Addressing Zinc Deficiency in Soil-Plant-Animal-Human Continuum

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ABSTRACT

Zinc is a critical micronutrient essential for metabolic and physiological processes across the soil-plant-animal-human continuum. Almost 17% of the global population is under severe zinc deficiency, specifically residing in Asia and Africa. In India, nearly 39% of soils are zinc-deficient, driven by intensive cropping, high reliance on NPK fertilizers, monocropping, limited use of micronutrient fertilizers and organic amendments and soil pH. Moreover, the zinc accumulated in husk of the grains are lost during milling aggravating zinc deficiency in people depending majorly on conventional staple grains. Therefore, it becomes imperative to address zinc deficiency via adopting several methodologies such as diet diversification, biofortification and crop diversification to and achieve nutritional security for the growing population and improving livestock productivity.

INTRODUCTION

Zinc is one of the most important micronutrient cations that plays a significant role in plant, animal and human metabolic functions. According to the All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (AICRP-MSPE) programme, deficiency in the soil identified with a content of less than 0.6 ppm occurs in almost 39% of Indian soil, majorly in Bihar (67%), Odisha (48%) and UP (29%) (Khokhar *et al.,* 2024) The availability of zinc in soil is influenced by pH. Although the availability of zinc in acidic soil is conventionally more, its affinity towards poorly crystalline iron oxides and hence their binding to form ternary complexes reduces its bioavailability. Similarly, in soil with pH more than 7, zinc forms unavailable compounds such as zinc carbonate or zinc hydroxide due to the presence of calcium carbonate that precipitates out the zinc. Moreover, the deficiency of zinc in Indian soils is aggravated by enhanced cropping intensity, adoption of high yielding varieties, heavy reliance on NPK fertilizers, neglected utilization of micronutrient fertilizers and organic matter, extensive acreage under monocropping and continuation of the same cropping system. Therefore, the crops generally grown on zinc deficient soil without or very less amount of micronutrient fertilizers remains deficient in zinc. The deficiency of zinc in grains is further worsened by the milling process that removes the husk compromising bran and germ where micronutrient accumulation is highest than that of the grain (Jiang *et al.,* 2023). Thus, in order to tackle the crisis of zinc it is imperative to adopt several methodologies that help achieve nutritional cum food and feed security.

Importance of zinc in plants

Zinc is absorbed from the soil as zinc ion (Zn^{2+}). Its sufficiency range in plants ranges from 27 to 150 ppm. Its critical functions of zinc in maintaining an optimum metabolic and physiological conditions within the plant are enumerated below (Oliveira *et al.,* 2023):

(i) Zinc is involved in the synthesis of tryptophane which is an essential amino acid.

(ii) It is responsible for the synthesis of phytohormones viz., indole acetic acid (IAA) and gibberellic acid required for general growth and development.

(iii) Zinc is critical in optimum functioning of the following enzymes

(a) Carbonic anhydrase – it is located in cytoplasm and chloroplast that facilitates the transfer of carbon dioxide necessary for photosynthesis. It is a critical indicator of zinc deficiency.

(b) Alcohol dehydrogenase – it plays an important role in responsible for anaerobic root respiration by catalysing conversion of acetaldehyde to alcohol.

(c) Superoxide dismutase – it provides protection from oxidation resulting from enhanced accumulation of reactive oxygen species (ROS) under stressed conditions.

(d) RNA polymerase – it is necessary for RNA synthesis

(iv) Zinc is responsible for stabilization and orientation of membrane protein because of its preferential binding with sulphydryl group.

(v) It is necessary for the stabilization of ribosomal fractions.

(vi) Zinc influences the translocation of transportation of nutrient within the plant system

Importance of enhancing zinc in soil-plant-animal-human continuum

Although zinc is biological a trace element, it is pivotal for numerous biological functions within animal and human body including catalytic functions as it serves at the co-factor of numerous enzymes, stabilization and folding of protein, homeostasis, boost immunity, synthesis of macromolecules such as lipids and DNA, and transcription and repair of nucleic acids. Its deficiency is associated with disorders related to skin, gastrointestinal, reproductive, neurological and immunological systems, which is often termed as hidden hunger. In animals, zinc deficiency leads a peculiar condition known as parakeratosis identified as thickened, encrusted skin particular in armpits and groin. Globally, zinc deficiency has been recorded in 17% of the population, with 24% and 19% in Africa and Asia, respectively. Considering all the above facts, inclusion of zinc in animal and human diet is necessary for maintaining their optimum functioning. Some of the methodologies that can be adopted for improving zinc content in diets are:

(i) ***Diet diversification*** – diet diversification is a sustainable, long-term strategy for tackling hidden hunger. It involves changing diets including conventional staple food to unconventional food items including millets, pulses, etc. offering a balanced diet. However, this strategy questions the affordability and accessibility of food stuffs, posing as a serious challenge to mitigate hidden hunger.

(ii) ***Biofortification*** - Biofortification is defined as "nutrient sensitive agriculture intervention" that aims to boost nutrient content in food crops through agronomic practices, conventional plant breeding or biotechnological practices. Agronomic biofortification is a strategy aimed at increasing the micronutrient content of the edible parts of food crops by applying mineral fertilizers either to the soil (basal application) or directly to the leaves (foliar application) or by seed treatment (Talsma *et al.,* 2017). Agronomic biofortification enables absorption of micronutrients by the roots from the soil on application of easily available zinc sources such as Zn EDTA, Zn HEDDA, etc. or by remobilizing it from the vegetative shoots to the grain on foliar application of zinc. Seed priming with zinc enables early absorption of zinc and storing it within its tissues and also promoting efficient germination particularly under stressed conditions such as drought, high temperature, etc.

(iii) ***Crop diversification*** – it involves introducing new crops or changing cropping systems on a farm, considering the potential benefits from high-value crops and the opportunities they create for complementary marketing. Crop diversification not only address hidden hunger *via* adoption of unconventional crops but also helps address stress conditions by serving as an insurance against crop failure and also aids to achieve "doubling farmer's income" scheme. It ensures the adoption of crops such as millets that are low resource requiring crops and are also a rich of micronutrients that are generally absent in conventional carbohydrate staples. Thus, this strategy is climate smart that bears the potential of alleviating micronutrient deficiencies.

CONCLUSION

Zinc is a vital trace element that plays a significant role in maintaining optimum physiological functions. Its worldwide deficiency has triggered numerous health ailments in human and livestock. Where a greater deal of emphasis is being laid on increasing the productivity of foodgrain crops, scientist and researchers are also employing several technologies to improve its nutrient content in the continuum to address hidden hunger of the growing population amidst climate change. However, improving the production of fodder crops have been largely overlooked that severely results in declining livestock productivity. Thus, under such a condition it becomes critical to improve nutritional quotient in the fodder crops grown in restricted area. Hence, effective implementation of strategies is essential for mitigating hidden hunger and improving the health and productivity of plants, animals, and humans alike.

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