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# Rice biofortification: A brief review

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**Abstract**
Green revolution significantly enhanced the productivity and achieved the food security problem of developing nations like India, but in terms of dietary diversification it is far away from the developed nations. About half of the global population reported to have deficiency of Zn, Fe and vitamin-A leading to impaired immune function, iron deficiency anemia and xerophthalmia respectively. To overcome the problems of micronutrient deficiencies, people advised to be cautious about the diversification of their daily diet, but most of the people can't afford to supplement their diet due to poor economic condition. Biofortification of staple crops like rice and wheat got significant scope to solve the problems of nutrient deficiencies. Agronomic biofortification of crops has advantages of cost effectiveness, rapid result, accessibility and ease in application of agro-techniques over breeding and biotechnology based biofortification. There are different agronomic biofortification methods i.e. variability in method of nutrient application, dose of nutrition, sensitive crop stages for nutrition, use of biofertilizers or plant growth promotors and minimum or zero tillage practice.

**Keywords:** rice, micronutrient deficiencies, biofortification, agronomic biofortification, anemia, crop diversification, food security

## Introduction
There was a trending population explosion after independence but no significant increase in food grain production to feed them led to food grain insufficiency. During green revolution era (1965-70) the introduction of high yielding varieties (HYV's) which are highly fertilizer responsive solved the problem of food grain insufficiency and the food grain production has now increased up to 257mt in India from 50.8mt during 1950-51. During pre-green revolution period the poverty was the major issue but it has been shifted to micronutrient malnutrition now-a-days i.e. night blindness, xerophthalmia, Iron deficiency anaemia etc. The main cause for this prevalence may be blamed to rare dietary diversity (Fig. 1) in under-developed and developing nations.

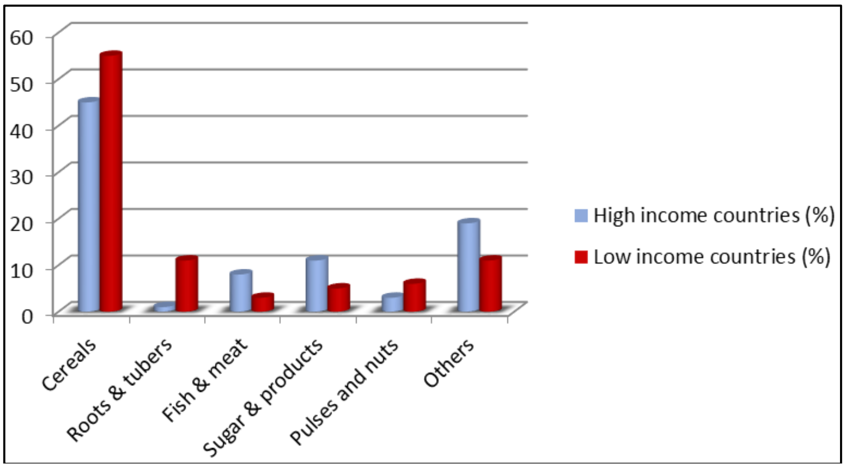


**Fig 1:** Dietary diversity by sources of dietary energy (FAO, 2008)

From the figure it is clearly observed that in low income countries they consume more cereals but less animal originated products like fish and meats and in other hand high income countries their proportion of energy source from other parts is higher than low income countries showing their diversity in foods**.** This imbalance in diet plan leads to micronutrient deficiency.

**Zinc deficiency scenario**

Zn is deficient in 50% of the world's agricultural soils and is recognized as the world's most critical micronutrient deficiency in crop. About 2 billion people in the world suffer from Zinc deficiency and near about 1.5 million children die each year from Zinc malnutrition. Globally, about 0.8 million people and nearly about 0.45 million children are at risk of dying each year from Zinc deficiency (WHO, 2015) [15].

