# How do soil characteristics influence restoration success in forested ecosystems?

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# Outline

Background

Summarize results of 3 studies:

1. Fertilization effects on oak on a mine site (2006)
2. Fertilization effects on American chestnut on a mine site (2008)
3. Fertilization and lime addition effects on oak, chestnut, and shortleaf pine (2009) – preliminary results

Conclusion

# Background

Often have a lack of topsoil for restoration projects

Need for offsite topsoil or “topsoil substitute”

Photo by NRDC

# Topsoil substitutes

**Summary of topsoil quality guidelines**

| Category | Soluble salts (dS/m or mmho/cm) | pH | Sand (%) | Silt (%) | Clay (%) | Texture class* | Organic Matter (%) | % Coarse fragments (> 2 mm in diameter)** | Sodium Adsorption Ratio (SAR)* |
|---|---|---|---|---|---|---|---|---|---|
| Ideal | < 2 | 5.5 to 7.5 | < 70 | < 70 | < 30 | L, SiL | ≥2.0 | ≤ 2 | < 3 for any texture |
| Acceptable | < 4 | 5.0 to 8.2 | < 70 | < 70 | < 30 | SCL, SL, CL, SiCL | ≥1.0 | 2.1 to 5.0 | 3 to 7 (SiL, SiCL, CL) 3 to 10 (SCL, SL, L) |
| Unacceptable | > 4 | < 5.0 or > 8.2 | > 70 | > 70 | > 30 | LS, SC, SiC, S, Si, C | <1.0 | > 5.0 | > 10 for any texture |

*L = loam; SiL = Silt loam; SCL = sandy clay loam; SL = sandy loam; CL = clay loam; SiCL = silty clay loam; LS = loamy sand; SC = sandy clay; SiC = silty clay; S = sand; Si = silt; C = clay.

**This guideline also includes no fragments larger than 1 ½ inch in diameter.

Utah State Univ. Extension

# Topsoil standards

- pH 5.0-8.2 to 6.0-7.0
- Organic matter >1% to 5-10%
- EC <2 $mS/m^2$ to <4 $DS/m^2$
- SAR <1.6 to <6
- P 5-45 ppm

# Topsoil standards

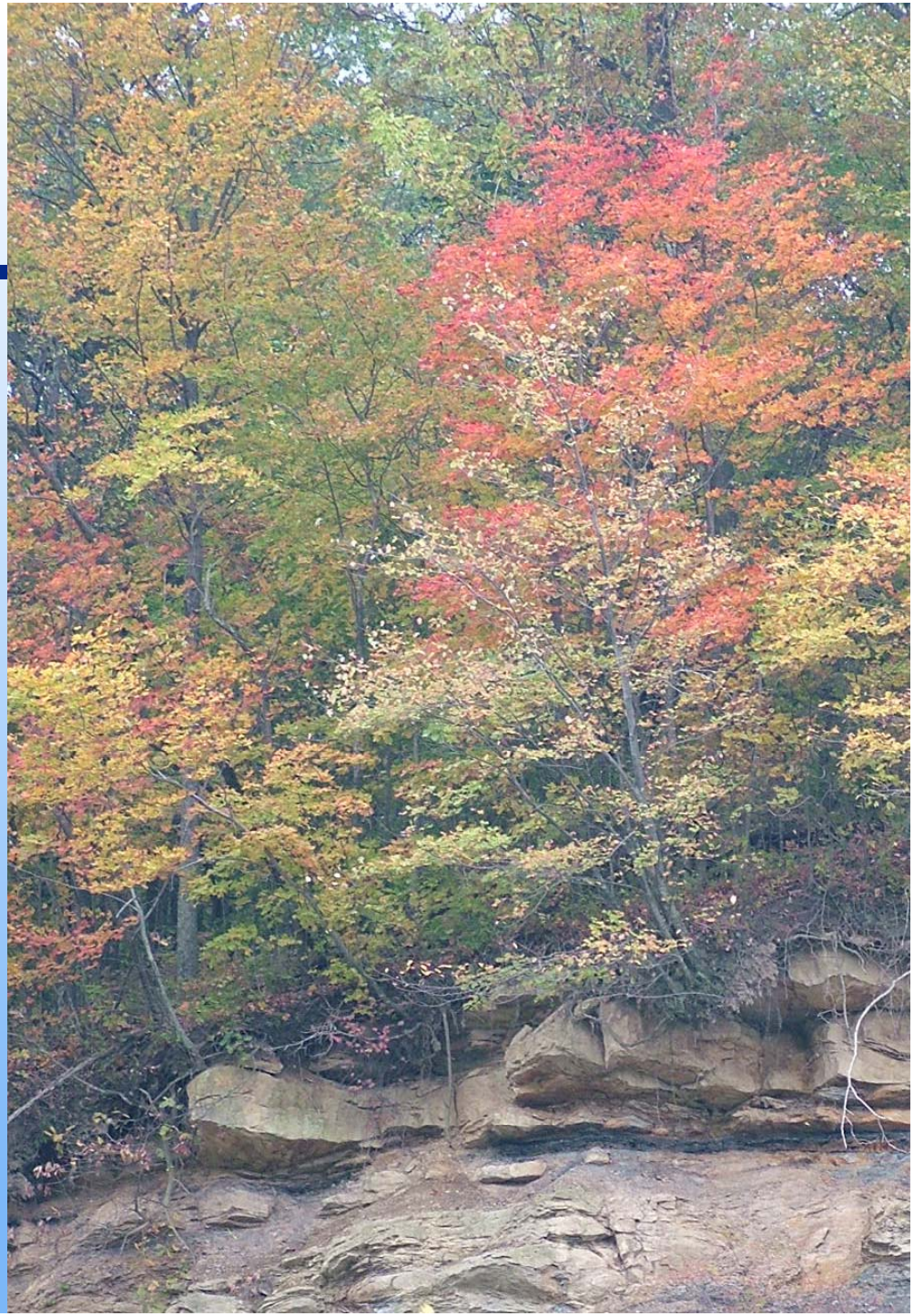
| | | substitute |
|---|---|---|
| pH | 5.0-8.2 to 6.0-7.0 | 6.5-7.5 |
| OM | >1% to 5-10% | <1% |
| EC | <0.2 to <4 DS/$m^2$ | <0.2 DS/$m^2$ |
| SAR | <1.6 to <6 | <1.6 |
| P | 5-45 ppm | 6-40ppm |

# Native soils in TN

P = 300 – 800 mg/kg
Ntot = 0.10 – 0.50 %

EC <0.1 mmhos cm

pH 3.6 – 7.0
4.5 – 5.3 typical



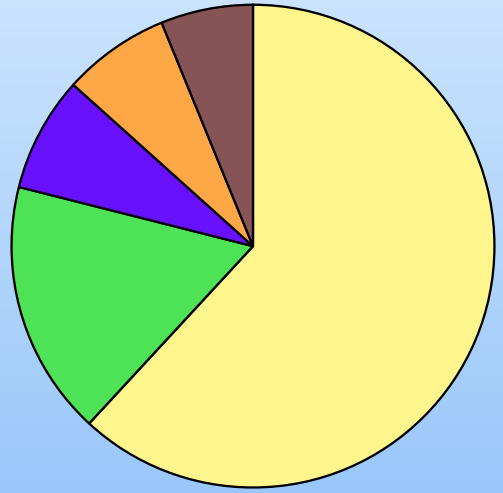
# What to expect?

