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Micronutrient fortification in cereals for mitigating malnutrition in India by Agronomic practices

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Abstract
Malnutrition is the condition that develops in humans when body doesn't get the right amount of dietary vital nutrients, vitamins, minerals; that are needed for maintaining healthy tissues and proper functioning of body. Malnutrition commonly affects all age groups in a community, but infants and young children are the most vulnerable because of their high nutritional requirements for growth and development. Globally 45% of the death among children under five of age are allied to under nutrition. 149 million children under age 5 years were estimated to be too short and 45 million were estimated to be wasted. Worldwide 2 billion people were affected with micronutrient malnutrition. In India 44% of small children under the age of 5 years were underweight. 72% of the infants and 52% of the married woman were suffering from the Fe deficiency. So, tackling micronutrient malnutrition is considered to be superlative investment that will generate a high return in socio-economic benefits and helps in increasing GDP of the country. There are several causes responsible for micronutrient malnutrition which includes lack of balanced diet, lack of good quality food, low concentration of micronutrient in cereals and poverty. There are different tactics for mitigating malnutrition in human beings which includes dietary diversification, artificial supplements, fortification and nutritional education. Among different types of fortifications biofortication through agronomic approach, can be the best way to increase the micronutrient levels in grains in a sustainable manner in which micronutrient fertilizer can be to the crop from the right source, at right time with right method which eventually increases micronutrient concentration in edible part of the cereal crops which will ultimately help in mitigating micronutrient malnutrition.

Keywords: Biofortification, fertilizers, humans malnutrition, micronutrient

1. Introduction

Malnutrition, defined as a serious public-health problem that has been linked to a substantial increase in the risk of mortality and morbidity. The term malnutrition generally refers to a deficiency of nutrition. Many factors can cause malnutrition, most of which relate to poor diet. The diets of the poor in developing countries usually consist of very high amounts of staple foods (such as, rice wheat and maize) but few micronutrient-rich foods such as fruits, vegetables, animals and fish products. Inadequate diet and disease, in turn, are closely linked to the general standard of living, the environmental conditions, and whether a population is able to meet its basic needs such as food, housing and health care. Malnutrition is thus a health outcome as well as a risk factor for disease and exacerbated malnutrition and it can increase the risk both of morbidity and mortality. Although it is rarely the direct cause of death (except in extreme situations, such as famine). There are different causes of malnutrition which include poverty, lack of balanced diet, lack of good quality food, lack of medical facility, lack of knowledge/illeratacy and low concentration of micronutrient in cereals. Micronutrients are essential for the normal growth of plants. Deficiencies of micronutrient drastically affect the growth, metabolism and reproductive phase in plants, animal and human beings. Wide spread deficiencies of micronutrients has been found in Indian soils. The number of people having insufficient Se intake is estimated to be between 0.5 and 1 billion people worldwide (Combs, 2001) [3]. About 3 billion people in the world are affected with micronutrient malnutrition. Nutrient sufficiency is the basis of good health, productive lives and longevity for everyone. Nutrient availability to people is primarily determined by the output of food produced from agricultural systems. If agricultural systems fail to provide enough food diversity and quantity to satisfy all the nutrients essential to human life, people will suffer, societies will deteriorate and national development efforts will stagnate. Importantly, plant foods provide most of the nutrients that feed the developing world.

