Iron biofortified cereals to reduce hidden hunger in Africa

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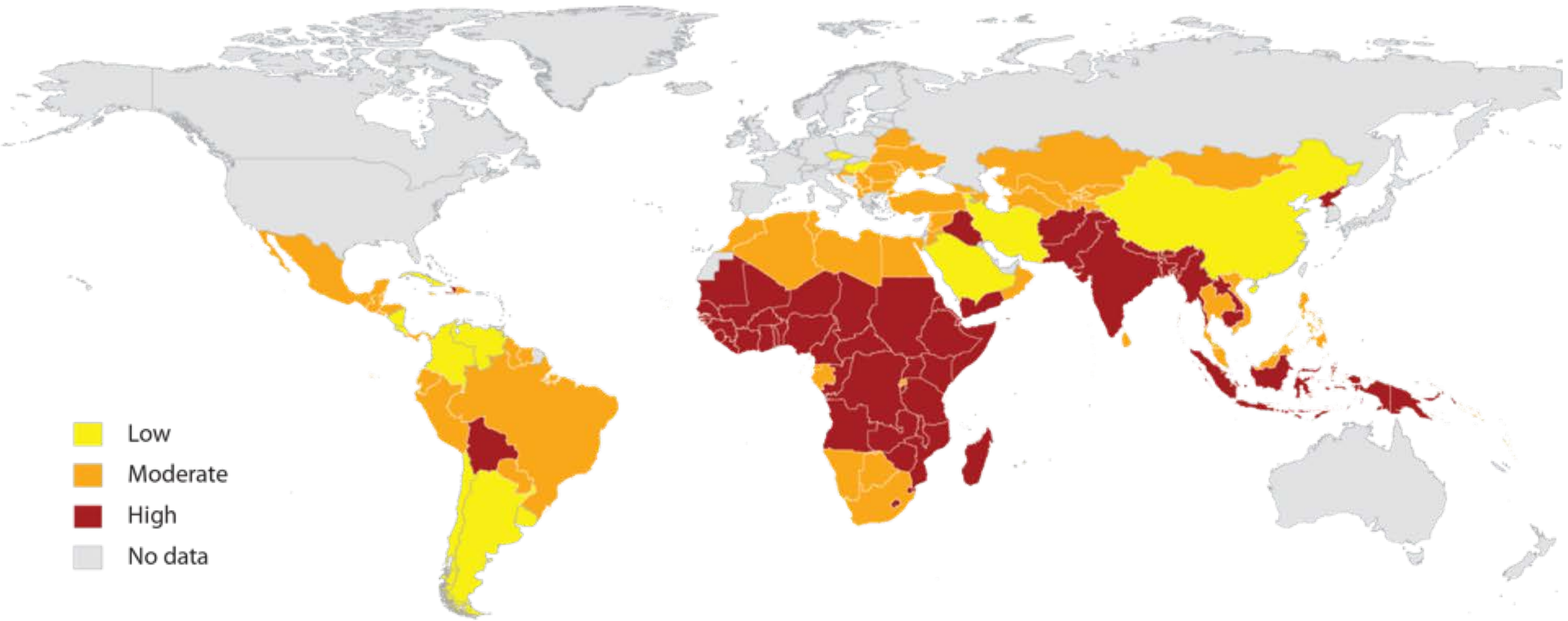
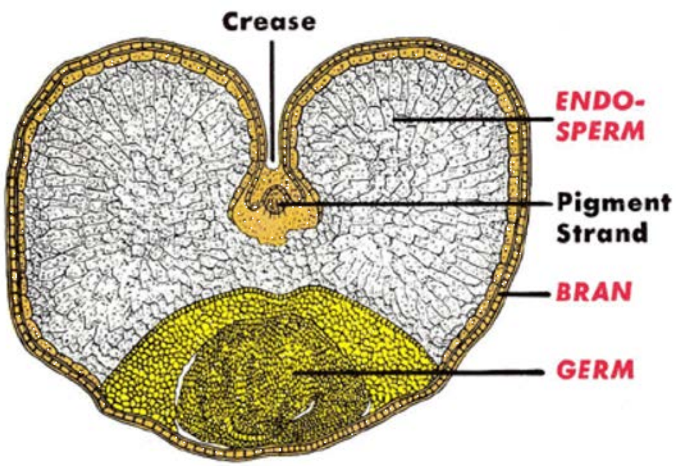
Hidden hunger affects one in three people globally

