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REVIEW ARTICLE **OPEN ACCESS**

Biofortification – A Potential Boost to Human Nutrition

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ABSTRACT
Billions of people in developing countries suffer from an insidious form of hunger known as micronutrient malnutrition. Even mild levels of micronutrient malnutrition may damage cognitive development, lower disease resistance in children, and reduce the likelihood that mothers survive childbirth. Hidden hunger also reduces the productivity of adult men and women due to increased risk of illness and reduced work capacity. In 2008, The Lancet published a landmark series of articles on maternal and child under-nutrition highlighting the extent of hidden hunger. Although food fortification and supplementation programmes have been effective, their overall success remains limited. Biofortification, that is, breeding crops for higher micronutrient content, is a relatively new approach. Biofortification can provide an additional instrument against the fight to reduce micronutrient malnutrition. Biofortification is a process where plant breeders explore crops genetic diversity in seed banks and create a crop that is rich in specific micronutrients. The ultimate goal of the biofortification strategy is to reduce mortality and morbidity rates related to micronutrient malnutrition and to increase food security, productivity, and the quality of life for poor populations of developing countries by breeding staple crops that provide, at low cost, improved levels of bioavailable micronutrients in a fashion sustainable over time. Pearl millet is one such crop. The crop has been biofortified to improve its iron and zinc nutrients. The Indian Council for Agricultural Research (ICAR) and the Indian Council of Medical Research (ICMR) plan to propose introduction of bio-fortification to the Planning Commission for the 12th Five Year Plan. There are two ways to biofortify crops—conventional plant breeding and transgenic methods. After the one-time investment is made to develop seeds that fortify themselves, recurrent costs are low, and germplasm may be shared internationally. It is this multiplier aspect of plant breeding across time and distance that makes it so cost-effective and sustainable. Nutritionally improved varieties will continue to be grown and consumed year after year, even if government attention and international funding for micronutrient issues fades. Biofortification provides a truly feasible means of reaching malnourished populations in relatively remote rural areas, delivering naturally fortified foods to people with limited access commercially marketed fortified foods, which are more readily available in urban areas. Biofortification and commercial fortification, therefore, are highly complementary. Nutritionists must determine the additional amount of a nutrient a food crop must provide to measurably improve nutrition and to fight against hidden hunger. They must account for nutrient losses after the crop is harvested, during storage, processing, or cooking, the bioavailability of the nutrient and the amount of the staple food actually consumed on a daily basis by age and gender. These data are then used to set breeding targets for specific nutrients in food for their biofortification to combat micronutrient malnutrition. Developing plant breeding tools, crossing, testing various lines for nutritional effects, eventual dissemination of nutritionally improved varieties, and measuring their effectiveness in reducing malnutrition, seems to a very promising line to fight against hidden hunger and improve human health in the years to come.
Key words: *Biofortification, malnutrition, hidden hunger, micronutrients, fortified varieties*

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INTRODUCTION

World's most serious, quite talked about but least addressed, one of the worst forms of non-communicable disease that is lifting its head as a major risk factor the chronic disease in the upcoming years is malnutrition. The human and economic cost of malnutrition is gargantuan, having a highest impact on the poor, children and women. As per the reports published by NFHS, UNICEF and WHO, in India, the rate of malnutrition is alarmingly high among the children, adolescent girls, pregnant and lactating women. Several factors can be accorded to this. Poverty, inadequate access to safe drinking water, ignorance, low agricultural productivity, clean disease-free environment, cultural factors, healthcare outreach, infections, loss of appetite, impaired absorption and utilisation of nutrients, particularly micronutrients, environmental xenobiotics, mother's nutritional status, lactation behaviour, women's education, sanitation, food security, nutrition security etc. all contribute to the poor health and nutrition status. The adverse effects of maternal malnutrition have a multigenerational effect on health &development and is a vicious cycle. Figure 1 portrays the vicious cycle of hidden hunger though out life.

