Biofortification of Food Crops with Zinc to Tackle Zinc Malnutrition in Human Population

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ABSTRACT

Among the different strategies to reduce Zn malnutrition in human populations, the agronomic bio-fortification is considered most sustainable and cost effective approach to enhance the zinc concentrations in grains of food crops and to address zinc deficiency in soils-plants-humans chain. Zinc has an important role in public health and its deficiency can cause many complications. Lack of a clinical syndrome of zinc deficiency has delayed its recognition as a public health problem. Zinc malnutrition affects billions of people in developing world. As India's soil are zinc deficient, so are India's women and children. Zinc deficiency in soils does not only reduce crop productivity, but it also leads to low-zinc food causing human malnutrition. Zinc deficiency is common in about 49% of Indian soils which is likely to increase to 63% by 2025. The problem is global; however, it is more acute in India as billions of people suffer from zinc malnutrition, also known as "hidden hunger" that is caused by lack of sufficient zinc in diet. Foliar zinc sprays to food crops growing on zinc deficient soils offers a practical and useful solution for an effective bio-fortification of food crops with zinc. Zinc requirements are highest for women because of their needs for reproduction and children for growth. The study targets rural women who consume large amounts of low-zinc cereal foods and little else. Foliar zinc application approach can be locally adopted for increasing dietary zinc intake to tackle women and children zinc malnutrition.

1. INTRODUCTION

Zinc plays an important role in cellular growth, cellular differentiation and metabolism being an important structural component of most proteins and contributes to the function of more than 200 enzymes. Over 25 per cent of the total population in India is at risk of inadequate Zn intake, largely infant, children and pregnant women (41-61 per cent). About 15 mg Zn is required daily by women and 5-10 mg zinc by infants and children and the same has to come from food crops mainly through the zinc fertilizers (Takkar, 2011). Zinc nutrition affects growth, immune system development and function, normal integrity of intestinal mucosa, pregnancy outcome and neuro-behavioural development. Now worldwide importance of Zn for plant, human and animal health become fully recognized and is contributing immensely in human and animal health became fully recognized and is contributing immensely in human and animal health and development besides increasing production and productivity in agricultural systems. The extent of problems associated with Zn deficiency may vary greatly with the locality, geography, geology of parent material, soil type, climate conditions, vegetations, livestock farming practices and quality and quantity of fertilizers, manures, and Zn concentration in the food and fodder harvested from these areas or regions for human and animal consumptions.

During the last four decades of intensive cultivation, using modern agricultural technologies of food production like *"Green Revolution monoculture cereal systems of rice-wheat"* to meet the growing demand of rapidly expanding population for food, fodder, fiber, fuel and fruits has been accelerating the processes of depletion of Zn from the finite soil resource in its flow to animals and human through the *"soil-water-plant-animal-human chain",* consequently resulting in decline in Zn contents of staple food crops and increase in its deficiency disorders both in human and animals. It is now well documented that Zn deficiency problem in human beings occurs dominantly in countries where soil are low in available Zn and cereals are the major source of calorie intake. Also in India rice and wheat are provided on highly subsidized price to resource poor population, suffering from malnutrition, thereby helps increasing their intake of diet low in Zn content. Bio-fortification is yet to be fully scaled up but much evidence and experience has been assembled to support its eventual effectiveness. Scientific evidence shows that agronomic bio-fortification is technically feasible without compromising agronomic productivity of food crops. Different interventions are currently being tried as major solution to minimize zinc malnutrition in humans. Food fortification and supplementation are being widely applied in some countries. However, these approaches are very expensive and not easily accessible by those living in rural areas in developing countries. As such, it is high time that scientists and farmers make sincere efforts to improve the nutritional quality of the produce to ensure healthy and productive lives especially to rural women and children. Bio-fortification is a new way to tackle malnutrition. Bio-fortification of cereal grains with zinc is a high priority area of research (Cakmak et al, 2010).

2. DEFICIENCY SYMPTOMS OF ZN

Zinc is involved in the biosynthesis of a plant hormone IAA (Indole Acetic Acid) and is a component of a variety of enzymes such as carbonic anhydrase, alchohol dehydrogenase etc. Zin plays a role in nucleic acid and protein synthesis and helps in the utilization of phosphorus and nitrogen as well as in seed formation. The semipermeability of the cell membrane is also maintained by Zn.

3. CRITICAL LIMITS OF DEFICIENCY

Plant roots can extract Zn from several sources but the availability of Zn in soils is not directly related to total Zn in Soil. In India DTPA extractable Zn is most widely accepted diagonistic tool for Zn nutrition of crop plants. Some critical values for soils and crops in India is given in Table 1.

Table 1-Critical limits of DTPA extractable Zn in different soils and crops in India

Soils	Crops	Critical limits (mg kg-1 soil)
Black	Rice	0.84-1.34
	Wheat	0.54
Red and Black	Rice	0.45-2.00
	Wheat	0.46-0.60
	Maize/Sorghum	1.00-1.20
Red	Rice	0.60-1.00
	Maize	0.65-.080
Alluvial Tarai and river belt	Rice	0.38-0.90
	Wheat	0.40-0.80
	Maize	0.54-1.00
	Rice	0.78-0.95

Source: Takkar et al., 1997, Singh 1992

4. SOURCE OF ZINC

There are four classes of Zn sources: inorganic, synthetic chelates, natural organic complexes inorganic complexes. The inorganic sources are sulphate, chloride, carbonate and oxides of Zn. Of these, sulphate is the most widely used source of Zn. Of the two sulphates, zinc sulphate heptahydrate (ZnSO4.7H2O) is most widely marketed and used Zn fertilizer in India. Of late ZnO is receiving some attention because of its high Zn content 0-80 percent as compared to 21 percent in ZnSO4. 7H2O and expecially in the context of making Zn coated zincated urea. O the synthetic chelates, Zn-EDTA is the material that is widely used in India and abroad. Zinc lignoulfonates and zinc polyflavonoids are the wood by-products of the paper industry an dhave not been practically tested in India so far.