Unfortunately, as a result of population pressures, many global food systems are not currently providing enough micronutrients to assure adequate micronutrient intakes for all people. This has resulted in an increasing prevalence of micronutrient deficiencies (e.g., iron deficiency, vitamin A deficiency, and iodine deficiency disorders) that now afflicts over three billion people globally mostly among resource-poor women, infants and children in developing countries. The consequences of micronutrient malnutrition are profound and alarming for human existence. Agricultural approaches to finding sustainable solutions to this problem are urgently needed. it is rarely the direct cause of death (except in extreme situations, such as famine), child malnutrition was associated with 54% of child deaths (10.8 million children) in developing countries in 2001. Billions of people around the world suffer from ‘hidden hunger’ or ‘micronutrient malnutrition. The diets of the poor in developing countries usually consist of very high amounts of staple foods (such as, rice wheat and maize) but few micronutrient-rich foods such as fruits, vegetables, animals and fish products. South Asia has the highest rates and by far the largest number of malnourished children in the world. Deficiency of Iodine (I), Iron (Fe) and Zinc (Zn) each affects about 35%, 40% and 33%, respectively, of the world population. So, tackling micronutrient malnutrition is considered to be best investments that will generate a high return in socio-economic benefits. There are several causes responsible for malnutrition which includes poverty, lack of balanced diet and good quality food, lack of medical facilities, lack of knowledge and low concentration of micronutrient in cereals. There are different approaches for mitigating malnutrition which include dietary diversification, artificial supplements, fortification, and nutritional education. Fortification is the practice of deliberately increasing the proportion of micronutrients in food, to improve its nutritional quality and thus public health. The fortification includes the mass fortification, home fortification, mandatory fortification and bio fortification. Biofortification is a process by which density of minerals and vitamins in food staples eaten widely by the poor's may be increased either through agronomic approach or through conventional plant breeding or through use of transgenic techniques. There are different constraints to genetic engineering, breeding approach as they are time consuming and costly. So, the best approach is agronomic approach, through which we can increase the micronutrient in grains in a sustainable manner.

Agronomic biofortification is of great importance in enriching seeds with Zn. Due to some degree of uncertainty whether the breeding strategy will be efficacious in enriching grains with Zn, the short-term agricultural tools like applying Zn fertilizers should be considered. In the target countries with high incidence of Zn deficiency, fertilizer strategy should be applied nationwide as a quick solution to the Zn deficiency problem in human populations. For the long-term, agronomic biofortification is a complementary approach to breeding strategy and is likely to be required for ensuring success of breeding efforts. In future, new research programs should be initiated focusing on development of most efficient Zn application methods for promoting Zn uptake and maximizing Zn accumulation in grain. Studying the bioavailability of grain Zn derived from foliar applications would be an important research topic in future. In case of greater bioavailability of the grain Zn derived from foliar application than from soil, Agronomic zinc (Zn) biofortification of food crops is an important complement to genetic Zn biofortification. Wheat, especially, has shown increased grain Zn concentration in response to soil and foliar applications of Zn- containing fertilizers (Cakmak *et al.*, 2010) [2]. Response of rice to Zn fertilization has been more variable than wheat, sometimes showing minimal effect of Zn fertilization on grain Zn content (Wissuwa *et al.*, 2008) [9]. The difference in physiology of Zn storage and grain- filling means that rice is more likely to transfer Zn taken up through the roots through the stem into the grain, making remobilization of Zn from leaves a less favourable mechanism, which means that Zn accumulated in the plant during the vegetative growth period or applied to rice leaves as foliar fertilizer may not reach the grain. There is apparent genetic variability within rice in the relative importance of root Zn uptake vs. leaf Zn remobilization (Wu *et al.*, 2010). Increasing the Zn and Fe concentration of food crop plants, resulting in better crop production and improved human health is an important global challenge. Among micronutrients, Zn deficiency is occurring in both crops and humans (Hotz and Brown 2004) [5]. Zinc deficiency in soils and plants is a global micronutrient deficiency problem reported in many countries (Alloway 2004) [1]. Zinc deficiency is responsible for many severe health complications, including impairments of physical growth system and learning ability, combined with increased risk of infections, DNA damage and cancer development. Plants emerging from seeds with low Zn have poor seedling vigor and field establishment on Zn-deficient soils. When seeds with low concentration of Zn are re-sown, the ability of the new crop to withstand environmental stresses at the early growth stages is greatly impaired. Convincing evidence about the role of Zn fertilizer strategy in improving grain Zn concentration in wheat (e.g., agronomic biofortification) has been obtained infield trials in Turkey. Applying Zn fertilizers to wheat grown in field in Central Anatolia improved not only productivity, but also grain Zn concentration. Depending on the application method, Zn fertilizers can increase grain Zn concentration up to three- or fourfold. The most effective method for increasing Zn in grain was the soil+foliar application method that resulted in about 3.5-foldincrease in the grain Zn concentration. The highest increase in grain yield was obtained with soil, soil+foliar and seed+foliar applications. When a high concentration of grain Zn is aimed in addition to a high grain yield, combined soil and foliar application is recommended. Alternatively, using seeds with high Zn concentrations at sowing together with foliar application of Zn is also an effective way to improve both grain yield and grain Zn concentration. Ozturk *et al*. (2006) studied changes ingrain concentration of Zn in wheat during the reproductive stage and found that the highest concentration of Zn in grain occurs during the milk stage of the grain development. Application of 2.0% ZEU with $Znso_4.7H_20$ recorded significantly higher Zn concentration in grain (23.0 mg/kg) and straw (177.7 mg/kg) of aromatic hybrid rice followed by 2.0% ZEU (ZnO). The Zn concentration in rice straw was 7-8 times higher than in grain. Application of ZEU was quite effective in rice because Zn was continuously absorbed by rice plant for longer period along with mineralized nitrogen and finally accumulated in to grain and straw (Shivay *et al.*, 2008) [8].