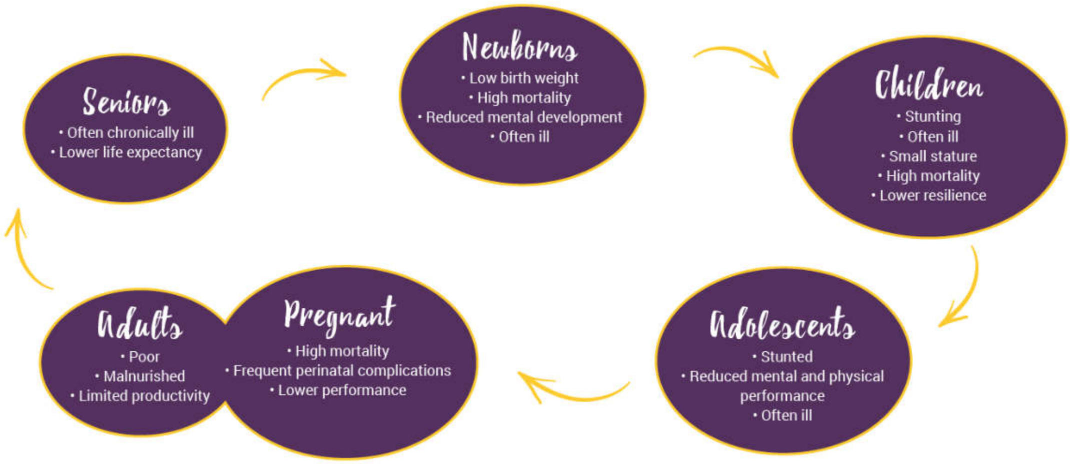

Figure 1. Hidden hunger throughout the life cycle

Hidden hunger

In India, for the country to achieve growth and development immediate attention is required towards combating malnutrition. Nutrition has to be the basis of judging national development. Besides protein energy deficiency, micronutrient deficiencies are enormous. Micronutrient deficiency that is generally referred to as the hidden hunger may not be the direct killer but may cause serious hazards. According to USAID OMNI [1] about half of the micronutrient deficient population of the world reside in India. The prevalence of anaemia according to NFHS 4 is nearly 58.5 per cent in children, 50 per cent in pregnant women and 53 per cent in non-pregnant women of reproductive age [2] estimated that about 74 per cent of Indian population suffer from anaemia due to iron deficiency, 62 per cent are at a risk of vitamin A deficiency and 31 per cent at iodine deficiency. Figure 2, clearly indicates lag in the progress against the global nutrition targets 2019 to be achieved by India [3].

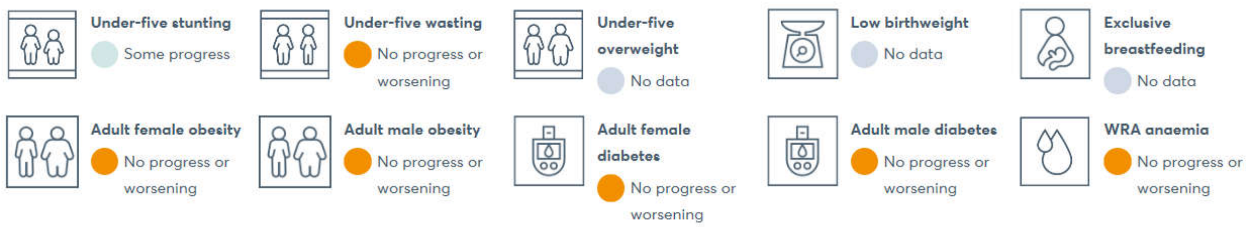

Figure 2. Progress against global nutrition targets 2019

Sources: UNICEF global databases Infant and Young Child Feeding, UNICEF/WHO/World Bank Group: Joint child malnutrition estimates, NCD Risk Factor Collaboration, WHO Global Health Observatory and Global Burden of Disease, the Institute for Health Metrics and Evaluation.

Notes: WRA = Women of a reproductive age; NA = not applicable. The methodologies for tracking differ between targets. Data on the adult indicators are based on modelled estimates.

Studies conducted by Hotz, and Brown [4] indicate that 25 – 33 per cent of the population that resides in developing nations of the world are at a risk of zinc deficiency. Though, few vitamin deficiencies such as beriberi, pellagra, scurvy has almost disappeared, diseases like night blindness, IDD, vitamin D, calcium, vitamin B_{12} deficiency *etc.* still persist. Anon [5] reported that several studies conducted by NNMB, NIN, ICMR in various states of India indicated that the diet is qualitatively deficient in micronutrients such as calcium, iron, riboflavin, vitamin A and folic acid.

