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Biofortification of Crops to Address Global Zn Deficiency

S. Sheelamary[1], K. Lakshmi[2] and G.K. Sujayanand[3]
[1] Scientist, Division of Crop Improvement,
ICAR-Sugarcane Breeding Institute, Coimbatore
[2] Senior Scientist, Division of Crop Improvement,
ICAR-Sugarcane Breeding Institute, Coimbatore
[3] Scientist, Division of Plant Biotechnology,
ICAR-Indian Institute of Pulses Research, Kanpur
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Introduction:

Bio-fortification is a strategy related to food in order to address widespread deficiencies of vitamin A, iron, and zinc. These deficiencies are more prevalent in low income countries. Bio-fortification is primarily targeted to the rural poor population as they rely on the local foods as their primary source of nutrition. Bio-fortification is considered as complementary to other micronutrient deficiency prevention strategies. This is because they are suffering financially to avail the commercially processed fortified foods. Bio-fortification, the increase of micronutrients in the edible parts of the plants, can be achieved by either mineral fertilization or plant breeding. Bio-fortification by mineral fertilization is a common practice in some countries that applied selenium-containing fertilizers as a short-term solution. Bio-fortification, the process of breeding nutrients into food crops, is a cost-effective, feasible means of delivering micronutrients to populations who may have limited access to diverse diets, supplements or commercially fortified foods. Crops bred for higher levels of micronutrients using conventional breeding methods have been released in several countries, and are now being grown and eaten by farmers and consumers. So far, it seems a sustainable and cost-effective approach for reaching bio-fortification in zinc and iron.

Bio-fortification is a modern technology to improve the nutritional value of the products by various breeding procedures like common selective breeding or by genetic engineering etc. The main objectives of this procedure is

- To improve the nutritional margin that helps the people who are suffering from malnutrition.

- To improve the protein and mineral content in the foods.
- Help the people who are suffering from disease like anaemia, deficiency of minerals etc.
- It is a modern technique to produce high production of crops which will make up the demand in population.

Importance of Zinc

Zinc is very important micronutrient for human health. Zinc performs exclusively large number of key functions; as it is important for human health, it is also called “metal of life”. Zinc behaves like anti-depressant to overcome the depression, for the patients suffering from Alzheimer's and Parkinson's diseases have lower blood zinc level and as a key role in the regulation of arterial blood pressure. It reduces the inhibition of hepatitis and liver problems. Zinc also regulates the thymus gland activity. Zinc, copper and magnesium deficiencies during pregnancy may cause infertility, congenital anomalies, pregnancy wastage. Zinc concentration also regulates the immune function. Deficiency aggravates the pathogen infection and disease.

Recommendation of dietary intake

Average daily recommended amounts for different ages are listed below in milligrams (mg): (NIH, US)

Life Stage	Recommended Amount	Life Stage	Recommended Amount
Birth to 6 months	2 mg	**Adults (men)**	11 mg
Infants 7–12 months	3 mg	**Adults (women)**	8 mg
Children 1–3 years	3 mg	**Pregnant teens**	12 mg
Children 4–8 years	5 mg	**Pregnant women**	11 mg
Children 9–13 years	8 mg	**Breastfeeding teens**	13 mg
Teens 14–18 years (boys)	11 mg	**Breastfeeding women**	12 mg
Teens 14–18 years (girls)	9 mg		

Availability of Zinc

Bioavailability of the zinc can be increased by hydrolysis of polyamines or by increasing the activity of phytase enzyme. Interaction between iron and zinc is also affects the zinc bioavailability. High dose of inorganic iron greatly reduced the zinc uptake as

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estimated by plasma changes. Increased protein uptake also tends to increase the zinc absorption because proteins have positive effect on zinc absorption. Zinc is found in a wide variety of foods. Animal source proteins like beef, chicken, cheese and eggs improves the zinc bioavailability, and possibly, amino acids released from proteins keep the zinc in solutions or protein binds with phytate. Red meat, an excellent source of zinc particularly great source, but more amounts is found in all kind of meat including beef, lamb and pork. Shellfish are healthy, low calorie source of zinc. Legumes are also rich in zinc especially in chickpea, lentil and beans. Hemp seed are healthy addition to the diet and can help in zinc intake. Eating pine nuts, peanuts, cashews and almonds are used to boost the zinc intake. Nuts are healthy diet which offers fats and fiber and other vitamins and minerals. Dairy products like milk and cheese provide a host of nutrients. Milk and cheese are the notable sources of zinc which contains high amount of available zinc which can be easily absorbed by the body. Eggs contains moderate amount of zinc which can meet our daily demand. Whole grains like wheat, quinoa, rice and oats contain some zinc. However like legumes, grains also bind with the phytates which in turn reduces its absorption by the body. Whole grains contain more zinc than the refined ones. Generally fruits and vegetables are poor sources of zinc. But some vegetables like potato, green beans are a good source of many important nutrients like fiber, B vitamins, magnesium, iron, phosphorous, manganese and selenium. Dark chocolate can be a source of zinc. However, it is also high in calories and sugars and can be eaten in moderation and not as a primary source of zinc.

