Pruning by the Numbers

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The Numbers?

- Need <u>measurable</u> benchmarks

1. To develop robotic pruning
   - What limbs to cut?
   - Threshold (when to stop?)
   - What & how much data needed?
2. To evaluate: how did we do?

Tall Spindle

- World Std.
- Productive, quality
- Common canopy features
- Minimal branching
- One simple target

Pruning Studies PSU, 2013 & 2014:

- Establish and confirm pruning rules
- Pruning Severity
- Pruning rule orders
- Outcomes
 - Define target(s) for Engineers
  - Refine manual pruning

Severity: LT Ratio Approach

- Measure diameter of each limb on tree
- Measure the trunk diameter at 30 cm
- Calculate sum [LCSA] and TCSA.
- Choose desired LT ratio.
- Prune largest successive limbs to desired LT ratio.

Severity: Max Limb Diameter Approach

- Measure sum[LCSA] / tree and TCSA on ~4 representative trees

- Establish target severity (LT ratio)

- Regression to establish max remaining limb diameter (MD)

- *MD (2013) = -0.87 +0.553 TC + 4.29 LT*

- Then need only measure TC to determine the maximum allowable branch diameter from LT ratio data. Cut off all larger limbs.

MD: Maximum Allowable Branch Diameter

LT = 1.25

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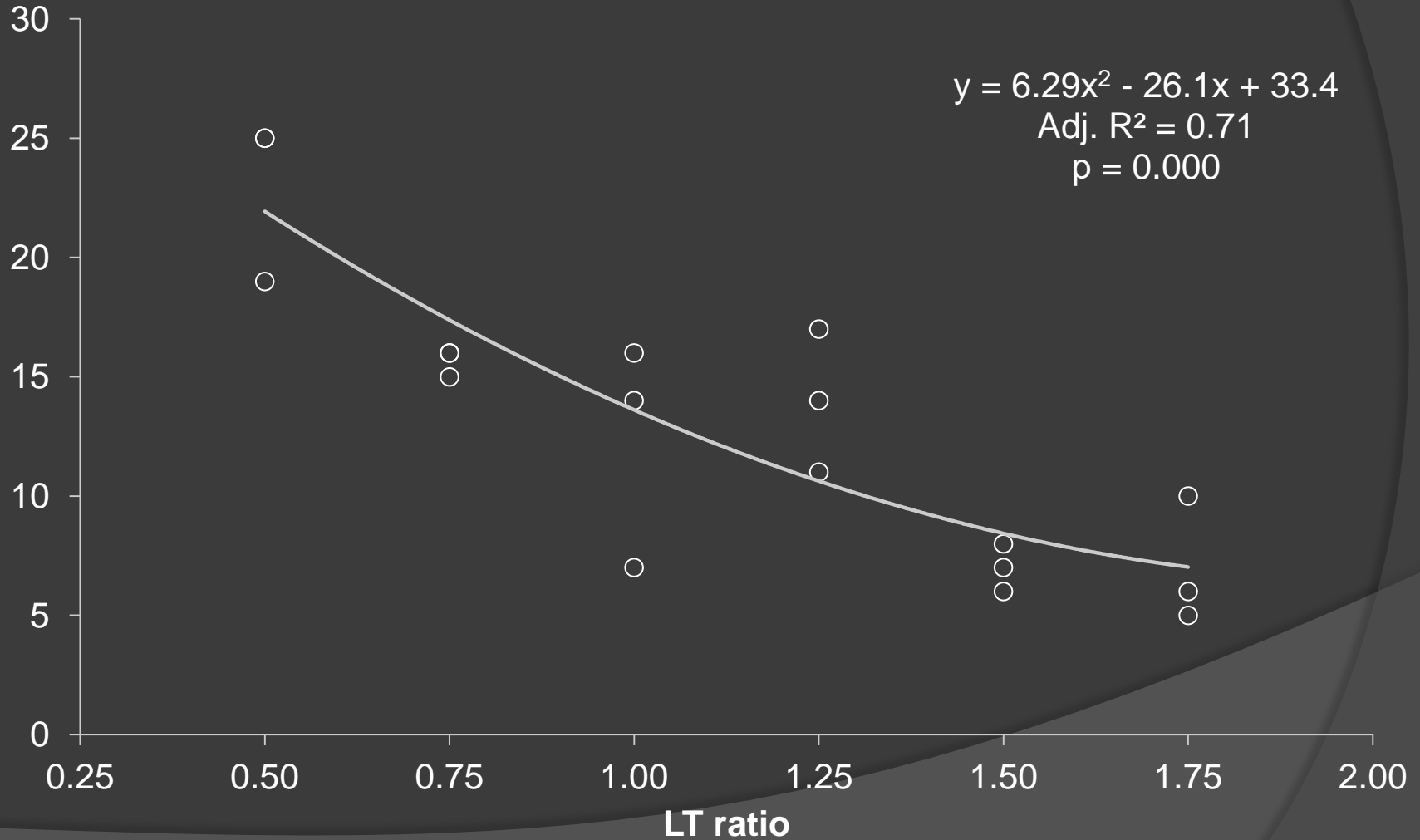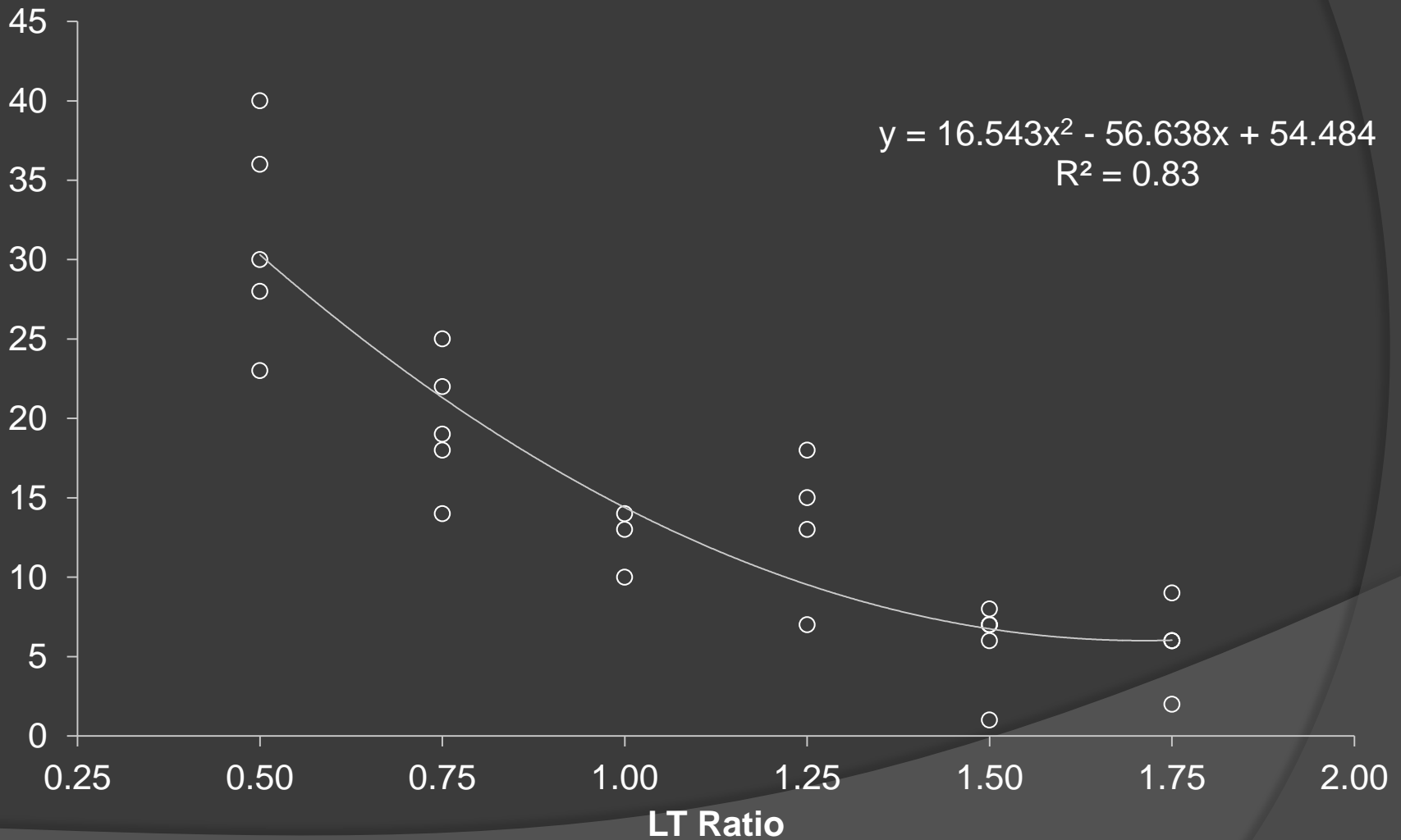LT = 1.25