Biofortification: Varieties and techniques

Enrichment of the germplasm with such micronutrients through conventional or molecular breeding techniques and genetic engineering are more promising methods to alleviate hidden hunger. Bio-fortification is a seed-based technology with minimum or no recurring cost once the varieties are developed and adopted. It can be sustained easily with complete benefit to the farmer as well as the end consumers. "The Harvest Plus: bio-fortification challenge programme is an interdisciplinary, global alliance of research and implementing institutions. It includes: β carotene (pro-vitamin A)- rich sweet potato, and cassava, zinc and iron– rich rice, wheat, maize, pearl millet, and beans. DBT network project on biofortification of rice, wheat and maize is currently being implemented by ICAR [6]. Iron biofortification in India seems to possess enormous potential [7].

Golden rice is an excellent example of beta-carotene and iron rich rice developed from transgenic technology. Development of micronutrient rich varieties within the species with appropriate gene pool would be an important part of conventional or molecular breeding. Moreover, this methodology would be quite time consuming. Genetically altered varieties with qualities from other plant species, ideally consumable assortments, is faster and with reasonable safety and security to wellbeing, protection of biodiversity, and cost.

Biofortification is a method of developing micronutrient rich staple food crops. Researchers from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as a team with Harvest Plus are working on iron-rich assortments of pearl millet [8]. Presently about 15 million people in about more than 30 countries grow and consume biofortified crops. In India, six staple crops have been focused to be biofortified. Pearl millet, sorghum and cowpea with iron, wheat and rice with zinc and lentils with iron and zinc. Presently, rice, wheat and pearl millet varieties that are biofortified are available to the farmers for cultivation [9]. India ranked tenth out of 117 countries that are suitable for iron rich pearl millet.

Meenakshi *et. al.,* [10] reported that the focus of biofortified pearl millet was to increase the absorption level of iron among people from 5 to 10 per cent and the yield by 1 per cent. Even though the amount of production of pearl millet is quite low compared to rice and wheat but is very strategic as it consumed by the poor section. Around 35 million individuals eat pearl millet that costs substantially less than rice and wheat and is thus an effective tool to fight anaemia. It has 50-65 ppm iron, about twice more iron than current wheat varieties [11].

The nutritional benefit provided by pearl millet is that it provides about 80 per cent of the daily iron requirement. The varieties developed are ICTP 8203-Fe-10-2 (*Dhanashakti*), ICMH 1201 (Shakti-1201), and are high yielding, mildew resistant, short duration, drought tolerant. In case of zinc rich wheat, India has been found suitable and ranked third among 1228 countries for investing in zinc wheat. The varieties developed are BHU-3, BHU-6 (*Chitra*) and provide up to 50 per cent of daily zinc requirement. They are high yielding, adapted to the target area of eastern gangetic plains and are disease resistant [12]. ICRISAT has developed the sorghum with higher iron and zinc content. The developed varieties has been reported to have an average iron content of 45 ppm and zinc content of 32 ppm against 30ppm and 20 ppm of iron and zinc respectively in the traditional varieties. It also has a higher protein (11.9 %) and low phytate content (4.14 mg/100g) when compared to the traditional varieties that contained about 10 per cent of protein and 7 mg / 100 g of phytate [13, 14]. Biofortified crops are farmer friendly, as no separate agricultural practice is required to grow them. Seeds of biofortified crops may be used years after year with their enhanced potential benefits.

The biofortification costs includes research & development, adaptive breeding, maintenance breeding and for dissemination. In initial years, investment is occurred in basic research and development. After identification of promising parent lines, the adaptive phase begins, where these traits are bred into popular varieties cultivated in target countries. This process can take up to 5 years. As dissemination takes place, certain costs of sustaining the high nutrient trait over time are incurred annually. Therefore, the bulk of the investment is up front. The cost of research and development used for the exercise of cost-effectiveness were derived from the budgets of Harvest Plus. These are then apportioned to countries taking into account projections of geographical allocations for plant breeders as well as export shares [10].

Once a bio-fortified crop is grown, farmers can easily grow it by sharing its seeds with others, so that they are adapted at different regions as well, also bio-fortified crops provides better nutrition using familiar foods, therefore bio-fortified is cost-effective and sustainable in nature as investment is done at initial stage only. Moreover, internationally improved seeds can be shared. Biofortified seeds are also likely to have an indirect impact in agriculture, as a higher trace mineral content in seeds confers better protection against pests, diseases, and environmental stresses, thereby increasing yield [15]. Biofortification in itself is not a panacea, but a very important balance to dietary variety and supplementation.

