

WILL RISING OZONE AFFECT CARBON UPTAKE BY VEGETATION?

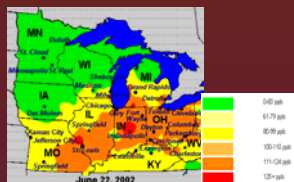
Altered photosynthesis and biomass production by soybean grown in future O₃ concentrations under open-air field conditions

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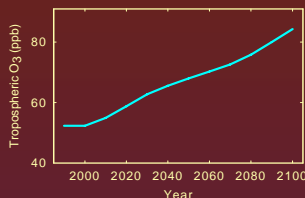
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Introduction

- ◆ Tropospheric ozone is rising at approximately 0.5 – 2.5% per year
 - ◆ More rapidly than atmospheric carbon dioxide concentration increased over the past century
- ◆ Ozone levels in central Illinois exceeded threshold (40 ppb) for soybean crop losses in 28 of 31 days of August 1999.



Midday ozone concentration over Midwestern United States on June 22, 2002. Concentrations above 60 ppb are considered hazardous to human health and damaging to plant life. (US Environmental Protection Agency Air Now website).

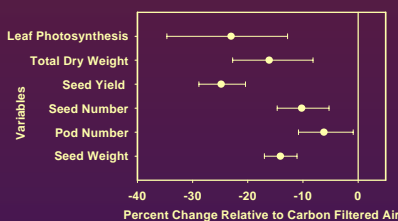


Intergovernmental Panel on Climate Change projection for global mean tropospheric ozone concentration given the "business as usual scenario". Global mean concentrations are expected to increase from 53 ppb to greater than 60 ppb by the middle of this century. (UN-IPCC 2001)

Recent Meta-Analysis

- ◆ Statistical summary of 53 peer-review publications on effects of elevated ozone on soybean.
 - ◆ Plants grown in carbon-filtered air were compared with plants grown in elevated ozone (> 30 ppb).
 - ◆ Leaf photosynthesis corresponds closely with lost yield.

Meta-analysis of elevated ozone effects on soybean. The mean percent (\pm 95% confidence intervals) reduction caused by elevated ozone (ca. 60 ppb) relative to ozone-free air. (Morgan et al., 2003)



Methods and Materials

- ◆ SoyFACE (Soybean Free Air Concentration Enrichment, www.soyface.uiuc.edu) is the first facility to elevate atmospheric ozone (1.21 x ambient) in replicated plots (n=4) under open-air conditions within an agricultural field.
- ◆ Simultaneous measurements of fluorescence and gas-exchange (assimilation vs. light and assimilation vs. intercellular [CO₂]) were made throughout the life of the crop.

Photosynthesis

- ◆ Measured assimilation at growth [CO₂] vs. light (A/Q) and assimilation vs. intracellular CO₂ (A/Ci) using open gas-exchange system with an integrated fluorescence head (Licor 6400).
- ◆ Biweekly samples of topmost fully expanded leaves.
 - ◆ 2 leaves per plot (134 samples)
- ◆ Two leaf cohorts were tracked for entire lifecycle.
 - ◆ 2 leaves per plot (324 samples)



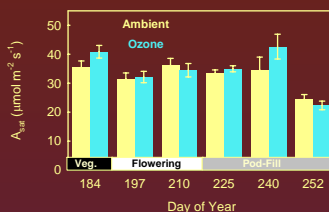
Biomass

- ◆ Biweekly aboveground harvest of 0.25 m² on 8 dates over the growing season (n = 96).
- ◆ Separated into stem, leaves, pods with seeds and litter.
- ◆ Dried to constant mass and weighed.



Results

- ◆ Growth in elevated ozone did not significantly alter photosynthesis in the topmost fully-expanded leaves.

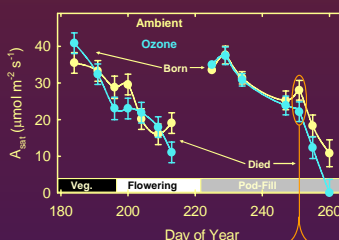


Light saturated photosynthesis from topmost leaves from soybean grown in ambient (63 ppb 8-hour daily average) or elevated (~75 ppb 8-hour daily average) ozone over the growing season. Each bar is the mean of 8 subsamples and error bars are \pm the standard error.

