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Insights into the Biofortification of Zinc and Iron in Rice

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Abstract

Combating malnutrition and achieving zero hunger is the need of the hour. Rice, being a staple food crop of more than half of the world, should be enriched with essential micronutrients. Zinc and Iron are the most essential micronutrients. Hence, to enrich the food crop with critical micronutrients, Biotechnology comes into the picture and facilitates by a technique called Biofortification. In this review, we aim to bring together some insights into the generation of biofortified rice, with an emphasis on Iron and Zinc. We also addressed the conventional and modern methods of biofortification, along with the scope and future perspectives.

Keywords: Rice; Biofortification; Iron; Zinc; *Oryza Sativa*

Introduction

Rice *(Oryza sativa)* is the staple food around the world, particularly in Asia, which is a major source of nutrition and dietary energy that accounts for 90% of global rice consumption. Rice has immense diversity, and it is estimated that more than 100,000 varieties of rice exist in the world [1]. India has an ancient heritage of rice cultivation and has over 70,000 cultivars of rice germplasm [2]. There are about 23 rice species that includes *Oryza sativa L.* which is cultivated in Asia that is further differentiated into indica and japonica subspecies [1] and *O.glaberrima Steud.* is cultivated in West Africa [3]. Nutritional enrichment can be defined as the process of increasing the nutritional content and number of vitamins and minerals like zinc, iron, carotenoids and provitamin A that improves nutritional quality in a staple crop like rice *(Oryza sativa)* by using certain biotechnological approaches that includes conventional plant breeding, agronomic practices or by using transgenic approaches.

The micronutrients like zinc (Zn) and Iron (Fe) are very important for the growth and development of plants and animals. But around, 50% of the world's population suffer from micronutrient deficiency of zinc, iron, selenium, calcium and magnesium and these deficiencies are leading to many health issues like malnutrition, dietary modification and diversification, supplementary nutrient supply, etc..,. Besides there are also certain macronutrient deficiencies that includes carbohydrates, proteins (essential amino acids), fats (essential fatty acids), macrominerals and water [4]. However, Zinc deficiency (ZnD) is one of the most common micronutrient deficiencies that mainly occurs due to poor diet and poor soils. It was first discovered in the 1960s and today, approximately one-third of the world's population is zinc deficient [5]. In humans, zinc deficiency is one of the major causes of malnutrition and it also leads to an increased risk of death from diarrhea, stunting, and hindered cognitive development [6]. Whereas in plants, Zinc is transported into crop plants directly from the soil, either in the form of Zn^{2+} or bound to an organic acid and thus accumulate in the roots of plants and then become translocated through the xylem to the shoots and leaves. Increased zinc concentrations in storage roots have been achieved by overexpression of the *A.thaliana* zinc transporters *AtZIP1* and *AtMTP1*, but shoot development in transgenic plants is impaired [7].

Zinc plays a vital role in growth and development of plants that includes membrane function, photosynthesis, gene expression, synthesis of hormones and protection against drought and pathogens. zinc is found at high levels of accumulation in seeds, indicating its importance in fertility [8]. Zinc deficiency in plants may lead to stunted growth and exhibit chlorosis on their leaves. Iron (Fe) deficiency in humans is one of the most common and severe micronutrient health interventions. Deficiency of iron causes IDA (Iron Deficiency Anemia) that has serious effects on health of children as well as pregnant women that leads to impaired cognitive development in children and premature births, mortality in women etc. IDA affects 32.9% of the world population, with the risk of being high anemic in Saharan Africa and South Asian countries [9]. Thus, enough iron content in rice would help to maintain the health of pregnant women and children in developing countries. Iron content in plants can be increased by changing soil conditions such as pH, moisture content, and aeration and through fertilizer application. Macronutrient content which is present in the soil also plays an important role in enhancing iron content in plants. [10,11] reported that Fe fertilizer through foliar application increases iron uptake and efficient translocation into the rice as compared to soil fertilizer.

