Responses of crops to ozone exposure: study of physiological parameters

Increasing population and decreasing acreages
Ozone: major phytotoxic pollutant, reduction in crop yields
Variability of ozone effects on yields among species

Mills et al, 2007
Bemevo project: Bio-indication and Memory Effect of an ozone exposition of plants (2017-2020)

Effect of drought following ozone exposure

Objectives:

1- Evaluation of ozone exposure effects in barley, rapeseed and tobacco,

2- Identification of early biomarkers of ozone sensitivity.
Experimental set-up

Experimentation in **Ecolab**: environmental simulator composed of three identical, closed and controlled chambers

**Ozone** fumigation for **7 or 14 days, 6h** during photoperiod, **O₃ concentrations**: **30** (control), **70, 90, 110** and **130 ppb**.
Ozone exposure applied during flowering:
- Most sensitive developmental phase,
- Spring ozone peaks occurring before summer droughts.

- Barley, *Hordeum vulgare* L. cv. RGT Planet,
- Tobacco, *Nicotiana tabaccum* L.
  - cv Bel-B (O$_3$ tolerant)
  - cv Bel-W3 (O$_3$ sensitive)
Methods

Measurements of physiological parameters:

• **Chlorophyll** content

• **Photosynthesis** parameters: $A$, $Fv/Fm$, $Vc_{\text{max}}$, $J_{\text{max}}$

• Membrane lipid analysis: $\omega_3$ index

\[
\text{\(\omega_3\) index} = \frac{\% \text{ C18:3}}{\% \text{ other fatty acids}}
\]

• Targets of oxidative stress: proteome carbonylation
Chlorophyll content and ω3 index

Ozone exposure is associated with a reduction in chlorophyll content and ω3

Potential ozone concentration threshold (to be confirmed): 90 ppb for chlorophyll and ω3

One-way ANOVA; P-value: *** < 0.001, ** < 0.01, * < 0.05
Results and discussion

Carbonylation of proteins

No significant effect of ozone on total soluble foliar protein content and on proteome carbonylation.

Increase in carbonylation level with natural senescence (14d 30 ppb ≠ 7d 30 ppb; p = 0.004, paired t-test)

FTC : fluoresceine thiosemicarbazide

One-way ANOVA; P-value: *** < 0.001, ** < 0.01, * < 0.05
Results and discussion

Photosynthesis parameters (14d exposure)

Net assimilation

Maximum carboxylation and electron transport affected by ozone at saturating PAR

=> Effect on net assimilation at saturating PAR after 14 days?

One-way ANOVA; P-value: *** < 0.001, ** < 0.01, * < 0.05
Principal Component Analysis

Axis 1:
- 61%
- 30 ppb
- 70 ppb
- 90 ppb
- 110 ppb
- 130 ppb

Axis 2:
- 19%

Variables: chlorophyll content, ω3 index, Fv/Fm

Poor discrimination between samples exposed to 30 ppb and 70 ppb of ozone
Efficient discrimination of samples exposed to > 90 ppb, according to doses along axis 1

Axis 1 strongly correlates with chlorophyll content and ω3 index
Results and discussion

Rapeseed

Principal Component Analysis

- Similar to barley

Poor discrimination between samples exposed to 30 ppb and 70 ppb of ozone
Efficient discrimination of samples exposed to > 90 ppb, according to doses along axis 1

Axis 1 strongly correlates with chlorophyll content and ω3 index
Results and discussion

Bel W3
(ozone sensitive)

Axis 2 : 25%
Axis 1 : 58%

Bel B
(ozone tolerant)

Axis 2 : 21%
Axis 1 : 51%

• Similar to barley and rapeseed
variables : chlorophyll content, ω3 index, Fv/Fm

• No discrimination of samples according to ozone exposure

30 ppb
70 ppb
90 ppb
110 ppb
130 ppb
Conclusion

• Barley resistant to ozone.

• Lipids and chlorophylls appeared more affected than proteins by oxidative stress.
• Alterations of chloroplast membranes seem to develop.

Barley, rapeseed, tobacco: Chlorophyll content and $\omega 3$ index good candidates as early biomarkers of ozone sensitivity.
(\(\omega 3\) index biomarker for Soil quality ISO/DIS 21479)

Perspectives
• Yield measurements necessary to classify the species and validate the markers

• 2018-2019 experiments: memory effect of such ozone exposures?
  - Analysis of the recovery after ozone treatment,
  - Analysis of memory effect: do plants exposed to ozone respond differently to subsequent drought stress?
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Bio-indication and Memory Effect of an ozone exposition of plants (BEMEVO)