LT = 1.25

Max. allowable branch diameter

Smaller diameter trunks

Trunk diameter
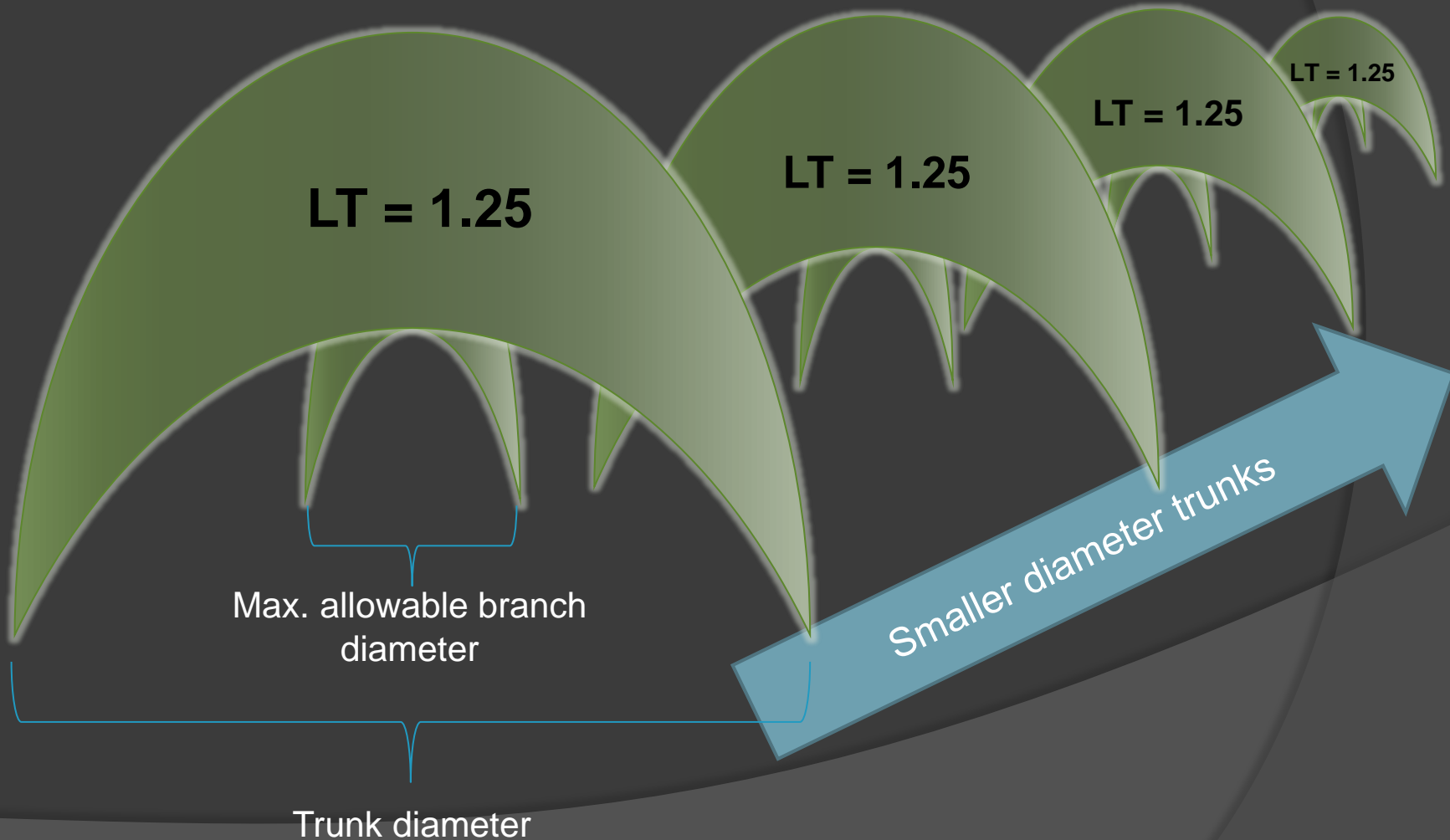
2013 Fuji Trial 5th leaf 'Brak'

