Will rising CO_2 affect Zn and Fe bioavailability in food grains?

The projections of climate change-induced decline in food production have become a matter of grave concern for food security across the world. Experimental evidences of elevated CO_2-induced reduction in grain micronutrients content, particularly Zn and Fe, further add to the problem[1]. Clearly, decline in food production together with depleted micronutrients content in food grains can potentially intensify the already existing acute problem of micronutrient malnutrition worldwide. In this context, I would like to draw the attention of the concerned scientific community to one more vital aspect of human nutrition that has so far remained untouched in elevated-CO_2 research, and that is 'bioavailability' of micronutrients (particularly, Zn and Fe) in food grains. Although no study till date has investigated this issue with intent, an insightful analysis of the available literature provides a compelling reason to suspect that besides a decline in micronutrients content in food grains, their bioavailability might also reduce under the rising atmospheric CO_2. This possibility stems from the differential uptake response of some nutritionally important macro- and micronutrients in food grains grown under elevated concentration of atmospheric CO_2. Owing to reasons hitherto unclear, drop in grain Zn and Fe concentrations under elevated CO_2 has often been reported (but never pinpointed and interpreted) to be significantly more pronounced than that in phosphorus. In a study by Seneweera and Conroy[2], P concentration in rice grown under elevated CO_2 was found to decline only by 5% compared to 28% decline for Zn and 17% for Fe. In a recent study, Seneweera[3] found no change in P concentration in rice grown under elevated CO_2. P concentration in brown rice was found to increase by ~ 10.3% (averaged over four levels of N application) under doubled concentration of atmospheric CO_2 (ref. 4). Similarly in wheat grown under elevated CO_2, a decline of only ~ 5% (average for two wheat cultivars) was observed in grain P concentration, whereas Zn and Fe concentrations were reduced by as much as 25% (ref. 5). Likewise, in another elevated CO_2 experiment with wheat[6], grain P concentration decreased by only 3.7% (averaged over two doses of N fertilization) compared to 30% decline for Fe and 15.1% for Zn. In an analysis of grain elemental composition of five wheat cultivars grown under elevated CO_2, Loladze[7] found only about 2.5% decline in P concentration as against ~ 15% for Fe and ~ 21% for Zn. In barley also, no decline in P concentration, rather a small increase, was observed under elevated CO_2, whereas grain Fe and Zn concentrations were substantially reduced in the same experiment[5]. A considerably fair number of studies, cited here or available elsewhere, with their results confirming the above discussed trends of no reduction or very small reduction in grain P in comparison to severe reduction in Zn and Fe concentration suggest that there must be an underlying science behind this trend.

Irrespective of the mechanisms involved therein, this observation could be of significance to human nutrition under the rising concentration of atmospheric CO_2. Since most of the grain P (around 75%) exists as phytic acid (an anti-nutrient which makes insoluble complex with micronutrients and reduces their bioavailability in the human digestive system)[8,9], proportionally lesser reduction in grain P compared to Zn and Fe can lead to higher ratios of phytic acid/Zn and phytic acid/Fe respectively (molar ratios of phytic acid/Zn and phytic acid/Fe serve as the indices of Zn and Fe bioavailability respectively; higher ratios indicate lower bioavailability). This indicates the possibility of decline in bioavailability of grain Zn and Fe in future high-CO_2 world. Furthermore, since higher doses of P fertilization are considered inevitable to sustain higher crop productivity under elevated CO_2 (ref. 10), this can also reduce Zn and Fe concentration in food grains owing to the widely established negative correlation of P with Zn and Fe, particularly in regions with poor phytoavailability of these micronutrients in their soils, e.g. India, China, Turkey, etc. Higher doses of P application can also increase the phytic acid content in food grains[11]. Since plant-derived food is the major source of nutrition for majority of the world's population, the depleted quantity together with reduced bioavailability of grain Zn and Fe under rising CO_2 can hurt human nutrition more severely than currently anticipated.

Despite these well-rationalized, and alarming future possibilities, it is surprising that this important aspect of human nutrition (i.e. possibility of CO_2-induced alteration in micronutrients bioavailability) is yet to be attended by the concerned researchers. Clearly, there is an urgent need of systematic studies on the impact of rising atmospheric CO_2 on bioavailability of micronutrients in all major food grains grown across all the soil and climatic conditions of world. This will help in precise estimation of climate change impacts on human nutrition and in the planning of biofortification programmes for sustaining human nutritional well-being in the face of the rapidly changing global climate.

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