Increasing Atmospheric Temperatures: Effects on Soil Respiration and Acclimation Adjacent to Four Deciduous Tree Species

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Introduction

- Increasing concentrations of atmospheric CO_2 and green house gases have increased average global:
  - temperatures at the Earth's surface
  - summer and winter temperatures
  - climate variability
- In mid-latitude temperate regions, project increase in:
  - Mean annual temperatures
  - Frequency in extreme temperature events in summer (IPCC, 1996)

- Forest ecosystems respond:
  - To increasing summer and winter temperatures, and growing season length
  - By change function and population dynamics, may respond with only 1^{o}C increase (Kirschbaun & Fischlin, 1996)
  - Through impacts on individual growth, survival, regeneration and reproduction
  - Based on lower hierarchal ecophysiological processes:
    - Respiration rates of woody tissues and roots,
    - net photosynthetic rates
    - allocation of resources

- Tree seedling establishment and survival especially important:
  - Important in forest succession
  - More affected by moderately increasing temperatures

- In some trees, respiration responds to increasing temperatures:
  - Determine geographic distribution (Criddle et al., 1996)
  - Increasing with short-term temperature increases
  - Acclimating to prevailing temperatures (Weger & Guy, 1991; Zogg et al., 1996; Burton et at., 1998)
  - Relative increase in respiration rate for a 10oC rise in temperature, Q10 (Atkin et al., 2000)

- Objective:
  - evaluate the physiological responses in seedlings of four deciduous tree species to increasing temperatures by measuring soil respiration
  - Determine the soil acclimation potential of each species to changing temperatures
- Hypothesis:
  - Soil respiration will increase with increasing atmospheric temperatures
  - All species will acclimate to increasing temperatures, but the Southern species will acclimate more affectively

Methods

- Open-top chambers (OTCs)
  - Located in Oak Ridge, TN
  - Three chambers of: ambient, ambient +2.5^{o}C, ambient +5^{o}C
  - Controlled by an automated system

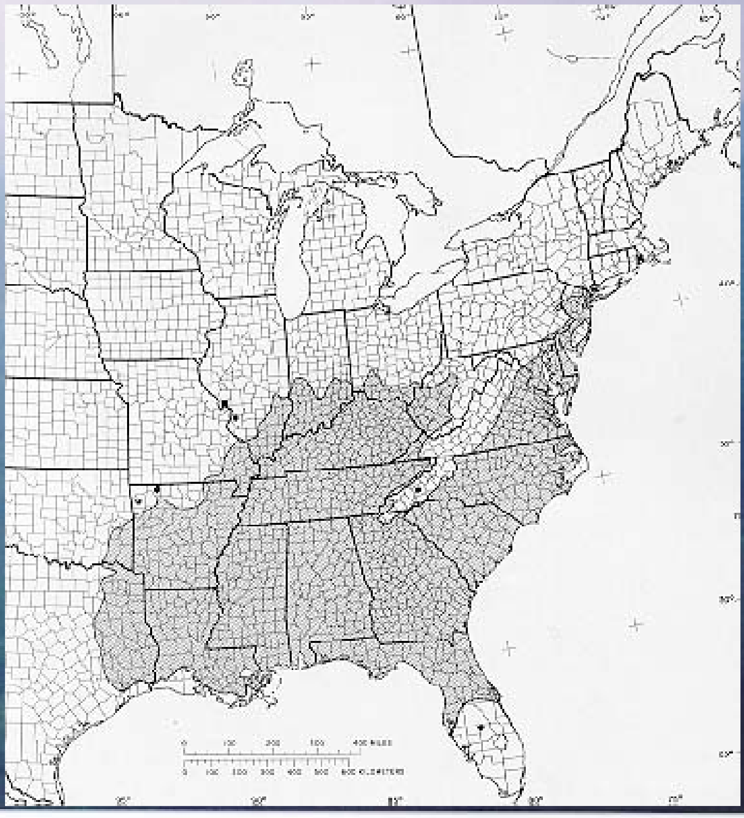
- Tree seedlings
  - One-year-old bare-root seedlings planted in early spring 2002
  - Five seedlings of each species per chamber directly planted into the soil
  - Species: *Betula alleghaniensis, Liquidambar styraciflua, Populus grandidentata,* and *Quercus rubra*