UNPRUNED

PRUNED TO 1.25 LT RATIO

No. Limbs Removed / Tree, 2013

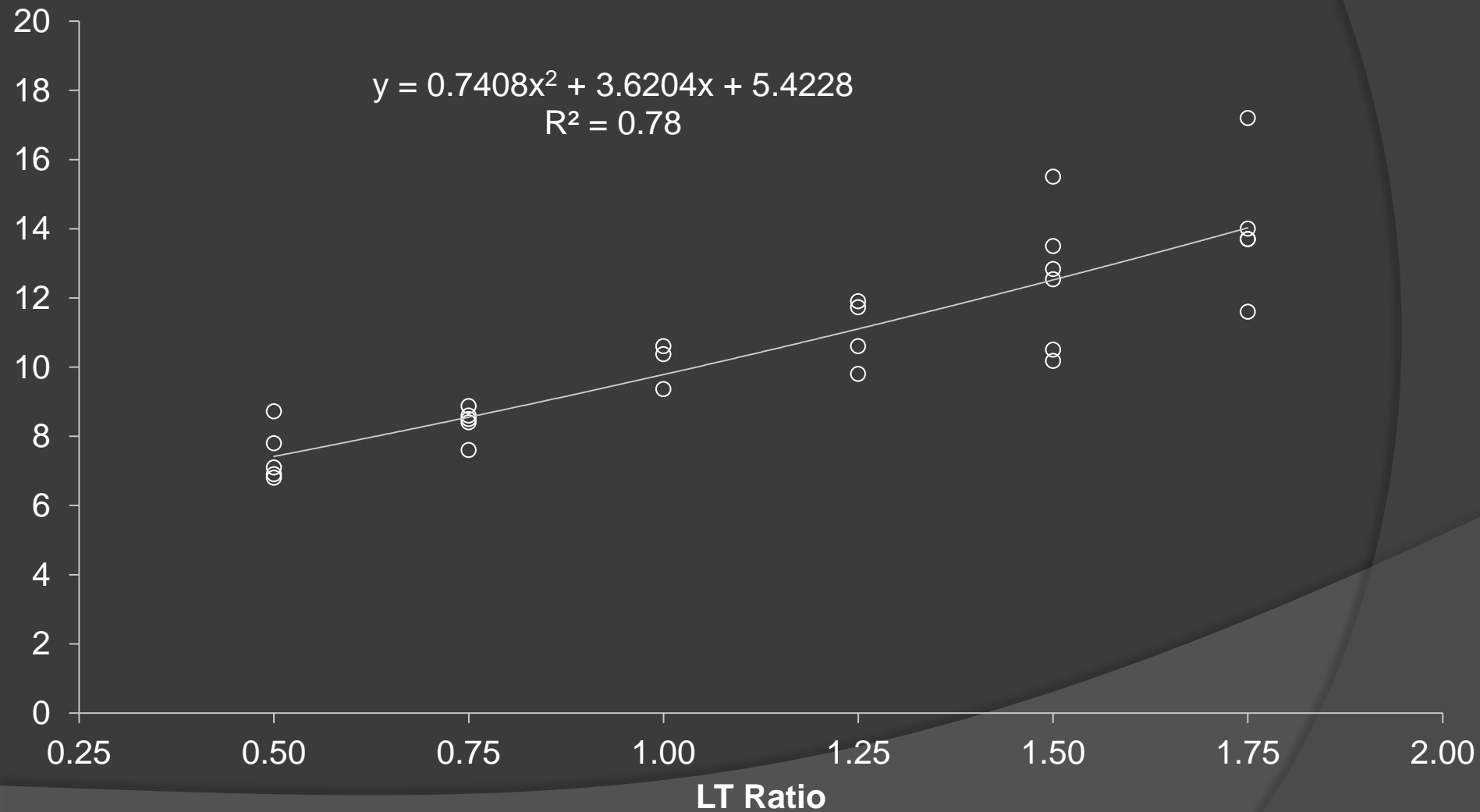
$y = 6.29x^2 - 26.1x + 33.4$
Adj. $R^2 = 0.71$
$p = 0.000$