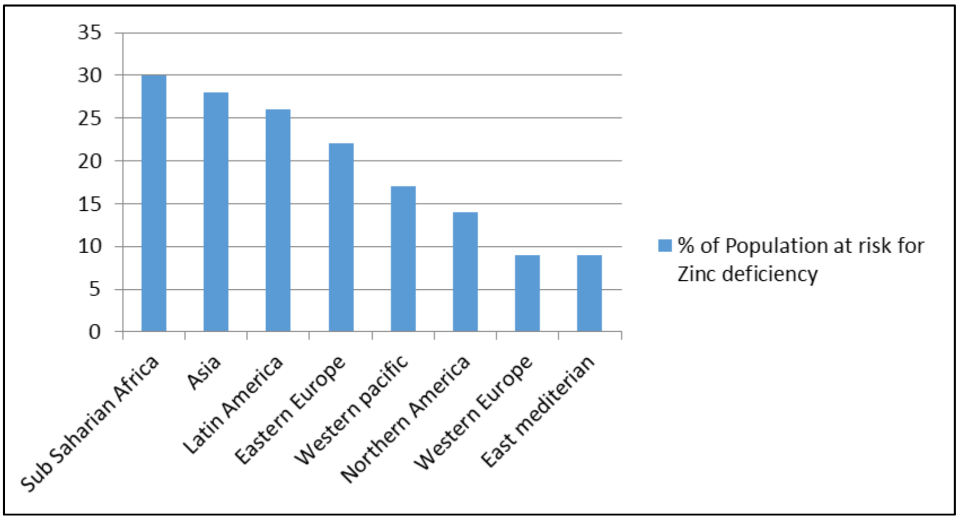


**Fig 2:** Global Zn deficiency scenario

India has one of the highest rates of Zn deficiencies in soils and diet of people. 50% of Indian soils are Zn deficient, rising to 63% by 2025 if no management is done. About 0.15 million children die each year in India due to Zn deficiency. Lack of Zinc is contributing to cases of diarrhea, 25% of global diarrhea deaths amongst children under the age of 5 (IZA, 2014) [4]. Zn fortification in staple food could save the lives around 48,000 Indian children per year (WHO, 2015) [15].

**Vitamin-A deficiency**

Vitamin-A deficiency causes night blindness and Xerophthalmia. Xerophthalmia (xeros = dryness; ophthalmia = pertaining to the eye) is the deficiency of serum (plasma) retinol concentrations (<0.35 µmol/l) (Hotz *et al*. 2007) [3]. Periodic vitamin A delivery in the community has been shown to reduce the risks of xerophthalmia (by ~90%) and mortality (by ~23–30%) in young children (WHO, 2009) [13].

**Iron deficiency anemia (IDA)**

*IDA* contributes 50% of global anemia (WHO, 2008) [14]**.** This is a common global health problem affecting developed as well developing countries**.** It occurs at all stages of the life cycle, but is more prevalent in pregnant women and young children. IDA can lead to maternal haemorrhage and is associated with 20% of all maternal death. The main risk factors for IDA include a i) Low intake of iron and poor absorption of iron from diets, ii) Diet containing high in phytate or phenolic compounds, and iii) Period of life when iron requirements are especially high (i.e. growth and pregnancy).

**Nutrition gap**

Recommended daily intake of vitamin A, Fe and Zn are 600µg, 15mg and 15mg respectively (RDA, 1989) [9]. Swarna is the most widely grown and consumed rice variety in India which constitutes 0.78mg Fe/100g white rice and 2.28mg Zn/100g brown rice. By consuming twice or thrice a day taking 100-150g rice/meal a person can get hardly 2-3mg Fe and 7-8mg Zn which is 1/5$^{th}$ and half of the recommended daily intake of Fe and Zn respectively.

**Approaches to relieve Zinc, vitamin-A and Iron deficiency**

There are several approaches can be taken to overcome the problems of micronutrient malnutrition, those may be chalked out as;

1. **Change of Diet**: Every person should have an idea of diversified diet and its importance and they shouldn't limit their diet with some specific crops only which may lead them to different malnutrition and may hamper their biochemical and physiochemical processes.
2. **Supplementation**: There are different packaged foods now available in market which are supplemented with some micro nutrients like Iodine, Iron, Zinc etc. to supplement human diet but they are rather costlier which rarely accessed by peoples of poor economic background.
3. **Bio-fortification**: This is the nutrient enrichment of mostly accessed food crops by people.

Three billion people having daily income less than 2US$ and 1.5 billion less than 1US$ cannot afford a diversified diet or industrially produced supplements. Saving one healthy life costs as little as $US 0.73-7.31 if both wheat and rice get biofortified.

**What is Biofortification?**

Biofortification is the development of nutrient dense staple food crops using the best conventional breeding practices and modern biotechnology, without sacrificing agronomic performance and important consumer preferred traits. Biofortification focused on making plant foods more nutritious as the plants are growing. In conventional fortification nutrients are added to the foods as they are being processed (Nestel *et al*., 2006) [8].

