DEVELOPMENT

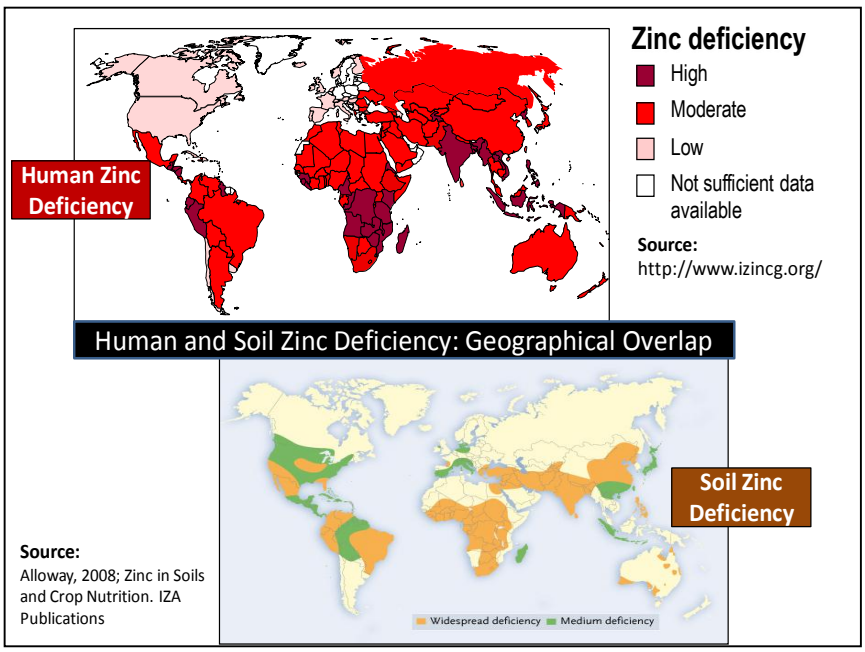
Agronomic Biofortification

Ismail Cakmak (Sabanci University)

Agronomic biofortification of food crops is a strategy, along with breeding/genetic engineering, for increasing micronutrient concentrations to reduce dietary deficiencies. Today, increasing micronutrient concentrations of stable food crops, especially in cereal grains, represents an important humanitarian challenge and a high-priority research area. Soil and foliar application of micronutrient fertilizer can be used for several different mineral micronutrients to varying effectiveness. Agronomic biofortification, especially in the case of foliar application, is highly effective for zinc and selenium, while also effective for iodine and cobalt. As an effective strategy for reducing micronutrient deficiency, zinc provides one of the best and quickest avenues for agronomic biofortification, particularly within cereal crops.

Zinc Deficiency in Human Populations and Crop Production

Zinc deficiency is a well-documented, global micronutrient deficiency problem both in human populations and in crop production. It is estimated that about 50% of the cereal-cultivated soils globally are deficient in plant-available zinc, leading to reductions in crop production and also nutritional quality of the harvested grains (1,2). Since cereals are inherently low in zinc, growing them on such potentially zinc-deficient soils further reduces grain zinc and thus the dietary intake of zinc when eaten. In many developing countries, cereals represent the major source of daily caloric intake. Dietary zinc deficiency is associated with severe consequences in human health, including impairments in brain function and development, weakness of the immune system to deadly infectious disease, and delays in physical development. As shown below, it is not surprising that the well-known zinc deficiency problem in humans occurs predominantly in the countries/regions where soils are low in available zinc, and cereals are a major staple.



HarvestPlus Zinc Fertilizer Project

The HarvestPlus Zinc Fertilizer Project, called HarvestZinc, is exploring the potential of various zinc-containing fertilizers for increasing zinc concentration of cereal grains and improving yield in target countries such as India, China, Pakistan, Thailand, Laos, Turkey, Zambia, Mozambique, and Brazil (see www.harvestzinc.org). The results obtained under the HarvestZinc project demonstrate that foliar or combined soil+foliar application of zinc fertilizers under field conditions is highly effective in increasing grain, especially in wheat. Zinc-enriched grains are also of great importance for crop productivity resulting in better seedling vigor, denser stands, and higher stress tolerance in

potentially zinc-deficient soils. Agronomic biofortification is essential for keeping sufficient amounts of available zinc in soil solution (by soil zinc applications) and in leaf tissue (by foliar zinc applications), which greatly contributes to the maintenance of adequate root zinc uptake. It also assists with transport of zinc from leaf tissue to the seeds during their reproductive growth stage. This approach is also required for ensuring and maximizing the success of biofortified food crops that are bred with higher levels of zinc..

Increasing grain zinc concentrations through foliar zinc applications is similar to increasing zinc concentrations in other parts of the grain such as the endosperm, which is the most commonly eaten part of wheat grain. Since phytate (an antinutrient that inhibits zinc bioavailability in humans) in the wheat grain endosperm is very low, or not detectable, the increases in zinc concentration in the endosperm (up to 3-fold) by foliar zinc spraying is important for human nutrition, as it could result in higher zinc bioavailability.

Additional results from the foliar zinc spray project include:

- Among wheat, rice, and maize, wheat has been found to be the most promising cereal crop for increasing zinc in grains through foliar zinc fertilization.
- Foliar zinc fertilizers can be sprayed on leaves together with fungicides/insecticides. When tested in different countries, there was no adverse effect observed of those pesticides on leaf zinc penetration and seed/grain zinc deposition.
- Increasing nitrogen fertilization of plants very positively affected shoot translocation and grain deposition of foliarly applied zinc.
- Among the zinc forms tested for foliar Zn application (ZnO, $ZnCl_2$, ZnEDTA, nano-sized ZnO particles, and ZnSO4), ZnCl2 and ZnSO4 gave the best result while ZnO and nano-sized ZnO particles were less effective in increasing grain zinc.
- Foliar spray solution pH and use of some adjuvants markedly affect the agronomic effectiveness of foliar zinc fertilizers. Reducing pH from 8.3 to 5 increased grain zinc concentration up to 60–70%.

1. Graham et al. 1992. Selecting zinc-efficient cereal genotypes for soils of low zinc status. *Plant and Soil* 146:241–250.

2. Cakmak, I. 2008. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant and Soil* 302: 1–17.