| **Topsoil** | **Spoil** | **Sandstone** |
|---|---|---|
| pH 4.4 | pH 7.4 | pH 7.5 |
| High Al | | Moderate nutrients |
| Low Ca, Mg, K | high Ca, Mg | Poor moisture retention |
| Low organic | | |
| Best moisture Retention | | Best fescue |
| Moderate fescue | good fescue | Good trefoil |
| Poor trefoil | best trefoil | |

From John C. Sencindiver and Ross Fugill, 1984

# No amendments, 50 years later:

**Mined**




**County average**

# "topsoil"

**Anthropogenic soil**

-pH 7.6

C 2%

C:N 20

Ca 11,000 ppm

Mg 1550

K 2500

P 775

**Succession long**

**Persistent annual and herbaceous perennial stage**

**Landfill**

pH 7.5

C 1%

C:N 35

Ca 11,000

Mg 1000

K 1000

P 150

**"Typical" sequence: annual, perennial, woody**

**Sand**

pH 7.5

C 0.1%

C:N 15

Ca 1000

Mg 400

K 600

P 100

**No successional sequence**

**Straight to woody stage**

From Rebele, 1992

# 1. Fertilization effects on oak on a mine site (2006)

A reduced seeding rate is used to give a moderate level of ground cover to minimize competition with trees

Should we reduce the fertilization rate as well?

Which benefits from the fertilization, the trees or the ground cover?

# Treatments

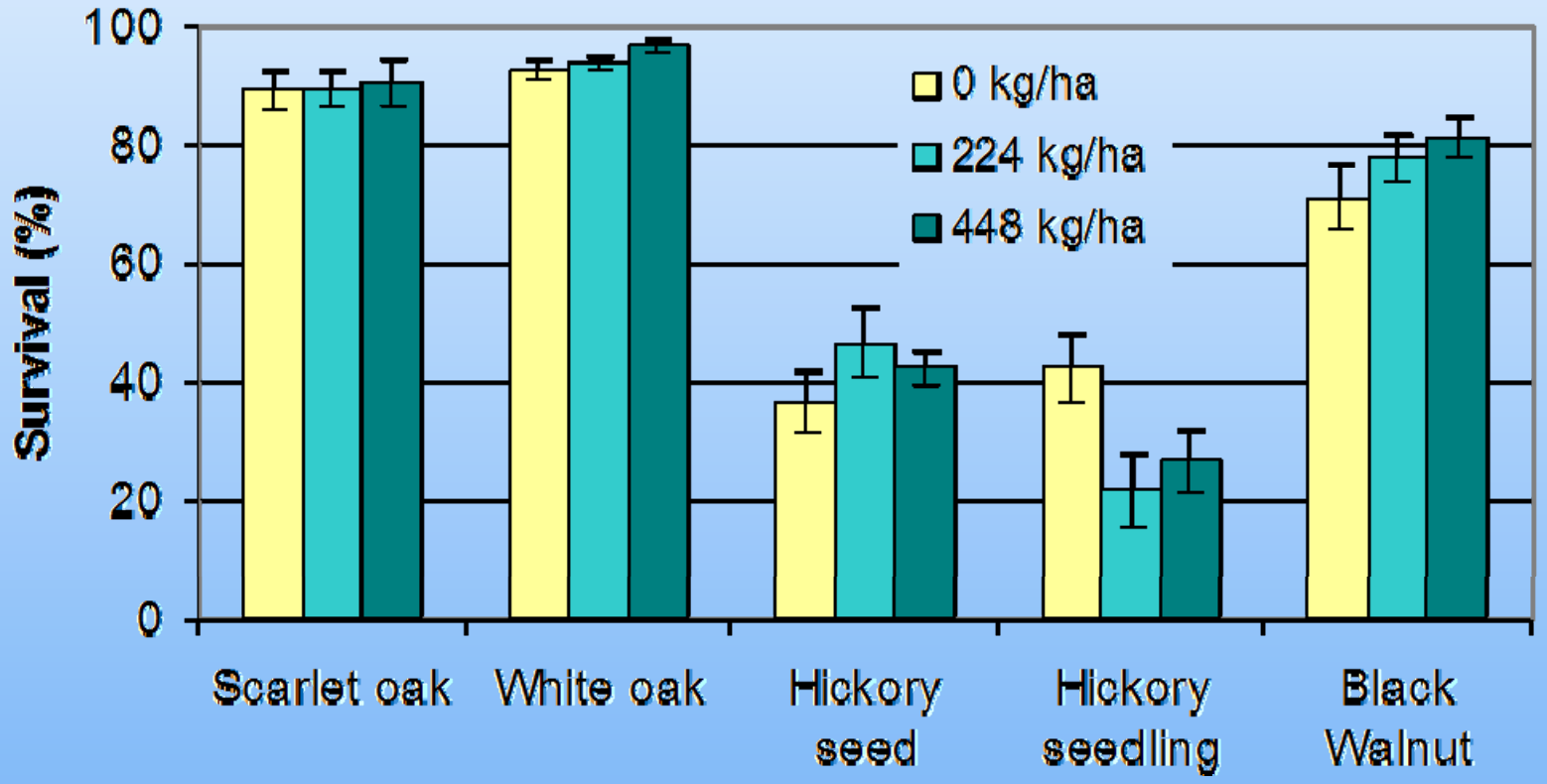
- 3 x 3 factorial with 3 replicates
- Seeded with native warm-season grasses and legumes at 59.4 kg/ha
  29.7 kg/ha
  5.9 kg/ha
- Fertilized with 10:20:20 at 448 kg/ha
  224 kg/ha
  0 kg/ha

