Biofortification

Delhi 25.04.2014

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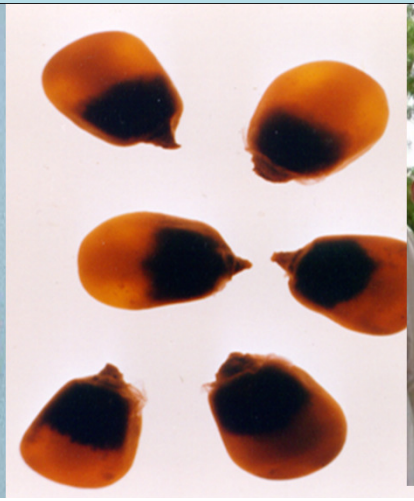
Deputy Director General (Crop science)
Indian Council of Agricultural Research, New Delhi

Biofortification is a strategy of genetic enhancement of micronutrients in staple food crops

Biofortification is the most economic and sustainable way of combating malnutrition problem

42% Indian population (mostly women and children) are malnourished : PM 2012

High iron rice
Vitamin C food crop
β-carotene + Vit E rice
Improved Potato and Tomato
Vitamin E and β-carotene maize
High iron/zinc Millet & QPM maize
Under utilized crops + Quinoa (FAO Y)

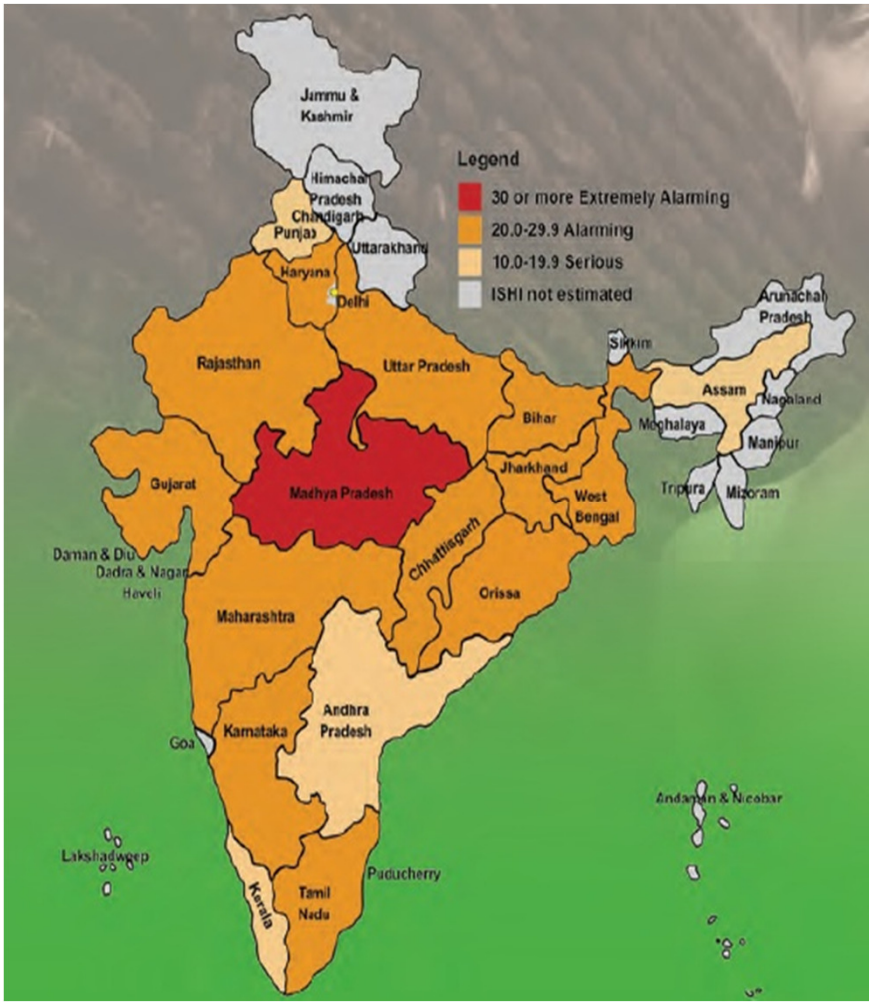


Malnutrition

India is one of the countries having problem of child malnutrition (World Bank)