LT ratio

No. Limbs Removed / Tree, 2014

$$y = 16.543x^2 - 56.638x + 54.484$$
$$R^2 = 0.83$$

LT Ratio

Maximum Remaining Limb Dia., 2013

$y = -2.59x2 + 10.1x + 3.71$
Adj. $R^2 = 0.61$
$p = 0.000$

LT ratio

Maximum Remaining Limb Dia., 2014

$$y = 0.7408x^2 + 3.6204x + 5.4228$$
$$R^2 = 0.78$$
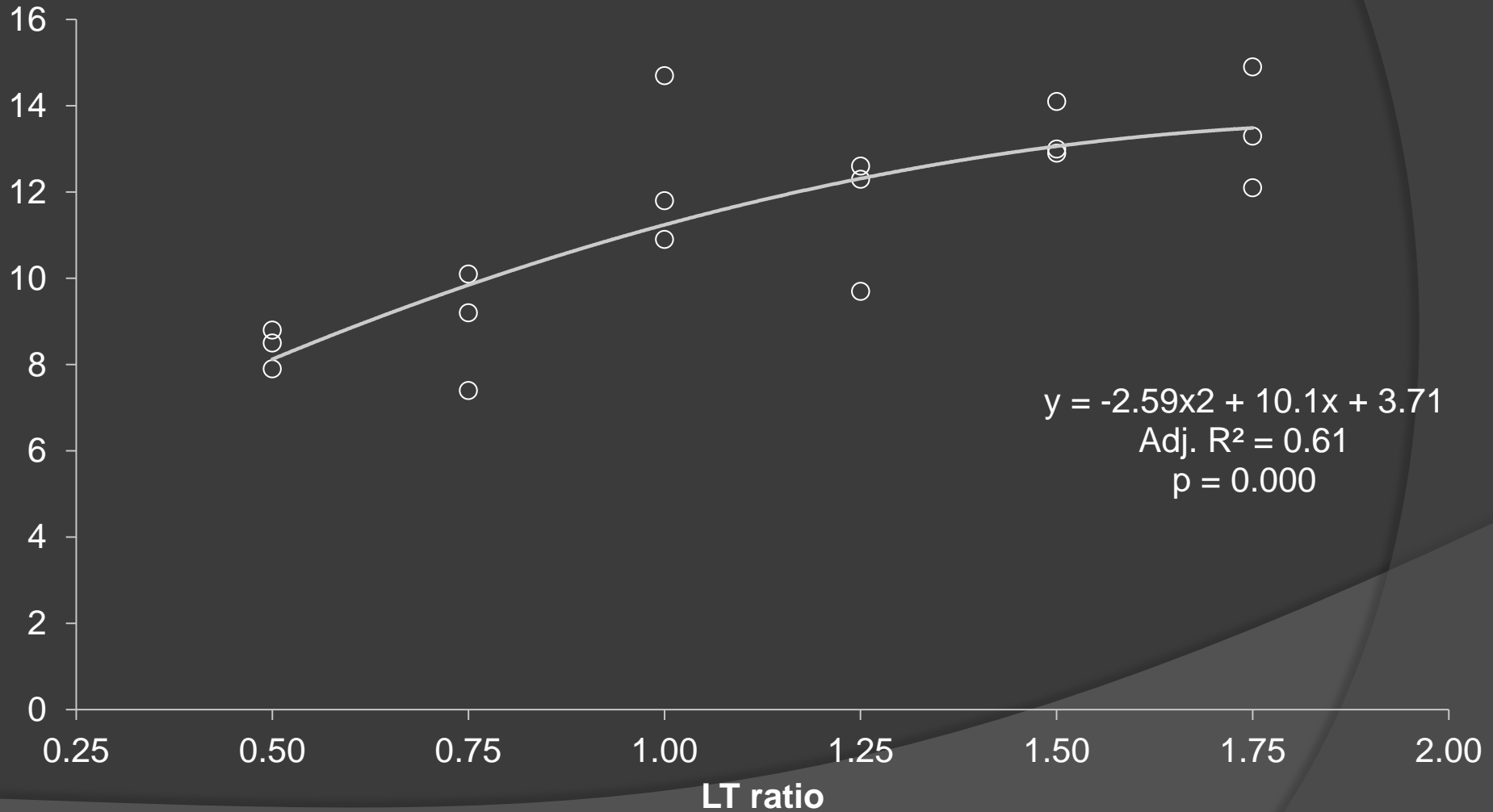
LT Ratio

Renewal Cut / Shoot

Renewal Shoots / Tree, 2013

$y = -10.21x + 23.82$
Adj. $R^2 = 0.65$
$p = 0.000$

Renewal Shoots / Tree, 2014

Scatter plot of Renewal Shoots / Tree vs LT Ratio with trend line.

