Food systems that prioritize nutrition and crops enhanced with bio fortification

[1*]**Dr. Ram Bajaj**
[1]RNB Global University-RNB Global City, Ganganagar Road,, Bikaner, Rajasthan 334601
e-mail-chairman@rnbglobal.edu.in

Abstract: Recognizing that economic growth alone isn't sufficient to improve nutritional well-being, there's been a shift in addressing malnutrition through a nutrition-sensitive approach in development. Biofortification, as a part of this paradigm, intervenes in food systems to deliver essential micronutrients through staple diets, especially to populations facing challenges in consuming diverse foods. Biofortified crops have the potential to meet 35–50% of the daily estimated average requirement of micronutrients. Despite being in the early stages, the state can play a role in establishing a robust value chain for biofortified products. The paper explores practical policy interventions in that direction.
Keywords Hidden hunger; biofortification; conventional plant breeding; value chain; brand building

1. Introduction:

A robust immune system stands as the primary defense against various health threats, including viruses like the coronavirus. Hidden hunger, stemming from micronutrient deficiency, poses a significant obstacle to a resilient immune system—a critical issue acknowledged by organizations such as FAO, IFAD, UNICEF, WFP, and WHO (2020).

Globally, an estimated 2 billion people grapple with malnutrition, a burden deemed unacceptably high (Fan et al. 2019). In South Asia, hidden hunger prevails more extensively than in any other region. The prevalence of anemia among pregnant women in South Asia is staggering at 52%, surpassing the global rate of 38%. Among children under five in Asia, 58% are affected (compared to 43% worldwide). Inadequate zinc intake is a concern for 30% of South Asia's population, exceeding the global figure of 17%. Alarmingly, 31–57% of preschool children in the region face Vitamin A deficiency. Tragically, almost half of childhood deaths are linked to malnutrition (Harding et al. 2018).

Rural Indians grapple with suboptimal diets, consuming a higher proportion of calories from whole grains but lacking in protein sources compared to the EAT-Lancet reference diet (Sharma et al. 2020). Despite the EAT-Lancet diet requiring a certain level of expenditure, most rural Indians allocate only a fraction of the needed budget, with minimal spending on meat, fish, poultry, dairy, and fruits (Gupta et al. 2021). Climate change exacerbates malnutrition in South Asia by diminishing iron, zinc, and protein in staple crops like wheat, rice, maize, and soybeans (Myers et al. 2014).The COVID-19 pandemic adds another layer of concern, potentially worsening all forms of malnutrition, including hidden hunger, amidst economic downturns and disruptions

(Osendarp et al. 2020). Micronutrient deficiencies not only impact physical health but also hinder cognitive development, educational outcomes, work productivity, and earnings, leading to a decline in overall societal welfare. In India, the economic cost of malnutrition is estimated at 2.5% of national income (Jitendra 2013), contributing to 9 billion disability-adjusted life years (Qaim et al. 2007).

2. A transformative change in the approach to addressing malnutrition

The acknowledgment that economic growth alone is insufficient to alleviate malnutrition prompted a shift in focus towards direct nutrition-sensitive interventions in the early 21st century (Gillespie et al. 2013). This echoes the global paradigm shift in the mid-1970s towards the basic needs approach, where policy changes were implemented to directly combat deprivation.

The sequence of events that brought malnutrition to the forefront of policy discussions began with widespread outrage during the 2007–08 global crisis and the publication of the initial Lancet Series in 2008 on maternal and child malnutrition. Frustration over the lack of noticeable improvements in the nutritional status of the masses led concerned individuals from the United Nations (UN), government, donors, and civil society to launch the Scaling Up Nutrition movement in 2010. This movement, grounded in the principle that everyone has a right to food and good nutrition, garnered the support of 61 national governments and four Indian states (Jharkhand, Maharashtra, Uttar Pradesh, and Madhya Pradesh). The subsequent Rome Declaration on Nutrition in 2014 at the Second International Conference on Nutrition further emphasized malnutrition in policy discussions.

These collective efforts materialized in Sustainable Development Goal 2 in 2015, aiming to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture." This goal explicitly highlighted the connections between agriculture and nutrition, marking a paradigm shift that necessitates all development programs and processes, especially those in the food system, to be nutrition-sensitive (Pingali and Sunder 2017).

