HarvestPlus Zinc Fertilizer Project: HarvestZinc

By Ismail Cakmak

The first phase of the HarvestPlus Zinc Fertilizer Project has assessed the potential for crop response to Zn-containing fertilizer in a number of target countries where soils are unable to produce staple foods with adequate Zn. Foliar spray of Zn fertilizers is highly effective in increasing Zn concentrations of cereal grains. However, attention should be paid to the timing of Zn spray. Soil application of Zn-containing fertilizers is more important for improving crop yields.

Zinc deficiency is a well-documented micronutrient deficiency problem both in human populations and in crop production globally. It is estimated that about 50% of the cereal-cultivated soils globally are deficient in plant available Zn, leading to reductions in crop production and also nutritional quality of the harvested grains (Graham et al., 1992; Cakmak, 2008). Since cereal grains/seeds contain inherently very low amount of Zn, growing cereal crops on potentially Zn-deficient soils further decreases grain Zn concentrations. It is, therefore, not surprising that the widespread occurrence of Zn deficiency in human populations occurs mostly in regions where cultivated soils are low in plant available Zn and cereal-based foods are the major source of daily calorie intake (**Figure 1**). Up to 75% of the daily calorie intake of the human beings living in the rural areas of the developing world comes only from cereal-based foods with very low Zn concentrations and also low bioavailability of Zn.

Common abbreviations and notes: N = nitrogen; Fe = iron; Zn = zinc.

Zinc deficiency causes severe impairments in human health, including impairments in brain function and development, weakness in immune system to deadly infectious disease and alterations in physical development. Zinc deficiency has been shown to be responsible for deaths of about 450,000 children under 5-years old annually (Black et al., 2008). Zinc deficiency is also becoming an important public health problem in developed countries. Low dietary intake of Zn is a known health issue in USA, UK and Australia—especially among women, children and elderly people (Watt et al., 2001; Gerrior, 2002). Today, increasing Zn concentration of stable food crops, especially cereal grains, is therefore, an important challenge and a high priority research area.