# Treatments hydroseeded in May 2006
# Planted:

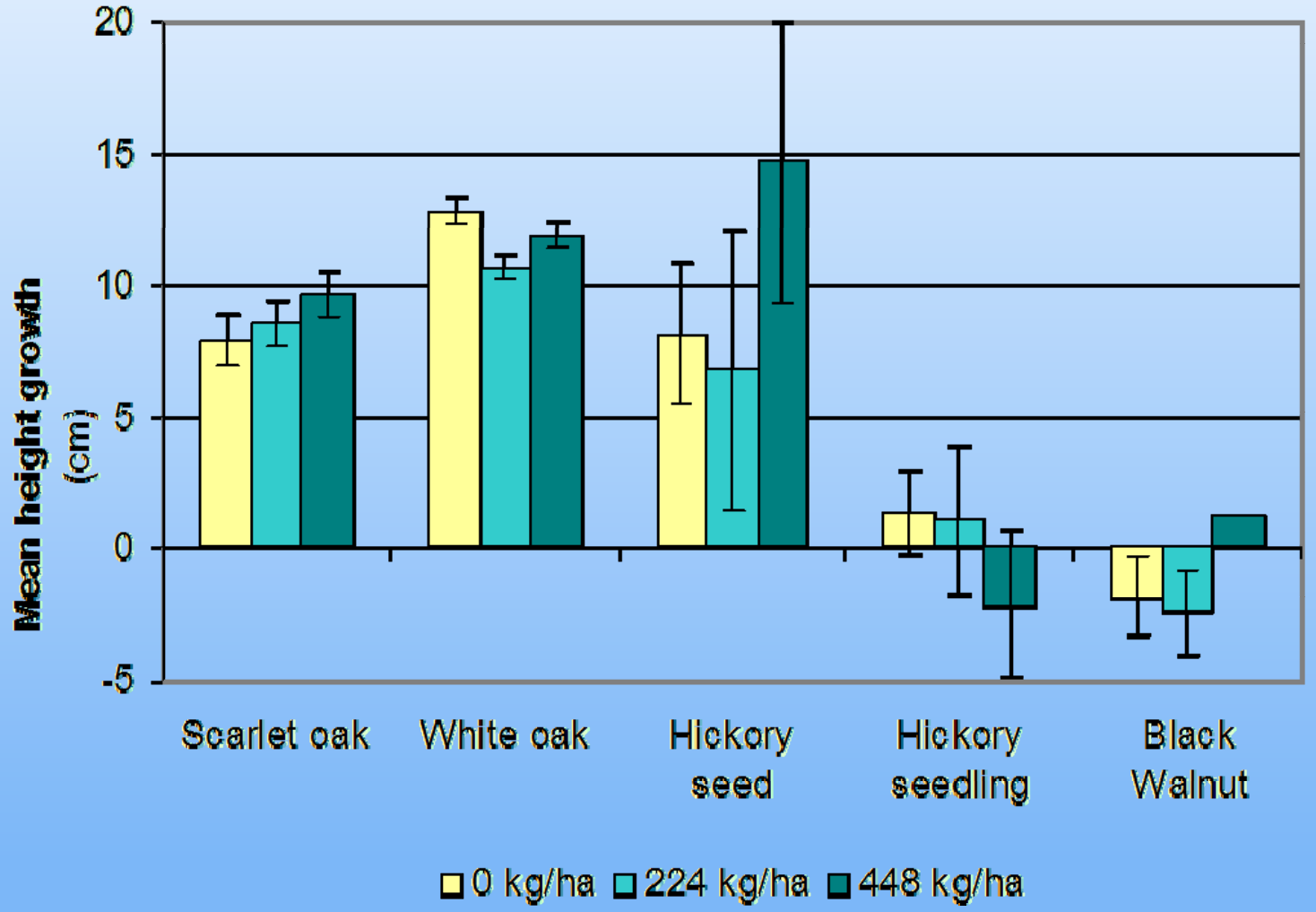
white oak (*Quercus alba*)
scarlet oak (*Q. coccinea*)
black walnut (*Juglans nigra*)
mockernut hickory (*Carya alba*)
mockernut hickory seed
Randomized 2.4m x 2.4m spacing

Mean ground cover was 5 - 30%, likely too low for substantial competitive effects.

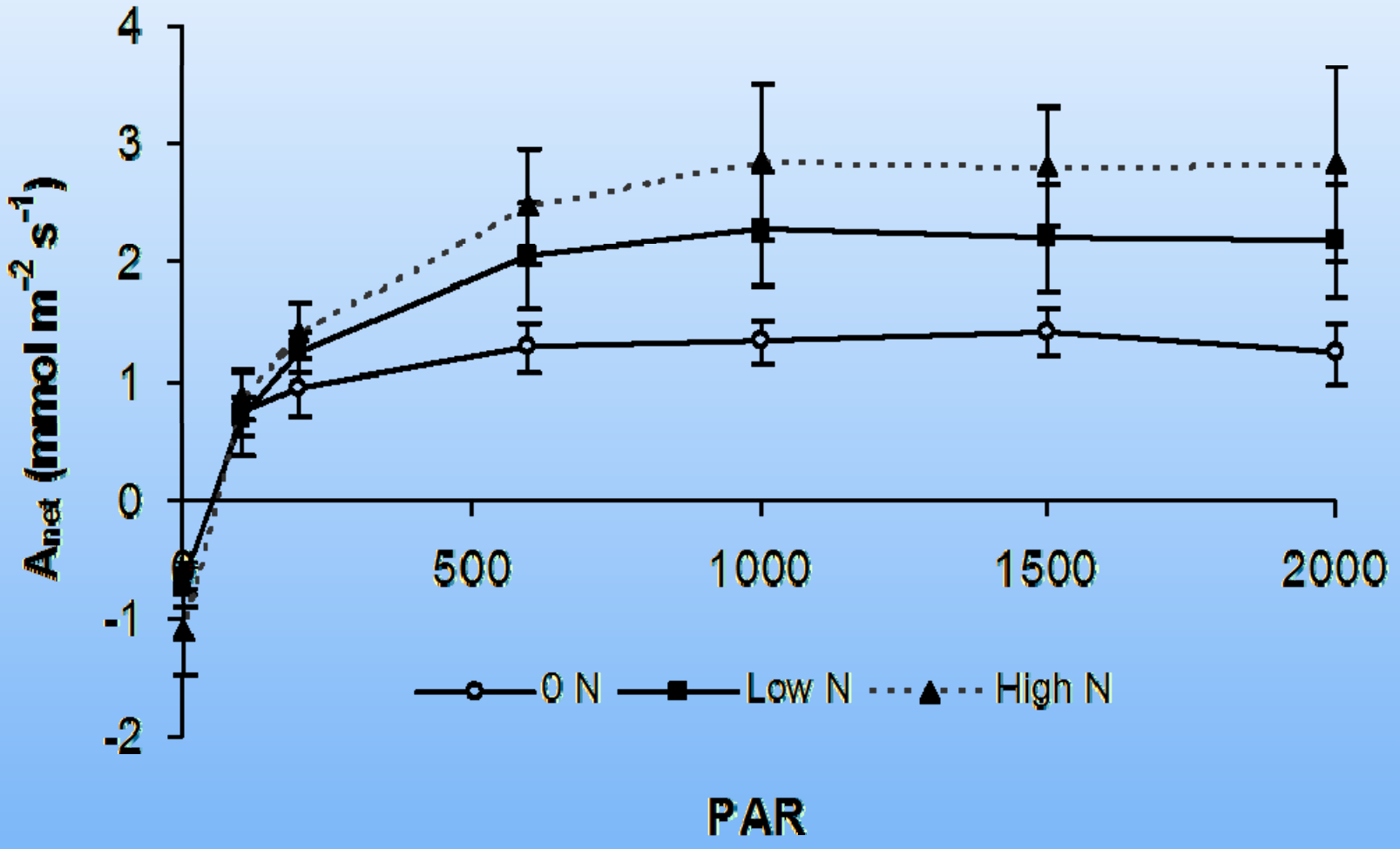
Fertilization had little effect on seedling survival.