Betula alleghaniensis

- Common Name: yellow birch
- Range: northern hardwood and lake states forests
- Optimal Growth Temperatures: below ambient temperatures at the field site
- Considered a “northern” species in this study

Liquidambar styraciflua

- Common Name: sweet gum
- Range: native to Tennesee and range extends southward
- Optimal Growth Temperatures: at prevailing local temperatures or warmer
- Considered as a “southern” species in this study



Populus grandidentata

- Common Name: bigtooth aspen
- Range: Northern hardwood region, incl. Lake States; Disjunct populations along s end of range
- Optimal Growth Temperatures: below ambient temperature at the field site
- Considered a “northern” species in this study

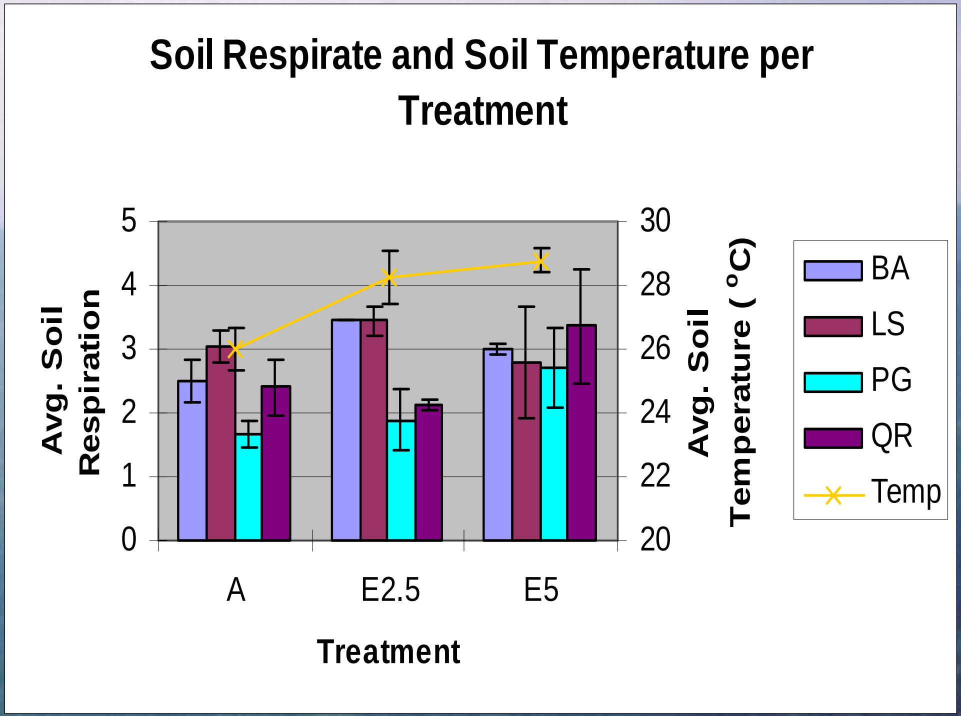
Quercus rubra

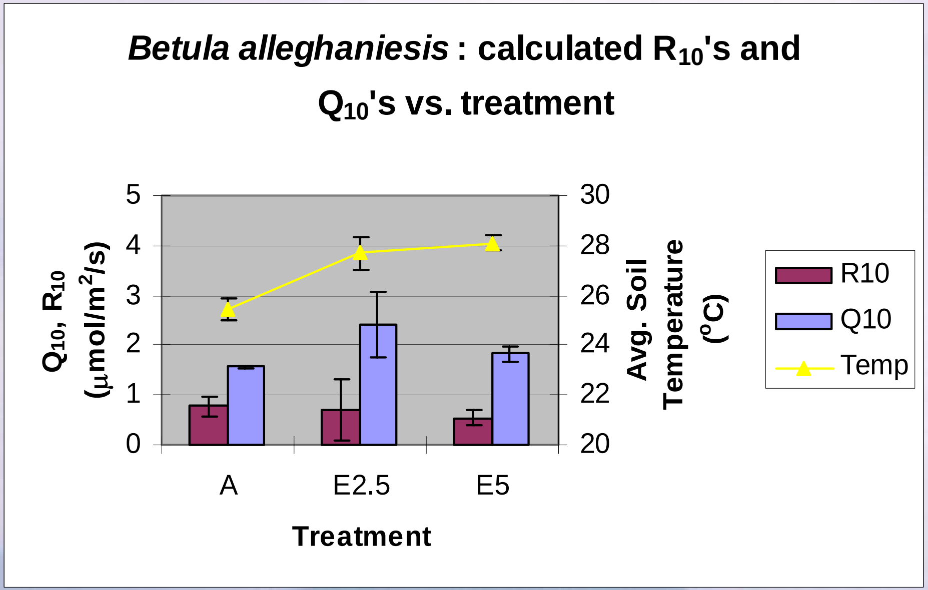
- Common Name: northern red oak