$y = -13.219x + 31.038$
$R^2 = 0.5396$
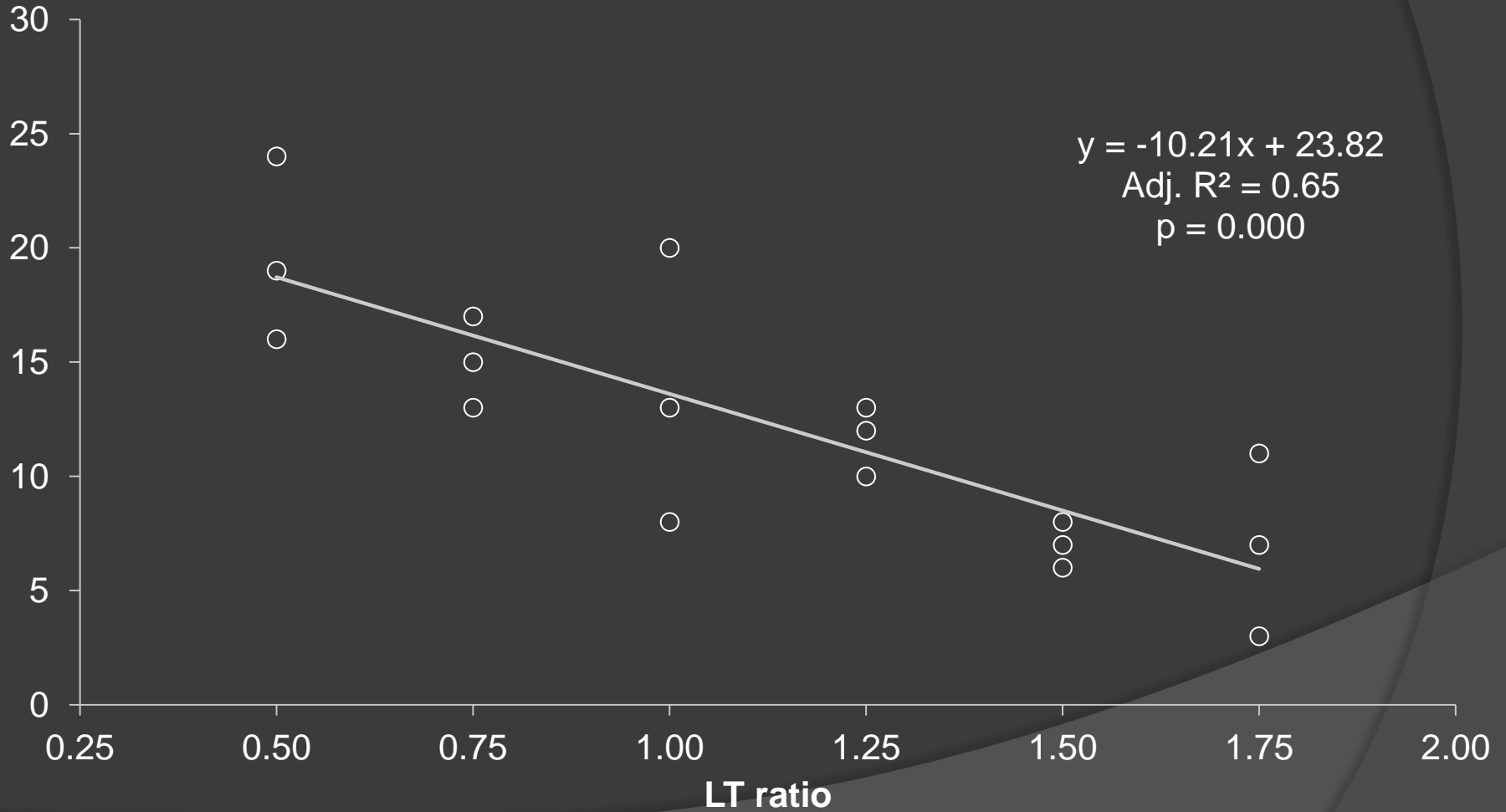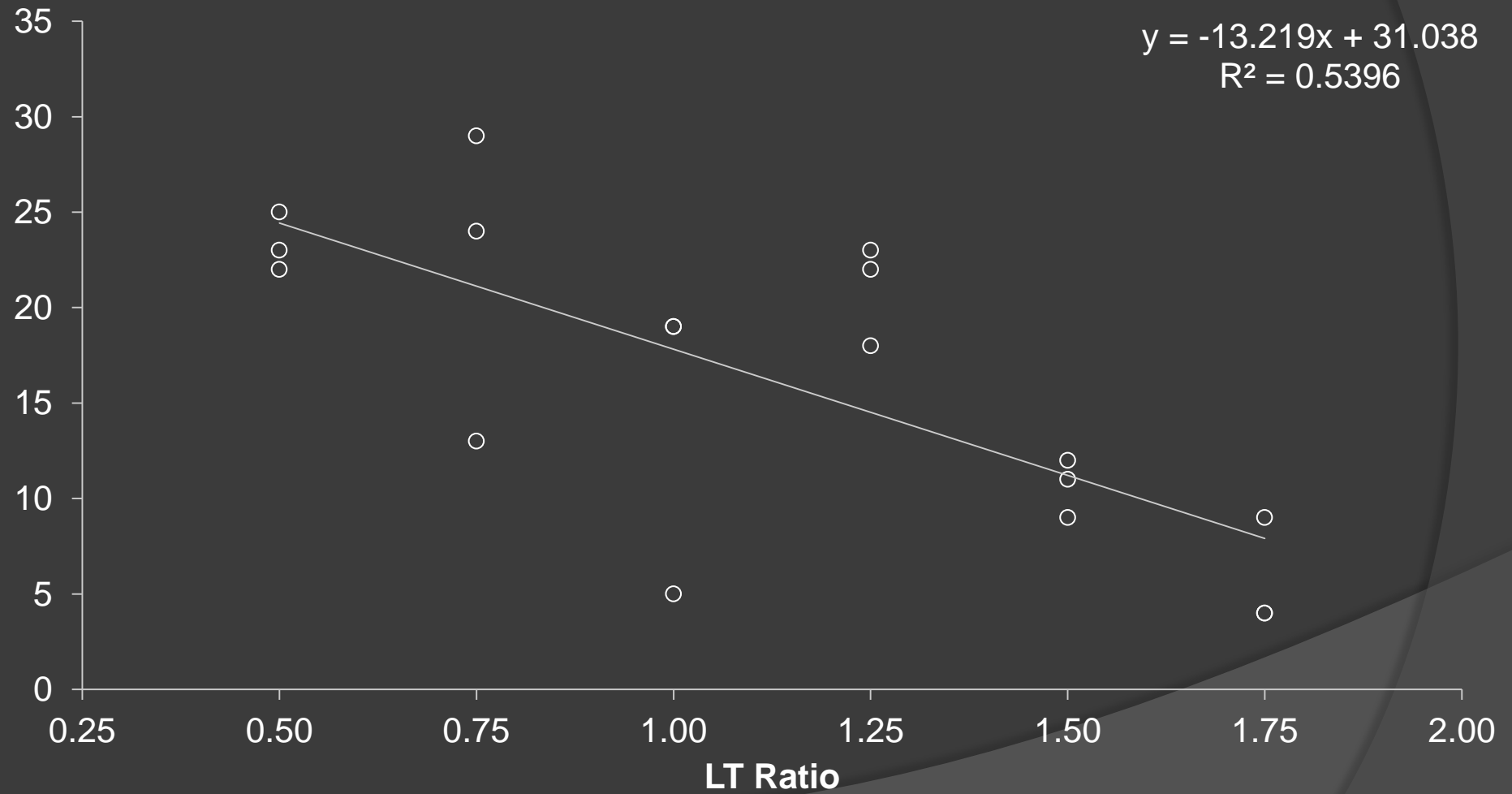