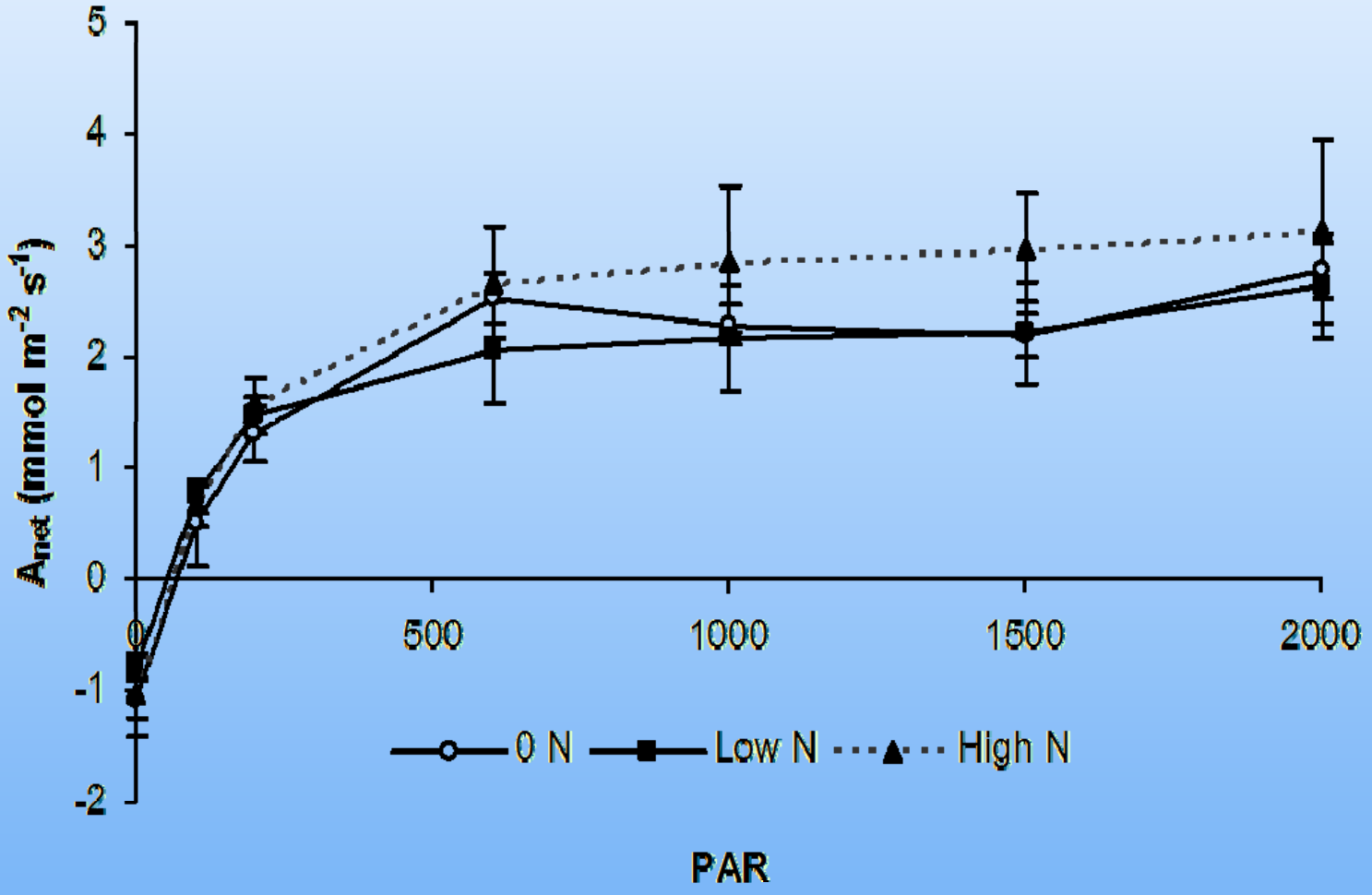
# Also no significant difference for RCD growth



# Hickory light response curve



# Scarlet oak light response curve



# Showalter et al. 2010

- Better growth of hardwoods in soils that approximate native soil: lower pH, better moisture retention
- Growth of Fraxinus americana greatly affected, growth of Quercus rubra little effected by soil chemistry
- Nutrient deficiency more pronounced in Fraxinus than Quercus

## Conclusion: trees are able to utilize and store nutrients applied with seed mix, BUT some species will benefit more than others, and effects may take several years to become readily visible

**2006**

**2008**

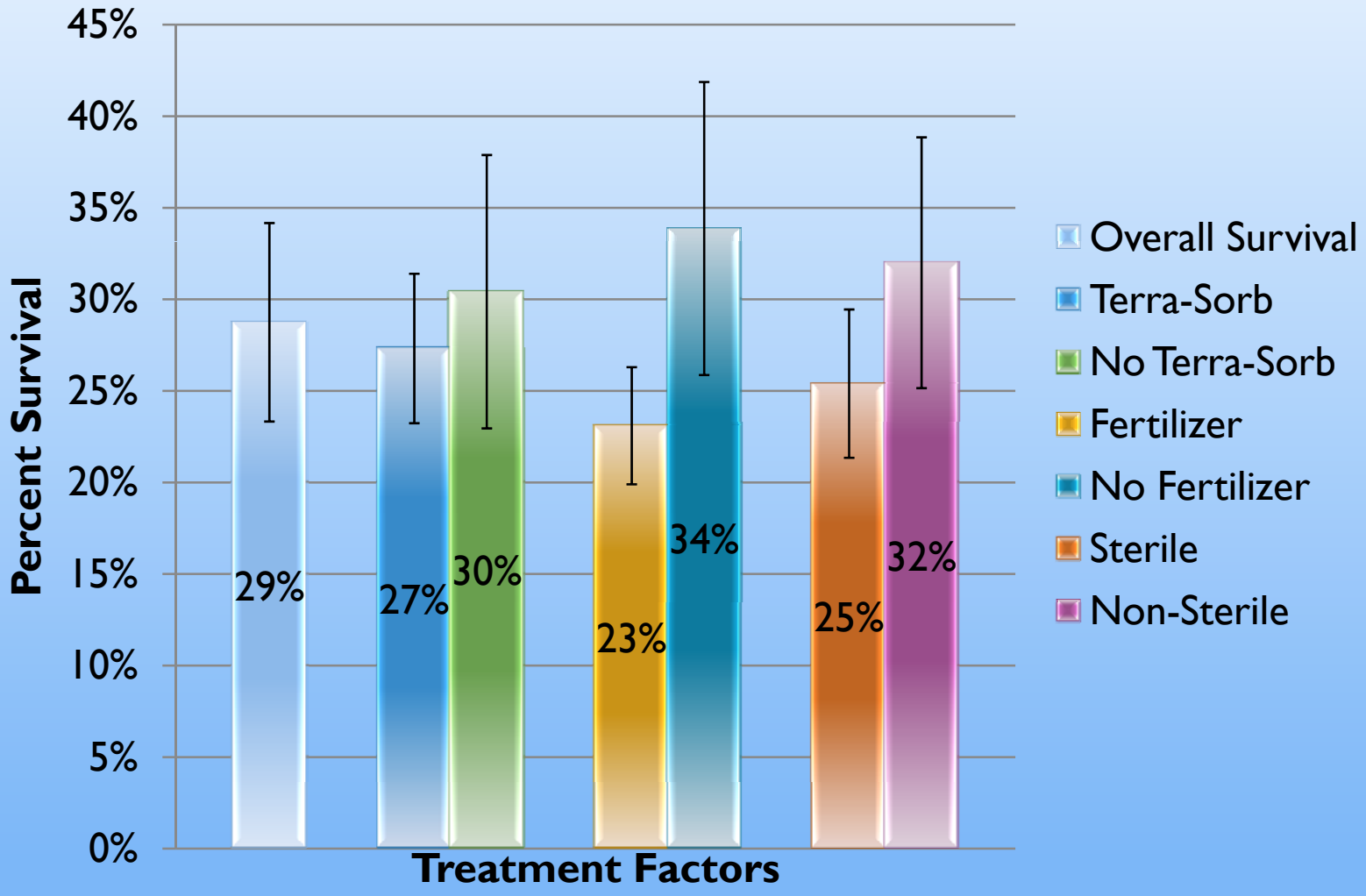
# 2. Fertilization effects on American chestnut on a mine site –

