CO_2 induced changes in mineral stoichiometry of wheat grains

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Background

Elevated carbon dioxide (eCO_2) is well known to stimulate wheat crop yield[1], but at the same time reduce the content of protein[2]. Dilution by carbohydrates[3] and reduced nitrogen (N) assimilation[4] have been suggested as explanations for the decrease in grain protein concentration. In addition, concentrations of Fe and Zn have been observed to significantly decrease under eCO_2[5], while effects on other minerals remain uncertain.

Minerals other than N are often not reported in experiments with wheat grown under eCO_2, but the effect on other plant nutrients could potentially follow the pattern of N. If a strong N-mineral relationship can be established, it would be useful in risk assessments.

Changes in nutrient content are of great concern for human nutrition, while alterations in nutrient uptake may be of importance for the biogeochemical cycling of elements in the agricultural ecosystem.

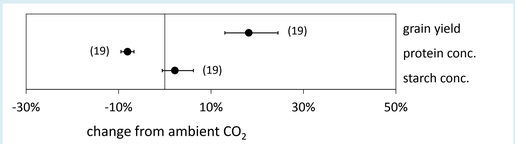
Hypotheses

1. **N and other minerals are diluted by starch under eCO_2.**
2. **The eCO_2 effect on protein and grain yield depends on exposure system design.**
3. **eCO_2 reduces concentration and enhances yield of N and other minerals.**
4. **eCO_2 effects on all important plant nutrients are strongly linked to the effects on N.**

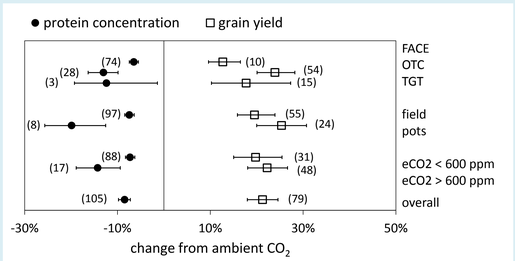
Methods

- Experimental data from the scientific literature was collected in a **database**, with additional unpublished data for grain minerals.
- 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 minerals vs. N were explored with **regression** analysis.

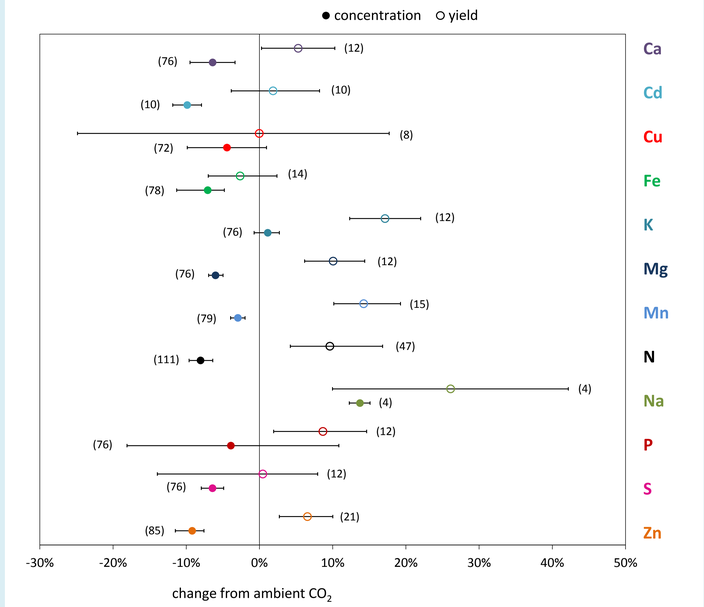
Results



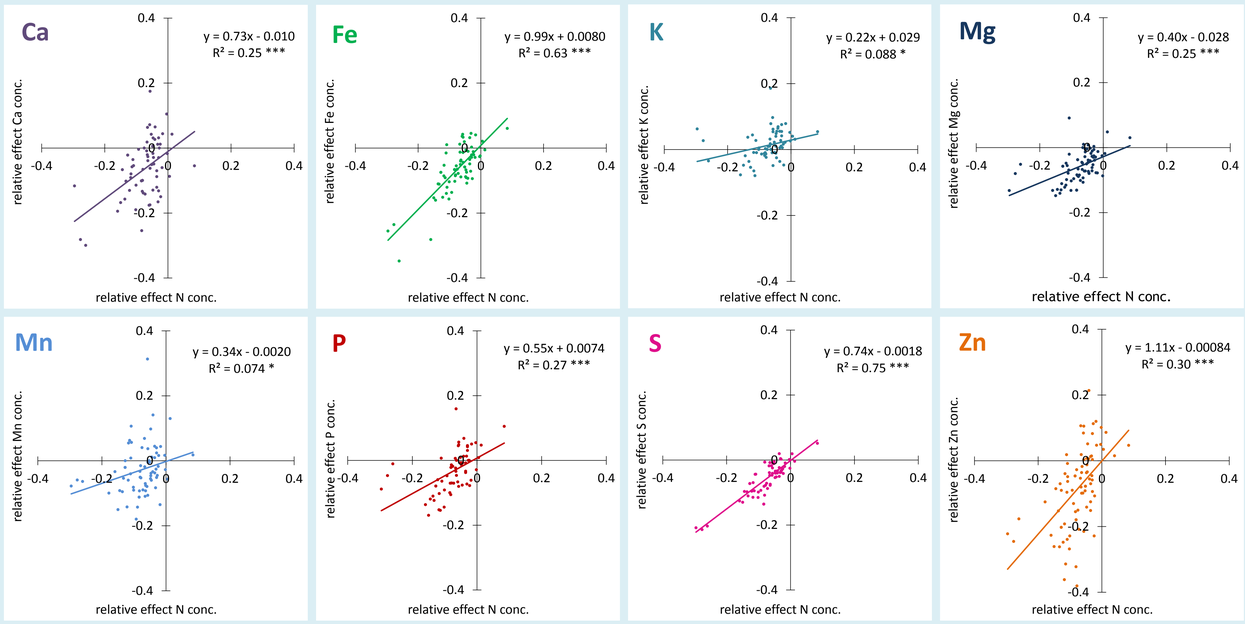
1. Meta-analysis showing the average effect of eCO_2 on wheat grain yield and concentration of protein and starch in 19 experiments, using ambient air as the control.



2. Meta-analysis showing the average effect of eCO_2 on protein concentration and grain yield using ambient air as the control. Subgroup analysis comparing exposure techniques (FACE, OTC and TGT), rooting environment (field and pots), and concentration of eCO_2 (using 600 ppm as a threshold). Numbers within brackets give the number of observations.



3. Meta-analysis showing the average effect of eCO_2 on concentration and yield of grain minerals using ambient air as the control. Numbers within brackets give the number of observations.



4. Figures showing the relative effect of eCO_2 on N concentration in relation to effects on other minerals (Ca, Fe, K, Mg, Mn, P, S, and Zn).

Conclusions

1. **No significant effect of eCO_2 on starch concentration → dilution hypothesis is not supported.**
2. **eCO_2 effects on protein and grain yield were dependent on exposure system design. Higher levels of CO_2 (> 600 ppm) did not significantly increase grain yield but reduce protein content.**
3. **eCO_2 effect varies among minerals → effects cannot solely be explained by dilution.**
4. **eCO_2 effects on Fe and S are strongly linked to effects on N, while effects on Ca, Mg, P and Zn show a moderately strong but significant relationship. eCO_2 effects on K and Mn are not linked to the reduction in N.**

Field experiment with open-top chambers (OTC), Östad, Sweden. Photo: Håkan Pleijel.

References

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