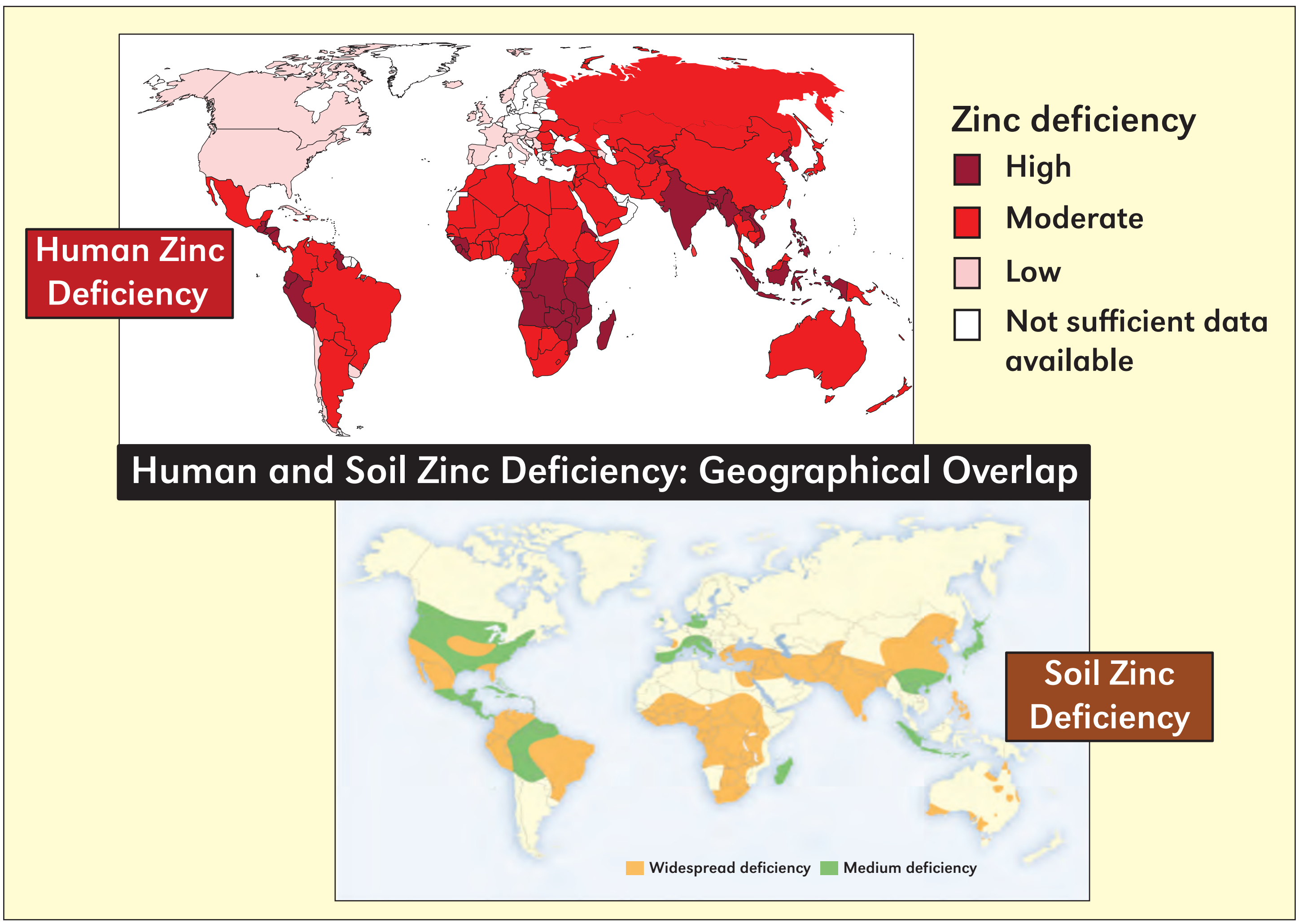

Figure 1. Geographical overlap of soil Zn deficiency and human Zn deficiency. (Sources: http://www.izinc.org; Alloway, 2008).

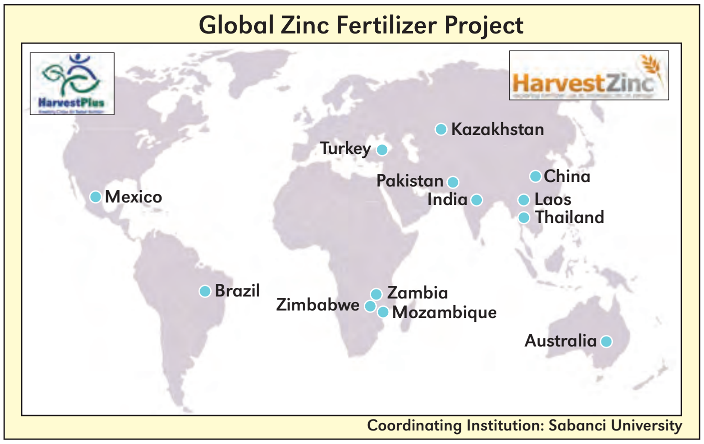

Figure 2. The countries where Zn fertilizers trials are conducted.

Agronomic biofortification (application of Zn fertilizers) represents a quick approach to the problem. Enrichment of cereal grains through application of Zn fertilizers promises to be a relevant and practical approach to improve Zn concentrations of staple food crops. Agronomic biofortification is essential for keeping sufficient amount of available Zn in soil solution (by soil Zn applications) and in leaf tissue (by foliar Zn applications) which greatly contribute to maintenance of adequate root Zn uptake and transport of Zn from leaf tissue to the seeds during reproductive growth stage. This approach is also required for ensuring the success of biofortification of food crops with Zn through use of breeding tools.

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HarvestPlus Zinc Fertilizer Project, called HarvestZinc is exploring the potential of various Zn-containing fertilizers for increasing Zn concentration of cereal grains and improving yield in different target countries such as India, China, Pakistan, Thailand, Laos, Turkey, Zambia, Mozambique, and Brazil (see www.harvestzinc.org). The program is coordinated by Sabanci University in Istanbul (**Figure 2**).