## Chris Miller (M.Sc.)

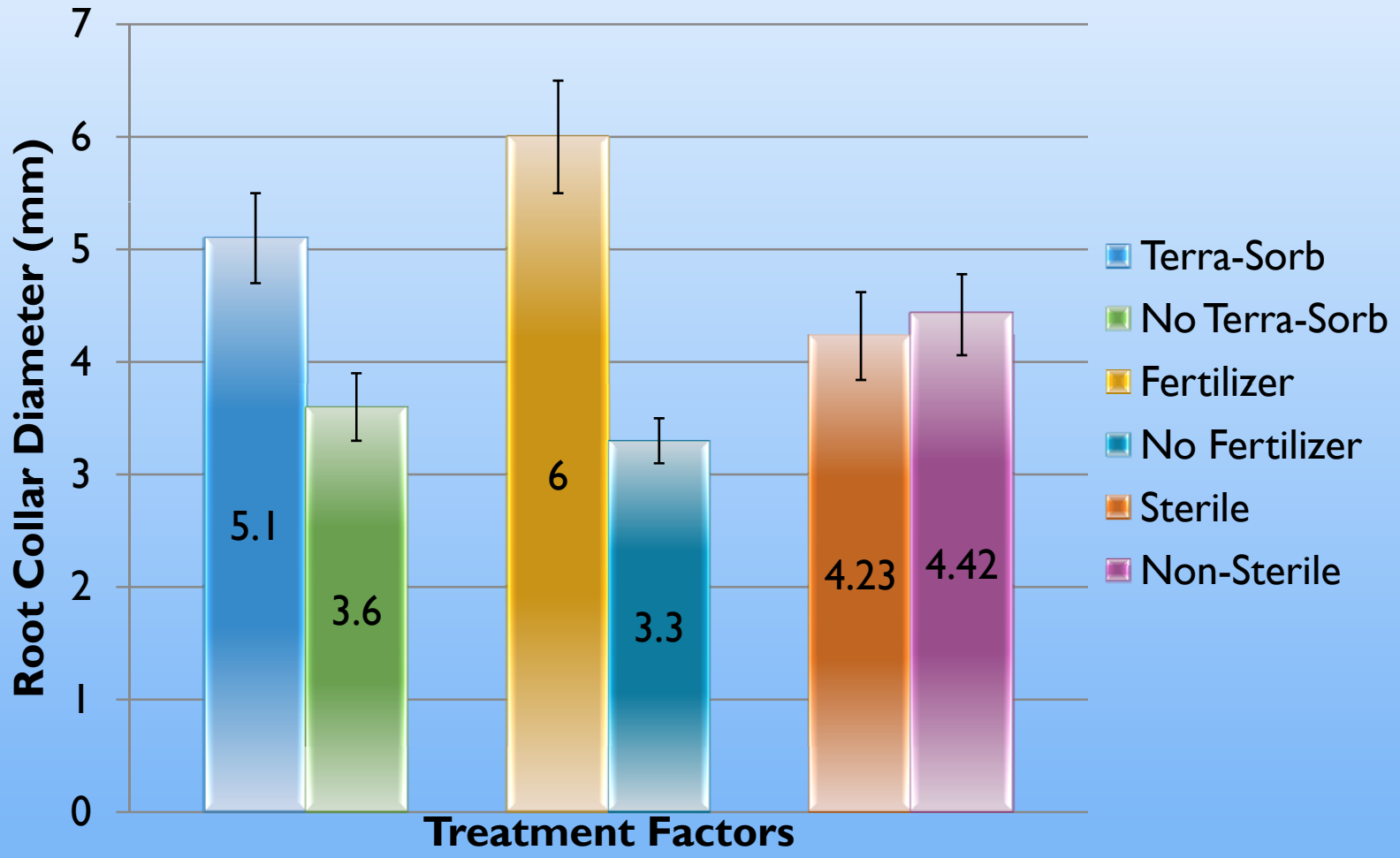
3 experiments:

- **Coal mine reclamation – planted in 2008**
  - **2x2x2 factorial (forest soil, terra-sorb, fert)**
    - **Pure American chestnut seed from ACF**
- **Quarry reclamation – planted in 2009**
  - **2x2x2 factorial (forest soil, terra-sorb, fert)**
    - **Pure American chestnut seed from ACF**
    - **Pure American and hybrid**
- **Greenhouse – 2009**
  - **2x2 factorial (terra-sorb, fert), hybrid**