Table 1: Effect of Zn-enriched urea (ZEU) on grain yield and grain Zn concentrations of aromatic rice grown under field conditions in India

Treatments	Zn added (kg/ ha)	Grain yield (ton/ ha)	Grain Zn conc. (mg /kg)
Prilled Urea		3.87	27
0.5% ZEU	1.3	4.23	29
1.0% ZEU	2.6	4.39	33
2.0%ZEU	5.2	4.60	39
3.0%ZEU	7.8	4.76	42

Pooniya *et al.*, (2009) [7] observed that the 2% ZEU (ZnSO4.H2O) is an excellent source of N and Zn for improved productivity of *Basmati* rice. The maximum concentrations of Zn in *Basmati* rice grain and straw was recorded with 0.2%foliar spray of ZnSO4.H2O. Increased Zn concentrations in food crops resulted in better crop production and would lead to improved human health (Table 2).

Table 2: Zinc fertilization on yield and Zn concentrations of *Basmati* rice (pooled data of 2 years).

Treatment	Zn concentration in grain (mg/kg)	Zn concentration in straw (mg/kg)
Zinc fertilization treatment		
Absolute control (no N/Zn)	16.2	125.4
Control (only N)	18.0	149.3
2.0% ZEU* ($ZnSO_4.H_2O$)	23.4	175.7
2.0% ZEU* (ZnO)	21.4	171.3
5 kg Zn/ha ($ZnSO_4.H_2O$)	22.1	169.3
5 kg Zn/ha (ZnO)	20.5	155.0
ZnO slurry	19.2	149.9
0.2% Foliar spray ($ZnSO_4.H_2O$)	24.1	178.5
S.E.m±	0.22	0.94
CD (5%)	0.61	2.67

Davari *et al.*, (2012) [4] studied the effect of different organic material concentration on the micronutrient concentration in the grain and observed that the combinations of FYM + RR+ B and VC + RR + B were at par and significantly increased N, P, K, Zn, Cu, Fe and Mn concentration in wheat grain over control. The increase in the nutrient concentration with FYM + RR + B or VC + RR + B was higher as compared to those obtained with other nutrient combination (Table 3).

Table 3: Effect of organic materials and bio fertilisers on nutrient concentration of wheat grain

Treatments	Grain yield (t/ha)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
CONTROL	2.64	43.3	6.2	30.1	32.2
FYM	4.32	45.3	7.3	32.3	35.7
VC	4.65	46.1	7.8	33.4	36.3
FYM+RR	4.86	45.7	7.6	33.7	36.7
VC +RR	5.19	47.1	7.8	35.6	37.6
FYM+RR+BF	5.37	47.4	8.2	36.3	38.6
VC+RR+B	5.55	48.3	8.5	37.5	39.8
S.EM ±	0.11	1.29	0.28	1.94	1.14
CD (5%)	0.36	3.97	0.86	5.99	3.51

Further, for mitigating micronutrient malnutrition at worldwide a Harvest plus zinc fertilizer project was Started by CGIAR 2002, a micronutrient project on zinc, with following objectives:

- To assess the potential of crop response to zinc containing fertilizers, in number of countries where soil is unable to produce stable food with adequate zinc.
- To promote and disseminate the practical and theoretical knowledge and experience during the project

Agronomic and human nutritional benefits resulting from use of micronutrient enriched seeds which include

- Improving a biotic stress tolerance
- Increasing resistance to diseases
- Higher yield
- Improving human nutrition

Therefore, it may be concluded that applying micronutrient fertilizer to the crop from the right source, right time and right method increases micronutrient concentration in edible part of the cereal crops which will ultimately help in mitigating micronutrient malnutrition.

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