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Biofortification of Crops to Overcome Malnutrition in India

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Abstract

About 33 percent of the global population is being witnessed with malnutrition or hidden hunger due to the deficiency of micronutrients *viz*., Iron, Zinc and Iodine and also Vitamins. There are variety of reasons which are responsible for deficiency of micronutrients in the food grains *viz*., cultivation of crops in deficient soils, problem soils like calcareous or alkali soils, poor fertilizer application, continuous application of straight fertilizers, mono cropping, high cropping intensity, poor application of organic manures, loss of nutrient during processing of food grains *etc*. Biofortification can ensure availability of food grains rich in minerals and vitamins which is possible by conventional breeding, genetic engineering, agronomic management techniques and proper post harvest processing methods. Through mass multiplication of biofortified varieties of staple food grains and creating awareness among the farmers, malnutrition of the people can be reduced and immunity can be improved.

Introduction

United Nations has set a goal to achieve zero hunger by 2030. Malnutrition other way called as hidden hunger affect around 33 percent of global population. It is mainly due to the deficiency of micronutrients which severely affects economic development of every country. Particularly Iron, Zinc, Iodine and Vitamin A deficiency affects major population of the world specifically in South East Asia and Africa. Iron deficiency impairs physical and mental health while Zn deficiency affects the immune system in children. Actual recommended dietary allowances as per ICMR recommendation is given in Table 1.

Reasons for the Mineral Deficiency in Food Grains

1. Cultivation of Crops in Deficient Soils

All the edible crops supply micronutrients but application of straight fertilizers led to emergence of micronutrient deficiency in soils which led to poor uptake of micronutrients and ultimately deficient situation in plants. It is mainly due to the intake of food crops deficient in micronutrients that are grown on soils deficient in micronutrients. Sandy soils are poor in fertility and retain less. Red black calcareous soils are rich in calcium carbonates and convert the Fe into insoluble Fe carbonates. Alkali soils have higher pH (> 8.5) which led most of the micronutrient unavailable to crops.

2. Value Addition and Processing of Food Grains

Rice is the dominant cereal staple food of most of the world's population. However, rice is a poor source of many micronutrients, especially iron and zinc which are

Table 1: Daily requirements of Zinc and Iron in Indian context (http://icmr.nic.in/final/rda-2010.pdf)

Group		Recommended daily allowance (mg/day)	
		Zinc	Iron
Adult med		12	21
Adult woman	Normal	10	17
	Pregnant	12	35
Children	1-3 years	5	9
	4-6 years	7	13
	7-9 years	8	16
Adolescents	Boys	11-12	21-28
	Girls	9-12	26-27

essential for human beings. Huge consumption of rice with low Fe and Zn content found to be the major reason for Fe and Zn malnutrition among the rice consuming population. In rice, milling is common process of value addition to remove the rice bran. Iron and other micronutrients are deposited in higher concentrations in the outer layers. The polished rice contains an average of only 2 mg kg^{-1} Fe and 12 mg kg^{-1} Zn, whereas the recommended dietary intake of Fe and Zn for humans is 10-15 and 12-15 mg, respectively (Krupa *et al*., 2017). However, genotypic differences do exist with regard to the distribution of micronutrients in different layers of rice grain.

What is Biofortification?

Biofortification is the process of enriching the nutrient content and vitamins in edible crops to nullify the malnutrition among the global population through techniques like crop breeding, transgenic or agronomic management practices. Biofortification commonly employed in staple food crops. In north India, wheat and potato are common while in south India rice and vegetables are common. Mostly, biofortification aimed at enriching the mineral content of the dominant and staple food crops of that region which will easily adopted without altering food habits of the people.

Strategies Used in Biofortification

Current strategies in biofortification are mineral fertilization, breeding and transgenic approaches. Now-a-days, micronutrient content and genetic variations has been already documented in many cultivated crops. Mainly the leafy vegetables having higher bioavailable micronutrients specifically Fe found to be better option to alleviate the malnutrition of micronutrients.

Crop Biofortification

Increasing the content of one or multiple micronutrients in staple food crops is commonly aimed sing conventional breeding techniques and it ensures higher vitamin or mineral by the poor population they depend on the specific staple food crop. For example, HarvestPlus (https://www.harvestplus.org) involved in developing and distributing varieties of staple food crops like rice, wheat, maize, cassava, pearl millet, beans and sweet potato which have higher concentration vitamin and minerals. In India, Pearl millet, rice and wheat were aimed at higher Zinc and Fe.

1. Cereal Biofortification

Biofortification can enhance oil content, amino acid and protein content with little improvement in iron, zinc or Provitamin A in cereals. Rice is one of the most well studied cereals for mineral biofortification. Other than rice, many cereals like wheat, maize, sorghum, barley have been tried for biofortification with micronutrients and vitamins. Rice have been tried with enriching beta carotene, Folate, Iron, Zinc, amino acid etc. Researches show that enrichment of carotenoids, Provitamin A, Iron, amino acid etc have been tried with Wheat. Maize have been tried with the enrichment of Provitamin A, Carotenoid, Vitamin E, Vitamin C, Lysine *etc*. Barely has been tried with biofortification of Zinc. This shows that wide research is being continuously taking place to address the malnutrition.

