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CO_2-induced changes in mineral stoichiometry of wheat grains

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A comprehensive review of experiments with elevated CO_2 (eCO_2) presenting data on grain mineral concentration in wheat grain was made. Data were collected both from FACE (Free-Air CO_2 Enrichment) and OTC (Open-Top Chamber) experiments. Analysis was made i) by deriving response functions for the relative effect on yield and mineral concentration in relation to CO_2 concentration, ii) meta-analysis to test the magnitude and significance of observed effects and iii) comparison of the CO_2 effect on the accumulation of different minerals in relation to accumulation of biomass and accumulation of N. Data were obtained for the following minerals: N, Zn, Mn, K, Ca, Mg, P, Fe, S, Cr, Cu, Cd and Na. In addition, data for starch, the dominating carbohydrate of wheat grain, were extracted. The responses ranged from near zero effects to strong negative effects of eCO_2 on mineral concentration. The order of effect size was the following (from largest to smallest effect) for the different elements: Fe, Ca, S, Zn, Cd, N, Mg, Mn, P, Cu, Cr, K and Na. Particularly strong negative impacts of eCO_2 were found in the essential mineral elements Fe, S, Ca, Zn and Mg. Especially Fe, Zn and Mg are nutrients for which deficiency in humans is a problem in today′s world. The rather large differences in response of different elements indicated that the CO_2-induced responses cannot be explained by a simple growth dilution model. Rather, uptake and transport mechanisms may have to be considered in greater detail, as well as the link of different elements with the uptake of nitrogen, the quantitatively dominating mineral nutrient, to explain the observed pattern. No effect of eCO_2 on starch concentration could be demonstrated. This substantiates the rejection of a simple dilution model, since one would expect starch concentrations to be elevated in order to explain reduced mineral concentrations by carbohydrate dilution. The concentrations of toxic Cd was negatively affected, in principle a positive environmental effect and possibly as a result of reduced transpiration under eCO_2, since uptake and transport of Cd is known to be related to transpiration. For elements with substantial data the response in OTC and FACE exposure systems could be compared and no large differences were observed. Our study shows that eCO_2 has a significant effect on the mineral composition of wheat grain. This has strong implications for human nutrition in a world of rising CO_2 concentrations. An altered chemical composition of biomass under eCO_2 is also of great importance for the biogeochemical cycling of elements in general.