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1968	Ph.D., Max-Planck-Institute for Plant Breeding Research (Prof. J.Straub), University of Cologne, Germany
1982	Habilitation in Botany, University of Basel, Switzerland
1970-1974	Assistant Professor, Institute of Plant Physiology (Prof. D.Hess), Stuttgart-Hohenheim
1974-1976	Research Group Leader, Max-Planck-Institute of Plant Genetics, Ladenburg/Heidelberg
1976-1986	Research Group Leader, Friedrich Miescher Institute, Basel, Switzerland
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Vitamin-A and Iron-Enriched Rices May Hold Key to Combating Blindness and Malnutrition: A Biotechnology Advance

The major micronutrient deficiencies worldwide concern iron, with 24% of the world's population (up to 60% in developing countries) or 1.4 billion women suffering from iron deficiency, anemia, and vitamin A and up to 800 million children, or 14% of the world population. The deficiencies are especially severe in developing countries where the major food staple is rice. To contribute to a solution of the problem we set out to genetically engineer rice toward an improvement in the supply of vitamin A and iron.

Iron deficiency is the consequence of a) low amounts of iron in the endosperm, b) high concentration of phytate (the major inhibitor of iron resorption in the intestine), and c) lack of sulfur containing proteins to enhance iron resorption. Consequently, we aimed at a) an increase in iron content via a ferritin transgene from *Phaseolus*, b) the reduction of the phytate in the cooked diet via a transgene for a thermotolerant phytase from *A. fumigatus*, and c) at the resorption-enhancing effect from a transgenic cystein-rich metallothionin-like protein from *Oryza*. All genes were under endosperm-specific control. The transgenic rice plants, so far, show a two-fold increase in iron, high activity of the phytase, and an increase of the cystein content of ~ 25%.

Rice endosperm does not contain any provitamin A. The latest precursor to the pathway is GGPP. Theoretically, four enzymes should complete the pathway. These are phytoene synthase, phytoene desaturase, zeta-carotene desaturase, and lycopene cyclase. The necessary genes for these enzymes had been isolated from daffodil (*Narcissus*). They could be complemented by a double-desaturase from *Erwinia*, catalyzing both desaturation steps. Transgenic rice carrying the genes in combination produced seeds with yellow endosperm. Biochemical analysis confirmed that the color was due to the presence of such amounts of provitamin A, that its content in the typical Asian rice diet (300 g of uncooked rice) alone would provide the necessary daily dose of vitamin A to prevent vitamin A-deficiency.

Both vitamin A and iron are combined by crossing. The material is transferred free of charge and without any restrictions for non-commercial use to developing countries. Arrangements with rice breeders for crossbreeding to local varieties have been initiated for the major rice growing countries in Asia, Africa, and Latin America.