Effects of CO_2 Concentration on Leaf Photosynthesis and Stomatal Conductance of Potatoes Grown Under Different Irradiance Levels and Photoperiods

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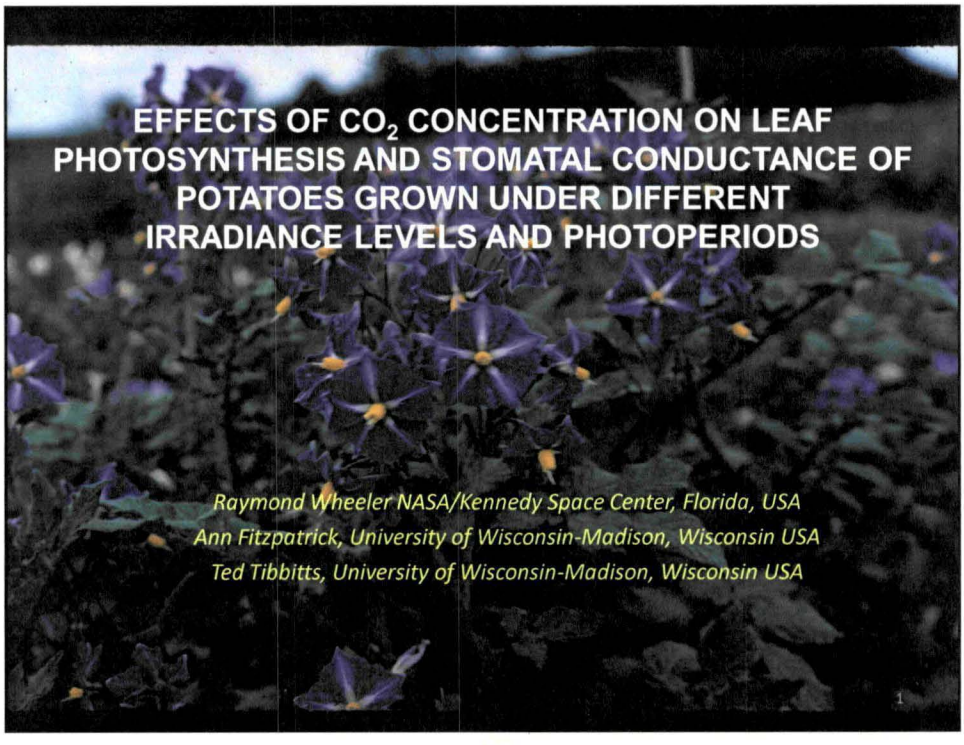
Potato (*Solanum tuberosum L.*) cvs. Russet Burbank, Denali, and Norland, were grown in environmental rooms controlled at ~350 µmol mol^{-1} (ambient during years 1987/1988) and 1000 µmol mol^{-1} (enriched) CO_2 concentrations. Plants and electric lamps were arranged to provide two irradiance zones, 400 and 800 µmol m^{-2} s^{-1} PPF and studies were repeated using two photoperiods (12-h light / 12-h dark and continuous light). Leaf photosynthetic rates and leaf stomatal conductance were measured using fully expanded, upper canopy leaves at weekly intervals throughout growth (21 through 84 days after transplanting). Increasing the CO_2 from ~350 to 1000 µmol mol^{-1} under the 12-h photoperiod increased leaf photosynthetic rates by 39% at 400 µmol m^{-2} s^{-1} PPF and 27% at 800 µmol m^{-2} s^{-1} PPF. Increasing the CO_2 from ~350 to 1000 µmol mol^{-1} under continuous light decreased leaf photosynthetic rates by 7% at 400 µmol m^{-2} s^{-1} PPF and 13% at 800 µmol m^{-2} s^{-1} PPF. Increasing the CO_2 from ~350 to 1000 µmol mol^{-1} under the 12-h photoperiod plants decreased stomatal conductance by an average of 26% at 400 µmol m^{-2} s^{-1} PPF and 42% at 800 µmol m^{-2} s^{-1} PPF. Under continuous light, CO_2 enrichment resulted in a small increase (2%) of stomatal conductance at 400 µmol m^{-2} s^{-1} PPF, and a small decrease (3%) at 800 µmol m^{-2} s^{-1} PPF. Results indicate that CO_2 enrichment under the 12-h photoperiod showed the expected increase in photosynthesis and decrease in stomatal conductance for a C_3 species like potato, but the decreases in leaf photosynthetic rates and minimal effect on conductance from CO_2 enrichment under continuous light were not expected. The plant leaves under continuous light showed more chlorosis and some rusty flecking versus plants under the 12-h photoperiod, suggesting the continuous light was more stressful on the plants. The increased rates of leaf photosynthesis with increased CO_2 concentration paralleled trends in biomass production (published previously) but were not proportional to the biomass yields.