More than 50% of women, 46% of children below 3 years are underweight and 38% are stunted

As per India State Hunger Index, all the states are with serious to alarming indices with M.P. most alarming (2008-09)



Breeding approach-

- Quality Protein Maize (QPM)
- Bajra (high iron and zinc) released in India

Transgenic approach - genes for nutritional traits in crops

Golden rice, high iron rice: classic and popular examples

Crop	Transgene traits
RIce	Provitamin A, High iron, antinutrients, Tocopherol, Folic acid
Maize	Protein, Provitamin A, Iron, Tocopherol, antinutrients, Folic acid
Wheat	High iron/zinc

Target crops

Five major cereal crops viz., rice, wheat, maize, sorghum and pearl millet, two small millets, viz., finger millet and foxtail millet and potato (8)

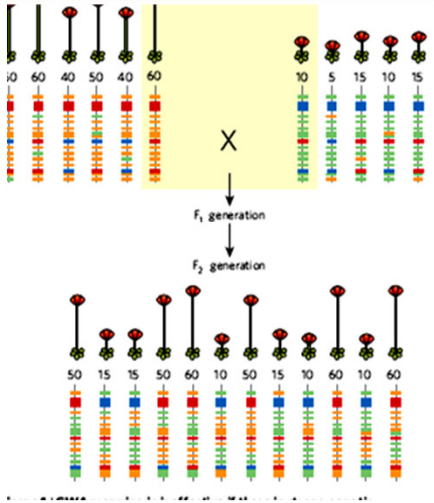
Seven institutes with NIN, NIANP and 36 associated centers (45)

Status of target crops

(through transgenics and conventional breeding)

Crop	Transgenics/Transgenes being introgressed into popular varieties	Conventional breeding
Rice	Golden Rice	High zinc rice, High protein rice
	High iron Rice	
Wheat		High protein, iron, zinc Low phytate High phytase
Maize		High protein

NATURE|Vol 456|11 December|doi:10.1038/nature07629



Next-generation genetics in plants

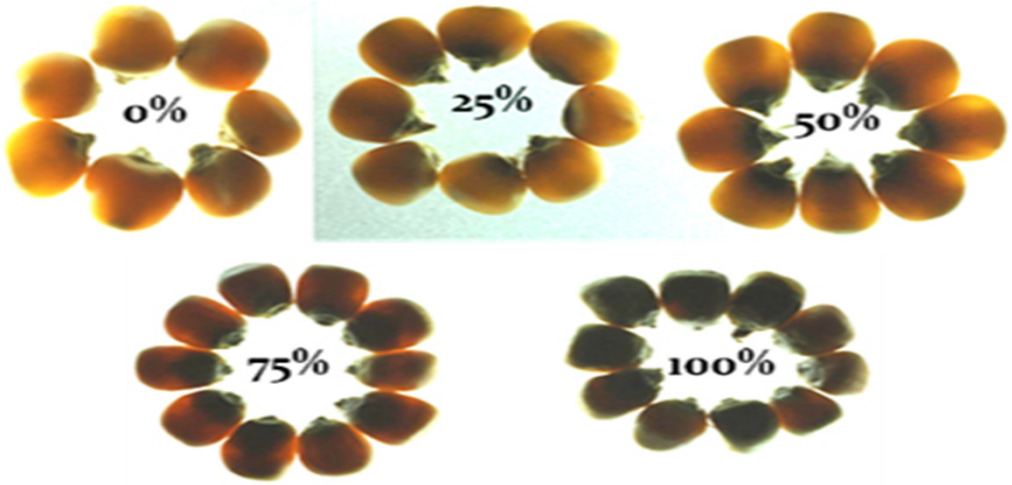
Magnus Nordborg[1] & Detlef Weigel[2]

Natural variation presents one of the fundamental challenges of modern biology. Soon, the genome sequences of thousands of individuals will be known for each of several species. But how does the genotypic variation that will be observed among these individuals translate into phenotypic variation? Plants are in many ways ideal for addressing this question, and resources that are unmatched, except in humans, have now been developed.