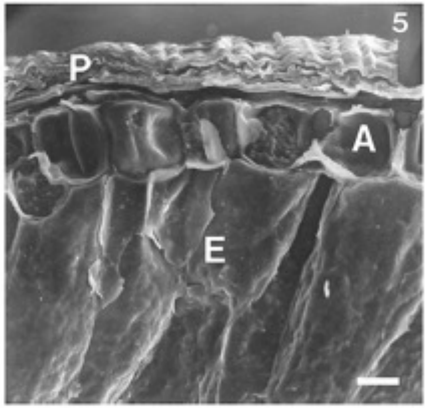


Iron deficiency = more than 2 billion
Zinc deficiency = 2 billion
Vitamin A deficiency = 150 million

Source: *WHO Global Health Observatory Database: http://apps.who.int/ghodata/*

Cereals are a poor source of micronutrients, particularly iron, in the human diet





- Low amount of iron (Fe) cereal grain, mostly in the outer bran and germ layers which are removed by milling.

- Typically bound to phytate and not bioavailable.

LETTER

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Increasing CO_2 threatens human nutrition

Samuel S. Myers[1,2], Antonella Zanobetti[1], Itai Kloog[3], Peter Huybers[4], Andrew D. B. Leakey[5], Arnold J. Bloom[6], Eli Carlisle[6], Lee H. Dietterich[7], Glenn Fitzgerald[8], Toshihiro Hasegawa[9], N. Michele Holbrook[10], Randall L. Nelson[11], Michael J. Ottman[12], Victor Raboy[13], Hidemitsu Sakai[9], Karla A. Sartor[14], Joel Schwartz[1], Saman Seneweera[15], Michael Tausz[16] & Yasuhiro Usui[9]

Dietary deficiencies of zinc and iron are a substantial global public health problem. An estimated two billion people suffer these deficiencies[1], causing a loss of 63 million life-years annually[2,3]. Most of these people depend on C_3 grains and legumes as their primary dietary source of zinc and iron. Here we report that C_3 grains and legumes have lower concentrations of zinc and iron when grown under field conditions at the elevated atmospheric CO_2 concentration predicted for the middle of this century. C_3 crops other than legumes also have lower concentrations of protein, whereas C_4 crops seem to be less affected. Differences between cultivars of a single crop suggest that breeding for decreased sensitivity to atmospheric CO_2 concentration could partly address these new challenges to global health.

experiments contribute more than tenfold more data regarding both the zinc and iron content of the edible portions of crops grown under FACE conditions than is currently available in the literature. Consistent with earlier meta-analyses of other aspects of plant function under FACE conditions[14,15], we considered the response comparisons observed from different species, cultivars and stress treatments and from different years to be independent. The natural logarithm of the mean response ratio (r = response in elevated [CO_2]/response in ambient [CO_2]) was used as the metric for all analyses. Meta-analysis was used to estimate the overall effect of elevated [CO_2] on the concentration of each nutrient in a particular crop and to determine the significance of this effect (see Methods).

We found that elevated [CO_2] was associated with significant decreases in the concentrations of zinc and iron in all C_3 grasses and le-

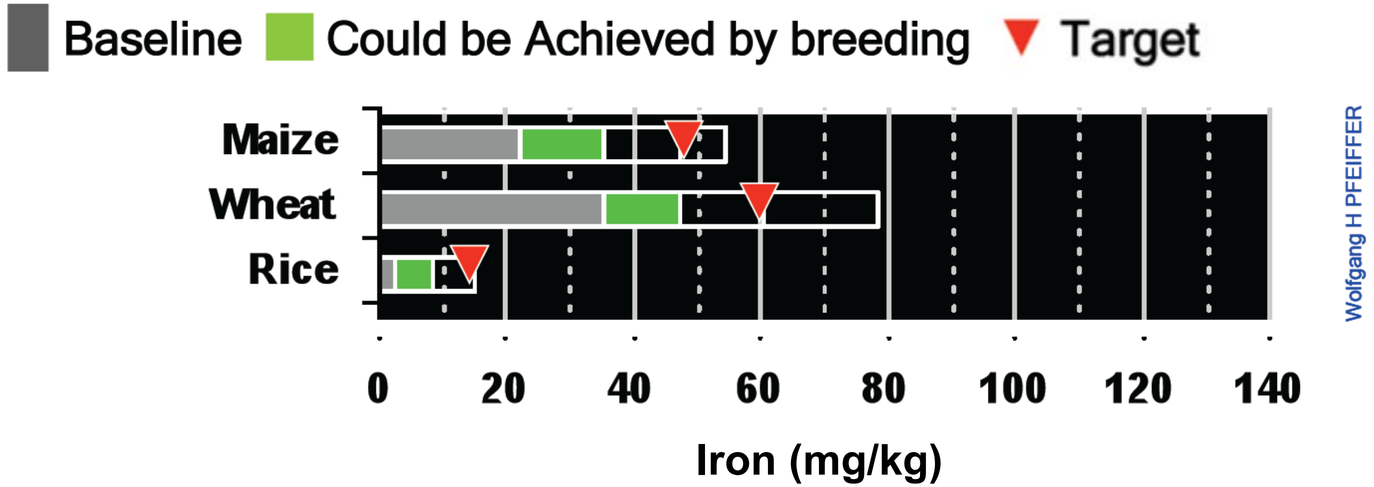
(Myers et al. 2014: *Nature* 510: 139-142)