Materials and Methods

- Potato (Solanum tuberosum L.)
  - Cvs. Russet Burbank, Norland, Denali
- Temperature: 16 C
- RH: 70%
- Light Source
  - High pressure sodium (400 W)
  - Metal halide (400 W)
- 19-L pots, peat-vermiculite media, watered 4 times daily with ½ strength modified Hoagland / Arnon nutrient solution

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Experimental Treatments

- Photosynthetically Active Radiation (PAR)
  - 400 µmol m^{-2} s^{-1}
  - 800 µmol m^{-2} s^{-1}
- Carbon Dioxide
  - 350 ppm (ambient circa 1987 !)
  - 1000 ppm
- Photoperiod
  - 12 h light / 12 h dark
  - 24 h light / 0 h dark

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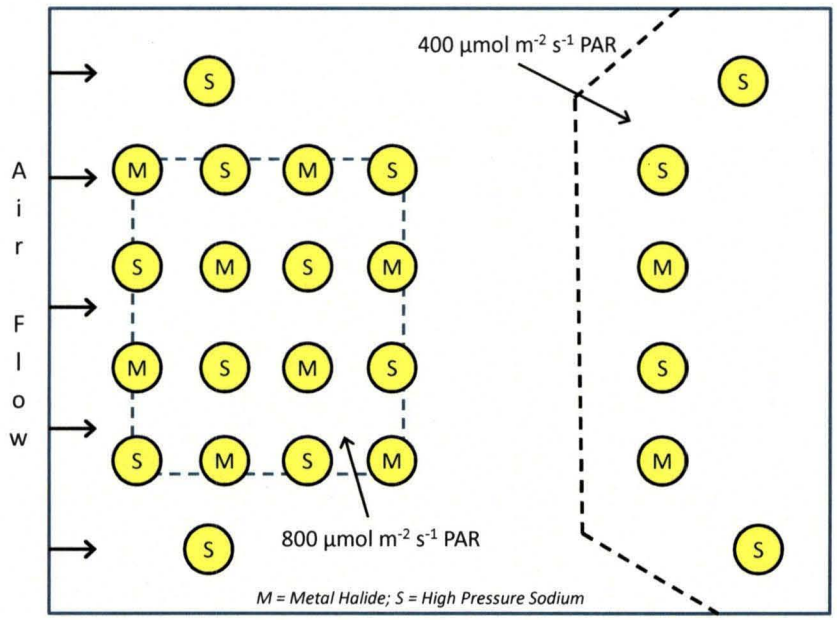
Arrangement of Lamps in Controlled Environment Room