Yield per tree, cumulative 2-year
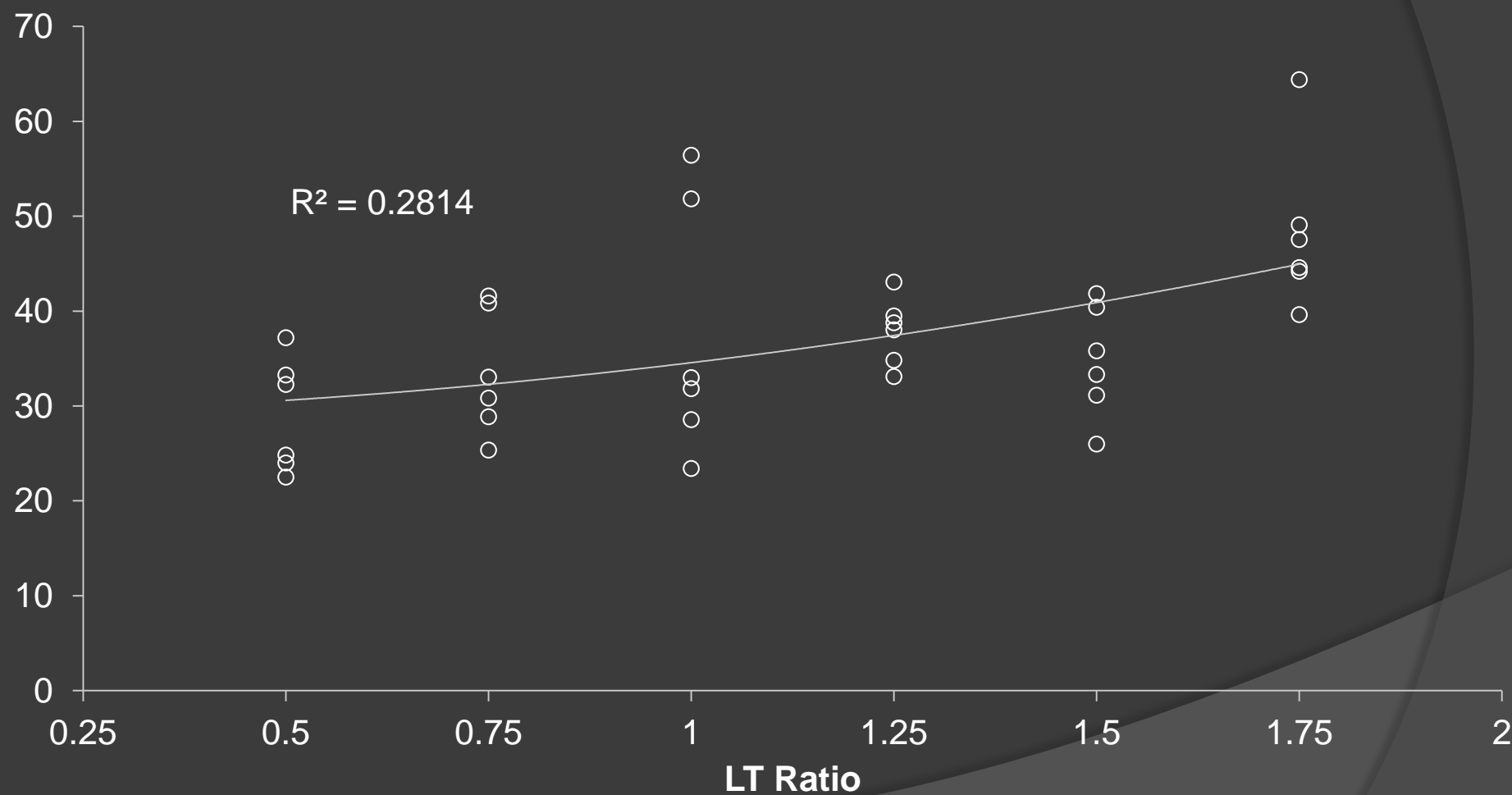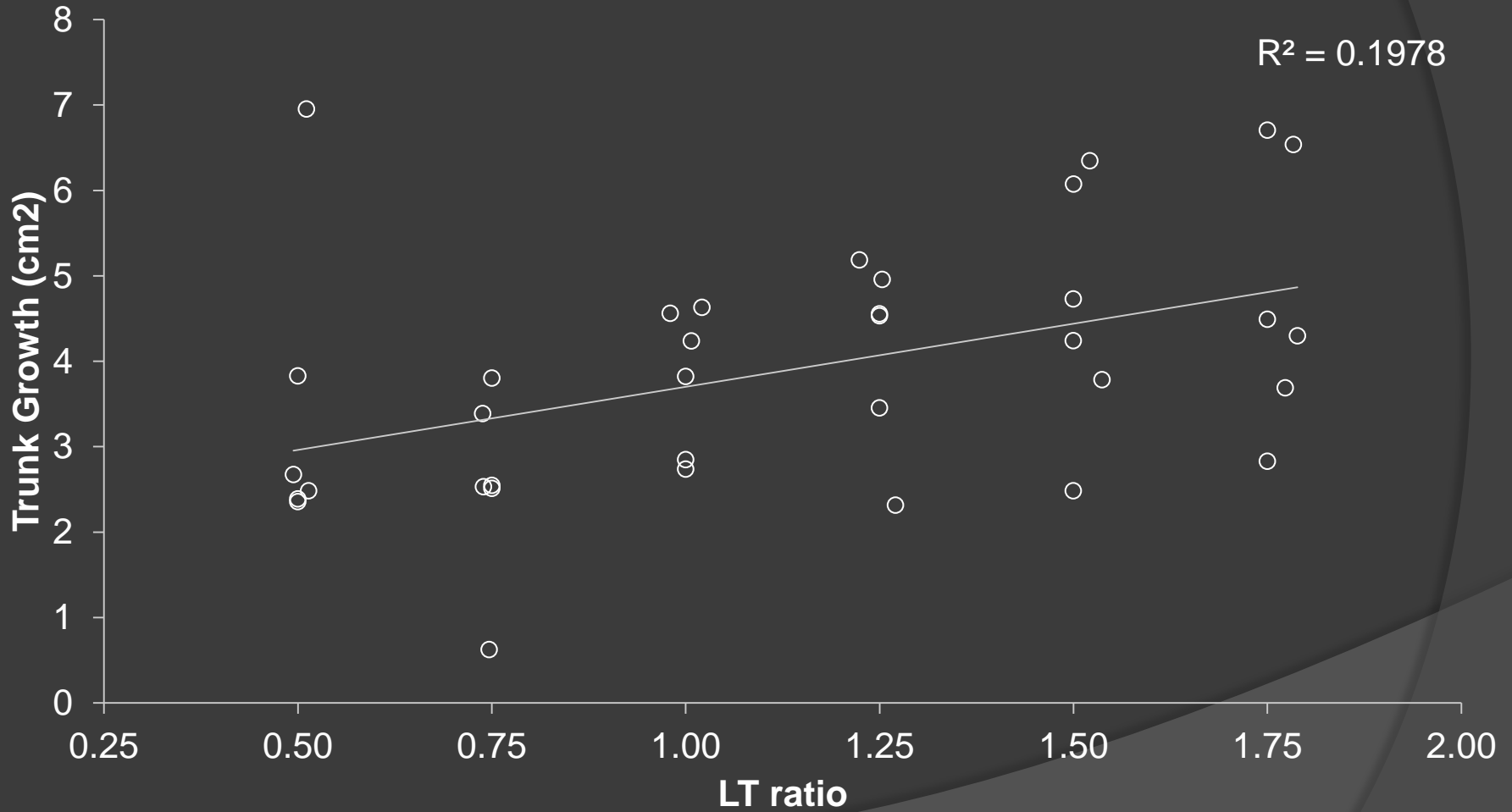
Fruit Size Distribution, 2013