5. INTERACTION OF ZINC WITH OTHER NUTRIENTS

Zinc interacts positively with N and K and negatively with P. Synergistics effects of Zn x N interaction are mainly due to increased availability of zinc in soils due to acid forming effect of N. Positive Zn x K interaction is attributed to the role of K in zinc translocation in plants. Antagonistic effect of Zn x P interaction has been the subject of intensive study in several countries. One of the reasons for the decrease in zinc concentration in plant tissue due to P fertilization is simply dilution caused by increased plant growth. This implies that farmers should not overuse phosphatice fertilizers, or else it would lead to reduced uptake of zinc by the crops. Zinc interacts antagonistically with all three secondary plant nutrients S, Ca and Mg. However, positive interaction in rice, wheat and mustard. Most available reports show negative interaction of zinc with Fe, Mn, Cu and Mo. Regarding B, it is created a protective mechanism in root ceel micro-environment against B uptakle.

6. ECONOMIC OF ZINC FERTILIZER USE

Trials carried on farmers' fields reveal that zinc application to crops is remunerative on zinc deficient soils. Over 7000 trials carried out in cultivatiors' fields with cereal crops, rice, wheat, maize and barley showed an 8.3 percent increase in mean grain response over NPK. The B:C ration varied from 2.8:1 to 3.5:1, which showed that it was profitable, as B:C ration over 2.5 is considered as remunerative to the farmers. Zn also has a significant effect on crop quality as shown in Table 2 (Source Kalwe et al., 2001).

Table 2. Effect of zinc on crop quality.

S. No	Crop(s)	Quality improvement
1	Rice, wheat, maize, mustard, chickpea, blackgram	Increase is energy value, total lipids, crude protein and carbohydrate content
2	Wheat, chickpea	Increase in lysine and histidine
3	Potato	Increase in ascorbic acid in tubers, reduced phenol content, enhanced reducing sugars, sucrose and total sugar
4	Sugarcane	Improvement in sucrose recovery and juice quality
5	Cotton	Increase in phenol tannin content of leaves, kernels and seed coat

7. CONCEPT OF AGRONOMIC BIOFORTIFICATION:

Keeping in view the importance to Zn in Human health as well as in improving the crop health, biofortification of ceral crops is most viable option to enhance the Zn content in the final product.

About 312 million people in India are deficient in zinc (Das and Green, 2013). This is to be achieved by improving zinc density of staple food crops consumed by these populations. A fast and cost effective way of addressing zinc deficiency in women and children is to apply zinc fertilizer to food crops. Research efforts that relate Zn deficiency in soils with human health and its remediation is only at its infancy in India. Studies have shown that foliar application of zinc fertilizer increased Zn concentration in rice, wheat and maize grain in soil with zinc deficiency (Shukla and Behera, 2011; Zou et al, 2012). Targeted intervention offer newer opportunities for better health of children and farm women. Once the stake holders are convinced and motivated and relies its importance and utility with the new technology, it will be self-sustainable as the cost of

Zn fertilizer application is quite low as compared to yield increase, monitory and health benefits. It offers a simple and highly effective solution to correct Zn deficiency problems in soils, crops and humans.

REFERENCES

[1] **Cakmak, 1 (2008).** Zinc – Crops 2007: Improving crop production and human health. Plant and Soil, 306:1-2.

[2] **Cakmak, (2010).** Biofortification of cereals with zinc and iron through fertilization strategy. 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1 – 6 August 2010, Brisbane, Australia.

[3] **Das, S and Green, A (2013).** Importance of zinc in crops and human health. Journal of SAT Agricultural Research; 11: 1-7

[4] **Kalwe, S. P., Das Soumitra and Biswas, B.C. (2001).** National Conference on Zinc in Health and Agriculture. ILZDA, New Delhi, p 1-10.

[5] **Singh Kuldeep (1992)** Critical soil level of zinc for wheat grown in alkaline soils. Fertilizer Research 31: 253-256

[6] **Shukla A. K and Behera, S.K. (2011).** Zinc Management in Indian Agriculture :Past, Present and Future. Indian J. Fert., 7(10), pp.14-33

[7] **Takkar PN, Singh, M V and Ganeshamurthy, A N.** In: Proceedings of National Symposium on Plant nutrient needs, Supply Efficiency and Policy Issues for 2000-2025., NAAS, New Delhi, 218-224

[8] **Takkar, PN (2011).** Zinc in human and animal health. Indian J. Fert.; 7: 46-66

[9] **Zou CQ, Zhang YQ, Rashid A, Ram H, Savasli E, Arisoy RZ, Ortiz-Monasterio I, Simunji S, Wang ZH, Sohu V, Hassan M, Kaya Y, Onder O, Lungu O, Yaqub MM, Joshi AK, Zelenskiy Y, Zhang FS, Cakmak I (2012):** Biofortification of wheat with zinc through zinc fertilization in seven countries. Plant Soil, 361:119–130