- Range: native to Tennessee and extends southward
- Optimal Growth Temperatures: at prevailing local temperatures or warmer
- Considered a “southern” species in the study

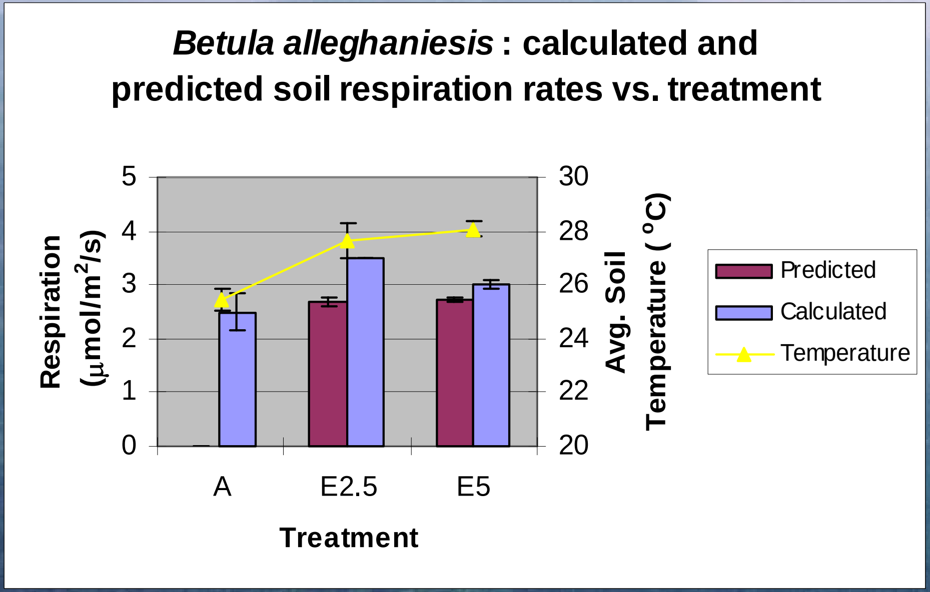
- Examined the respiratory responses using Li-cor technology
  - Measurements taken at intervals throughout the day and season to record responses of soil respiration to a wide temperature range
  - Soil respiratory acclimation evaluated by:
  - Q_{10}=10^(x-variable * 10) [increase respiration per increase 10^{o}C]
    - R_{10}=Q_{10}(10^intercept) [Base rate value at 10^{o}C]
    - X-variable and intercept calculated with ANOVA statistical test
  - Using Ambient Q_{10} and R_{10}, calculated the predicted Q_{10} and R_{10} for each species per treatment and compared these to those calculated directly from data

