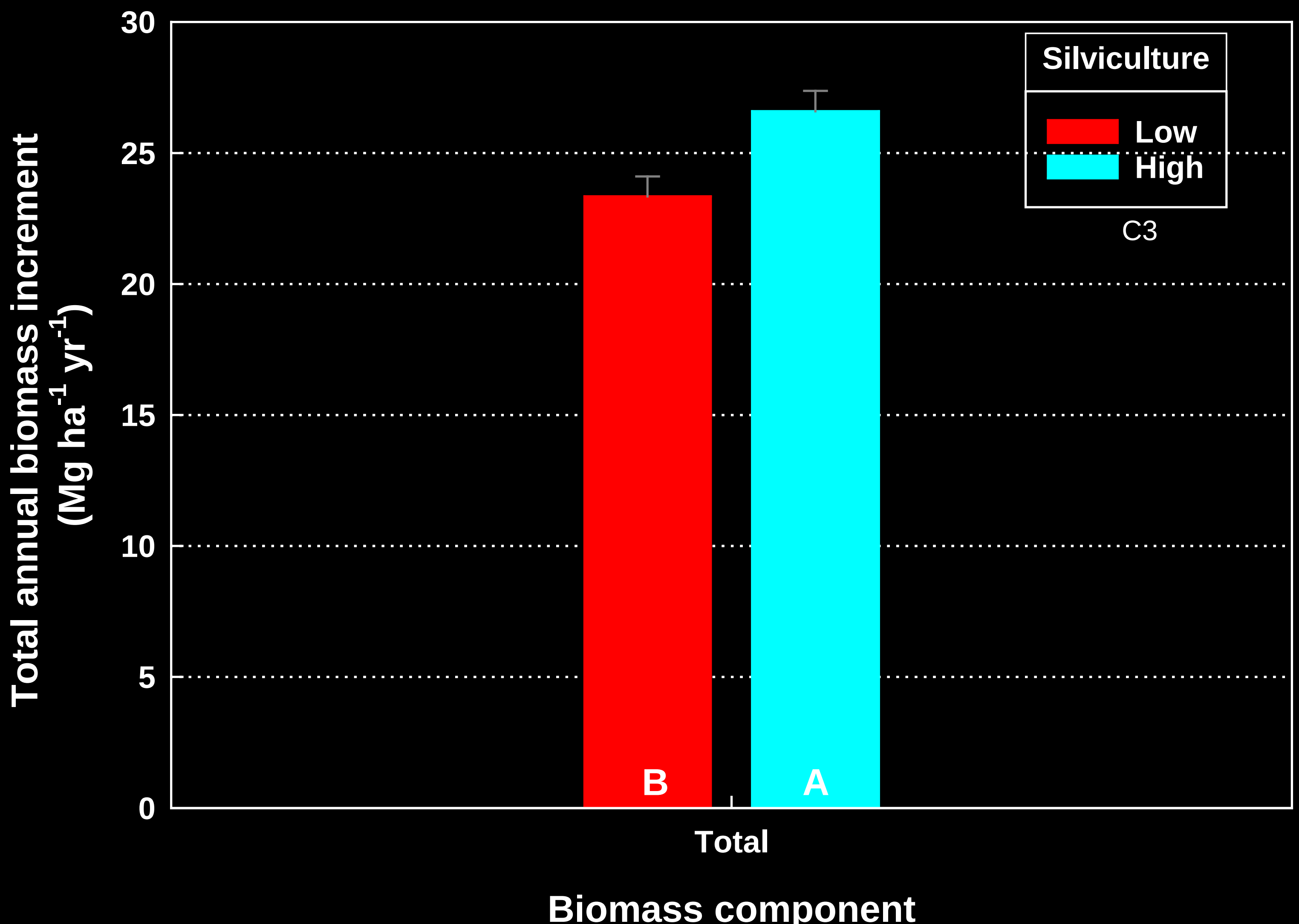
'Total' includes stem, branches, foliage and coarse roots but excludes fine roots (<2mm diameter)