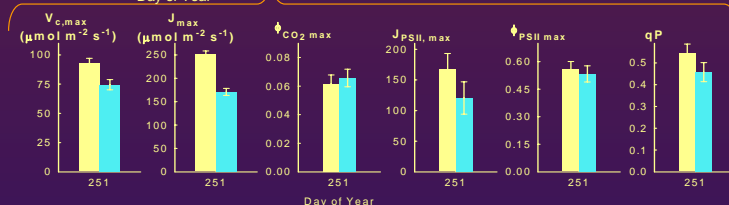
Analysis of variance of fixed effects on photosynthetic parameters of topmost leaves grown in ambient and elevated [O₃] using repeated measures in a complete block design. There were no significant effect of elevated ozone on the light saturated photosynthesis (A_{sat}), maximal rate of carboxylation (V_{cmax}), maximal rate of electron transport for RuBP regeneration (J_{max}), ratio of V_{cmax} to J_{max} (an indication of acclimation), limitation to photosynthesis imposed by diffusion through the stomata, the quantum efficiency of CO₂ fixation (ϕ_{CO_2}), maximal rate of electron transport through photosystem II (J_{PSII,max}), the quantum efficiency of photosystem II (ϕ_{PSII}) or proportion of open reaction centers in photosystem II (qP).

	F	p-value
A _{sat}	3.96	0.0881
V _{cmax}	0.06	0.8151
J _{max}	0.21	0.6593
V _{cmax} / J _{max}	0.47	0.4972
Stomatal limitation	0.00	0.9530
ϕ_{CO_2}	0.65	0.4341
J _{PSII,max}	0.07	0.8028
ϕ_{PSII}	2.52	0.2106
qP	8.15	0.0290

- ◆ As leaves aged, elevated ozone caused a progressive and significant decreases in carbon assimilation and electron transport.



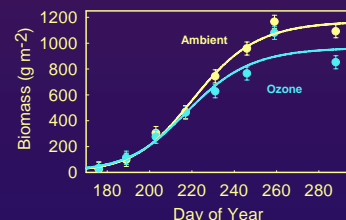
Light saturated photosynthesis of two leaf cohorts grown in ambient (63 ppb 8-hour daily average) or elevated (75 ppb 8-hour daily average) background ozone over their entire lifetime. Photosynthesis decreased as younger leaves gradually replaced the measured cohort. In the final days, the effect of elevated ozone significantly altered photosynthesis as seen in the additional photosynthetic parameters shown below. Each bar is the mean of 8 subsamples and the error bars are \pm the standard error. Values of 0 indicate the absence of leaves at that time point.



- ◆ These ozone-induced decreases drove the 22% decrease (240 g/m², p=0.007) in dry-matter production and the 20% loss (143 g/m², p=0.022) in reproductive yield.



Elevated ozone caused accelerated senescence and early maturation of seeds seen in this photograph in mid-September. Ozone concentration was maintained at 75 ppb with marked control as seen by the sharp contrast between inside and outside the ring.



Aboveground dry-matter production of soybean grown in ambient (63 ppb 8-hour daily average) or elevated (75 ppb 8-hour daily average) background ozone. Curves are the fit to the means of each treatment (n = 4). Divergence in treatments coincides with beginning of pod-filling.

Conclusions and Implications

- ◆ Elevated ozone damage to photosynthesis is cumulative with greatest losses occurring late in a leaf lifecycle.
- ◆ Premature senescence compounds leaf photosynthetic losses decreasing total canopy assimilation.
- ◆ Plant dry-matter production loss exceeds losses in photosynthesis.
- ◆ Seed yield was decreased 22% by a 21% increase in ozone.
- ◆ Small increases (~20%) in tropospheric ozone have a large impact on assimilation and growth of soybean.
- ◆ Seed yield loss suggests that rising ozone over the next 30 yrs would cost US agriculture \$600 million per year in soybean losses alone at today's prices.
- ◆ Photosynthetic loss corresponds closely to seed yield loss, avoiding damage to photosynthesis may be key to protecting future crop yields.

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