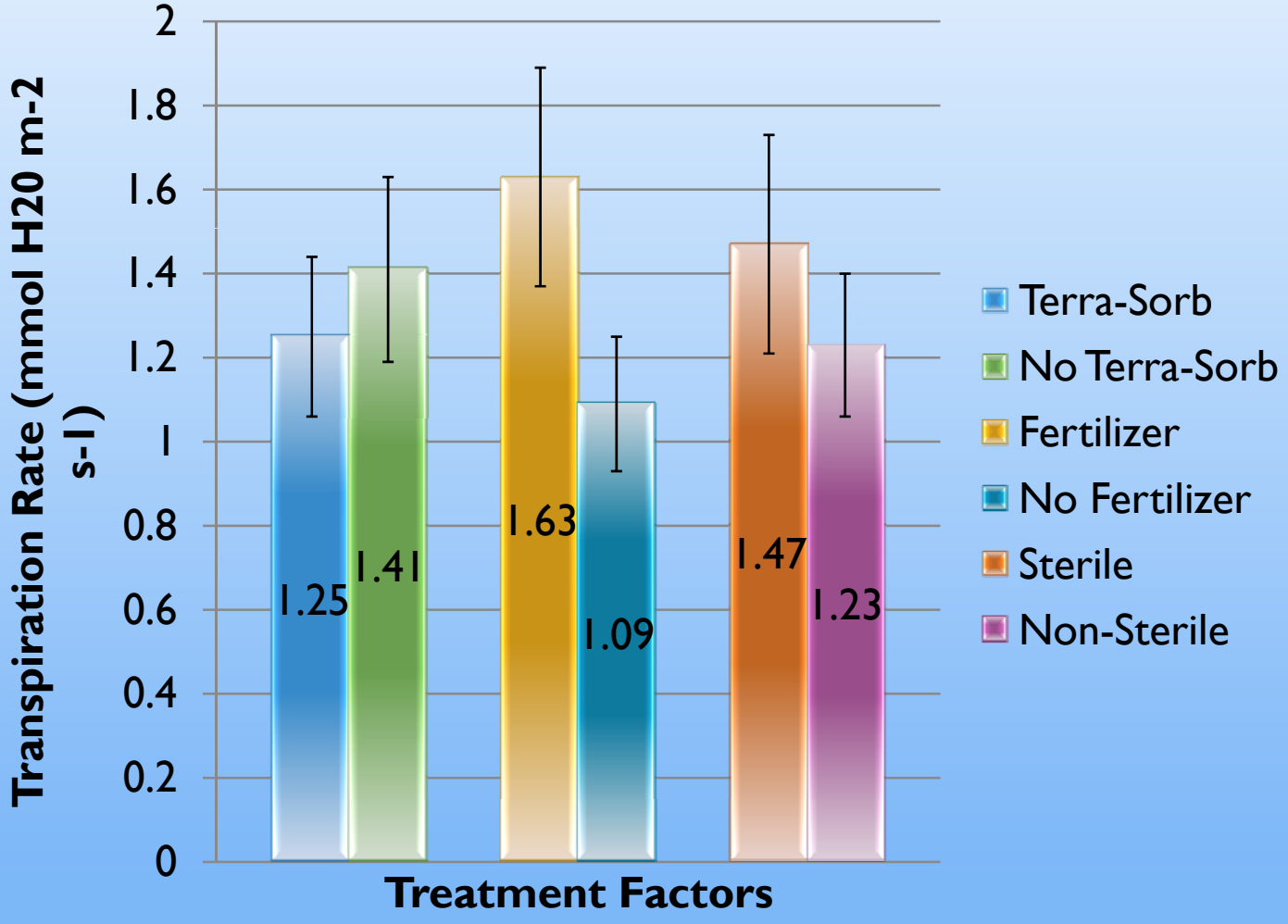
# Coal mine site



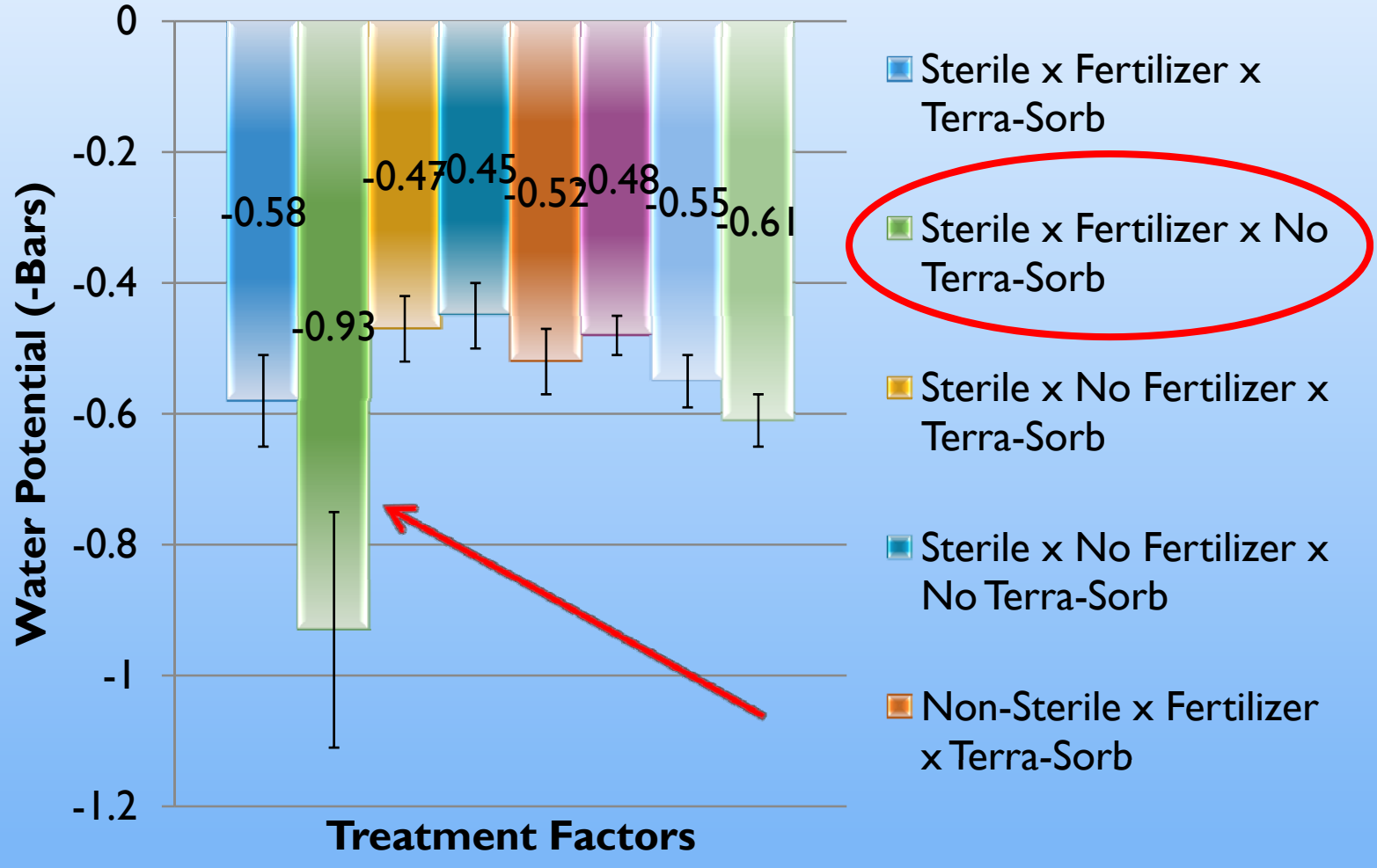
# Coal Mine site



# Higher transpiration rate in fertilized seedlings



# Osmotic adjustment on dry site, with soil microbes lacking



# Summary

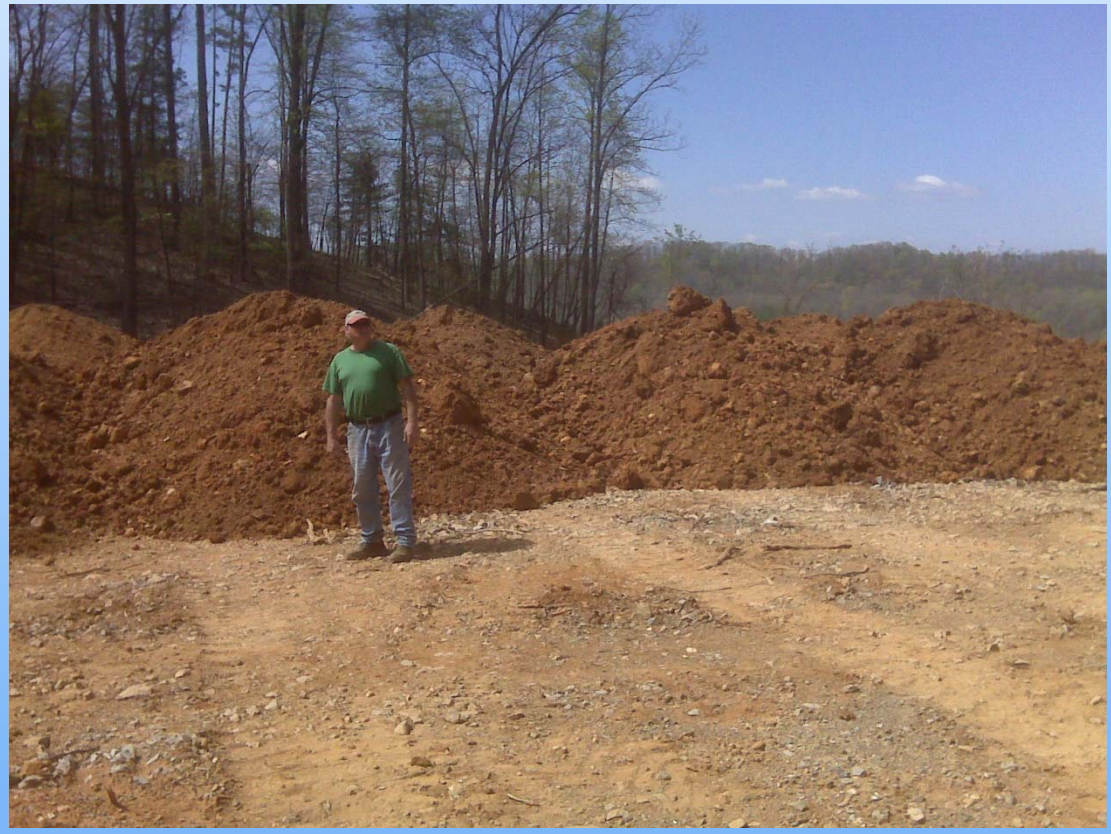
Similar results across sites:

- Fertilization reduced survival
- Fertilization increased growth: height, root collar diameter, leaf area, leaf dry weight
