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Agronomic Zinc Biofortification in Cereal Crops

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SUMMARY

Zinc (Zn) deficiency is a common disorder of humans in developing countries. Zinc (Zn) is the key constituent that involves in many physiological processes of plant growth and metabolism, inadequate supply of Zn reduce crop yield. In more than 22 developing countries, at least 60% of the Zn in human diets is derived from C3 grains and legumes. Zn is essential for carbohydrate metabolism, DNA and RNA synthesis, and other processes. An important approach to preventing Zn deficiency in humans is Zn biofortification, i.e., the use of agronomic practices, or biotechnology to increase the Zn content of food crops. The effect of Zn biofortification (via application of six rates of Zn fertilizer to soil) on Zn bioavailability in grain and flour and its impacts on human health was evaluated. Zn biofortification increased Zn availability in standard and refined flour, it did not reduce the bioavailability of Fe, Mn or Cu in wheat flour. Dietary deficiencies of Zn and Fe are a serious global public health problem affecting over two billion people and causing a loss of 63 million life-years annually. These cases of malnutrition are more acute in populations of Africa, South and South East Asia where cereals, the major staple foods, are low in dietary Zn and Fe. Rice is of major importance particularly in South and South East Asia because it contributes more than two thirds of the energy intake of its population. Zinc concentration in rice grains can be enriched by: i) biofortification with popular Zn fertilizers ii) manipulating Zn transporters and ligands in rice plants. iii) efficient germplasm screening for higher bioavailable Zn . All these methods depend on fertilizer or the soil or both as the source of Zn to produce Zn enriched grains.

INTRODUCTION

Zn biofortification can be achieved more rapidly by an agronomic approach (i.e., by fertilizer application) than by conventional breeding or biotechnology. The problem of low Zn availability to plants is exacerbated or caused by when rice is grown in submerged soils. Application of Zn fertilizer is the most common option to overcome such problems. But recovery of applied Zn by rice hardly exceeds 2% of the applied amount. .About a third of the world's population is estimated to be at risk of Zn deficiency, which is especially prevalent in children under 5years of age because of their relatively large demand for Zn to support growth and development. Deficiencies of Zn and other micronutrients in developing countries are also reported to cause great economic losses and have a considerable effect on the gross national product by decreasing productivity and increasing the healthcare costs.

Bio fortification

Greek word "bios" means 'life' and Latin word "fortificare" means 'make strong'. Bio fortification is the process of increasing the content and bioavailability of essential nutrients in crops during plant growth through genetic and agronomic pathways (Bouis *et al.,* 2011) .Bio fortification refers to increasing genetically the bio-available mineral content of food crops (Brinch-Pederson *et al.,* 2007). It is the idea of breeding crops to increase their nutritional value. Genetic biofortification involves either genetic engineering or classical breeding (Saltzman *et al*., 2013). A example of Golden Rice was developed in the year 2000 by genetic engineering.

Objectives of Bio fortification

- The objective is to develop micronutrient dense staple crops on achieve pro vitamins A, iron and zinc concentrations that can have a measurable impact on nutritional status.
- Improve micronutrient and mineral content.
- Improve Oil content in food products.
- Improve Vitamin content.
- Bio-efficiency studies to determine the effect of bio-fortified crops on micro-nutrients.
- Scaling up production and distribution of improved varieties.

Need for Bio fortification

Bio fortification aims to combat malnutrition in communities in developing countries that do not majorly consume manufactured food products (Bouis and Welch, 2010).The world population was continuously increasing, suffer from a lack of food, so that fighting hunger continues to be a challenge for humanity.On the other hand, the World Health Organization estimates that, worldwide, 1.5 billion people are overweight (WHO 2011).Increasingly, these two forms of malnutrition, underweight and overweight, are occurring simultaneously within the different countries (Gillespie and Haddad 2003; FAO 2006).

Bio fortification involves increasing the density and bioavailability of key essesntial nutrients, especially micronutrients, in staple foods such as grains.Cereals meet 60% of energy and protein needs of human. Upto 75% of the daily calorie intake of the developing world people living in the rural areas comes only from cereal-based foods with very low Zn concentrations (Cakmak, 2012).

- Un-hulled rice : 27-42 mg Zn/kg grain.
- Polish rice: 13-15 mg Zn/kg grain.
- Wheat grains: 38-47 mg Zn/kg.
- A diet of 300-400g cereals/day will supply only 4-6 mg Zn/day in the case of rice and 11-18 mg Zn/day in the case of wheat.