Density: Low has more foliage and CR, high has more stem



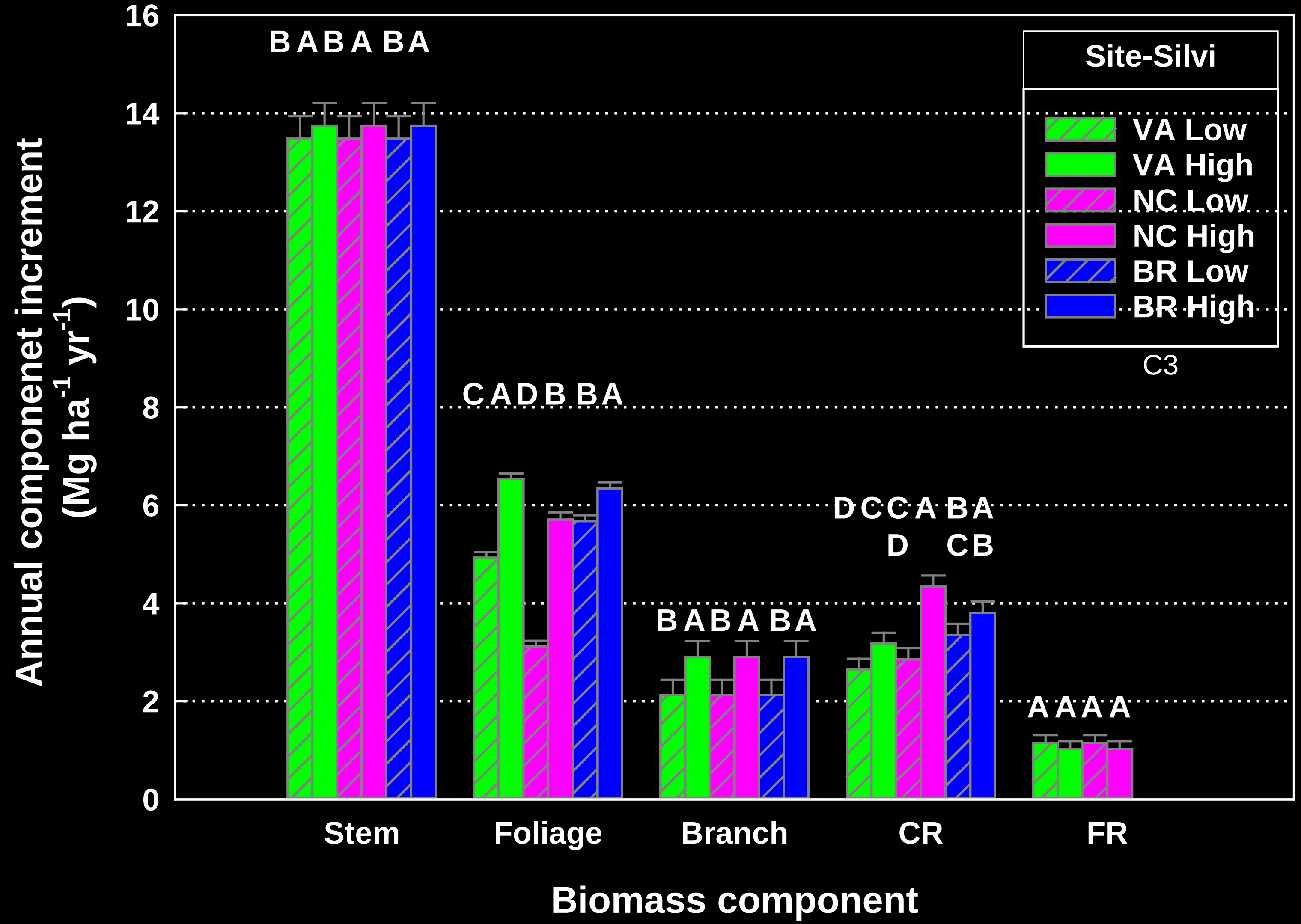
Density has large effects on partitioning – high density partitions more to stem – perhaps to maintain position in canopy

Silviculture: No site x silviculture effects for total biomass



‘Total’ includes stem, branches, foliage and coarse roots but excludes fine roots (<2mm diameter)

Silviculture: Good silviculture needed foliage in US but results in relatively small effects on stem production



RW20: What did we learn

- Unable to test our hypothesis that growth is greater in BR because less C partitioned to fine root but this is unlikely based on current data
  - Still working to collect data needed to test this hypothesis
  - However, it appears we will reject this hypothesis
    - If there is a difference based on fine root partitioning then very little C is partitioned to FR in BR
    - It may be that the relevant partitioning changes are those related to stem where BR trees partition more to stem than US trees – due to lower R, light competition…
  - We will be testing the hypothesis when we get the data