- Fertilization increased transpiration rate, but not photosynthetic rate

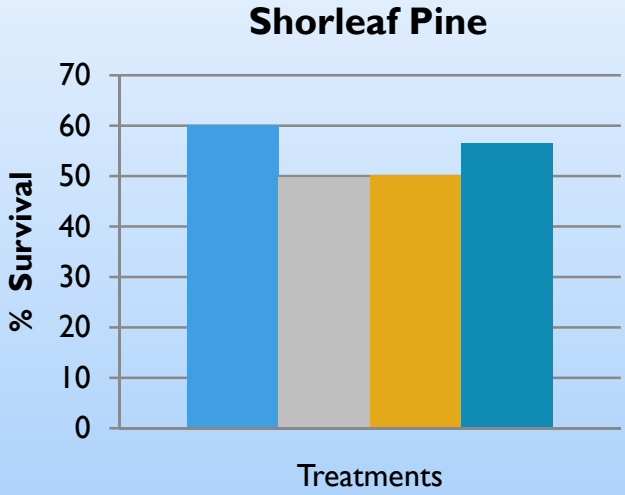
# 3. Fertilization and lime addition effects on oak, chestnut, and shortleaf pine (2009) – preliminary results

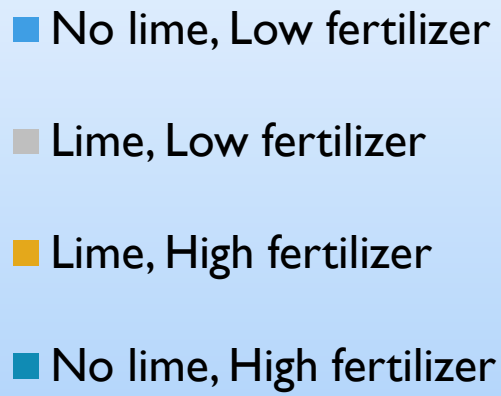
Initial pH 6.5

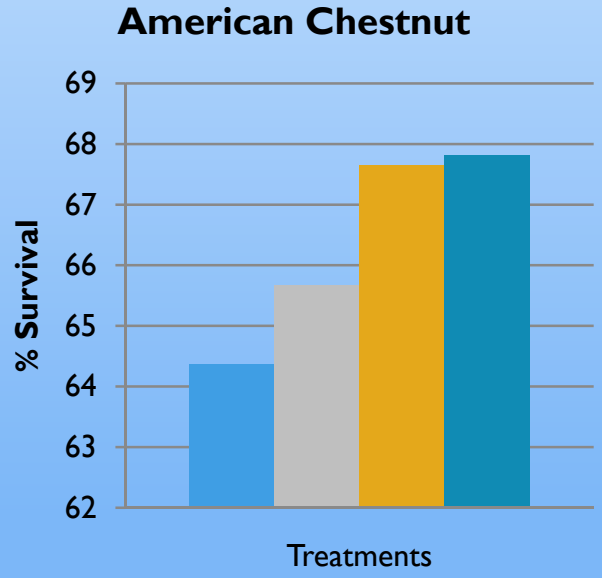
Split plot design
Fertilizer:
Water sol. 20-20-20
400 or 100 lb./ac
Lime addition:
"Liquid-lime" 2 ton/acre equiv. or none