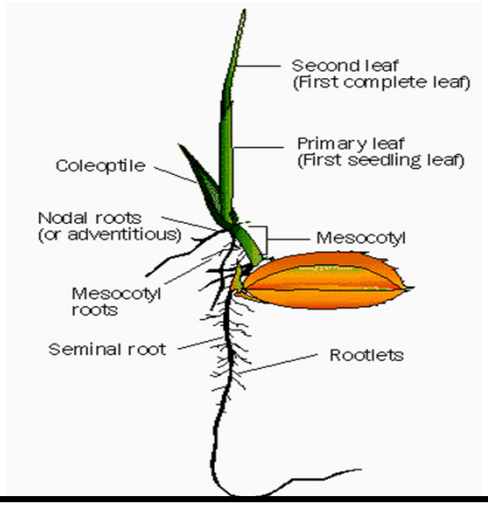
Maize

- Production: 21.57 mt
- Target: 45 mt in 2020
- Export 4.8 mt in 2011-12 (` 5000 Cr.)
- QPM; *Shaktiman*

Development of Quality protein maize (QPM Hybrid 9)



Biofortification of Provitamin A in Rice Endosperm



PS (*psy*)

Phytoene (1)

PDS (*crtI*)

Lycopene (2)

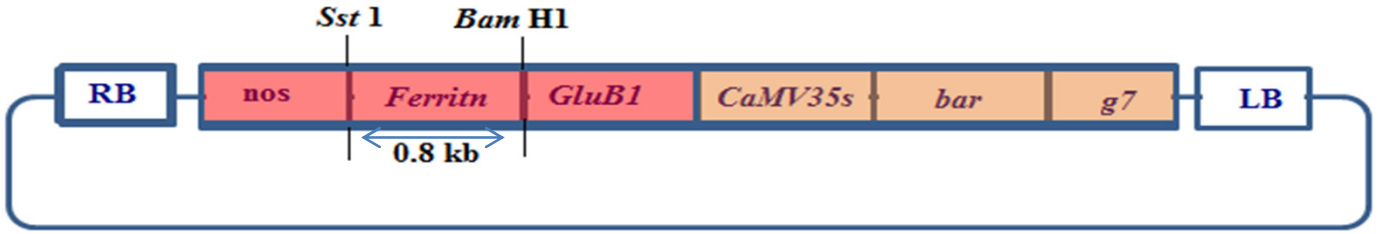
LC (*lyc*)

α-carotene β-carotene (3)

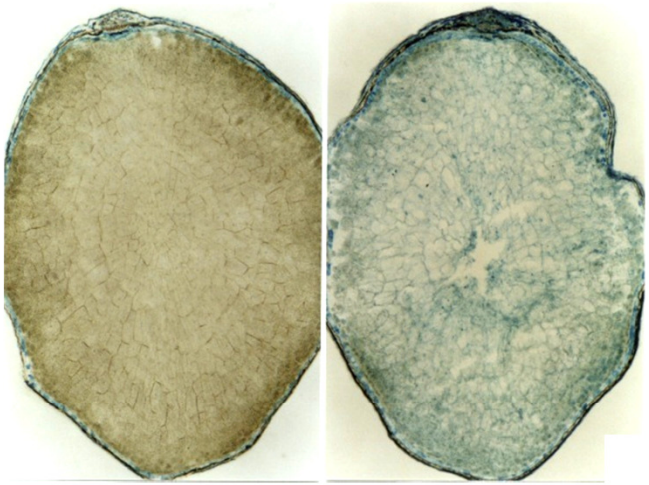
9.4 µg/g, in homozygous lines

Datta *et al* PBJ, 2003,2005,2006
Parkhi *et al* MGG, 2005,2006
Rai *et al* 2003,2006

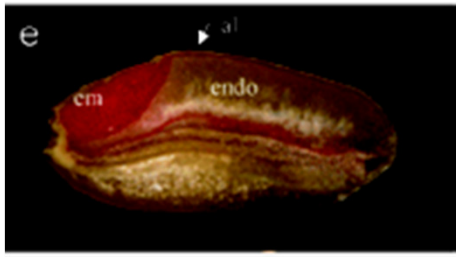
Iron Biofortification: *Ferritin* Gene from Soybean