2. Pulses Biofortification

India is the largest producer of the pulses and also the largest consumer on the global scenario. Due to its high protein, low in calorific value and glycaemic index, there is an increasing trend in consumption of pulses at global level. Pulses with other cereals provide good opportunity in the food industry. In recent times there is no much work on the biofortification of pulses when compared to cereals like rice, wheat and maize. Hence, there is a great scope for biofortification of pulses to reduce malnutrition among the rural people.

Breeding/ Genetic Manipulation/ Biotechnological Approaches

Biofortification through conventional breeding is the most accepted method of biofortification. Transgenic breeding is used when there is limited or no genetic variation in nutrient content among crop varieties. Researches are being carried out worldwide with biofortification using GM technology. Genetically modified golden rice in Philippines found to have elevated beta carotene which can be easily converted to Vitamin A in human being. Biofortified sorghum has been developed using GM technology in Kenya which has higher amino acid, protein, vitamin A, vitamin E and zinc.

Agronomic Interventions

Agronomic biofortification is the application of micronutrients through chemical fertilizer by means of soil application, foliar application, seed/ coating with fertilizers to enhance the concentration of nutrients in edible parts of crops. Soil application of micronutrients has the very less use efficiency. Researchers found that foliar application of zinc sulphate and iron sulphate can increase the Zn and Fe contents in seeds, a simple and effective option to increase grain Zn and Fe and productivity which can combat the Zn and Fe malnutrition India.

Biofortification of Multiple Elements

Research evidences shows that in the regions of major staple food with rice, found to be with zinc, iodine, iron and selenium malnutrition among the people. Hence, increasing concentrations of these micronutrients in rice grain can solve the hidden hunger.

Biofortified Crop Varieties to Build Nutritional Immunity in India

The focus has been on the development of high yielding varieties primarily to feed the ever increasing population. Till now more than 5600 varieties of different crops have been released of which numbers of biofortified varieties are negligible. These biofortified varieties assume great significance to achieve nutritional security of the country. Many crops with biofortified varieties (Table 2) have been released in India (Gulave and Kshirsagar, 2020).

Table 2: Biofortified varieties released in India

Sl. No.	Crop	Mineral content	Variety
1	Rice	Protein - 10.3%	CR Dhan 310
		Zinc - 22.6 ppm	DDR Dhan 45
2	Wheat	Zinc - 42.0 ppm	WB 02
		Iron - 40.0 ppm	
		Zinc - 40.6 ppm	HPBW 01
		Iron - 40.0 ppm	
3	Maize	Provitamin A - 8.15 ppm	Pusa Vivek QPM9
		Lysine - 2.67%	
		Tryptophan - 0.74%	
		Tryptophan - 0.91%	Pusa HM 4 improved (Hybrid)
		Lysine - 3.62%	
		Tryptophan - 1.06%	Pusa HM 8 improved
		Lysine - 4.18%	
		Tryptophan - 0.68%	Pusa HM 9 improved
		Lysine - 2.97%	
4	Pearl millet	Iron - 73.0 ppm	HHB 229
		Zinc - 41.0 ppm	
		Iron - 73.0 ppm	AHB1200
		Iron - 81.0 ppm	Phule Dhanshakti
		Iron - 87.0 ppm	Phule Mahashakti
5	Barnyard millet	Calcium - 452.5 ppm	Phule Bharti 1
6.	Lentil	Iron - 65.0 ppm	Pusa ageti massor
7	Mustard	Erucic acid - < 2.0%	Pusa mustard 30
		Erucic acid - < 2.0%	Pusa double mustard 31
		Glucosinolates - < 30.0 ppm	
8	Cauliflower	Beta carotene - 14.0 mg/ 100 g	Pusa Beta Kesari 1
9	Potato	beta carotene - 90.0 mg/ 100 g	Bhu sona
10	Sweet potato	Anthocyanin - 90.0 mg/ 100 g	Bhu krishna
11	Tomato	Beta carotene - 5.93 mg/ 100 g	Phule kesari

Sl. No.	Crop	Mineral content	Variety
12	Pomegranate	Iron - 5.6-6.1 mg/ 100 g	Solapur lal
		Zinc - 0.64-0.69 mg/ 100 g	
		Vitamin - 19.4-19.8 mg/ 100 g	
13	Mango	Beta carotene and vitamin C	Pusa surya, Pusa pitamber

Limitations and Challenges in Biofortification

Agricultural and nutrition science should go side by side for the greater success of biofortification. Transgenic crops face more regulatory procedures compared to their conventionally bred crops. Most biofortified crop varieties are not popular throughout the country. Consumption of different crops in different region makes the limited success and distribution of biofortified crops.

Conclusion

Malnutrition persists in many developing countries which pose a great challenge to the normal well being of people. Biofortification is a vital option to ensure the availability of food grains rich in minerals and vitamins to the people affected by malnutrition. Biofortification is possible by variety of techniques *viz*., conventional breeding, genetic engineering and agronomic management techniques to enrich the nutrient concentration in food grains and also post harvest processing techniques to avoid losses during value addition. Already researchers have developed biofortified varieties of many crops but the awareness to be created among the farmers and seeds of fortified crop varieties should be made available for cultivation. Enriching the staple food grains with micronutrients and vitamins is the effective way to address human malnutrition and to build nutritional immunity in India.

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