# IMPROVING MICRONUTRIENT VALUE OF RICE THROUGH BREEDING

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**Contents**



**Summary**

Micronutrient deficiency or hidden hunger affects more than 3.7 billion people worldwide, according to WHO figures from 1999, predominantly women and children because of their physiological needs. Iron and zinc deficiencies cause impaired immune function, complications in pregnancy and childbirth, poor child growth and learning ability, and reduced labor productivity. In 1992, IRRI began to examine the effect of certain soil characteristics on the iron content in the grain. This was expanded in 1995 to include zinc, and in collaboration with the University of Adelaide, Australia, mineral analysis was rendered. Germplasm screening showed large genetic variation for Fe and Zn in brown rice. Common cultivars contain about 12 mg Fe $kg^{-1}$ to 25 mg Zn $kg^{-1}$. Some traditional varieties have double these amounts. The genetics of the high Fe trait showed the importance of additive and dominance gene action, but with minimal effect of the environment. Moreover, three QTLs for the high-Fe trait were tagged in rice chromosomes. High-Fe and -Zn traits can be combined with improved agronomic traits.

IRRI identified improved rice with high yielding ability and high concentrations of iron and zinc in the grain. Due to the high consumption of rice in developing countries, the extra iron and zinc would have meaningful impact on human nutrition and health.

## 1. Introduction

High-yielding varieties of rice, wheat, maize, and other food staples are now grown widely in developing countries. Over the past three decades, cereal production has grown faster than demand. As a result, lower food prices and higher farm incomes have contributed to reduced protein-energy malnutrition (PEM) among the poor. Food staples are inexpensive sources of calories and protein, but are poor sources of essential vitamins and minerals.

Mineral and vitamin deficiencies, now known as hidden hunger, affect a far greater number of people in the world than PEM. Nutritional anemia, mostly due to low iron intake, is widespread among developing countries. Low dietary intake and bioavailability of iron, blood loss due to parasites, and unmet demand associated with rapid growth and pregnancy lead to iron deficiency.

WHO estimates that nearly 3.7 billion people are iron-deficient and that the problem is severe enough to cause anemia in 2 billion people. Of this figure, 40% are non-pregnant women, while 50% are pregnant. An estimated 58% of pregnant women in developing countries with anemia will give birth to infants with low birth weight and depleted iron stores. The WHO also estimates that 31% of children under five years of age are suffering from iron deficiency anemia or IDA.

In general, iron deficiency and anemia have profound negative effects on human health and development, including limited learning capacity during childhood, impaired immune function, and reduced labor productivity. More evidence has shown that iron deficiency leads to complications during pregnancy and childbirth, such as lower birth weight among infants, poor growth in childhood, higher incidence of diarrhea, and morbidity.

Producing enough food to maintain the worlds population is not enough. Even if energy requirements are met, billions of undernourished, poor people will continue to live in poor health, with low productivity and an inferior quality of life. Nutritious foods that meet minimum daily nutritional requirements must be produced and made available to the population. Supplementation, fortification, and education have been successful in reducing iodine deficiency and such intervention programs must be continued and extended to the iron deficiency problem. For other micronutrients, such programs are expensive, and unlikely to reach all of those at risk. Another strategy in alleviating iron-deficiency anemia is reducing etiological factors, such as parasites. More important is improving dietary intake by balancing cereal-based diets with vegetables and animal products. However, vegetables and animal products are expensive, seasonal, subject to spoilage, and difficult to store and transport. Availability of these food items in some countries is not even one-fourth of the daily requirements of the population. Thus, there is a need to develop low-cost, long-term solutions to improving the nutritional quality of food staples to complement existing interventions. This need can be met by the improvement of nutritional quality of food staples.