Schematic diagram of expression vector containing Soybean *ferritin* gene

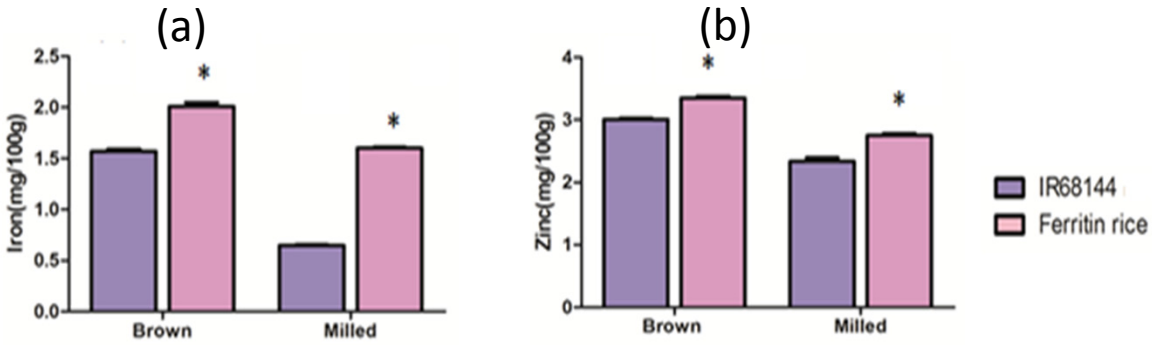


Histochemical localization of iron by Prussian blue



Histochemical localization of zinc in seeds by dithiozone staining

High iron/zinc GM Rice with X
2.5 more iron in polished seed



Analysis of mineral content of brown and milled transgenic and control rice by AAS (a) iron (b) Zinc

Vasconcelos et al, Plant Science, 2003

DEVELOPMENT OF HIGH IRON RICE

GM Crops and Food: Biotechnology in Agriculture and the Food Chain 3:4, 310-316; October/November/December 2012; © 2012 Landes Bioscience

Molecular breeding of *Osfer2* gene to increase iron nutrition in rice grain

Soumitra Paul,[1] Nusrat Ali,[1] Dipak Gayen,[1] Swapan K. Datta[1,2] and Karabi Datta[1,*]

[1]Plant Molecular Biology and Biotechnology Laboratory; Department of Botany; University of Calcutta; Kolkata, India; [2]Division of Crop Science; Indian Council of Agricultural Research (ICAR); Krishi Bhavan; New Delhi, India

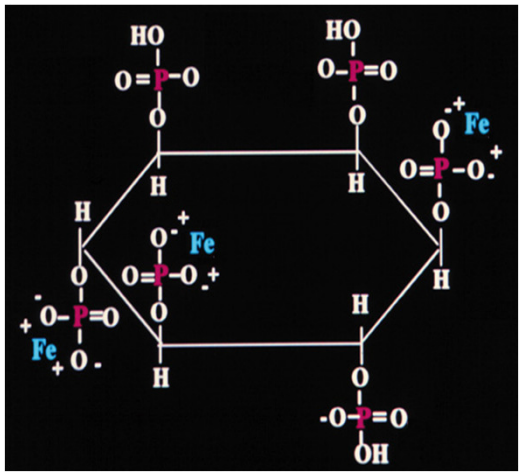
Plant Cell Tiss Organ Cult
DOI 10.1007/s11240-012-0286-7

REVIEW

Loading and bioavailability of iron in cereal grains

Soumitra Paul · Nusrat Ali · Sailendra N. Sarkar · Swapan K. Datta · Karabi Datta

Nutrition Bioavailability
Reduction of Phytic acid Level



Phytic acid

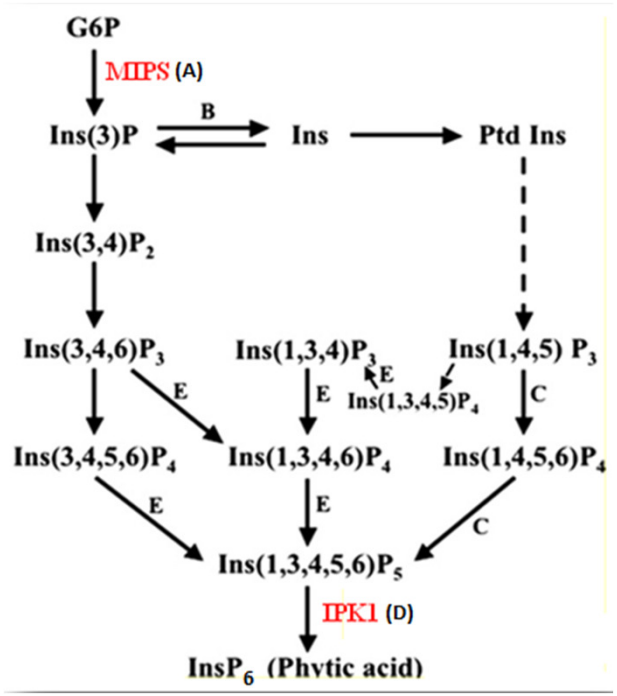
Besides sequestering inorganic phosphate, phytic acid due to it's six highly negatively charged anion, is a potent chelator of mineral cations