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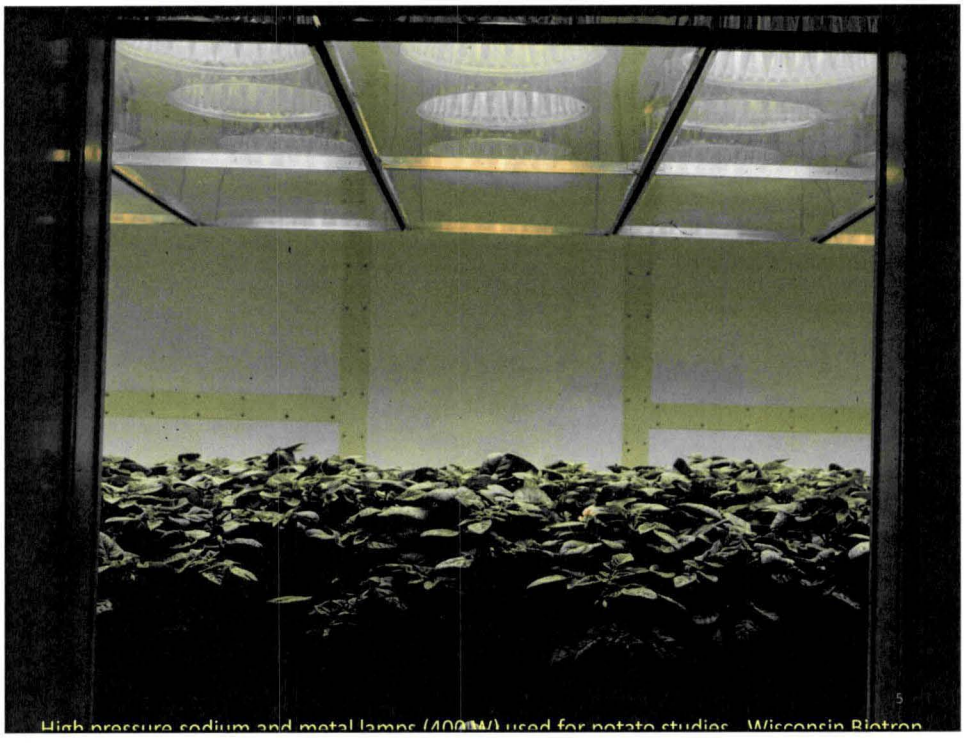

High pressure sodium and metal lamps (400W) used for potato studies - Wisconsin Biotron

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Measurements

- Leaf CO_2 uptake rate (net photosynthesis)
- Leaf stomatal conductance
- Leaf chlorophyll content
  - Measurements taken in the middle of photoperiod
  - Fully expanded upper canopy leaves
  - 3 measurements per plant, 4 plants per cultivar
  - Measurements at 21, 28, 35, 42, 56, 70 and 84 days
  - Chlorophyll, leave disks at 35 and 70 days, soaked in ethanol and determined spectrophotometrically

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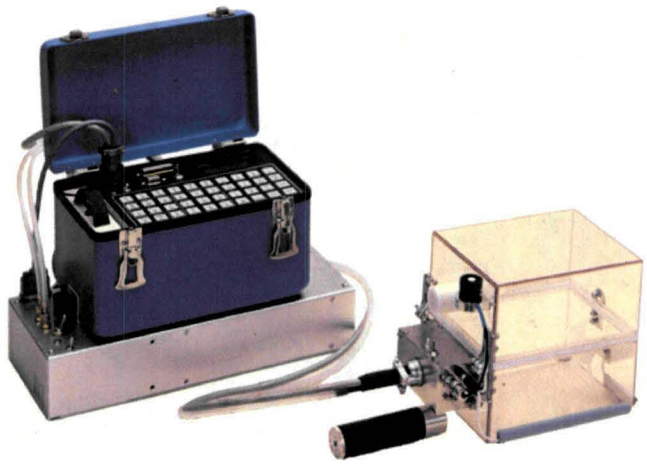
Li-Cor LI-6000 Portable Photosynthesis Unit



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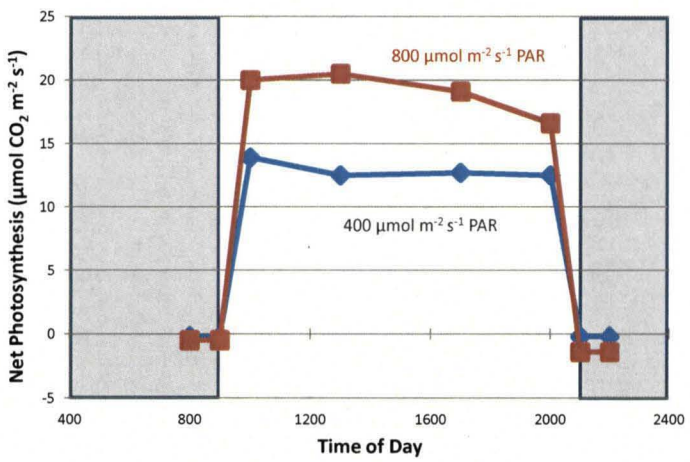
Diurnal Photosynthetic Rates