Results

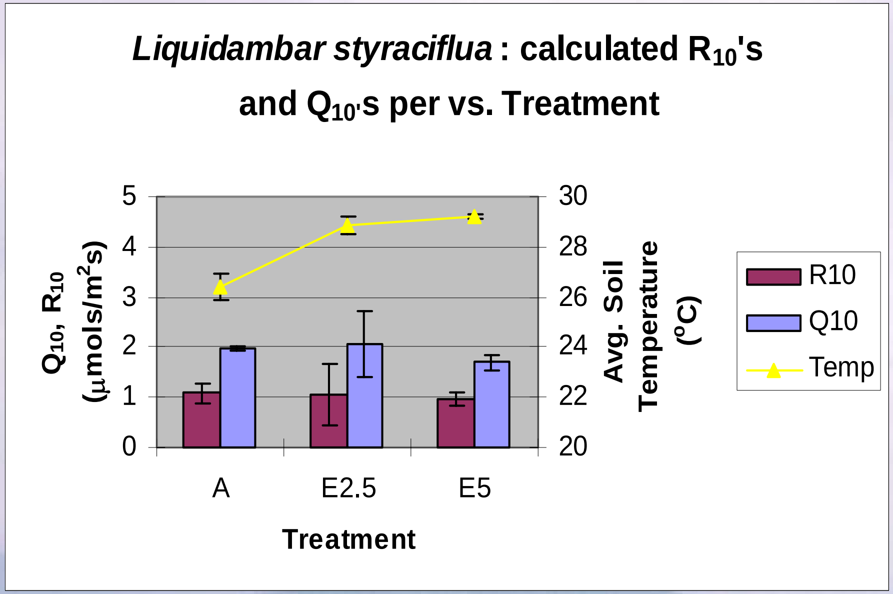
- Significant increase in soil temperature between ambient and ambient +5^{o}C temperature treatments ($p=0.0000$)
- Significant increase in soil respiration between ambient and ambient +5^{o}C temperature treatments in all plant species, except L. styraciflua
  - BA $p=0.0008$
  - LS $p=0.2876$
  - PG $p=0.0000$
  - QR $p=0.0026$