Based on the results obtained within the 1st Phase of the project (2008 to 2011), the reaction of cereal crops to Zn fertilization showed large variation between the countries and even within a given country in terms of grain yield response. Increase in grain yield upon Zn applications ranged between 0 to 22%. In some locations in India, Pakistan and Turkey, wheat grain yield was increased up to 22% by soil Zn applications. In contrast to the large variations in grain yield among countries and even within a given country, the results with grain Zn

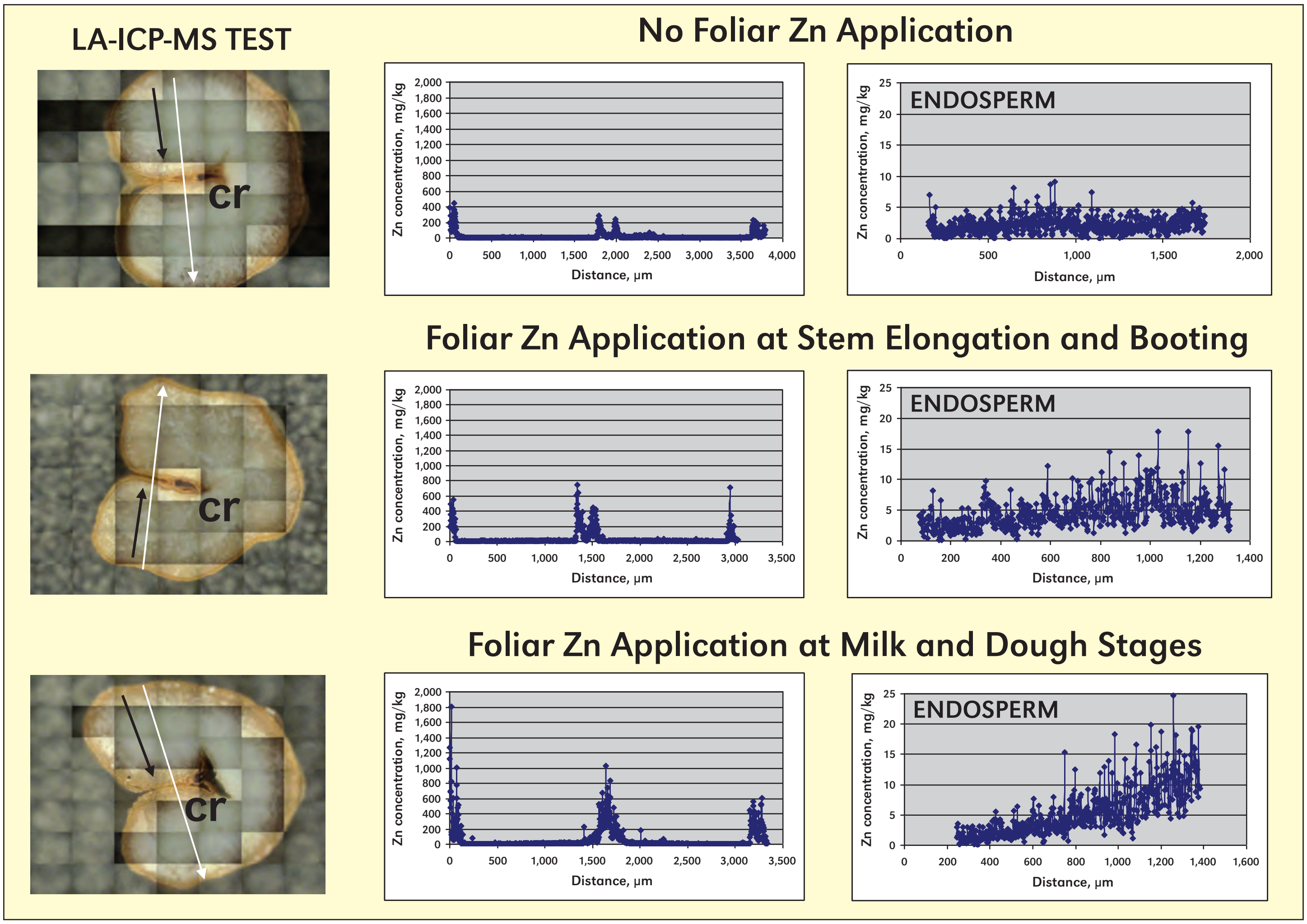

Figure 3. Changes in Zn concentrations of the endosperm part of wheat seeds from plants which were treated by $ZnSO_4$ at different growth stages under field conditions. Changes in Zn concentration were measured by using LA-ICP-MS (Laser Ablation Inductively Coupled Plasma Mass Spectrometry). Black arrow on seeds (left side) shows the studied area on endosperm. White arrow shows the studied area on the entire cross section. Distance on the x-axis represents the length of the studied section (places) on the seeds that are shown with the black or white arrows. For more detail see: Cakmak et al., 2010.

Zinc Day events held in Pakistan (top) at Faisalabad and China (bottom) at Weinan-Xian.

concentrations were highly consistent. Grain Zn concentrations were significantly increased by foliar Zn applications while soil Zn application was less effective. Among wheat, rice and maize, wheat has been found to be the most promising cereal crop for increasing Zn in grains through foliar Zn fertilization. In this aspect, maize appears to be less responsive. In case of wheat, particular increases in grain Zn concentration after foliar application of Zn were observed in each country (an average of about two-fold).

The trials also showed that the timing of foliar Zn application is a critical issue in maximizing grain Zn concentration (Cakmak et al., 2010). According to the results obtained from several field tests, foliar spray of Zn late in growing season resulted in much greater increases in grain Zn concentration when compared to the earlier foliar applications of Zn (**Figure 3**). Increases in concentration of whole grain Zn through foliar Zn applications were also well reflected (proportionally) in all grain fractions analyzed, especially in the endosperm, the part predominantly consumed in food products in target countries.