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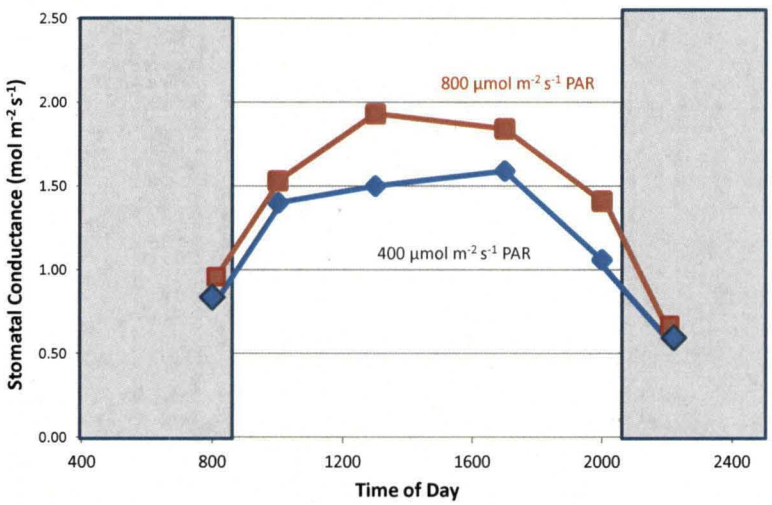
Diurnal Stomatal Conductance Rates



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Mobile carts with potato plants for light, CO_2, and photoperiod studies, Wisconsin Biotron

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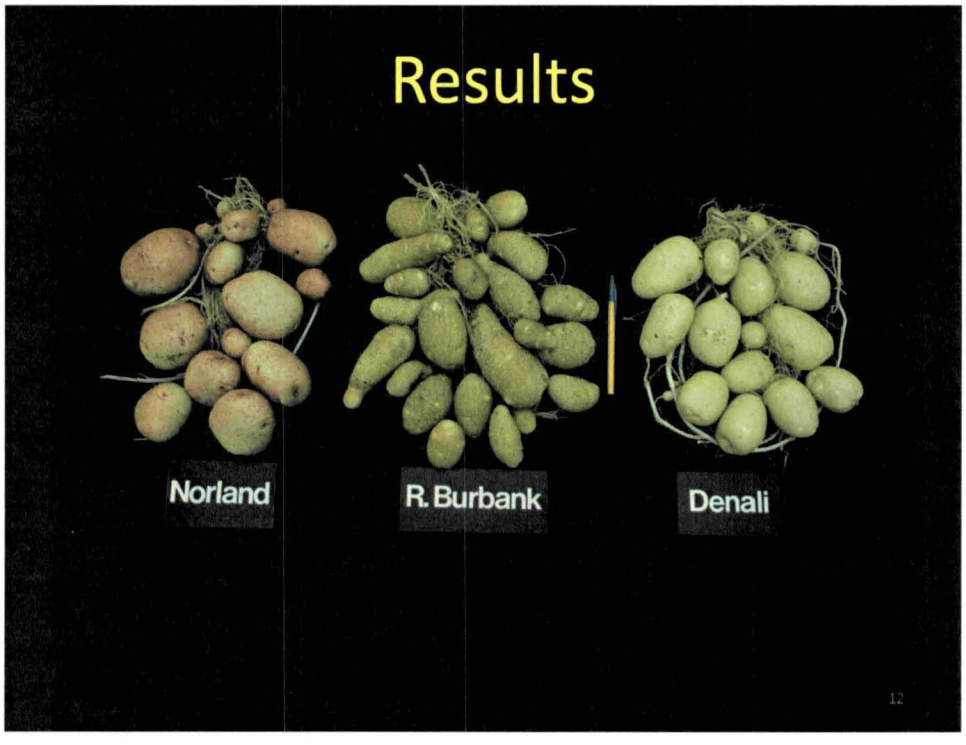
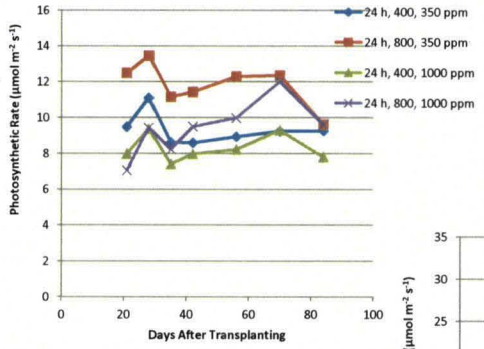
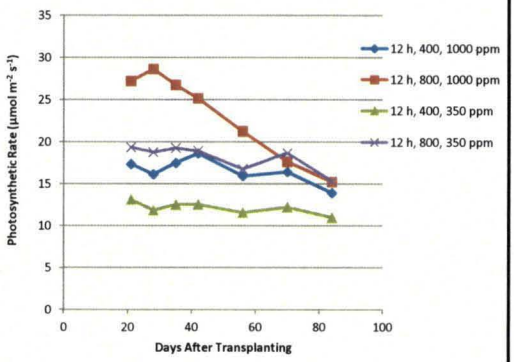
Ann Fitzpatrick taking leaf gas exchange measurements on potatoes, Univ. of Wisconsin Biotron