How Bio fortification Works

Mostly using conventional breeding, researchers develop new varieties with high ;Testing in different terrain, soils, climates; release of best varieties by varietal release committees; Deliverable to farmers ; Value proposition to mothers- same price but protect family from nutrient deficiencies.
Biofortification is cost- effective, centralized investment.

Agronomic Bio fortification

- Agronomic biofortification is the application of micronutrient containing mineral fertilizer to the soil and plant leaves (foliar), to increase micronutrient contents of the edible part of food crops (Valenca *et al*., 2017).
- The ferti-fortification of Zn is a promising and cost-effective measure to increase Zn concentration (agronomic biofortification) in cereal grain to comat Zn malnutrition
- An example of biofortification is a Wheat variety known as Atlas 66, which has high protein content in comparison to the existing wheat.

Agronomic approaches to Bio fortification:

- Adequate fertilization
- Method of fertilization
- Time of application
- FYM application (INM)
- Crop rotation
- Intercropping

(Rengel *et al*., 1999)

Agronomic Bio Fortification with Zn through Fertilizer Application

Soil Zn applications at the time of sowing had little effect on the concentration of Zn in the grain under field conditions, whereas foliar Zn sprays were very effective in improving the grain Zn. The timing of foliar Zn fertilizer application is an important determinantion of its effectiveness in terms of biofortification (Welch *et al.,* 2013). In both wheat and rice, foliar Zn applications are particularly effective in enriching the grain with Zn if they are applied at a later rather than an earlier developmental stage, preferably during grain-filling.

Fig 1: Average changes in grain Zn concentration caused by soil, foliar and soil+foliar applications of Zn in the form of ZnSO4 to wheat, rice and maize.

Foliar applied Zn is phloem-mobile and can be readily translocated into developing grains in wheat.

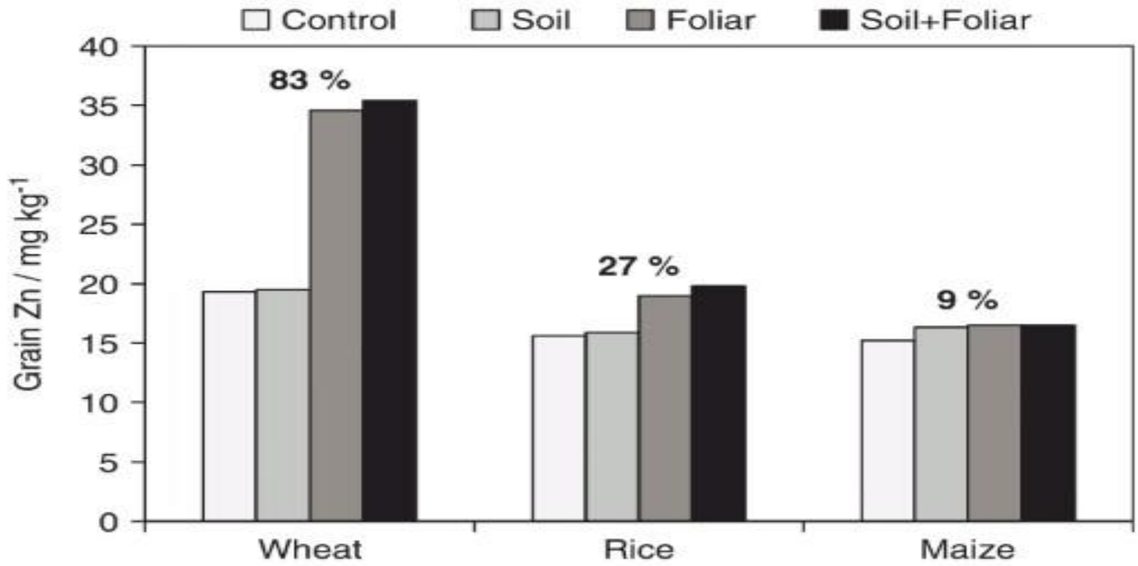
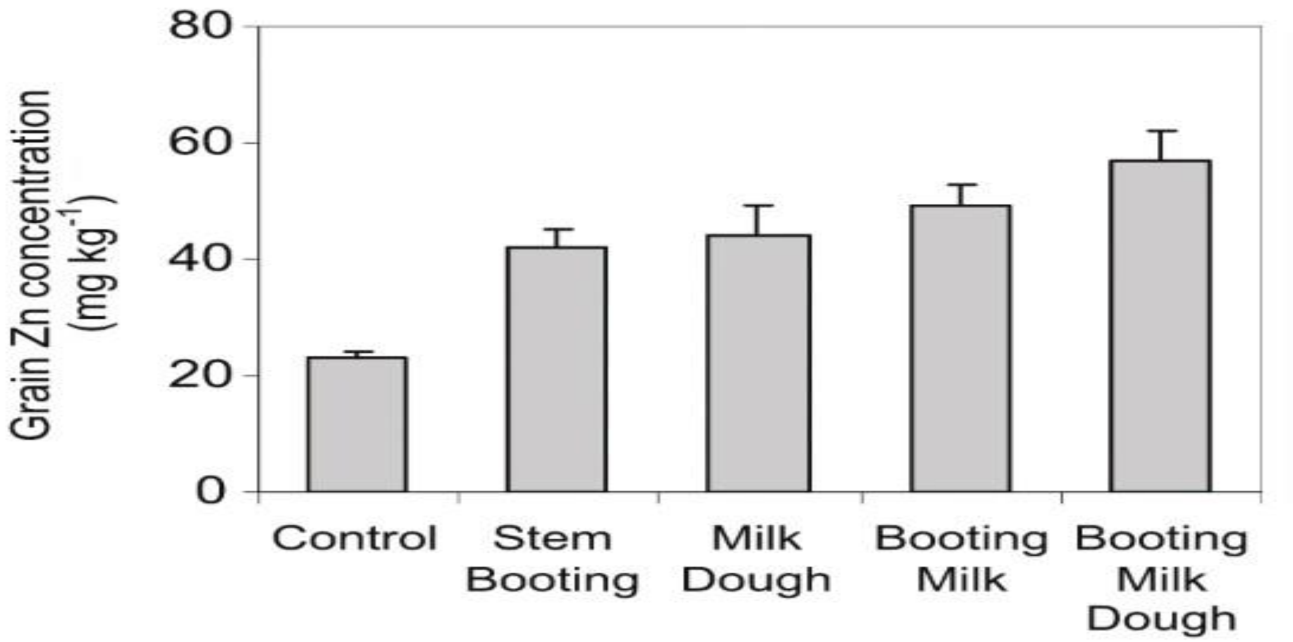