Biofortification – a sustainable alternative to supplements and food fortification

Conventional Rice Golden Rice

- ✓ Fortifying plants with biology
- ✓ One time investment
- ✓ Reaches rural populations

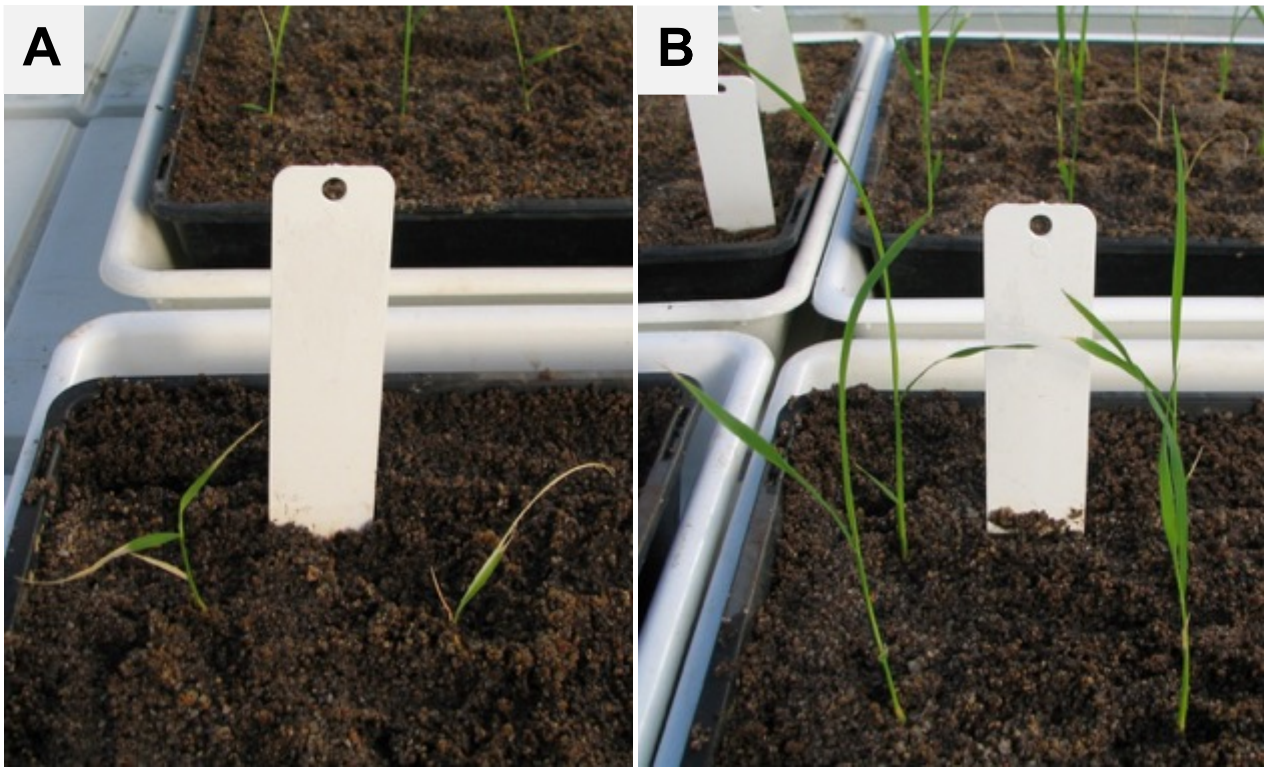
Conventional breeding has failed to biofortify the major cereals with Fe



Biotechnology offers new possibilities to reach Fe biofortification targets

With a single gene we can genetically engineer rice to be more effective at mining soil for Fe