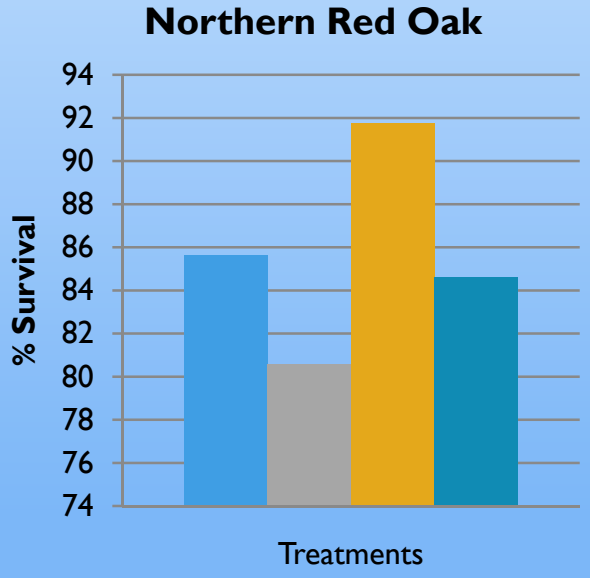


# Percentage of seedlings with buds flushing Apr. 16

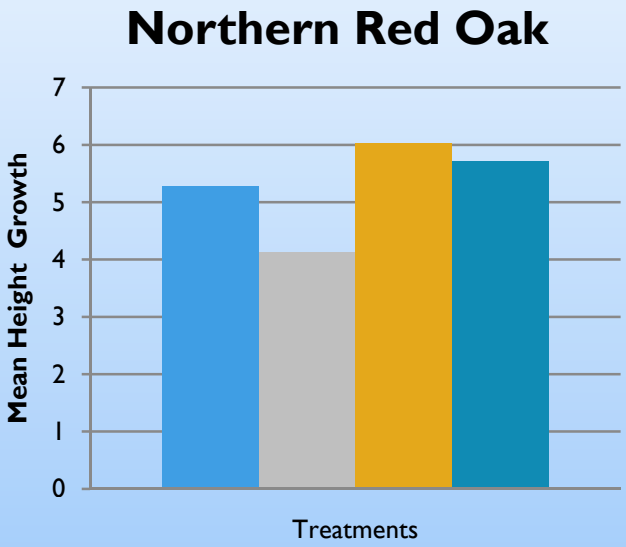


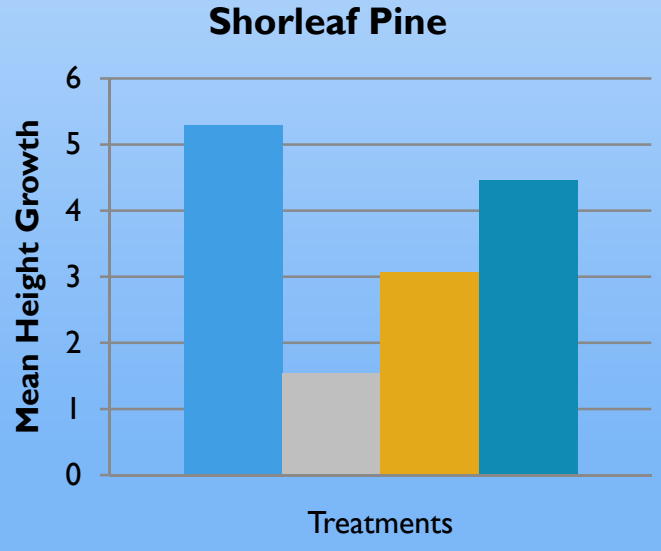



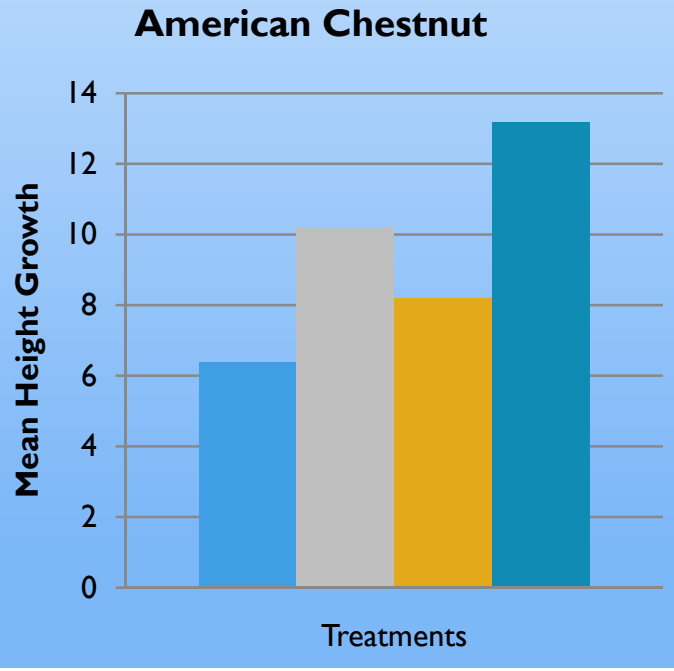



# First season height growth

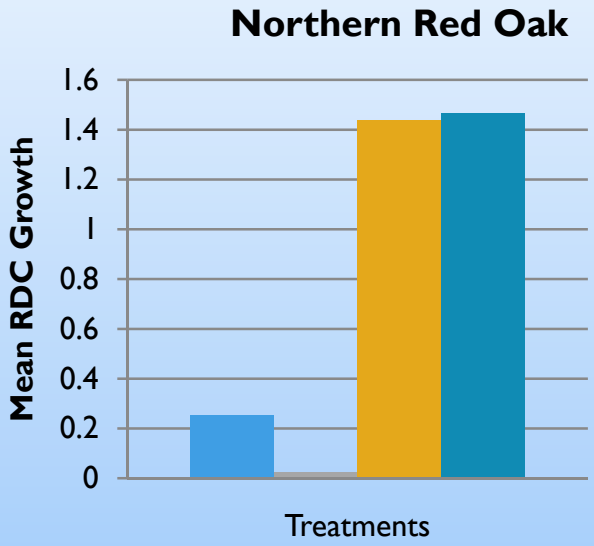



- No lime, Low fertilizer
- Lime, Low fertilizer
- Lime, High fertilizer
- No lime, High fertilizer



# First season diameter growth

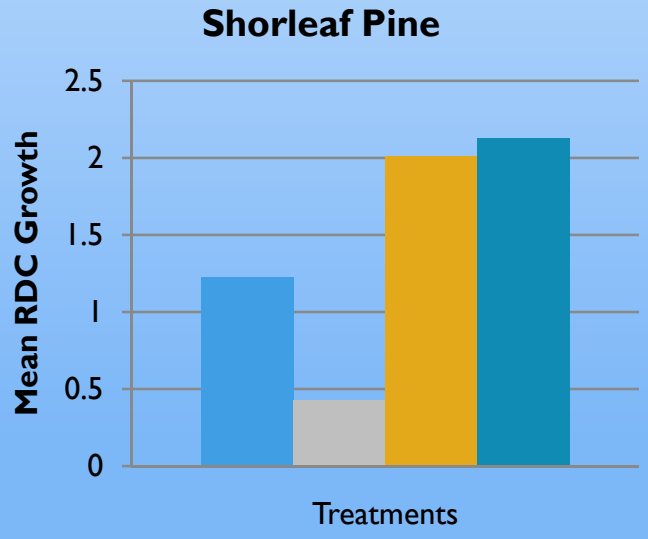


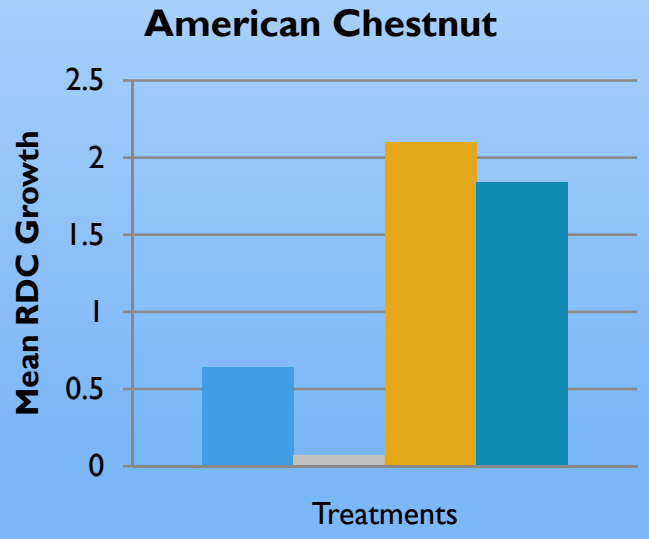

No lime, Low fertilizer

Lime, Low fertilizer

Lime, High fertilizer

No lime, High fertilizer



# Conclusion

- Fertilization is more important than other treatments for hardwood seedling establishment
- Treatment effects on survival are generally opposite to the effects on growth
- Long-term effects unknown

Many thanks to:

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