The nutritional quality of crops can be improved by breeding. The philosophy of breeding for nutritional improvement has been developed and is well perceived. However, an important requirement is that the improved varieties with nutritional characteristics must meet farmers' agronomic criteria. In the case of increasing micronutrients, such as iron and zinc in the grain, improvement of both nutritional characters and agronomic criteria should be concurrent. High micronutrient content in the seed will certainly possess a significant advantage of rapid crop establishment, especially in nutrient deficient soil. It is reported that the seed is the main mineral nutrient source for the seedlings and that the seed-iron content is high in plants adapted to soils, which are low in available iron.

## 2. Rice and Micronutrients

Rice is the staple food of 2.4 billion people in developing countries. Over the past three decades, the number of rice consumers has increased by 70%. At the same time, rice production nearly doubled, contributing to a substantial increase in rice consumption and caloric intake per capita, particularly in Asia. Half of the world's rice production is consumed where it is grown - in resource-poor farm households.

Among the important cereals, rice has the highest food and food energy yield. Rice provides 35-59% of the energy consumed by the Asian population. The contribution of rice to dietary protein intake is about 69% in South Asia and about 51% in South East Asia.

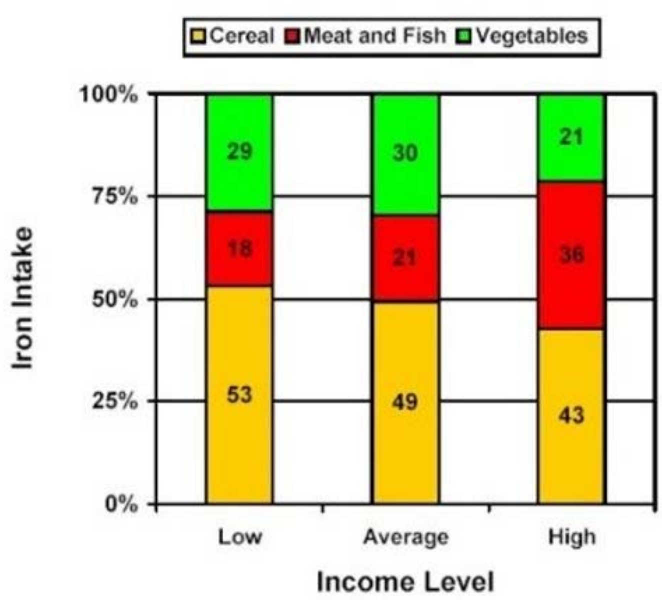


Figure 1. Pattern of iron intake from different food groups by Filipino households of varying income levels (IFPRI 1984/85).

The rice grain has no pro-vitamin A carotenoids, but has small amounts of iron and zinc that are substantial when consumed in large amounts. A nutritional survey conducted in the Philippines suggested that about 50% of the iron intake, even among high-income households, come from the cereals, rice and corn (Figure 1). The problem of iron deficiency was also revealed in this survey (Figure 2).