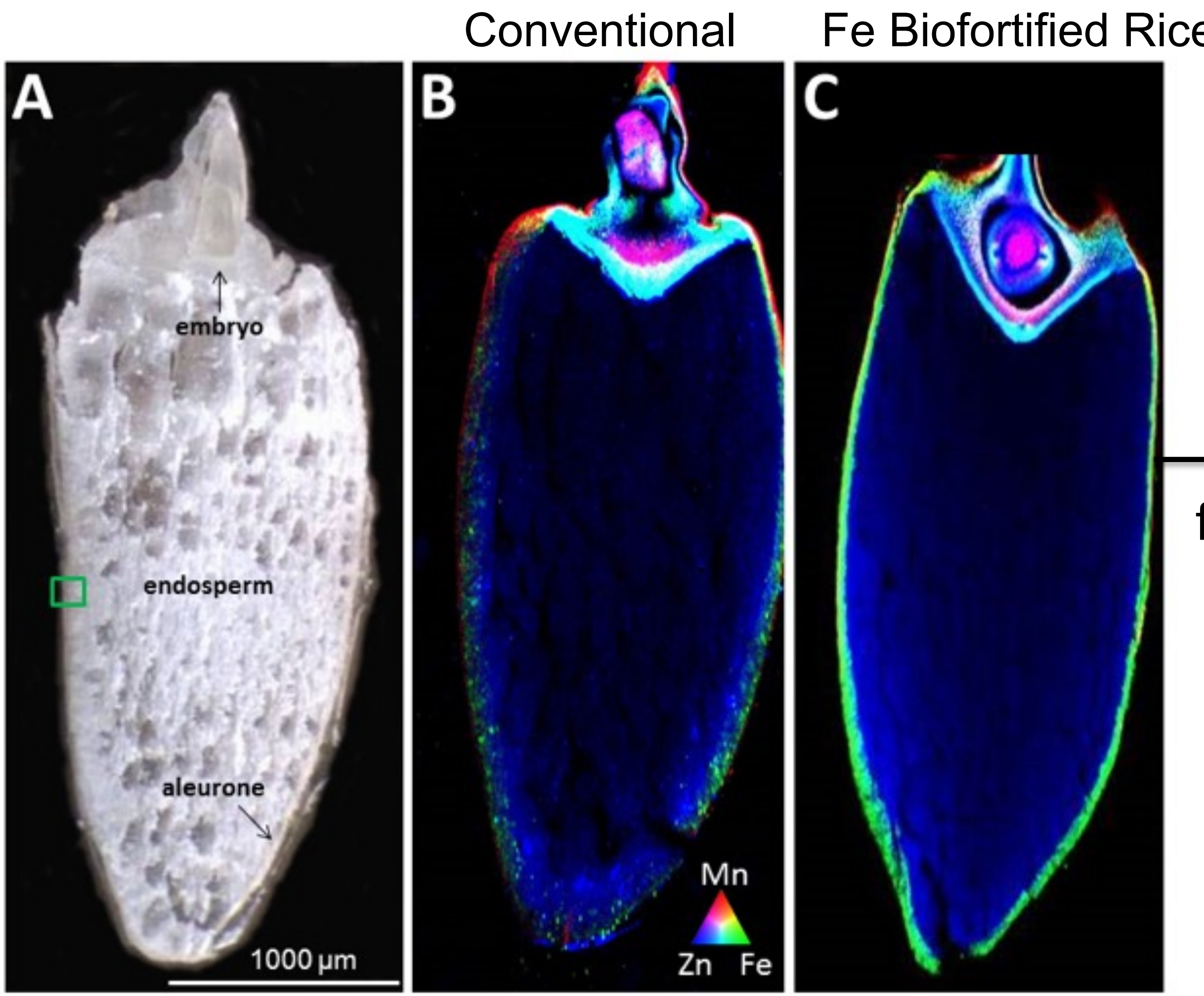
Conventional — Fe Biofortified Rice



Seedlings growing in UC Davis soil mix, pH 8.5

(Johnson 2013: *Functional Plant Biology* 40, 101-108)

