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Hidden hunger and need for rice biofortification with iron and zinc- An overview

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ABSTRACT

Rice is a major food and energy source of more than half the world population. The grain is a major source of carbohydrate and even protein. There are a number of varieties grown in Kerala having high medicinal value. However, rice is a poor source of essential micronutrients such as Fe and Zn. Micronutrient malnutrition, and particularly Fe and Zn deficiency affect over three billion people worldwide, mostly in developing countries. Biofortification through breeding and genetic engineering is the best tool to enhance the iron and zinc content of rice to meet the problem of malnutrition and dietary supplementation.

Keywords: Biofortification, Fe, Zinc, QTLs, nutrients, molecular breeding.

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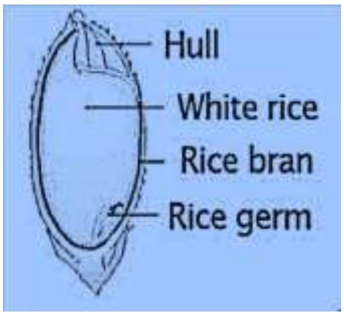
INTRODUCTION

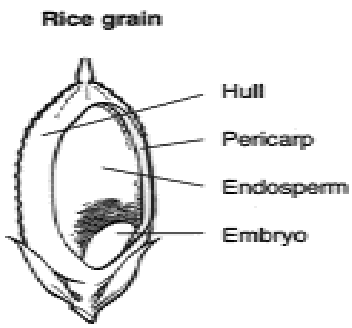
Rice is the major agricultural crop in India covering a total area of 37.4 million hectares, which is the worlds largest rice area.. Rice, *Oryza sativa* (2n = 24) belonging to the family Gramineae or Poaceae, is the second most important cereal crop and staple food for more than half of the world's population. It is grown under diverse cultural conditions and over wide geographical range. The slogan '**Rice is Life**' is more appropriate for India as this crop plays a vital role in our National food security and is a means of livelihood for millions of rural household. The current trends of rice productionThere is usually a double or even triple croppings of paddy in India i.e. summer (AUS) and winter(AMAN).

Plants are annual or sometimes perennial herbs. Leaves flat, linear, acuminate with 2-partite, lanceolate, ligulate, inflorescences spikelets 3 flowered , lower two florets are represented by two empty lemmas; fertile lemma laterally compressed, finely granulate, hispid, ciliate, coriaceous, usually 3-5 nerved, awn less or with awns of variable length; palea as long as lemma, keeled. Flowers bisexual, lodicules 2, bi-lobed, semi fleshy; stamens 6, filaments capillary. Style short, stigmas feathery and laterally exerted. Fruit caryopsis, oblong, angular, free or adnate to the lemma and palea.

The structure of the rice grain is separated into three parts (Figure. 1). The germ (Scutellum, plumule and radicle) is the heart of the grain, which sprouts when the seed is planted. It is rich in vitamin B, vitamin E, protein, unsaturated fat, minerals, carbohydrates and dietary fiber. The endosperm constitutes the largest part of the grain. It is composed chiefly of carbohydrates in the form of starch, with some incomplete protein and traces of vitamins and minerals.



(A)



(B)

Figure 1A & B. Structure of rice grain

Composition of Rice Grain

Bran is composed primarily of carbohydrate cellulose with traces of vitamin B (including thiamin, niacin and B-6), minerals (including iron, phosphorus, magnesium and potassium) and incomplete proteins. The outer husk or hull is inedible but is often used for fuel or fertilizer. Rice grain contains 80% starch, 7.5% protein, 0.5% ash and 12% water. The proportion of amylose and amylopectin in starch determines the cooking and eating qualities of rice. In spite of the fact that rice is a primary source of carbohydrate, it is also a good source of protein, but it is not a complete protein, which means that it does not contain all of the essential amino acids in sufficient amounts for good health, and should be combined with other sources of protein, such as nuts, seeds, beans, fish or meat (Wu et al. 2003)[1] in order to provide a balanced nutrient intake.

Uses:

Rice is used as a staple food by more than 60 percent of world population. Cooking of rice is a most popular way of eating. Rice starch is used in making ice cream, custard powder, puddings, gel, distillation of potable alcohol, etc. Rice Bran used in confectionery products like bread, snacks, cookies and biscuits. The defatted bran is also used as cattle feed, organic fertilizer (compost), and medicinal purpose and in wax making. Rice bran oil is used as edible oil, in soap and fatty acids manufacturing. It is also used in cosmetics, synthetic fibers, detergents and emulsifiers. It is nutritionally superior and provides better protection to heart. Flaked Rice is made from parboiled rice and used in many preparations. Puffed rice is made from paddy and used as whole for eating. Parched Rice is made from parboiled rice and is easily digestible. Rice Husk is used as a fuel, in board and paper manufacturing, packing and building materials and as an insulator. It is also used for compost making and chemical derivatives. Rice Broken is used for making food item like breakfast cereals, baby foods, rice flour, noodles, rice cakes, etc. and also used as a poultry feed. Rice straw mainly used as animal feed, fuel, mushroom bed, for mulching in horticultural crops and in preparation of paper and compost. The paddy is used as seed.