- What can we do now:
  - Identify and use genotypes that partition lots of C to the stem
  - Identify density that produces the maximum value for your end product
    - Drew will be discussing this issue
  - Make sure we are applying the best silviculture possible

- Remember these results are from one varietal
  - Otávio found differences in TBCF and stem partitioning among RW20 genotypes

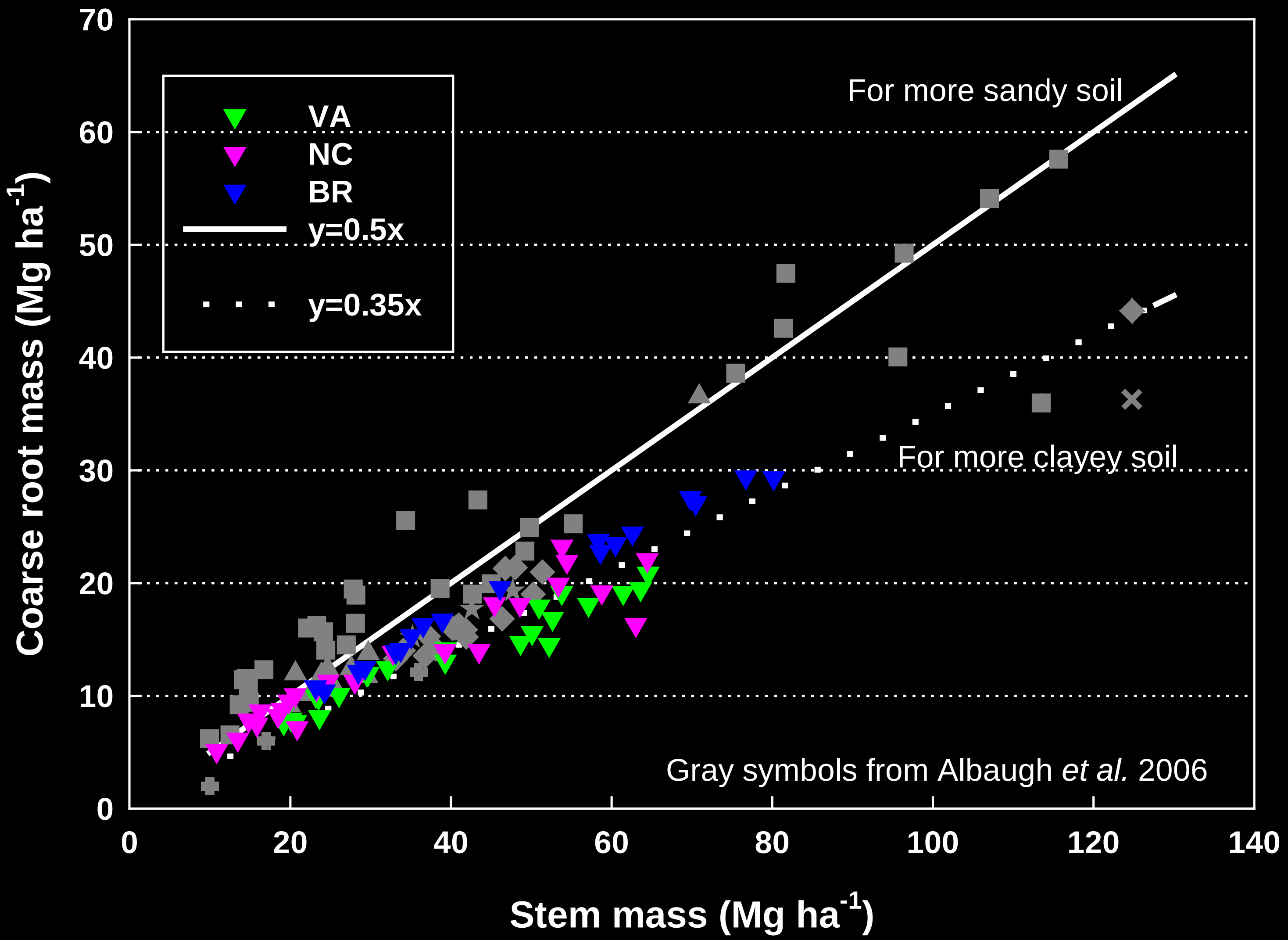
RW20: What explains growth differences between US and BR