Leaf Photosynthetic Rates





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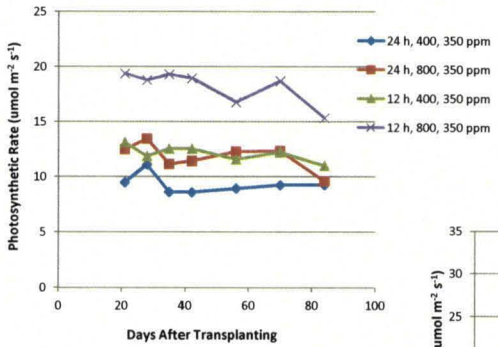
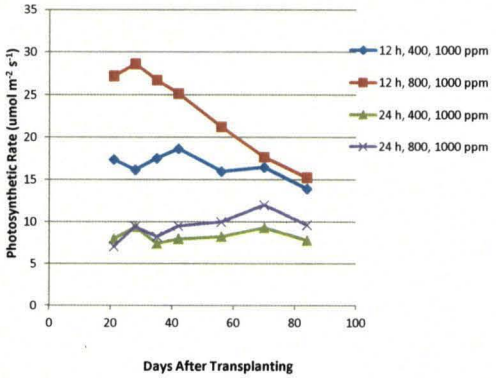
Leaf Photosynthetic Rates





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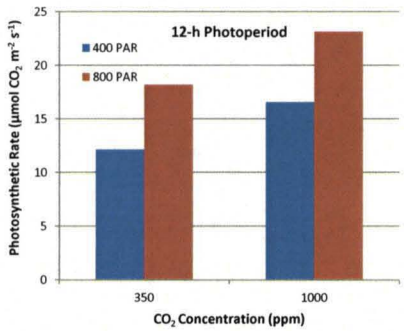
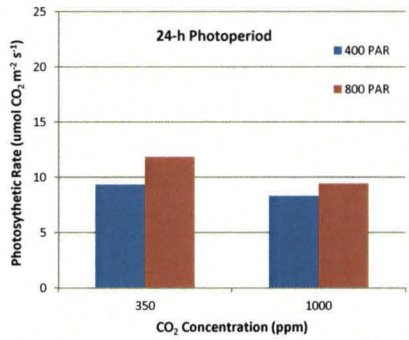
Leaf Photosynthetic Rates (for all Cultivars, all dates)





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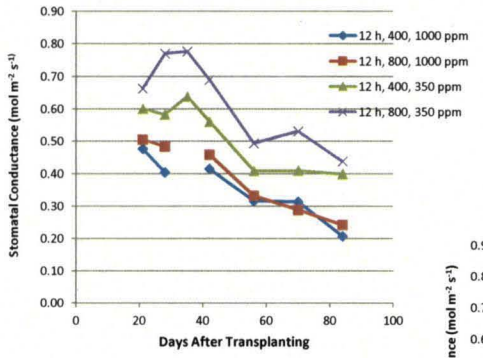
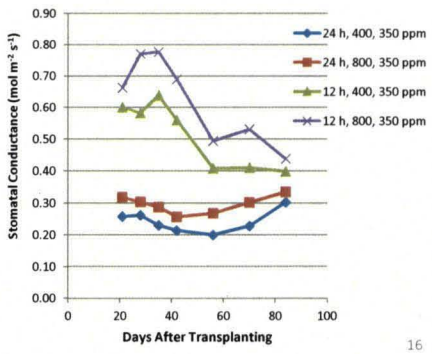
Stomatal Conductance Rates





