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 $\sim$350 $\mu$mol mol$^{-1}$ (ambient during years 1987/1988) and 1000 $\mu$mol mol$^{-1}$ (enriched) CO$_2$ concentrations. Plants and electric lamps were arranged to provide two irradiance zones, 400 and 800 $\mu$mol 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 $\sim$350 to 1000 $\mu$mol mol$^{-1}$ under the 12-h photoperiod increased leaf photosynthetic rates by 39% at 400 $\mu$mol m$^{-2}$ s$^{-1}$ PPF and 27% at 800 $\mu$mol m$^{-2}$ s$^{-1}$ PPF. Increasing the CO$_2$ from $\sim$350 to 1000 $\mu$mol mol$^{-1}$ under continuous light decreased leaf photosynthetic rates by 7% at 400 $\mu$mol m$^{-2}$ s$^{-1}$ PPF and 13% at 800 $\mu$mol m$^{-2}$ s$^{-1}$ PPF. Increasing the CO$_2$ from $\sim$350 to 1000 $\mu$mol mol$^{-1}$ under the 12-h photoperiod plants decreased stomatal conductance by an average of 26% at 400 $\mu$mol m$^{-2}$ s$^{-1}$ PPF and 42% at 800 $\mu$mol m$^{-2}$ s$^{-1}$ PPF. Under continuous light, CO$_2$ enrichment resulted in a small increase (2%) of stomatal conductance at 400 $\mu$mol m$^{-2}$ s$^{-1}$ PPF, and a small decrease (3%) at 800 $\mu$mol 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
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
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
Li-Cor LI-6000 Portable Photosynthesis Unit

Diurnal Photosynthetic Rates

Net Photosynthesis (μmol CO₂ m⁻² s⁻¹)

800 μmol m⁻² s⁻¹ PAR

400 μmol m⁻² s⁻¹ PAR

Time of Day
Diurnal Stomatal Conductance Rates

Mobile carts with potato plants for light, CO₂, and photoperiod studies, Wisconsin Biotróin
Ann Fitzpatrick taking leaf gas exchange measurements on potatoes, Univ. of Wisconsin Biotron

Results

Norland  R. Burbank  Denali
Leaf Photosynthetic Rates

Days After Transplanting

Photosynthetic Rate (mmol m⁻² s⁻¹)

Leaf Photosynthetic Rates

Days After Transplanting

Photosynthetic Rate (mmol m⁻² s⁻¹)
Leaf Photosynthetic Rates (for all Cultivars, all dates)

Stomatal Conductance Rates
Stomatal Conductance Rates

Stomatal Conductance (for all Cultivars at all Dates)
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 CO₂ under 12-h photoperiod; but under 24-h photoperiods increased PAR resulted in only small increases in photosynthesis, while increased CO₂ had a negative effect on photosynthesis.
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 and 24-h photoperiods
- Stomatal conductance rates were higher under 12-h versus 24-h photoperiods

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
I apologize for being 25 years late in presenting these findings!