- No
  - Genetic differences – eliminated with study design
  - Difference in foliage longevity, increased flushing – Albaugh *et al.* 2010
  - Leaf level physiology – Samuelson *et al*. 2010, Yáñez *et al*. 2017
  - Light – Albaugh *et al.* 2018
- Could be
  - Allocation patterns – AB vs BG not for coarse roots but maybe for fine roots, partition to stem in BR?– Albaugh *et al*. in prep
- Yes, in part
  - Light – more diffuse light at bottom of crown in BR, foliage survives
  - Weather – BR more mild – Albaugh *et al.* 2018
  - Canopy – Albaugh *et al.* 2020
  - Individual tree growth efficiency – Albaugh *et al.* 2020

Potential for managing

- Next up to test
  - Nutrient use and nutrient use efficiency

RW20: Adjust our estimates of coarse root per unit stem mass based on soil texture?



RW20: Hypotheses explaining differences in growth NA vs SA

- Genetic differences
- Difference in foliage longevity, increased flushing
- Leaf level physiology
- Greater sunlight intensity
- Higher solar radiation intensity
- Higher sun angle
- Different day length
- Longer growing season
- Better climate, continuous growth
- Foliage distribution
- Allocation patterns – less BG
- High nutrient availability
- Lower respiration cost due to cool nighttime temperature in SA
- Longer period able to fix C (change in phenology) – no dormant season
- Less evaporative demand / better water availability
- Lack of pathogens and native pests

RW20: Some answers we are getting

- Is growth better in BR?
  - BR growth is greater than US growth – 2-3x absolute, 3-5 year time gain

- Light - Is light use efficiency (LUE, growth per unit intercepted light) the same the US and BR?
  - LUE is the same among sites (so is GE)
  - Similar amount of incoming light likely because BR has more rain
  - More rain ➔ more clouds ➔ more diffuse light ➔ foliage lower in canopy can survive (higher LAI) but may not contribute much to overall C gain
  - There are differences in LUE due to genotype and density – need to understand better as these can be managed

- Weather - Is heat sum per unit of volume growth the same in the US and BR?
  - Site does affect the cumulative volume degree hour relationship.
  - Favorable weather plays a part in explaining growth differences but something other than heat sum must be influencing observed growth differences
  - May need to filter environmental conditions better

RW20: Some answers we are getting

- Canopy - Are crown architecture variables influenced by site (branch diameter, branch number, LCL, HTLC, foliage mass, branch mass, leaf area, canopy density)?
  - No effect when trees are about the same size
  - When trees are different sizes effects can be large
  - Stand developmental processes and spacing overwhelm these characteristics
  - Foliage mass the same but SLA different so leaf area different across site

- Canopy - Is leaf area distribution with in the crown influenced by site?
  - Yes, need to account for these differences in future modeling work

- Canopy - Is the individual tree volume increment vs leaf area relationship influenced by site and/or foliage distribution with in the crown?
  - Site does influence relationship - BR has greater individual tree GE, but not stand scale GE
  - Foliage distribution is significant even when site is included – indicative of species plasticity but something other than foliage distribution is influencing the observed growth differences among sites

- Biomass/partitioning – partitioning differences where US sites allocate much more to fine roots not likely but there may be opportunities to use information about partitioning to improve result in US – why is there more partitioning to stem in BR?
  - No apparent differences in growth efficiency (GE), similar to no differences in LUE
  - Relative to other genotypes, less stem growth in C3 may be due to total BG C

RW20: Take home lessons

- Leaves grow trees

- Current thinking about using ideotype as a guide to how clones will respond to silviculture
  - Stand development and silviculture have a large effect on canopy architecture – there is variation in how genetic entries respond to these treatments across site

- Current thinking about why trees grow so fast in BR
  - Likely a function of multiple factors -
  - Not – foliage longevity, leaf level physiology, foliage distribution (by itself)
  - ‘Good’ weather – more moderate temperatures, no ‘winter’, no hurricanes, no tornadoes
  - Light – but only that there may be more diffuse light allowing foliage lower in canopy to survive
  - Greater individual tree GE – need to determine what causes this – biomass analysis indicates no stand scale site effect on GE
  - High SLA low in the crown – may indicate better water use efficiency
  - Appears to be greater partitioning to stem in BR – need to examine potential causes for this effect (e.g. less respiration in BR…)

Plan to work with more detailed models