Biofortification in crop plants is one of the effective ways to combat these prevailing nutrient deficiencies. The international multidisciplinary Harvest Plus (Biofortification Challenge) program has played a vital role behind the expansion of biofortification which was launched in 2004 by the Consultative Group on International Agricultural Research (CGIAR) and the International Food Policy Research Institute (IFPRI) [12,13]. The key intention of this project was to develop biofortified crops that are rich in zinc, iron, and vitamin A to overcome nutrient deficiencies in developing countries like Africa and Asia. Before 1999 when golden rice was first biofortified as a staple crop by genetic engineering to tackle vitamin A deficiency, only conventional biofortified crops were investigated [14]. Later, transgenic biofortification approach for different cereal crops is used globally to overcome nutritional deficiencies in developing countries and to enhance the nutritional level of cereals, legumes, vegetables, oilseeds, fruits, and fodder crops [15].

"Biofortification or biological fortification" refers to the process of enhancing the content and density of vitamins and minerals that are improving nutritional quality in a staple crop through conventional plant breeding or agronomic practices or transgenic approaches [16]. This food-based approach is one of the promising and sustainable strategies to resolve issues like malnutrition and hidden hunger. Rice *(Oryza sativa)* was the first staple crop to be biofortified. Later many varieties of crops were developed by this approach to increase the content of specific micronutrients [17]. The two key advantages of biofortification are that it is an effective and cheaper alternative to traditional ways and second it is an easy means to reach rural populations that only have limited access to market and healthcare facilities. But once it gets implemented, it will help to lower the micronutrient deficient population, which depends on supplementation and fortification programs [18].

Biofortified crops that have been released so far include vitamin A orange sweet potato, vitamin A maize, vitamin A cassava, iron beans, iron pearl millet, zinc rice, and zinc wheat. Hidden hunger, also known as micronutrient deficiency, afflicts more than 2 billion individuals world- wide, or one in three people globally (FAO 2013) and 805 million people lack enough calories to eat [19]. This process involves the screening of germ plasm of staple crops for nutritional qualities and to identify QTLs for crop improvement, this is the advanced version in crop breeding, which is very common method now-a-days for nutritional improvement in staple as well as non-staple crops. Biofortification has now advanced from traditional methods to transgenic means. This involves selecting or developing cultivars of staple crops for a high quantity of specific micronutrients. Three basic approaches exist to achieve nutritional enrichment in crops there are as follows:

Conventional biofortification

Production of staple crops with desirable agronomic traits or nutrients by conventional crossbreeding methods of the plants bearing naturally higher amounts of the desired micronutrient.

Agronomic biofortification

Agronomic biofortification is carried out by using sprays or fertilizers that are rich in micronutrients and are absorbed by the edible parts of plants.

Transgenic biofortification

This process involves the introduction of new genes or existing genes with minimal bioavailability that are responsible for increasing the levels of micronutrients in crops [4]. Biofortification essentially improves the already grown crops and they do not require any significant change in eating behavior, food habits, educating masses, or food processing.

Conclusion

Currently, approximately one-half of the world's population is malnourished, lacking micronutrients such as zinc and iron which are necessary to ensure human health [13]. Biofortification can include agronomic applications, such as the use of fertilizers and foliar sprays, as well as the generation of new crop varieties with elevated levels of micronutrients using new breeding technologies, such as genetic engineering and transgenic approaches [5]. This review presents the state of plant biotechnology to address zinc deficiency and iron deficiency across the world today. The health benefits of zinc and iron both in terms of crops and human health, have been discussed. Recent research has focused on the overexpression of genes that are responsible for zinc and iron uptake, transfer, and accumulation in plant tissues, such as rice seed. The review described in this paper will thus help to increase zinc and iron accumulation in staple crops as well as enable existing zinc and iron stores within crops to become more bioavailable for the human diet [5]. Biofortification is now a proven technology to fight against micronutrient malnutrition and hidden hunger, especially in developing countries where most people depend upon staple food crops, which are inherently low in micronutrient concentrations. Enhanced use of fertilizers with required micronutrients, conventional breeding, and genetic

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engineering are used to develop biofortified crops, and it is being introduced in many countries as a strategy to improve human health. No single type of intervention can, by itself, solve the problem of micronutrient malnutrition. So, Biofortified crops with increased levels of micronutrients such as iron, zinc, provitamin A, etc. can provide sufficient micronutrients that are deficient in the diets of the people living in developing countries.