Fruit Size Distribution, 2014
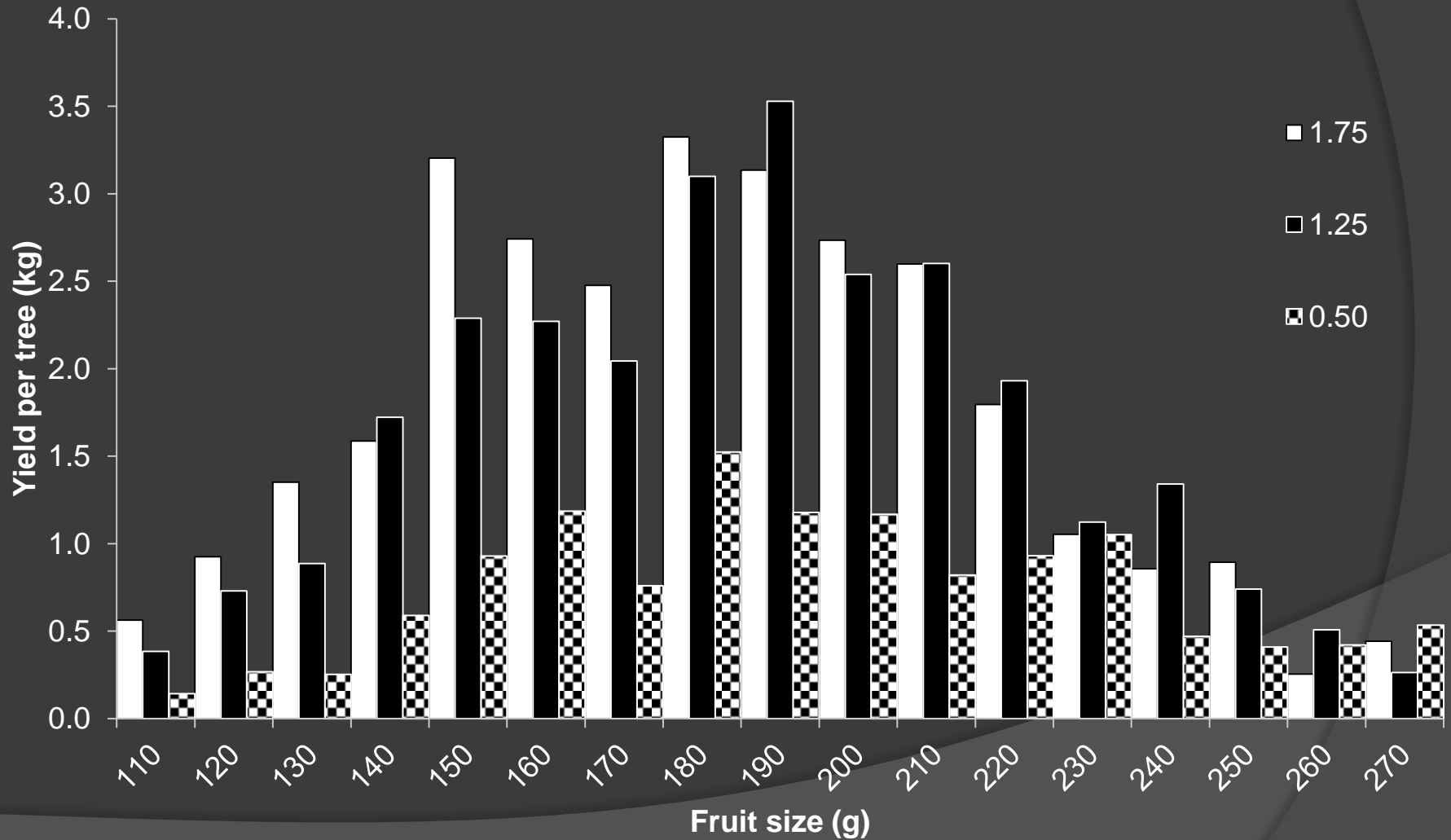
2014 Fruit Size Distribution
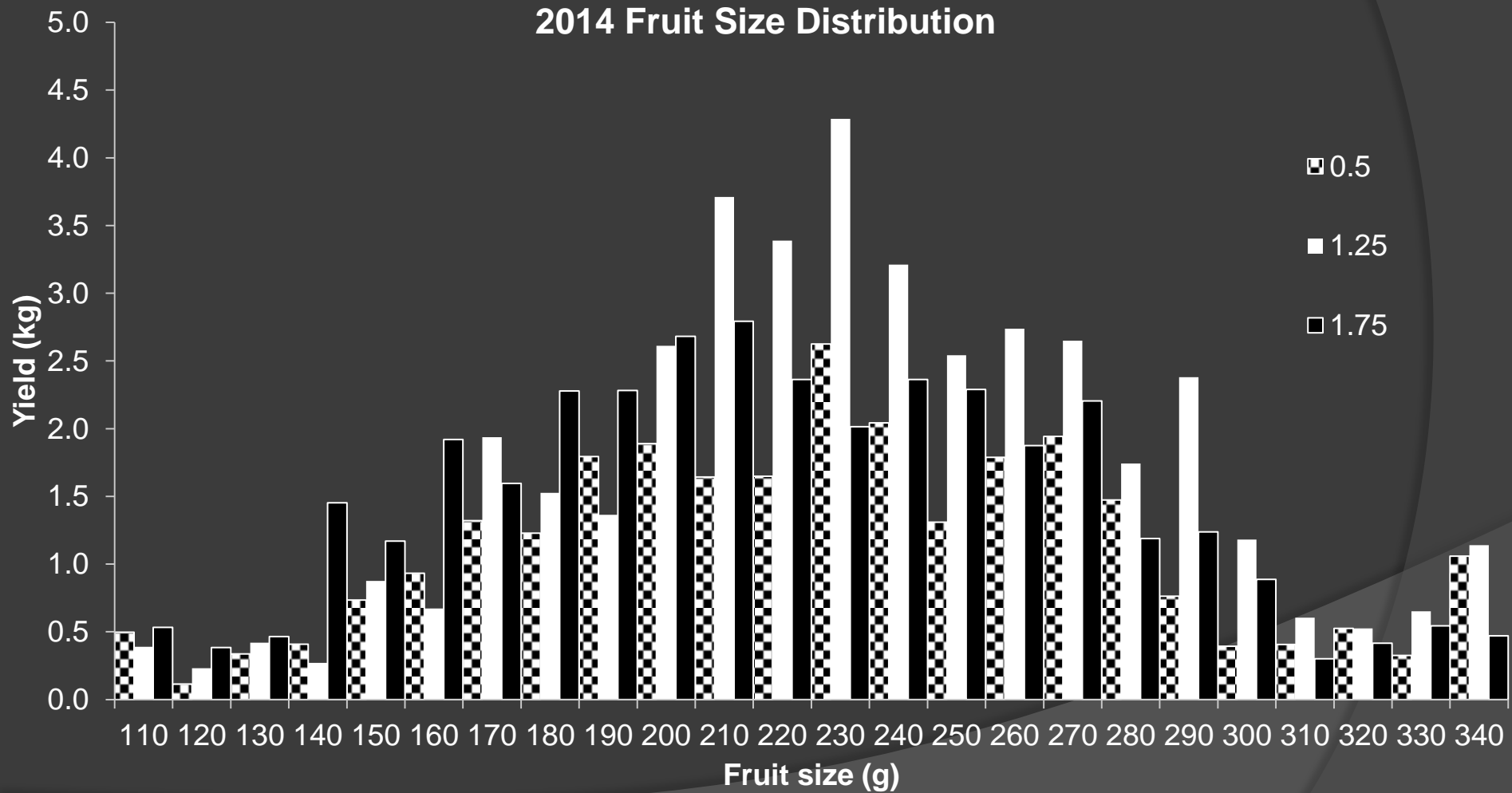
Trunk Growth, 2014