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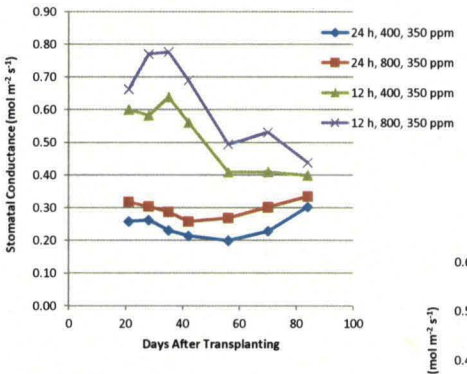
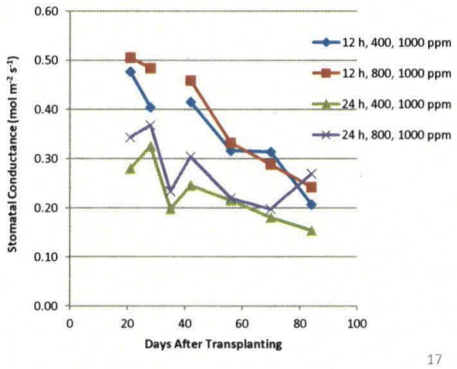
Stomatal Conductance Rates





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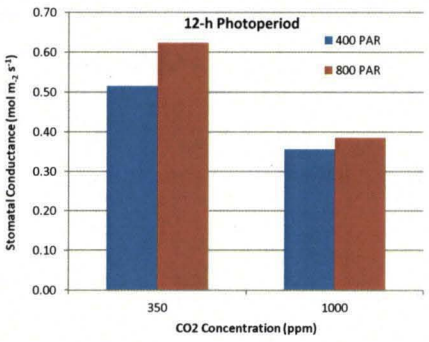
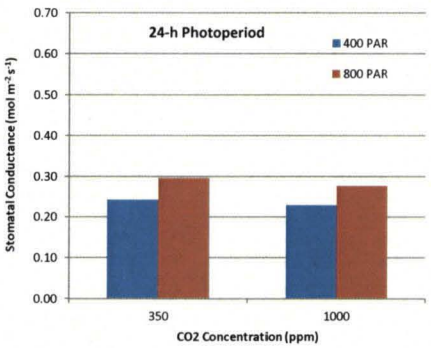
Stomatal Conductance (for all Cultivars at all Dates)





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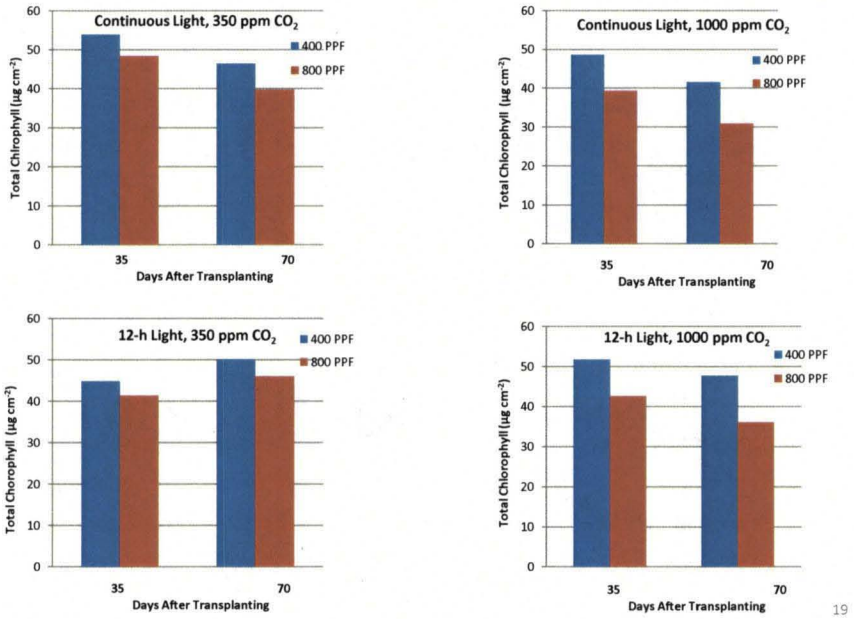
Potato Leaf Chlorophyll Content