Fig. 2: Effect of foliar application of Zn (Znso4 @0.5% [w/v]) on grain at different growth stages in wheat grown under field conditions



Source : Ozturk *et al* 2006

Strategic advantages of Biofortification

- Targets the poor: eat high levels of food staples.
- Rural-based: complements fortification and supplementation.
- Cost-effective: research at a central location can be multiplied across countries and time.
- Sustainable: investments are front loaded, low recurrent costs.
- Increase in nutritional value.
- Healthier populations with strong and quick immune responses to infections.

- Mineral packed seeds sell to farmers because, as recent research developments proved that seeds rich in trace elements are stronger to resist against biotic and abiotic streeses including disease and environmental stresses (Bouis, 2003).

Disadvantages of Biofortification

- High production costs. i.e. equipment, technology, patenting,etc.
- Loss of wild type rice varieties.
- Poor rural population have limited access and resources to purchase biofortified foods.
- Low substantial equivalence. i.e. inability to provide high micronutrient and protein content compared to supplements.
- Resource-poor farmers cannot afford application of mineral fertilizers, especially micronutrient fertilizers.

CONCLUSION

Application of Zn-containing fertilizers represents a quick and useful solution to biofortification of cereal grains.Fortification of fertilizers with Zn would be an excellent investment for humanity and for crop production in India.In case of greater bioavailability of the grain Zn derived from foliar application than from soil, agronomic biofortification would be a very attractive and useful strategy in solving Zn deficiency related health problems effectively. Agronomic biofortification is of great importance in enriching seeds and straw with micronutrients. Foliar application of micronutrients results significantly higher micronutrient recovery percent over soil application.Two-three foliar sprays of Zn (0.5% Znso4) on later growth stages offers a practical and useful means for bio-fortification with Zn. Applications of Zn to soil to ensure sufficient availability of Zn for root uptake and foliar applications of Zn to enrich vegetative tissues with Zn and thus enhance Zn remobilization into grains are key agronomic interventions for achieving successful biofortification of food crops with Zn.

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