CONCLUSION

Using traditional breeding methods biofortified crops can develop, on condition that there is sufficient genetic variation in crop populations for the desired trait (such as high protein content). In staple grains such as rice, it is not possible to improve certain complex traits such as vitamin-A using conventional breeding strategies, as there are no natural varieties of rice contain this vitamin. All plants produce pro-vitamin A, but only in the plant's green organs and not in the seed storage part. In vegetatively propagated varieties (such as cassava and potatoes) conventional breeding is also very difficult, due to the scarcity of genetically well-defined breeding lines [16], not only this but it can also change some important traits of the crop desired by the consumers such as taste. Therefore, agricultural biotechnology methods and in specific genetic engineering are very useful complementary strategy for developing more nutritious crops

Thus, a reasonable method for fighting hidden hunger would be through a novel method of 'bio-fortification' of staple nourishment crops. As it is a financially savvy, dependable and practical approach. Bio-fortification is endeavoured in staple crops that are lacking in specific micronutrients by consolidating the gene(s) to combine a specific supplement which is insufficient in that specific yield. This strategy, particularly, in developing nations includes developing the staple food increasingly nutritious by utilizing both conventional plant breeding and biotechnological approaches. Traditional breeding procedures could be fruitful when there is good amount of variability for the characteristics between and within the developed species.

REFERENCES

1. USAID OMNI (2005). *Micronutrient Fact Sheet, India*. Available online at: http://www.cdc.gov /immpact/micronutrients/
2. International Institute for Population Sciences (2016). *India Fact Sheet - NFHS-4 (2015-16).* Mumbai: International Institute for Population Sciences. Available online at: http://rchiips.org/NFHS/__pdf /NFHS4/India.pdf
3. UNICEF-State of World's Children, Report, (2019), special edition
4. Hotz, C., and K. Brown. (2004). Assessment of the risk of zinc deficiency in populations and options for its control: International Zinc Nutrition Consultative Group Technical Document1 ICAR Reporter, 2012. April- June 2012. http://www.icar.org.in/files/ICAR-Reporter-April-June-2012.pdf
5. Anonymous 2010. Research and development in millets. Present status and future strategies. National seminar on millets-2010; Directorate of sorghum research, Hyderabad, November, 2010.
6. K N Rai, 2012. Coordination of Biofortification Research and Development Activities in Grain and Tuber Crops to Enhance Nutritional Security in India. http://www.icrisat.org/DC-Projects/Coordination.pdf
7. Stein A, Meenakshi J, Qaim, JV, et.al. Potential impacts of iron biofortification in India; Social Science and Medicine, 66: 1797-1808, 2008
8. Harvest Plus (2010), Country Crop Profile: Iron Pearl Millet in India, Harvest Plus, IFPRI, Washington, D.C., (http://www.harvestplus.org/sites/default/files/Country%20Crop%20Profile_India%20Iron%20Pearl%20Millet.pdf)
9. Harvest Plus (2019), Iron-Pearl Millet Strategy, Harvest Plus, IFPRI, Washington, D.C., (http://www.harvestplus.org/sites/default/files/HarvestPlus_Pearl_Millet_Strategy.pdf
10. J.V. Meenakshi, Nancy Johnson, Victor M. Manyong, Hugo De Groote, Josyline Javelosa, David Yanggen, Firdousi Naher, Carolina Gonzalez, James Garcia and Erika Meng, 2007. How cost-effective is biofortification in combating micronutrient malnutrition? An ex-ante assessment. Harvest Plus. http://www.ifpri.org/sites /default/files/publications/hpwp02.pdf
11. Sood, J. (2011). India set to grow biofortified crop. http://www.downtoearth.org.in/content/india-set-grow-biofortified-crop
12. "Nutrition Security for India– issues and the way forward" INSA Position paper, www.insa.ac.in
13. "Micronutrient security for India- priorities for research and action" INSA Position paper, (2011) www.insa.ac.in
14. G. Anil, Ravikiran K.T. Mohammed R., Phuke R. M. Sadaiah K. Kumar P.B.A (2018), Inheri,tance studies on grain iron and zinc concentration and agronomic traits in sorghum [*Sorghum bicolor* (L.) Moench]Journal of Cereal Science Volume 83, p252-258.
15. Welch R. M. and Graham R. D. (2004). J. Exp.Bot. 55: 353-364.
16. Anonymous, (2012). Biotechnology and Biofortification. International Service for acquisition of agri-biotech application. Pocket K No. 27. http://www.isaaa.org/resources/publications/pocketk/27/default.asp

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