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Conclusions

- Upper canopy leaf photosynthetic rates decreased with canopy age, particularly under the 12-h photoperiod.
- In general, leaf photosynthetic rates were greater under 12-h versus 24-h photoperiods; consequently, light conversion to biomass was much more efficient under 12-h photoperiods.
- Potato leaf photosynthetic rates increased with PAR and with CO_2 under 12-h photoperiod; but under 24-h photoperiods increased PAR resulted in only small increases in photosynthesis, while increased CO_2 had a negative effect on photosynthesis.

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Conclusions

- Upper canopy stomatal conductance rates decreased with canopy age under the 12-h photoperiod, but showed little change under 24-h lighting
- Potato stomatal conductance increased with PAR and decreased with CO_2 under both 12-h and24-h photoperiods
- Stomatal conductance rates were higher under 12-h versus 24-h photoperiods

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Conclusions

- Except for plants grown under 12-h photoperiods at 400 PAR, leaf chlorophyll of upper canopy leaves content decreased with age
- Leaf chlorophyll content decreased with increased PAR
- Leaf chlorophyll content under 24-h photoperiods decreased with increased CO_2, but under 12-h photoperiods, increased CO_2 had mixed effects chlorophyll content

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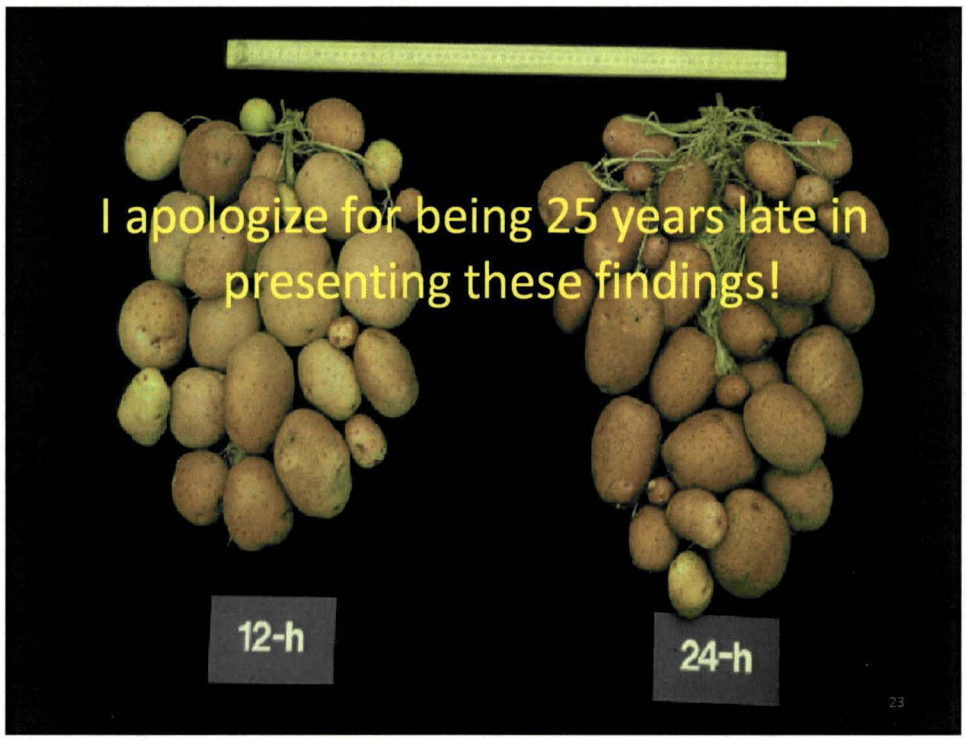
I apologize for being 25 years late in presenting these findings!
12-h
24-h
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