Food supplements

This is the way of consumption of micronutrients in the form of pills, powders and solutions. This will be supplemented when the diet cannot provide an adequate amount of nutrition. Supplements can be given in to improve the health in a short term basis. Folic acid, iron and zinc supplements have been helpful for children and pregnant women; however, this method is not cost-effective, especially for low-income consumers. Supplementation is a relatively cost-effective method. Supplements for folic acid, zinc, and iron could show different physiological responses and absorption than consuming them in food.

Agronomic bio-fortification

Agronomic bio-fortification is one of the major agricultural strategies to enhance the grain concentration of micronutrients. Application of iron sulphate ($FeSO_4$), zinc sulphate ($ZnSO_4$) and as alone or in combination either soil and foliar application increased the height of plants, number of tillers, spike length, number of spikelets per spike, number of grains per spike, thousand grain weight, economical yield, biological yield and harvesting index, calcium, magnesium, iron, zinc, copper and protein contents. Among different Zn and Fe concentrations applied either soil supplement or foliar spray, combine foliar spray of 0.5% $ZnSO_4$ and 1% $FeSO_4$ significantly improved the maximum growth or quality attributes of wheat. Bio-fortification is one of the major agricultural strategies to enhance the concentration of micronutrients in grains to minimize the malnutrition. Combination of Zn and Fe as foliar spray (0.5% $ZnSO_4$ and 1% $FeSO_4$) increased the yield traits of wheat crop as well as quality parameters of grains. Foliar application method is more appropriate for availability of nutrients to plants for optimum growth as compared to soil application method. Combined application of Zn and Fe (0.5% ZnSO4 and 1% FeSO4) through foliar spray is recommended to enhance the productivity of wheat crop with good quality of grains

Industrial fortification

Industrial fortification is described as the addition of micronutrients in different foods during industrial processing. The World Health Organization recommends the addition of zinc to wheat and maize (also known as corn) flours. However, the addition of this micronutrient to foods has generally been confined to infant formula milks (in the form of zinc sulphate), complementary foods and ready-to-eat breakfast cereals. In some countries, such as Indonesia, it is mandatory to add zinc to wheat noodles, while other countries like Mexico have voluntary fortification programmes where zinc and other micronutrients are added to wheat and corn flours used for preparing bread and tortillas, milk and food supplements provided in social programmes. More recently, several Latin American countries have expressed some interest in fortifying cereal flours with zinc. According to the Food Fortification Initiative in 2012 at least 20 countries had mandatory zinc fortification for wheat flour, and three countries had it for maize flour, although the level of implementation varied among countries. From a public health perspective, mandatory fortification of staple foods with zinc has the potential to reach everyone in a population, particularly vulnerable groups. Effective fortification of staple foods with zinc can help ensure access and equity to adequate zinc in the diets of all children and women, especially those who are less well off.

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Crop Bio-fortification with Zn

Bio-fortification is different from fortification because in former Zn concentration of the edible parts is increased either through agronomic practices or through different breeding strategies, while in later Zn nutrients are added in foods during industrial processing. Bio-fortification is most appropriate intervention to overcome the malnutrition due to higher acceptability, affordability, sustainability and lower associated disability adjusted life years. Maize is one of the leading cereal crops with reference to production, and it is very popular due to diverse functions. Maize kernels can be consumed as parched, fried, boiled, roasted, fermented and ground for use in making of breads, tortillas, gruel, porridges, cakes and alcoholic beverages. In maize kernels, germ contains almost 80% of the kernel's minerals, while endosperm contains <1% only. Zinc is important mineral with the context of malnutrition, and this mineral also has significant variability in maize. Average zinc contents of maize kernels are 20 µg/g, and 30% of these are located in the endosperm. Per capita consumption of maize is 290 g/day in women and 170 g/day in children of 4–6 years in the African countries where maize is consumed as staple food crop. Therefore, it could be inferred that based on the kernel zinc variability and per capita consumption of maize, this is suitable crop for zinc biofortification.

Bio-fortification through plant breeding is a sustainable approach to improve the nutritional profile of food crops. Bio-fortification to improve the nutritional profile of crops has increased importance in many breeding programs in the past decade. The key micronutrients targeted have been iron, zinc, selenium, iodine, carotenoids, and folates. In recent years, several bio-fortified crops including common beans and lentils have been released by Harvest Plus with global partners in developing countries, which has helped in overcoming micronutrient deficiency in the target population.