**Options for bio fortification**

There are several options for biofortification, among which genetic and agronomic biofortification are mostly used. Agronomic biofortification alternatively termed as ferti-fortification. Ferti-fortification, a term coined by Prasad (2009) [10] involves fertilizing crops with micronutrients. It gives immediate results and in, general, goes well along with an increase in yield. Biofortification may therefore present a way to reach populations where supplementation and conventional fortification activities may be difficult to implement and/or limited.

**Examples of biofortification projects include**

1. Iron-biofortification of rice, beans, sweet potato, cassava and legumes;
2. Zinc-biofortification of wheat, rice, beans, sweet potato and maize;
3. Provitamin-A carotenoid-biofortification of rice, sweet potato, maize and cassava;
4. Amino acid and protein-biofortification of maize, sorghum and cassava.

There are some biofortified crops which are released for Asian countries;

- Iron and Zinc fortified pearl millet for India (2012)
- Zinc fortified rice for India and Bangladesh (2013)
- Zinc fortified wheat for India and Pakistan (2013).

**Reason for rice biofortification**

Rice is a staple food crop for more than a billion people. The rice endosperm (starchy and most edible part of rice seed) is deficient in many nutrients including vitamins, proteins, micronutrients etc. The Aleurone layer of dehusked rice grain is nutrient reach but is lost during milling and polishing. Unprocessed rice becomes rancid i.e. smelly or unpleasant in taste. Rice supplies 30-50% of daily calorie intake. Rice farming is the major source of employment in most of the part in India and globally. Rice plays an important role in food security for its wider adaptability.

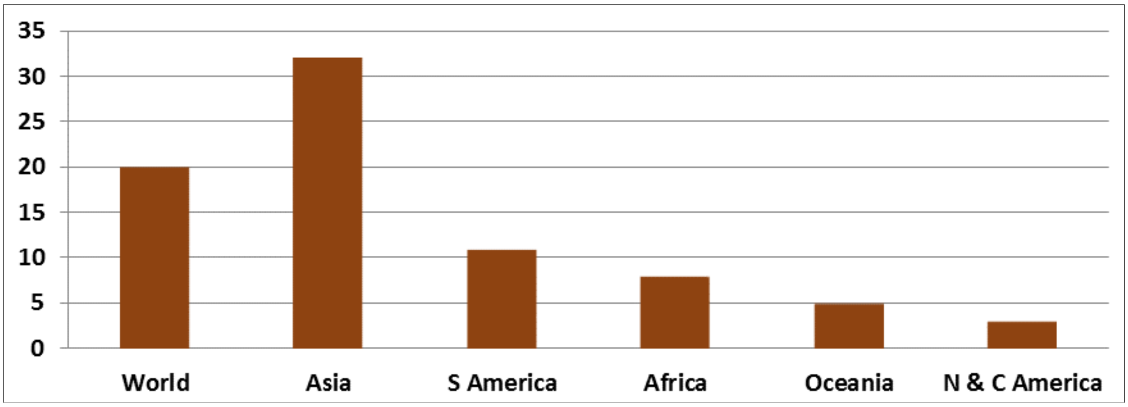


**Fig 3:** Rice calorie supply as % total calories (by region)

**Different losses of nutrients in rice grain**

Rice endosperm, Embryo and bran contain 32%, 13% and 55% of Iron respectively and they also contain 57%, 9% and 34% of Zinc respectively. During de-hulling, polishing and cooking about 20.7%, 17.05% and 36.61% Zn loss occurs. Rice is mainly grown in flooded soil where zinc is not much available to the crop as they bound to sulphur and carbonate in reduced condition.

**Golden rice - A GM food crop**

It is a genetically modified provitamin A (β-carotene) enriched rice genome. All the credits of golden rice go to Rockefeller foundation, EU and the Swiss federal institute of technology**.** Professor Ingo Potrycus and Dr. Peter Beyer considered as the founder of β-carotene enriched golden rice. They used *crtl gene* from soil bacterium (*Agrobacterium tumifascience)* and *Daffodil* gene for modification of the genetic makeup. Golden rice cannot be achieved by breeding. There are two grades of golden rice;

- Golden rice1 (SGR1): Promoter is modified here and it contain 5-7µg β-carotene per gram of rice.
- Golden rice2: Replacement of daffodil Pys with maize gene and contain 31 µg β-carotene per gram of rice.

