No further stimulation of wheat yield by CO_2 above 600 ppm?

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Background

Elevated carbon dioxide (eCO_2) is well known to stimulate wheat crop yield. In his extensive analysis of then available data, Amthor (2001)[1] found indications of a saturation of wheat grain yield (GY) stimulation around ~700 ppm.

Our study contains an update of Amthor´s (2001) study, using a much larger body of data. It also includes a statistical meta-analysis and covers further agronomically important response variables: grain mass (GM), grain number (GN), harvest index (HI), specific grain mass (GM) and grain protein concentration (GPC). Earlier studies have indicated positive CO_2 effects on GY and GN, negative effects on GPC and minor effects on HI and GM[2,3].

Since there have been reports of different responses to eCO2 in different types of exposure systems[4] we also studied the response of GY to eCO_2 in different rooting environments and types of experiments.

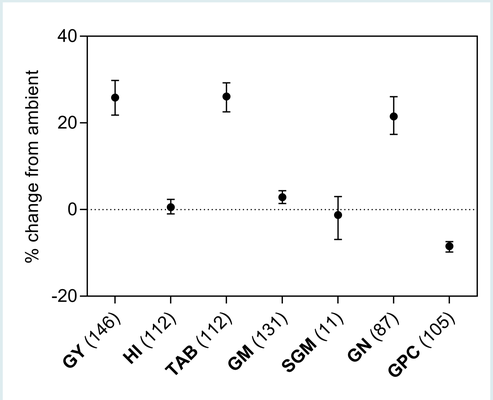
Hypotheses

1. **Effects of eCO_2 on wheat yield and yield components are non-linear and saturate at concentrations around 700 ppm.**
2. **The effect on GN by eCO_2 is similar to that on GY, while effects on GM and HI are small.**
3. **Effects of eCO_2 differ between different types of rooting and exposure systems.**

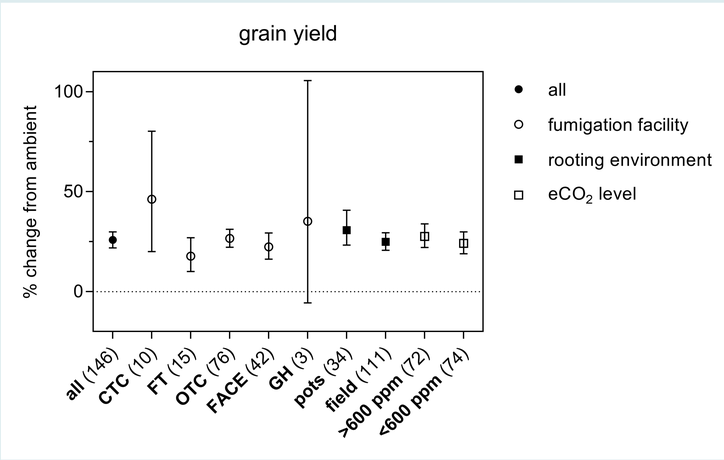
Methods

- Experimental data from the scientific literature (Web of Science) was collected in a **database**.
- Un-weighted **meta-analysis** was conducted in MetaWin[6] using ambient CO_2 treatment as the control and the natural log of the response ratio as effect size.
- Relationships between relative effects on GY, GN, HI and GPC were explored using **regression analysis**, assuming zero effect at 350 ppm CO_2.
- **Linear and non-linear relationships** were compared using Akaike Information Index (AIC).
- **Outliers** were identified using the ROUT method[6].

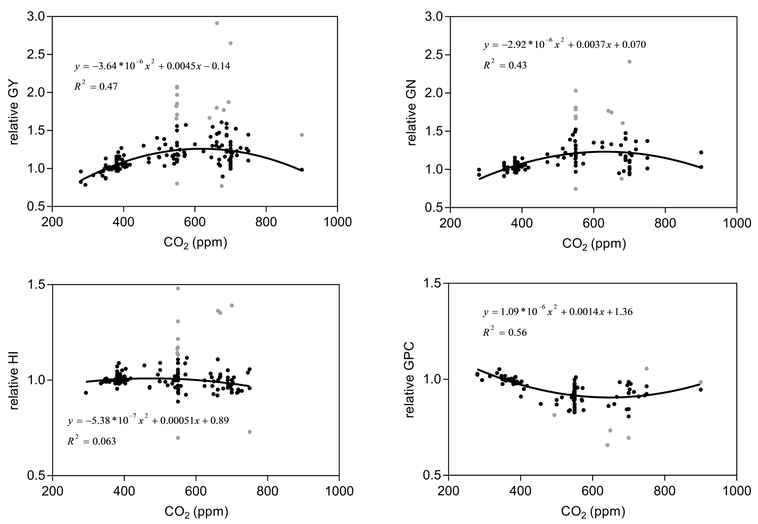
Results



1. Meta-analysis showing the average effect of eCO_2 on wheat grain yield (GY), harvest index (HI), total above-ground biomass (TAB), average grain mass (GM), specific grain mass (SGM), grain number (GN) and grain protein concentration (GPC). Numbers in brackets denotes the number of observations for the different variables. A consistent pattern was obtained with positive effects around 20% on GY, TAB and GN, near-zero effects on HI, GM and SGM and a significant negative effect (-8%) on GPC.



2. Meta-analysis showing the average effect of eCO_2 on grain yield in different exposure systems, rooting environments and at CO_2 concentrations > or < 600 ppm.. Numbers in brackets denotes the number of observations for each comparison. Effects in different exposure systems were not significantly different. The largest confidence limits were obtained for the exposure systems with the fewest observations: closed-top chambers (CTC), field tunnels (FT) and greenhouse (GH). Effects in open-top chambers (OTC) and Free-Air CO_2 Enrichment (FACE) were similar with small confidence limits. Pot grown plants responded slightly but not significantly stronger to eCO_2 than field grown. The effect of CO_2 exposure > 600 ppm was larger, but very close to that of CO_2 < 600 ppm.



3. Response functions for the eCO_2 effect on grain yield (GY), grain number (GN), harvest index (HI) and grain protein concentration (GPC). Please note different y-axis scales in upper and lower panels. Non-linear functions resulted in considerably stronger relationships (AIC), but using a polynomial with higher than second order did not lead to further improvement. The maximum of the response function for GY is at 618 ppm CO_2, 632 ppm for GN and 647 ppm for GPC. The response of HI was very small. Extrapolation of the response function for GY suggested a pseudo-compensation point at 31 ppm CO_2. Points in grey are observations that were excluded from the response function based on the ROUT method[6].

Conclusions

1. **The positive effect of eCO_2 on GY and GN is non-linear and does not further increase at CO_2 concentrations slightly above 600 ppm.**
2. **The negative effect of eCO_2 on grain protein concentration similarly did not increase beyond ~650 ppm CO_2.**
3. **Effects of eCO_2 on GY, GN and TAB were of the same magnitude.**
4. **Only very minor effects of eCO_2 were obtained for GM , SGM and HI.**
5. **There were only very small and non-significant differences in the effect of eCO_2 between different exposure systems and rooting environments.**

Mini-Free-Air CO_2 Enrichment (mini-FACE) at University of Hohenheim

References

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