References

1. Khush GS (1997) Origin, dispersal, cultivation, and variation of rice. Plant molecular biology 35(1): 25-34.
2. Siddiq EA (1992) Rice in India potential areas for research and development. Oryza (India).
3. Vaughan DA, Morishima H, Kadowaki K (2003) Diversity in the Oryza genus. Curr Opin Plant Biol 6(2): 139-146.
4. Kiran K (2020) Advanced Approaches for Biofortification. In Advances in Agri-Food Biotechnology. Springer p:29-55
5. Hefferon K (2019) Biotechnological approaches for generating zinc-enriched crops to combat malnutrition. Nutrients 11(2): 253.
6. Black RE, Bhutta ZA LHA, Caulfield LE, De Onnis M, Ezzati M, et al. (2008) Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 371: 243–260
7. Gaitán-Solís E, Taylor NJ, Siritunga D, Stevens W, Schachtman DP (2015) Overexpression of the transporters At ZIP1 and At MTP1 in cassava changes zinc accumulation and partitioning. Frontiers in Plant Science 6: 492.
8. Noulas C, Tziouvalekas M, Karyotis T (2018) Zinc in soils, water and food crops. J Trace Elem Med Biol 49: 252-260.
9. Kassebaum NJ, Jasrasaria R, Naghavi M, Wulf SK, Johns N, et al. (2014) A systematic analysis of global anemia burden from 1990 to 2010. Blood the Journal of the American Society of Hematology 123(5): 615-624.
10. Wei Y, Shohag MJI, Yang X, Yibin Z (2012) Effects of foliar iron application on iron concentration in polished rice grain and its bioavailability. Journal of agricultural and food chemistry 60(45): 11433-11439.
11. Yuan L, Wu L, Yang C, Lv Q (2013) Effects of iron and zinc foliar applications on rice plants and their grain accumulation and grain nutritional quality. Journal of the Science of Food and Agriculture 93(2): 254-261.
12. Brooks' S (2010) Rice biofortification: Lessons for global science and development. Taylor & Francis.
13. White PJ, Broadley MR (2009) Biofortification of crops with seven mineral elements often lacking in human diets–iron, zinc, copper, calcium, magnesium, selenium, and iodine. New Phytologist 182(1): 49-84.
14. Beyer P, Al-Babili S, Ye X, Lucca P, Schaub P, et al. (2002) Golden rice: introducing the β-carotene biosynthesis pathway into rice endosperm by genetic engineering to defeat vitamin A deficiency. The Journal of nutrition 132(3): 506S-510S.
15. Xiaoyan S, Yan Z, Shubin W (2012) Improvement Fe content of wheat (Triticum aestivum) grain by soybean ferritin expression cassette without vector backbone sequence. Journal of Agricultural Biotechnology.
16. Bouis HE (2018) Biofortification: an agricultural tool to address mineral and vitamin deficiencies. In: Food fortification in a globalized world. Elsevier San Diego pp: 69-81.
17. Haas JD, Beard JL, Murray-Kolb LE, Del Mundo AM, Felix A, et al. (2005) Iron- biofortified rice improves the iron stores of nonanemic Filipino women. J Nutr 135 (12): 2823-2830.
18. Bouis HE, Welch RM (2010) Biofortification a sustainable agricultural strategy for reducing micronutrient malnutrition in the global south. Crop Sci 50(Supplement_1): S-20–S-32.
19. McGuire S (2015) FAO, IFAD, and WFP. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO, 2015. Adv Nutr 6(5): 623-624.

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