Summary

- **LT ratio worked well for setting severity**
- **Removing next largest branch to threshold is ~3/4 of the required pruning**
- **Max L diameter worked better!**
  - "Smoothing" the input data?
  - Easily taught to laborers
- Simple Severity Rule for Engineers

MD Method:

- Scan LCSA and TCSA in 4 trees / block
- Set desired severity level (LT)
  - 1.25 produced best yield / large fruit
- Calculate threshold diameter for largest remaining branch (MD)
- Prune off everything larger!

MD Method of Pruning Severity

- Note: LT ratio will change with tree age
  - After full canopy is achieved, target LCSA will remain static (renewal pruning)
  - TCSA will continue to increase
  - calculate target LCSA per acre
  - Measure trunk of each tree to determine that tree's share of LCSA.

Mature Tree MD Example
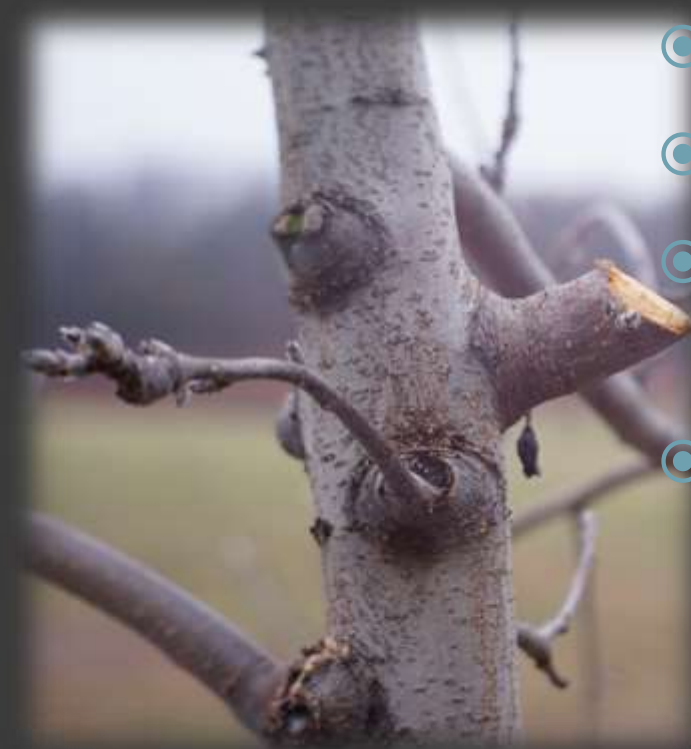
- Goal: 150,000 fruits/ A on 1210 TPA
- 6 fruits / LCSA = 25k LCSA / A
- ~21 cm^2 LCSA / tree
  - Adjust LCSA + / - based upon TCSA(?)
- Goal can be adjusted
  - Mgt. goals
  - Site capability
  - Cultivar, etc.

Pruning Rule Orders

1. Remove all >MD limbs with renewal cut
2. Remove all pendant / upright limbs
3. Thin out horizontal limbs to 6 per m
4. Prune each remaining limb to a single horizontal axis.

Summary: Size Matters

- Goal: to do 70% pruning = 90% benefit
- Can we reach this goal with one rule?

Thank You!
Edwin Winzeler &
Melanie Schupp