Phytic acid strongly binds to mineral cations like Fe^{2+} , Zn^{2+} , Ca^{2+}, Mg^{2+} to form a mixed salt called **phytate**

Hence to increase mineral (Fe^{2+}) as well as phosphorus bioavailability the reduction of phytic acid levels in rice seeds is required

1D-myo-inositol 3-phosphate synthase (MIPS) and **inositol 1,3,4,5,6-pentakisphosphate 2-kinase** (IPK1) are two key enzymes in phytic acid biosynthesis.

Down regulation of these two enzymes in tissue specific manner by RNAi technology may play important role to reduce phytic acid level in seeds.



Ali *et al. Rice* 2013, 6:12
http://www.thericejournal.com/content/6/1/12

Rice
a SpringerOpen Journal

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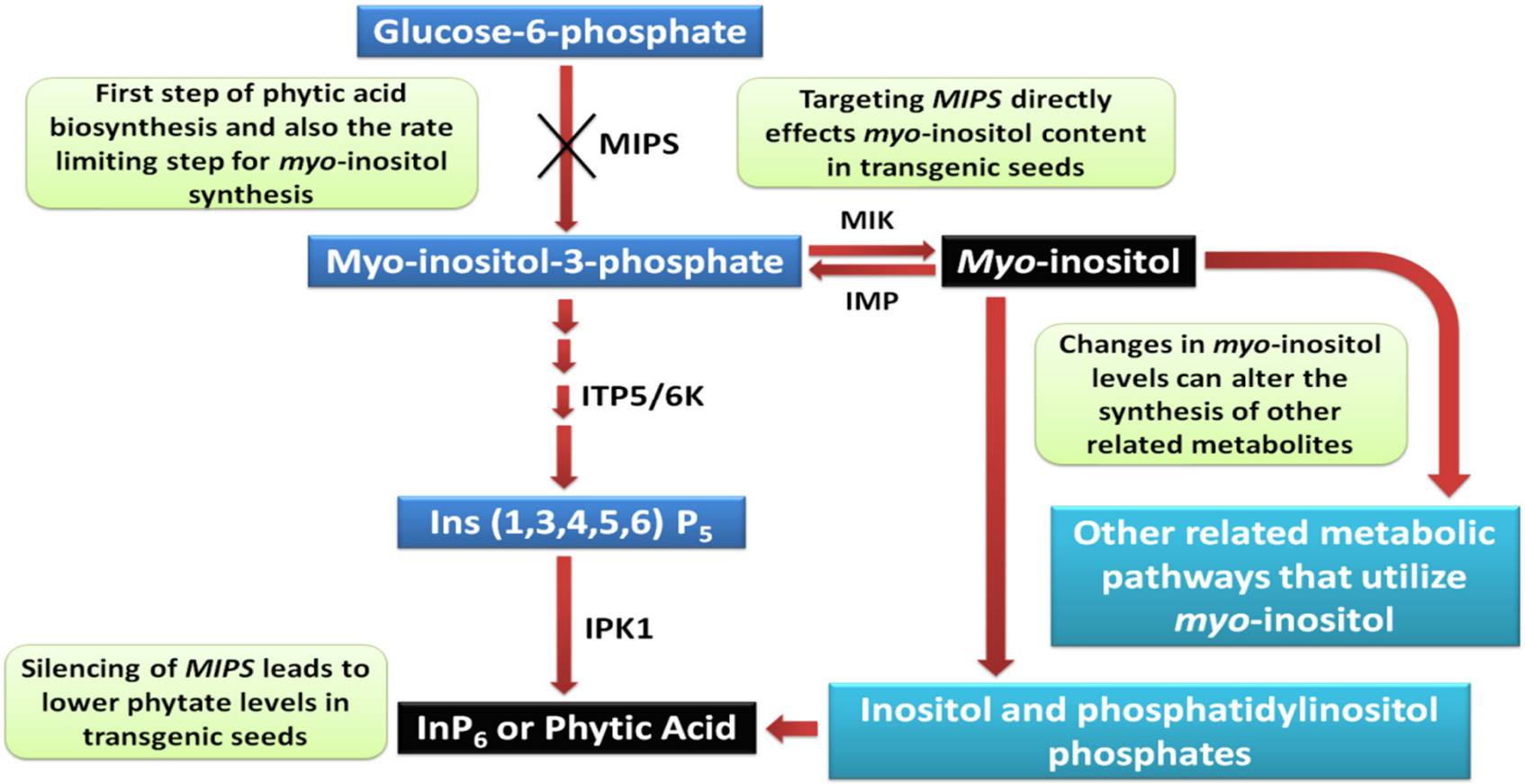
RNAi mediated down regulation of *myo*-inositol-3-phosphate synthase to generate low phytate rice