Rice and Health

Health benefits of rice can be found in more than forty thousand varieties of this cereal available in the world. The two main categories include whole grain rice and white rice. Whole grain rice is not processed much, therefore it is high in nutritional value, whereas white rice is processed so that the bran or outer covering is removed and it has less nutritional value. Rice can also be defined by the length of each grain. Indian or Chinese cuisines specialize in long grained rice, whereas western countries prefer short or medium sized grains. Rice is extremely nutritious (Umadevi, et al 2012)[2] As rice is rich in carbohydrates, it acts as fuel for the body and aids in normal functioning of the brain. Rice is an excellent source of vitamins and minerals like niacin, vitamin D, calcium, fiber, iron, thiamine and riboflavin. Rice abounds in resistant starch, which reaches the bowel in undigested form. It aids the growth of useful bacteria for normal bowel movements. Eating rice is extremely beneficial for health, just for the fact that it does not contain harmful fats, cholesterol or sodium. It forms an integral part of balanced diet. As rice is low in sodium, it is considered best food for those suffering from high blood pressure and hypertension. Whole grain rice like brown rice is rich in insoluble fiber that can possibly protect against many types of cancers. Many scientists believe that such insoluble fibers are vital for protecting the body against cancerous cells. The husk part of rice is considered as an effective medicine to treat dysentery. A three month old rice plant's husks is said to contain diuretic properties. Chinese people believe that rice considerably increases appetite, cures stomach ailments and indigestion problems. Medical experts say that powdered rice can be applied to cure some forms of skin ailments. In Indian subcontinent, rice water is duly prescribed by Ayurveda practitioners as Brown rice is said to contain high levels of neurotransmitter nutrients that can prevent Alzheimer's disease to a considerable extent. Rice bran oil is said to have antioxidant properties that promotes cardiovascular strength by reducing cholesterol levels in the body. Rice can also prevent chronic constipation. The insoluble fiber from rice acts like a soft sponge that may be pushed through intestinal tract quickly and easily. Brown rice and whole grains are said to be rich in insoluble fiber.

Medicinal rice

Rice varieties which are used either as medicine or as ingredient in medicinal preparations were largely available in Kerala. Some of varieties out of wide variability in medicinal rices grown by farmers in Kerala are Njavara, Chennellu, Kunjinellu, Erumakkari, Karuthachembavu, Kavunginpoothala etc. Njavara, is the unique medicinal rice variety from Kerala deserves special mention in this regard. This variety is known as "Shashtikam" in Sanskrit due to its extra short duration, coming to harvest within 60-70 days. Indigenous medicinal preparation using Njavara along with Kurunthotti ("Sida") rejuvenates the muscles and nerves. Two types of Njavara have been identified, the white glumed and black glumed, both of which are used in Ayurvedic medicines treatments. Chennellu and Kunjinellu are varieties indigenous to North Kerala. One type of Chennellu with bright red grains, grown as an upland variety in parts of Kannur district is used in treatment of diarrhoea and vomiting. Pokkali rices, refers both to the peculiar system of 'rice cultivation' in the coastal saline soils of Kerala.

Biofortification

Biofortification is defined as the enhancement of micronutrient levels of staple crops through biological processes, such as plant breeding and genetic engineering (Bouis 2002. Bouis and Welch 2010)[3,4]. It could be effective in reducing the problem of malnutrition as part of a strategy that includes dietary diversification, supplementation, commercial fortification and other aspects. Harvest Plus is a CGIAR initiative which started "biofortification" umbrella through which international agricultural and research centers have made efforts to develop new breeds of staple foods that are rich in vitamins and minerals. Biofortification has multiple advantages, including the fact that it capitalizes on the regular daily intake of a consistent amount of staple food by all family members.

Importance of biofortification in rice

Rice is one of the global staple foods being cultivated since 10,000 years and provides 70–80% or more daily calorie intake for 3 billion people, which is almost half of the world's population. The grain has large genetic variability in micronutrient concentration. In comparison with other cereals, rice contains low nutritional value (Table 1). Currently, polished rice contains an average of only 2 parts per million (ppm) iron (Fe) and 12 ppm of zinc (Zn). In many Asian countries, rice provides 50–80 percent of the energy intake of the poor but it does not provide enough essential micronutrients to eliminate "hidden hunger," in particular iron deficiency anemia (IDA) and zinc deficiency. In many of these Asian countries,

Table 1:Micronutrient status of rice vis-à-vis other cereals.