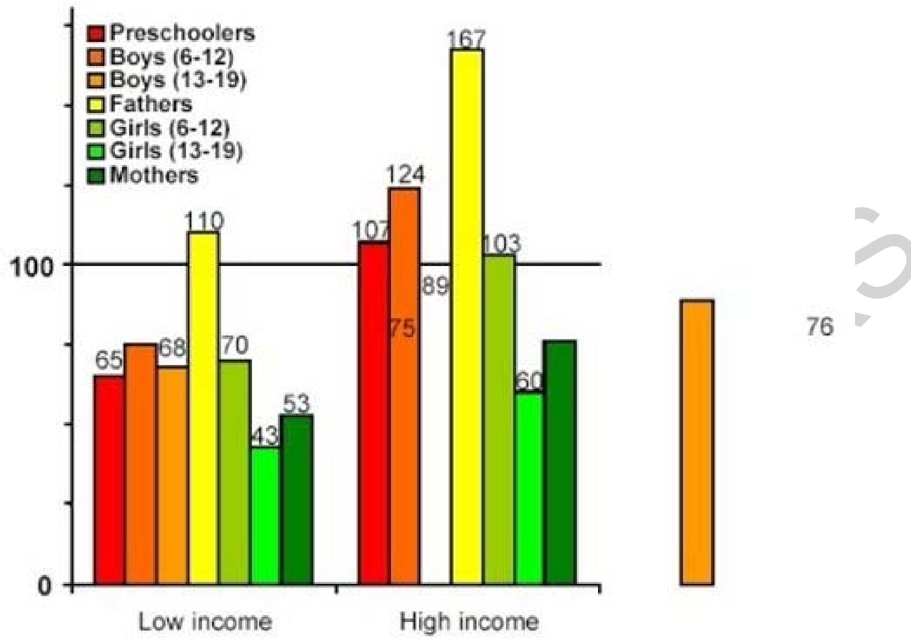


Figure 2. Ratio of Filipino households iron consumed to recommended daily allowance at varying income levels (100 as the adequacy level) (IFPRI 1984/85).

In countries where the staple food is rice, per capita consumption is as high as 87 to 214 kg year$^{-1}$. A slight increase in nutrients in rice could result in healthier people amongst those who depend on rice. However, rice is considered a starchy staple without much attention being paid to its nutritional aspects. There had been little or no work on improving its nutritive value, other than the efforts of IRRI in the 1960s and 1970s to improve the protein content in rice. Research priorities for improving grain quality that were discussed and recommended at international rice research conferences held in 1985 and 1990 did not focus on nutritive values. Instead, milling, cooking, and eating qualities were considered high priority research items. This was possibly because IRRIs experience with breeding for protein content was not successful. Among the popular cereals, rice, as normally consumed, is lowest in iron, with an average of only 5 to 6 mg kg$^{-1}$ after milling. However, other studies have proven the potential to exploit the genetic variation in seed content of iron and other minerals without the general negative impact on yield commonly observed with increasing protein in many crops. The relationship between yield and mineral content may be positive, particularly in mineral deficient soil. Although rice is not considered a major mineral supplier, any increase in mineral concentration could significantly help reduce the iron and zinc deficiency problem among target populations.

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**Biographical Sketches**

**Dr. Glenn B. Gregorio** is an affiliate scientist (Plant Breeder) at the Plant Breeding, Genetics, and Biochemistry Division in the International Rice Research Institute (IRRI). Dr. Gregorio leads several projects of IRRI which includes varietal improvement for tolerance to salinity and other soil related abiotic stresses, breeding for micronutrient-dense rice for human nutrition, and development of molecular marker assisted selection technology for abiotic stress tolerance and micronutreint dense traits.

**Dr. Dharmawansa Senadhira** (deceased) was one of the most successful international rice breeders. He bred several high yielding in Sri Lanka and other rice growing countries. While at IRRI, he spearheaded rice breeding flood prone environments, and micronutrient dense rice.

**Dr. Tin Htut** is working at the Central Agricultural Research Institute, Yezin, Pyinmana, Myanma Agriculture Service, at the Ministry of Agriculture of Myanmar. Dr. Htut is a horticulutrist, agronomist, and a food legume breeder. He earned his Masters degree in Plant Breeding from North Carolina State University, Raleigh, North Carolina, USA and his Ph.D. in plant breeding as an IRRI scholar at the University of the Philippines at Los Baños where he studied the inheritance of grain iron density in rice.

**Dr. Robin D.Graham** is a Professor at the University of Adelaide, and Head of the Crop Nutrition Group at the Waite Agricultural Research Institute in Australia. His involvement in research s includes: micronutrients in the food chain; cultivar differences among staple-food crops in ability to extract micronutrients from soils, cultivar differences in ability to load micronutrients into food grains, and the genetics and molecular biology of such traits; the role of adequate micronutrient nutrition in resistance to disease, product quality and in the sustainability of cropping systems. Nutrients of particular interest include iron, zinc, copper, manganese, iodine, boron, and pro-vitamin A carotenoids.