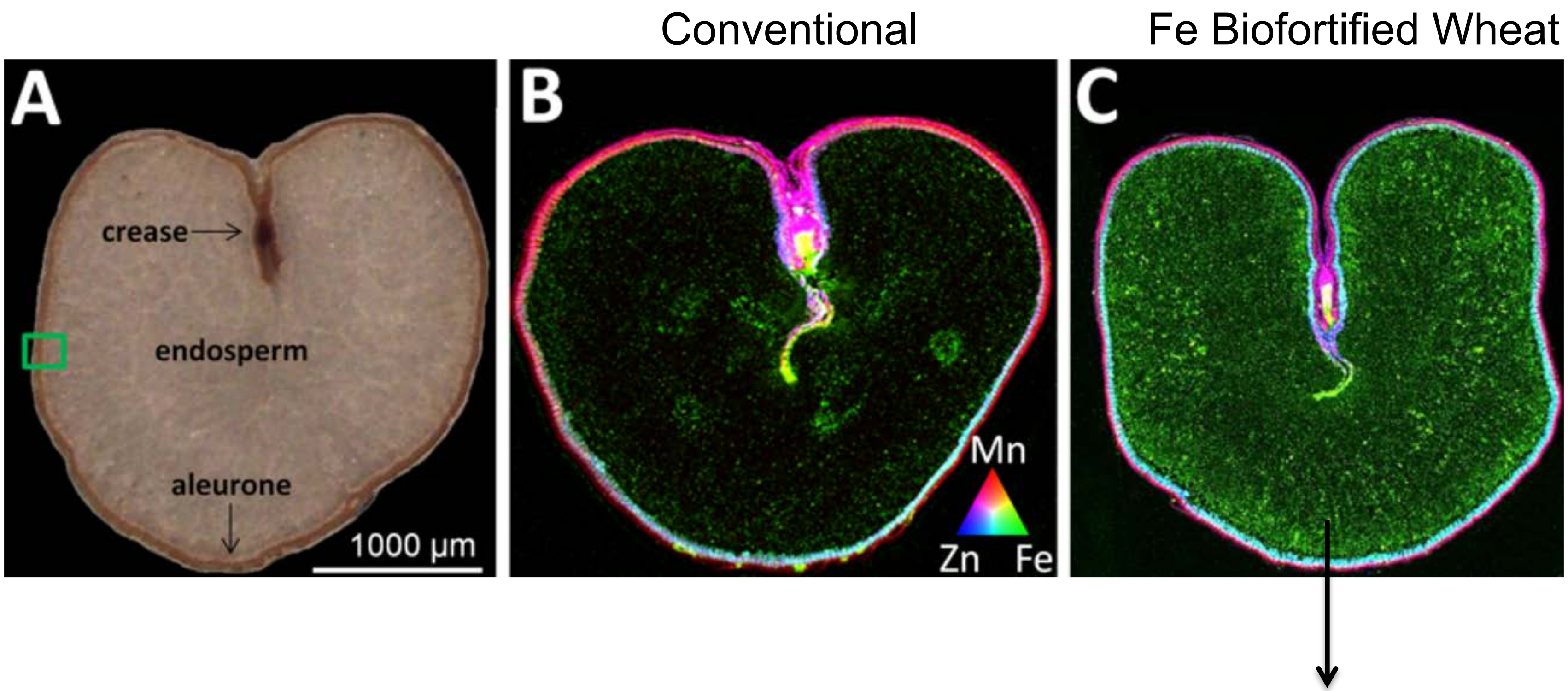
The rice plants produce Fe biofortified grain



Green color indicates four-fold more Fe

(Johnson et al. 2011: *PLoS ONE* 6, e24476)
(Kyriacou et al. 2014: *Journal of Cereal Science* 59, 173-180)

With the same genetic engineering approach we can produce Fe biofortified wheat



Green color indicates two-fold more Fe

Commercialization of Fe biofortified rice in Bangladesh within the next 5 years

- 80% of cultivated land area is used to grow rice.
- in 2013 became the first country to commercialize genetically engineered Bt brinjal (eggplant).
- Currently field testing genetically engineered potato, cotton and rice.
- Could be an important “starter” country for Fe biofortified rice (and possibly wheat) to launch to rest of Asia.
- How to get into Africa? Rice in West and Central Africa; wheat in North Africa.

Reshaping attitudes towards agricultural biotechnology for better nutrition

- Conventional breeding can deliver a range of biofortified crops (provitamin A cassava, Fe biofortified pearl millet and beans, etc.) but it misses many key areas.

- Agricultural biotechnology can address those areas and produce crops with huge impact – Fe biofortified rice and wheat, Golden Rice.

- Costs of discovery, development and authorization (deregulation) of a genetically engineered crop can exceed $100 million!

- By supporting commercialization of genetically engineered crops in developing countries (e.g. public-private partnerships) developed countries like Australia can help realize the benefits of biofortified crops in Africa and other regions impacted by hidden hunger.

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