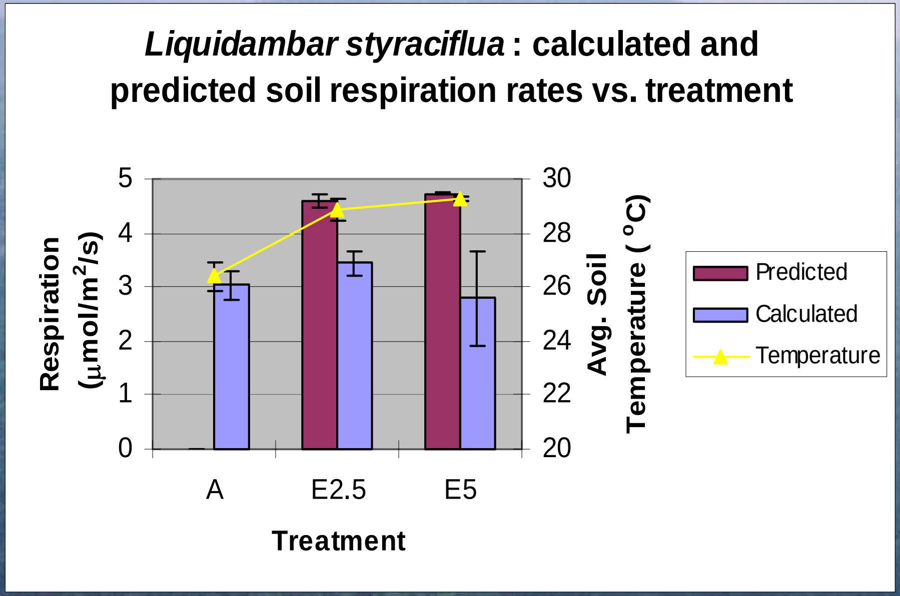




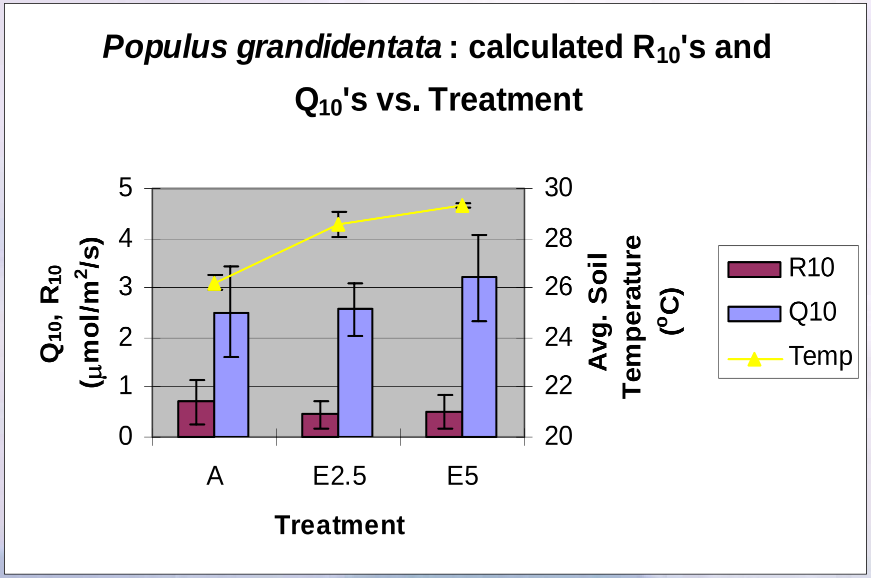


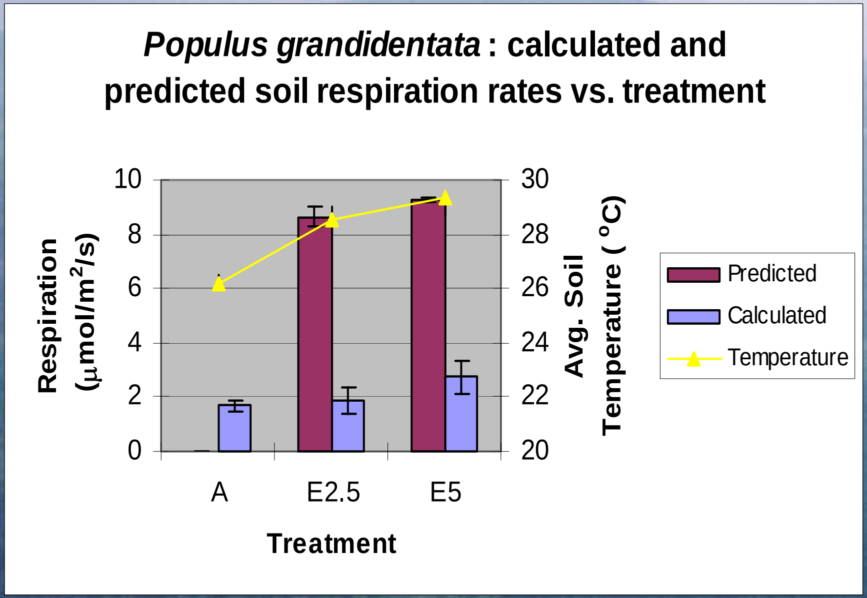
- Q10 did not vary significantly with increasing temperatures
- R10 did not vary significantly with increasing temperatures
- Predicted respiration significantly increased between the ambient and ambient +5°C treatments ($p=0.0000$)
- Respiration did not vary significantly compared to predicted values