Crop	Protein (%)	Iron (ppm)	Zinc (ppm)
Rice	6–7	2–34	10–33
Wheat	13–14	25–55	25–65
Maize	8–11	10–63	13–58
Sorghum	10–15	10–65	14–55
Pearl millet	6–21	30–146	25–85
Small millets (finger millet, foxtail millet)	8–20	37–142	5–60

IDA affects nearly 60 percent of the population. Because of the high per capita consumption of rice in these countries, improving its nutritive value by increasing iron and zinc levels in the grain can have significant positive health outcomes for millions of people. Therefore, rice alone cannot meet the recommended daily allowance (RDA). Healthy and productive populations require adequate amounts of essential vitamins and minerals.

Iron deficiency is the most pervasive form of malnutrition and a leading cause of anemia. High zinc seeds are more vigorous and better able to withstand weed competition, and pathogen and pest attack (Gregorio et al. 2000)[5]. Deficiencies of zinc, iron and vitamin A in human population of developing countries were noticed and particularly, zinc deficiency is the fifth major cause of diseases and deaths in these countries. Health problems caused by zinc deficiency include anorexia, dwarfism, weak immune system, skin lesions, hypogonadism and diarrhea (McClain et al. 1985)[6]. Males aged 15 to 74 years need about 12 to 15 mg of zinc daily while females aged 12 to 74 years need about 68 mg of zinc daily (Sandstead 1985)[7]. Iron dependent anemia in turn leads to maternal mortality, preterm births

(Scholl et al. 1992)[8], decreases immunity (Kandoi et al. 1991)[9] and increases placental weight (Wingerd et al. 1976)[10] during pregnancy. Further, the iron requirement is highest during 7–9 months of pregnancy (O'Brien et al. 1999)[11]. Crops bred for increased uptake and utilization of trace minerals (eg, zinc and iron) could be harnessed to simultaneously improve crop productivity and human nutrition (Graham and Welch 1996)[12.]

Rice is a major source of dietary carbohydrate for more than half of the world's population (Zimmermann and Hurrell 2002)[13]. To meet the energy needs, in the past 40 years, agricultural research in developing countries has tried to increase cereal production at its center. However, agriculture must focus on not only to produce more food but also better quality food. Biofortification of staple food crops for enhanced micronutrient content through genetic manipulation is the best option available to alleviate hidden hunger with little recurring costs (Welch and Graham 2004, Monasterio et al. 2007, Anuradha et al. 2012)[12,14,15]. Hence, rice was included in biofortification program (Graham et al. 1999)[16], targets are low income households who have limited access to commercially marketed fortified foods that are more readily available in urban areas. In all crops studied, it is possible to combine the high micronutrient density trait with high yield economically. Biofortification is an important tool for controlling micronutrient deficiencies. Getting consumers to accept biofortified crops will be a challenge, but with the advent of good seed systems, the development of markets and products, and demand creation, this can become a reality (Nestel et al. 2006)[17].

The Researchers have found that the procedure for increasing the iron content of rice grains also has the added benefit of enhancing zinc levels in rice. According to International Rice Research Institute in Philippines, the nutritional value of rice needs to be improved more so that it benefits mankind. Efforts are made to increase the micronutrient value of rice by mixing traditional methods of growing crops and modern biotechnology. National institutions in Bangladesh, Indonesia, China, Vietnam, India, the Philippines, and elsewhere are screening their own germ plasm to breed for high iron and zinc. A number of iron storage protein and iron transport genes from other food crops are also being evaluated in transgenic plants. The institute further states that development of rice with high iron and zinc compounds could be possible through biofortification. That can also induce high quality yields, which could be eagerly accepted by farmers as well as rice consumers. Plant breeding is an excellent 'tool' for micronutrient nutritional enhancement in combating the problem of malnutrition. The micronutrient density traits are stable across environments and it is possible to improve the content of several limiting micronutrients together. High nutrient density not only benefits the consumer but also produces more vigorous seedlings in the next generation.

Malnutrition is the most common cause of zinc deficiency and 25% of the world's population is at risk of zinc deficiency (Maret and Sandstead 2006)[18]. In Asia and Africa, it is estimated that 500 to 600 million people are at risk for low zinc intake (Source: http:// www.harvestplus.org/ 2010)[19].

