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Soil zinc and cadmium availability and uptake by wheat (Triticum aestivum L.) as affected by long-term organic matter management

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Zinc (Zn) deficiency is a widespread problem in human mineral nutrition. It is mainly caused by imbalanced diets with low contents of bioavailable Zn. This is in particular a problem in populations depending on cereals such as wheat (Triticum aestivum L.) as a major source of this essential micronutrient element. Increasing Zn concentrations in wheat grains (biofortification) is therefore an important challenge. At the same time, increased uptake of the toxic heavy metal cadmium (Cd) must be prevented. Agronomic practises influence soil properties such as pH and soil organic carbon and thus also have an indirect effect on phytoavailable soil Zn and Cd concentrations and the uptake of these metals by wheat in addition to direct inputs with fertilizers and other amendments. This study investigated the effects of long-term organic matter management on the phytoavailability of soil Zn and Cd and their uptake by wheat on plots of two Swiss long-term field trials. In one trial (DOK), a farming system comparison trial established in 1978, we compared plots under conventional management with mineral fertilization either in combination or not with farmyard manure application to plots under biodynamic organic management and control plots with no fertilizer application. In the second trial (ZOFE), established in 1949, we compared different fertilizer regimes on conventionally managed plots, including plots with application of mineral fertilizers only, farmyard manure, or compost and control plots with no fertilizer application. Soil physico-chemical and biological properties were determined at the beginning of the growing season. Soil Zn and Cd availabilities were assessed by the Diffusive Gradients in Thin Films (DGT) method and by DTPA extraction before and after wheat cultivation. Additionally, various wheat yield components and element concentrations in shoots and grains were measured at harvest. In the ZOFE trial, soil Zn and Cd concentrations were lowest in the mineral fertilizer and highest in the farmyard manure treatments, where metal export via crop harvests and inputs through farmyard manure dominated soil metal mass balances in the long-term, respectively. DGT-available Zn and Cd correlated negatively with soil pH, total organic carbon and microbial biomass in both trials. They were lowest in the biodynamic and compost treatments and highest in the control treatments. In the ZOFE trial, wheat yields on mineral fertilized plots exceeded the other treatments by more than a factor of two. Cd concentrations in wheat shoots and grains showed a strong positive correlation with DGT-available soil Cd. They were lowest in biodynamic and compost treatments. In contrast, shoot and grain Zn concentrations correlated more closely with total and DTPA-extractable than with DGT-available soil Zn in the ZOFE trial and they poorly correlated with both Zn availability indicators in the DOK trial. Despite these differences, the study reveals that long-term organic matter management has an important influence on the availability of both elements in soil and their uptake by wheat.