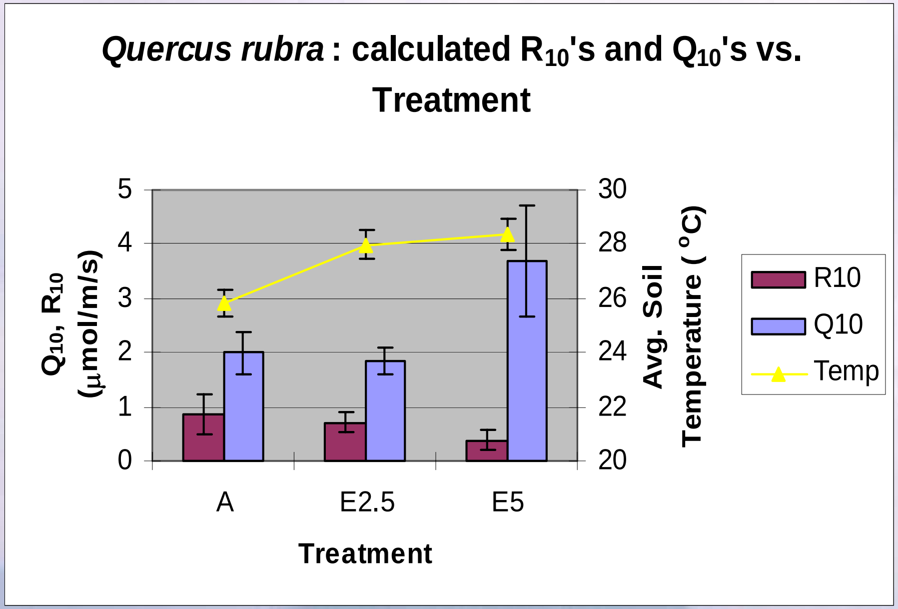


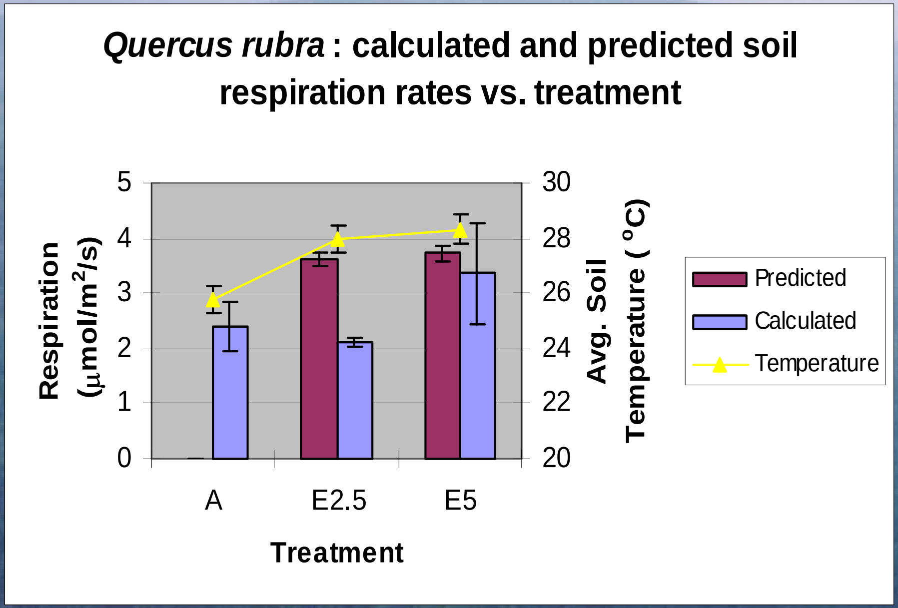
- Q_{10} did not vary significantly with increasing temperatures
- R_{10} did not vary significantly with increasing temperatures
- Predicted respiration significantly increased between the ambient and ambient +5ºC treatments (p=0.0000)
- Respiration decreased significantly compared to predicted values (p=0.0060)





- Q10 did not vary significantly with increasing temperatures
- R10 did not vary significantly with increasing temperatures
- Predicted respiration significantly increased between the ambient and ambient +5oC treatments (p=0.0000)
- Respiration decreased significantly compared to predicted values (p=0.0004)





- Q10 did not vary significantly with increasing temperatures
- R10 did not vary significantly with increasing temperatures
- Predicted respiration significantly increased between the ambient and ambient +5oC treatments (p=0.0000)
- Respiration decreased significantly compared to predicted values (p=0.0029)

Discussion

- The northern species had difficulty with increased soil temperatures
  - *B. alleghaneisis* did not acclimate
  - *P. grandidentata* had high mortality
- The both southern species acclimated to increased temperatures
- May affect species composition within some areas, especially at the southern boundary of the northern species’ range
  - If the temperature increases too quickly and/or dramatically, species won’t have time to migrate
  - Seedling survival of northern species may be too low to continue populations in certain areas

- species succession may change with mortality and acclimation

- *P. grandidentata*, a northern species, did acclimate = may retain some species diversity, though in lower numbers
- With knowledge of acclimation and mortality rates of various trees, may be able to save threatened species with transplantation and leave those that will survive
- More research needed on effects of soil moisture and increasing atmospheric CO_2 levels on acclimation, mortality, and other physiological responses on trees

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