Another important finding in the past 3 years under the HarvestPlus Zinc Fertilizer Project was related to the role of N nutrition in enriching cereal grains with Zn (and also Fe). Nitrogen-nutritional status of plants appears to be a very critical factor in: i) root uptake, ii) root-to-shoot translocation, and iii) grain accumulation of Zn and Fe (Kutman et al., 2011; Aciksoz et al., 2011). Increasing N supply very positively affected root uptake, shoot translocation and grain deposition of Zn.

New Tasks and Challenges

Based on evidence that foliar Zn application is highly effective and promising in doubling grain Zn concentration at any location tested, for example in wheat, it is important to motivate and encourage farmers to spray Zn to increase grain Zn as well as grain yield. The following strategies can be employed for motivation (and encouragement) of farmers to spray Zn unless there is no Zn deficiency problem in soils:

- to demonstrate that plants emerging from high Zn-seeds: i) have improved seedling vigor and hence ii) better yield (besides human nutritional effects);
- to evaluate the applicability of Zn together with widely used insecticides and/or fungicides on wheat and rice in the target countries.

Applying Zn-containing compound fertilizers into soil will ensure a better and healthy root system and maintain high amounts of plant available Zn pools in growth medium which will significantly contribute to enhanced root uptake of Zn. In the second phase of the project (2011 to 2014), special attention will be paid to these tasks for motivation of farmers to include Zn in their soil and foliar fertilization programs.

Zinc Day Events

Delivery of the project results to farmers (end-users) is a vital issue for the success of the project. One of the major goals of the second phase of the HarvestZinc project is, therefore, to promote and disseminate the practical and theoretical knowledge and experiences gained during the project. An important attention is being paid to the organization of ***Zinc Days*** in the target countries for the agronomists/crop consultants, extension staff, farmers and decision makers at the different stages of the project to increase awareness of the importance of Zn nutrition in human health and crop production. BC

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