Nusrat Ali[1], Soumitra Paul[1], Dipak Gayen[1], Sailendra Nath Sarkar[1], Swapan K Datta[1,2] and Karabi Datta[1*]



Related Publications

Ali *et al. Rice* 2013, **6**:12
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PLOS | ONE

Development of Low Phytate Rice by RNAi Mediated Seed-Specific Silencing of Inositol 1,3,4,5,6-Pentakisphosphate 2-Kinase Gene (*IPK1*)

Nusrat Ali[1], Soumitra Paul[1], Dipak Gayen[1], Sailendra Nath Sarkar[1], Karabi Datta[1*], Swapan K. Datta[1,2]

1 Plant Molecular Biology and Biotechnology Laboratory, Department of Botany, University of Calcutta, Kolkata, West Bengal, India, **2** Division of Crop Science, Indian Council of Agricultural Research (ICAR), New Delhi, India

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Comparative analysis of nutritional compositions of transgenic high iron rice with its non-transgenic counterpart

Dipak Gayen[a], Sailendra N. Sarkar[a], Swapan K. Datta[a,b], Karabi Datta[a,*]

[a] Plant Molecular Biology and Biotechnology Laboratory, Department of Botany, University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700019, WB, India
[b] Division of Crop Science, Indian Council of Agricultural Research (ICAR), Krishi Bhavan, Dr. Rajendra Prasad Road, New Delhi 110001, India

Research highlights:

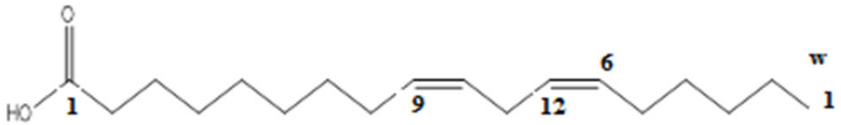
The nutritional composition of grains of high iron transgenic rice (FR-19-7, the transgenic IR68144 line developed,Vasconcelos et al,2003) is comparable to
that of non-transgenic counterpart.

The nutritional components of transgenic ferritin seeds are well within the accepted range of reported values.

Based on the substantial equivalence concept of OECD, the analysed transgenic seeds are safe for human consumption

Maintenance of Rice Nutritional Quality During Storage

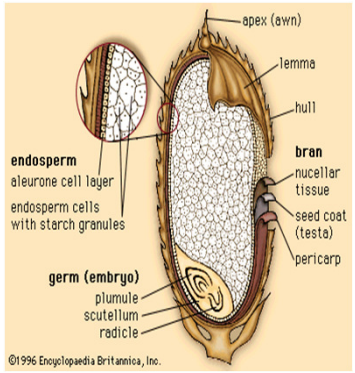
Rice grain deterioration is the common problem of rice storage .
LOX (lipoxygenase) activity in rice grain is localized in the bran milling fraction . It catalyzes the addition of molecular oxygen to polyunsaturated fatty acids



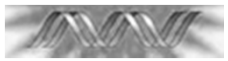
Linoleic acid (18:2)