Molecular studies

Several QTLs (quantitative trait loci) have been mapped for micronutrient content in rice grains using various germplasm sources including wild species. Using selective genotyping approach three loci associated with high content of iron and zinc in grain were mapped on chromosome 3, 4 and 8 in Chittimutyalu, a landrace and four loci on chromosome 3, 4, 6 and 12 were mapped in Ranbir Basmati at DRR. Two loci from chromosome 3 and one locus from chromosome 4 were found to be common between the two donors for iron and zinc metabolism. In the segregating population derived from Samba Mahsuri/Chittimutyalu, recombinant sd1 gene from Samba Mahsuri and aroma gene from Chittimutyalu were identified with maximum background genome of Chittimutyalu and high concentrations of iron and zinc in grains. Attempts are required to be done to identify the regions associated with iron and zinc contents in the grains. Molecular breeding involving the utilization of DNA markers for selection of plants based on the iron and zinc contents is suggested to be the best strategy.

CONCLUSION

Plant breeding and biotechnology tools are good for fighting micronutrient malnutrition. The final permanent solution to micronutrient malnutrition is breeding staple foods that are dense in minerals and vitamins to provide a low-cost, sustainable strategy for reducing levels of micronutrient malnutrition. Molecular marker technology expedites the development of rice varieties with improved iron and zinc contents through identified genomic regions. Iron and zinc contents in brown and milled rice of national and international germplasm need to be estimated for identification of donors for future deployment in the nutritional breeding program and also to get mapping information on association of iron and zinc contents in grains. Rice lines in the genetic background of elite rice varieties possessing optimum concentration of zinc in the endosperm will be developed and released for cultivation.

REFERENCES

1. Wu JG, Shia C and Zhanga X. Estimating the amino acid composition in milled rice by near-infrared reflectance spectroscopy. Field Crops Research 2003;75(1):1–7.
2. Umadevi M, Pushpa R, K.P. Sampathkumar K P, Debjit Bhowmik . Rice-Traditional Medicinal Plant in India .Journal of Pharmacognosy and Phytochemistry 2012;1 (1):6-12

3. Bouis HE. Plant breeding: A new tool for fighting micronutrient malnutrition. Journal of Nutrition 2002;132:491–494.
4. Bouis, HE. and RM. Welch. Biofortification—a sustainable agricultural strategy for reducing micronutrient malnutrition in the global south. Crop Sci. 2010;50: S20–32
5. Gregorio GB, Senadhira D, Htut H and Graham RD. Breeding for trace mineral density in rice. Food and Nutrition Bulletin 2000; 21:382–386.
6. McClain, Craig J, Edward J, Kasarskis JR and Allen JJ. Functional consequences of zinc deficiency. Progress in Food and Nutrition Science 1985;9:185–226.
7. Sandstead HH. Requirements of zinc in human subjects. Journal of the American College of Nutrition 1985;4:73–82.
8. Scholl TO, Hediger ML, Fischer RL and Shearer JW. Anemia vs. iron deficiency: increased risk of preterm delivery in a prospective study. American Journal of Clinical Nutriton 1992; 55:985–988.
9. Kandoi A, Bhatia BD, Oandey S, Sen PC and Satya K. Cellular immunity status in anaemia in pregnancy. Indian Journal of Medical Research 1991;94:11–15.
10. Wingerd J, Christianson R, Lovitt WV and Schoen EJ. Placental ratio in white and black women: relation to smoking and anemia. American Journal of Obstetrics & Gynecology 1976;124:671–675.
11. O'Brien KO, Zavaleta N, Caulfield LE, Dong-Xiao Yang and Abrams SA. Influence of prenatal iron and zinc supplements on supplemental iron absorption, red blood cell iron incorporation, and iron status in pregnant Peruvian women. American Journal of Clinical Nutrition 1999;69:509–515.
12. Welch RM and Graham RD. Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany 2004;55:353–364.
13. Zimmermann MB and Hurrell RF. Improving iron, zinc and vitamin A nutrition through plant biotechnology. Current Opinion in Biotechnology 2002;13(2):142–145.
14. Monasterio I, Palacios-Rojas N, Meng E, Pixley K, Trethowan R and Pena RJ. 2007. Enhancing the mineral and vitamin content of wheat and maize through plant breeding. Journal of Cereal Science 46:293–307.
15. Anuradha K, Surekha A, Anil K B, A PB, Mallikarjuna Swamy B P, Longvah T, Sarla N. Evaluating rice germplasm for iron and zinc concentration in brown rice and seed dimensions Journal of Phytology 2012;4(1):19-25.
16. Graham RD and Welch RM. Breeding for staple food crops with high micronutrient density. Working papers on agricultural strategies for micronutrients no. 3. Washington, DC, USA: International Food Policy Research Institute1996.

17. Nestel P, Bouis HE, Meenakshi JV and Pfeiffer WH. Biofortification of staple food crops. Journal of Nutrition 2006;136:1064–1067.
18. Maret W and Sandstead HH. Zinc requirements and the risks and benefits of zinc supplementation. Journal of Trace Elements in Medicine and Biology 2006’20(1):3–18.
19. Source: http:// www.harvestplus.org/ 2010