**Some β - carotene enriched popular rice varieties are**

- **IR 64, IR 36**: Mega varieties with broad Asian coverage
- **BRRI dhan 29**: The most popular *boro* rice variety in Bangladesh
- **PSB Rc 82**: The most popular Rice variety of Philippines
- **OS 6561**: Most popular in Vietnam
- **Chehirang**: Leading variety in Indonesia
- **Swarna**: Important in India.

**Agronomic approaches to biofortification**

Major agronomic approaches to biofortification are Fert-fortification, tillage and use of Plant growth promoting rhizobacteria and cyanobacteria. Ferti-fortification includes different strategies like source of nutrients, amount of nutrient application and time of nutrient application.

Li *et al* (2007) [5] found that wheat plants applied with recommended dose of N and K from fertilizer sources have higher grain and straw Zn and Fe concentration as compared to control, PK, NP, NPK, ½ org fertilizer + ½ N and Org fertilizer source. Pooniya and Shivay (2011) [9] reported that foliar application of zinc sulphate (0.2%) gave higher grain and straw zinc concentration followed by application of 2% ZEU (zinc enriched urea) in basmati rice. Shivay *et al* (2008) [12] found that increase in zinc application increased zinc concentration on rice and wheat grains but the optimum level of zinc application they didn't suggested, so it needs further experiment to find out where is the optimum level of application. Chakmak *et al.* (2010) [1] found from the experiment conducted to find out in which stages the efficiency of zinc foliar application is more to fortify the wheat grain and found that single or double application may not be beneficial rather that much of dose can be split applied in different growth stages to have greater effect. From the experiment they got the result that foliar zinc treatment on stem elongation, booting, milk and dough stage increase the grain zinc concentration significantly. From the experiment of Yilmaz *et al*. (1997) [16], it can be observed that combined soil and foliar application of zinc gave higher zinc concentration in grain and shoot followed by seed and foliar application rather than single application as soil, seed and as foliar.

Tillage has also significant influence on nutrient content and uptake of plants. Lindsay and Norvell (1978) [9] reported that DTPA extracted Zn was higher in no tillage and DTPA extracted Fe was higher in minimum tillage condition than conventional tillage practice, which may be due to stabilized soil aggregation and optimization of soil health. They also found that the effect of soil tillage on the Fe and Zn concentrations in the last expanded leaf of sorghum plants was in favor of minimum tillage practice than no tillage and conventional tillage. Plant growth promoting rhizobacteria has also reported to be significantly affecting Fe and Zn enrichment in plants. Rana *et al*. (2012) [11] observed that recommended doses of fertilizers combined with *Providentia sp.* (plant growth promoting rhizobacteria) show the extreme result provoking the dominance of the treatment over other treatments to accumulate iron and zinc in wheat grain.

There are different nutrient enriched crops have been developed since 2007, some of which are mentioned in Table 1.

**Table 1:** Different nutrient enriched crops release year of initial lines

| Crop | Nutrient | Release year of Initial line |
|---|---|---|
| Sweet potato | Pro vit. A | 2007 |
| Bean | Fe, Zn | 2011 |
| Pearl millet | Fe, Zn | 2011 |
| Rice | Fe, Zn, Pro vit. A | 2012 |
| Maize | Pro vit. A | 2013 |
| Wheat | Fe, Zn | 2013 |
| Cassava | Pro vit. A | 2014 |

## Advantages and limitations of rice biofortification

Rice biofortification have certain advantages i.e. increase in nutritional value, reduced adult and child micronutrient caused mortality, reduced dietary deficiency diseases and healthier population with strong and quick immune responses to infections. With these advantages, biofortification of rice has also certain limitations i.e.

1. High production cost i.e. equipments, technology, patenting etc.
2. Potential negative interaction of biofortified rice on other plants/ non- GM rice crops causing loss of wild type rice varieties.
3. Low substantial equivalence i.e. inability to provide high micronutrient and protein content compared to supplements.
4. Poor rural populations have limited access and resources to purchase biofortified rice.
5. Genetic engineering methods used may compromise immunity in humans i.e. introduced increased risk of allergenicity.

## Conclusion

Awareness of dietary diversity must be followed up to alleviate micronutrient malnutrition. As people of under developed nations cannot afford to supplemented and diversified foods, research and development of nutrient enriched biofortified crops should carried out to face this problem. There are several aspects of biofortification but agronomic aspect (Ferti-fortification) is simpler one and is mostly followed. The concept of food security therefore may be now a day well defined as Access of nutritious foods at an adequate amount.

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