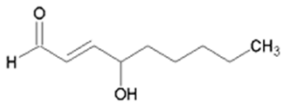
LOX

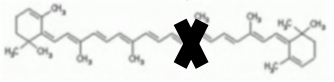
ROS



DNA damage **Protein damage** **Cell membrane** **Fatty acid oxidation** **Carotene oxidation**







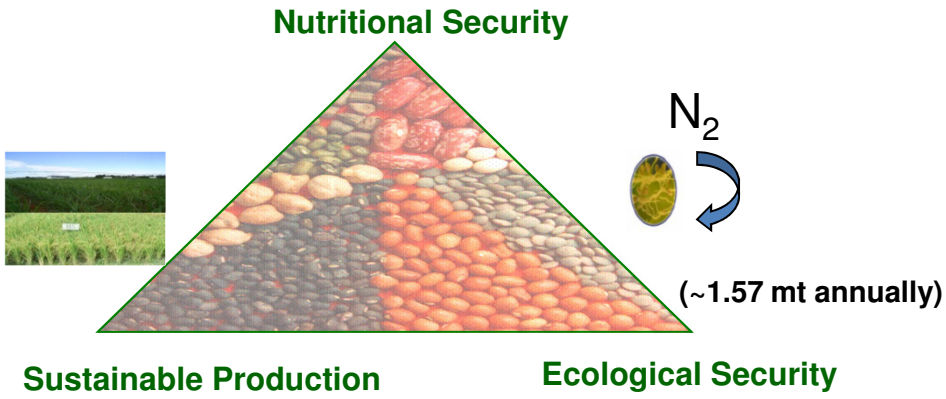
Cell death

Nutritional loss

Physiological causes of seed nutritional deterioration and viability

Pulses' Research In India

Why Pulses....



Pulses are rich source of nutrients

Pulses (Dals)	Energy (K.Cal)	Protein (%)	Carbohydrate (%)	Fat (%)
Chickpea	360	21	60.9	5.3
Pigeonpea	335	22	57.6	1.7
Greengram	334	25	56.7	1.3
Blackgram	347	24	59.6	1.4
Cowpea	323	29	54.5	1.0
Lentil	343	27	59.0	0.7
Horse gram	330	24	56.5	1.1
Peas (dry)	315	26	56.5	1.1
Rajmash	346	23	60.6	1.3
Mothbean	330	24	56.0	0.6
Lathyrus	345	27	57.0	-

Mineral Content in Pulses (mg/100 g)

Pulses	Ca	P	Fe	Mg	Zn	Folic acid (µg/g)
Chickpea	114	387	6.2	168	8.6	5.5
Pigeonpea	124	304	5.8	133	6.4	-
Mungbean	124	326	7.3	171	11.7	6.3
Urdbean	154	385	9.1	185	16.2	-
Pea	75	298	5.1	124	-	2.7
Lentil	69	293	4.8	94	11.8	4.3

Lentil: a nutritious grain legume

Protein	20-25%
Carbohydrate	50-60%
Fat	0.7-0.8%
Ca	60-70 mg/100g
Fe	7-8mg/100g
Folates	216-290µg/100g

Standing Up for GMOs

ON 8 AUGUST 2013, VANDALS DESTROYED A PHILIPPINE "GOLDEN RICE" FIELD TRIAL. OFFICIALS AND staff of the Philippine Department of Agriculture that conduct rice tests for the International Rice Research Institute (IRRI) and the Philippine Rice Research Institute (PhilRice) had gathered for a peaceful dialogue. They were taken by surprise when protesters invaded the compound, overwhelmed police and village security, and trampled the rice. Billed as an uprising of farmers, the destruction was actually carried out by protesters trucked in overnight in a dozen jeepneys.

The global scientific community has condemned the wanton destruction of these field trials, gathering thousands of supporting signatures in a matter of days.* If ever there was a clear-cut cause for outrage, it is the concerted campaign by Greenpeace and other nongovernmental organizations, as well as by individuals, against Golden Rice. Golden Rice is a strain that is genetically modified by molecular techniques (and therefore labeled a genetically modified organism or GMO) to produce β-carotene, a precursor of vitamin A. Vitamin A is an essential component of the light-absorbing molecule rhodopsin in the eye. Severe vitamin A deficiency results in blindness, and half of the roughly half-million children who are blinded by it die within a year. Vitamin A deficiency also compromises immune system function, exacerbating many kinds of illnesses. It is a disease of poverty and poor diet, responsible for 1.9 to 2.8 million preventable deaths annually, mostly of children under 5 years old and women.†

Rice is the major dietary staple for almost half of humanity, but white rice grains lack vitamin A. Research scientists Ingo Potrykus and Peter Beyer and their teams developed a rice variety whose grains accumulate β-carotene. It took them, in collaboration with IRRI, 25 years to develop and test varieties that express sufficient quantities of the precursor that a few ounces of cooked rice can provide enough β-carotene to eliminate the morbidity and mortality of vitamin A deficiency.‡ It took time, as well, to obtain the right to distribute Golden Rice seeds, which contain patented molecular constructs, free of charge to resource-poor farmers.

The rice has been ready for farmers to use since the turn of the 21st century, yet it is still not available to them. Escalating requirements for testing have stalled its release for more than a decade. IRRI and PhilRice continue to patiently conduct the required field tests with Golden Rice, despite the fact that these tests are driven by fears of "potential" hazards, with no evidence of actual hazards. Introduced into commercial production over 17 years ago, GM crops have had an exemplary safety record. And precisely because they benefit farmers, the environment, and consumers, GM crops have been adopted faster than any other agricultural advance in the history of humanity.

New technologies often evoke rumors of hazard. These generally fade with time when, as in this case, no real hazards emerge. But the anti-GMO fever still burns brightly, fanned by electronic gossip and well-organized fear-mongering that profits some individuals and organizations. We, and the thousands of other scientists who have signed the statement of protest, stand together in staunch opposition to the violent destruction of required tests on valuable advances such as Golden Rice that have the potential to save millions of impoverished fellow humans from needless suffering and death.

— Bruce Alberts, Roger Beachy, David Baulcombe, Gunter Blobel, Swapan Datta, Nina Fedoroff, Donald Kennedy, Gurdev S. Khush, Jim Peacock, Martin Rees, Phillip Sharp

*B. Chassy *et al.*, "Global scientific community condemns the recent destruction of field trials of Golden Rice in the Philippines"; http://chn.ge/143PyHo (2013). †E. Mayo-Wilson *et al.*, *Br. Med. J.* **343**, d5094 (2011). ‡G. Tang *et al.*, *Am. J. Clin. Nutr.* **96**, 658 (2012).

10.1126/science.1245017

Roger Beachy is a Wolf Prize laureate; President Emeritus of the Donald Danforth Plant Science Center, St. Louis, MO, USA; and former director of the U.S. National Institute of Food and Agriculture.

David Baulcombe is a Wolf Prize laureate and Royal Society Professor in the Department of Plant Sciences of the University of Cambridge, Cambridge, UK. He receives research funding from Syngenta and is a consultant for Syngenta.

Gunter Blobel is a Nobel laureate and the John D. Rockefeller Jr. Professor at the Rockefeller University, New York, NY, USA.

Swapan Datta is Deputy Director General (Crop Science) of the Indian Council of Agricultural Research, New Delhi, India; the Rash Behari Ghosh Chair Professor at Calcutta University, India; and a former scientist at ETH-Zurich, Switzerland, and at IRRI, Philippines.

Nina Fedoroff is a National Medal of Science laureate; a Distinguished Professor at the King Abdullah University of Science and Technology, Thuwal, Saudi Arabia; an Evan Pugh Professor at Pennsylvania State University, University Park, PA, USA; and former President of AAAS.

Donald Kennedy is President Emeritus of Stanford University, Stanford, CA, USA, and former Editor-in-Chief of *Science*.

Gurdev S. Khush is a World Food Prize laureate, Japan Prize laureate, and former scientist at IRRI, Los Baños, Philippines.

Jim Peacock is a former Chief Scientist of Australia and former Chief of the Division of Plant Industry at the Commonwealth Scientific and Industrial Research Organization, Canberra, Australia.

Martin Rees is President Emeritus of the Royal Society, Fellow of Trinity College, and Emeritus Professor of Cosmology and Astrophysics at the University of Cambridge, Cambridge, UK.

Phillip Sharp is a Nobel laureate; an Institute Professor at the Massachusetts Institute of Technology, Cambridge, MA, USA; and President of AAAS.

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Biofortification breeding is the most economic and sustainable way of combating malnutrition problem

Thank you