The UN General Assembly declared 2016–25 as the Decade of Action on Nutrition, based on the Rome Declaration of Nutrition, and established institutional mechanisms. Five international organizations collaborated for the first time, publishing annual reports titled State of Food Security and Nutrition in the World. The International Food Policy Research Institute (IFPRI) commenced publishing annual Global Nutrition Reports. Various governments, including India and other SUN countries, implemented measures to combat hidden hunger. India's National Nutrition Strategy of 2016 incorporated biofortification through micronutrient-dense foods. In 2017, the country initiated the POSHAN Abhiyaan, a flagship program (Menon et al. 2021; Suri and Kapur 2020).

3. Biofortification for combating hidden hunger

Dairy and livestock products, fruits, vegetables, and pulses are rich sources of micronutrients, yet individuals in impoverished regions of developing countries often fall short in incorporating these foods into their diets. In India, investments directed at improving staple crops led to a sustained reduction in food prices following the green revolution, but accessibility and affordability remain significant barriers to other nutrient-dense foods. The failure of markets to encourage the necessary dietary diversity for nutritional security calls for state intervention through supplementation, fortification, and the innovative approach of biofortification (Pingali and Sunder 2017).

Biofortification, involving the augmentation of vitamin and mineral content in crops through conventional plant breeding, agronomic practices, and transgenic techniques, emerges as a potential solution. Although current biofortified crop varieties primarily employ conventional plant breeding methods, they may not match the nutrient levels found in industrially fortified foods. Nevertheless, biofortification can play a crucial role in increasing daily micronutrient intake. Plant breeders strive to enhance the nutrient content of crops to meet a significant portion of the daily estimated average requirement, thereby alleviating deficiencies in the population.

The extent of nutrient deficiency varies based on factors such as age group, gender, and various other considerations (Bouis et al. 2017). Using symbols such as Cf for per capita consumption of the staple, Df for the density of the mineral/vitamin to be enhanced, Rp for the retention of the mineral/vitamin after processing, storage, or cooking, and Bc for the percentage availability after consumption, the additional nutrient supplied through biofortification (ENb) can be represented as:

$$EN_b = C_f D_f R_p B_c \qquad \ldots(1)$$

The additional percentage of the estimated average requirement supplied (AE) can be calculated by dividing ENb by the estimated average requirement (E) of the specific mineral/vitamin:

$$A_E = \frac{EN_b}{E} \qquad \ldots(2)$$

This formula allows for the quantification of the contribution of biofortification to meeting the estimated average requirement of essential nutrients, providing a valuable metric for evaluating the effectiveness of biofortified crops in addressing nutritional deficiencies.

Biofortification emerges as a highly effective and sustainable strategy to combat hidden hunger, providing essential micronutrients to vulnerable populations in a cost-efficient manner. In rural areas, the consumption of biofortified crops by farm households plays a crucial role in reducing malnutrition, leveraging the predominantly rural nature of poverty in South Asia to its advantage. As markets develop, urban households also gradually incorporate these nutrient-rich foods into their diets.

The diffusion of biofortified crop varieties has been significant in developing countries, benefitting millions of people. In 2019, 8.5 million farming households across 14 countries in Africa, Asia, and Latin America benefited from cultivating these varieties. Notably, biofortified pearl millet fortified with iron reached 500,000 people in India in 2018, with 240,000 farmers cultivating it in 2019 (Foley et al. 2021).

Studies examining the impacts of biofortification on poor farmers in rural areas show positive outcomes. Biofortification increases micronutrient intake among children and women, with benefits directed towards lower-income groups. Consumers in several countries express acceptance or preference for biofortified foods. These crops provide 35–50% of the daily estimated average requirement of micronutrients.

Biofortified beans, pearl millet, wheat, rice, cassava, maize, and sweet potato have been proven to supply significant percentages of the estimated average requirement for iron, zinc, and vitamin A. Recent studies confirm that cooking methods do not degrade biofortified maize with zinc, and consumers are willing to pay a premium for these crops.

Randomized control trials in India demonstrate the effectiveness of biofortified crops in reducing micronutrient deficiencies. For example, pearl millet fortified with iron and zinc, when fed as a staple to 2-year-old children, meets physiological requirements for iron and over 80% of the physiological requirement for zinc. Biofortified pearl millet has been associated with improved iron status, cognitive skills, and physical activity in schoolchildren.

Biofortification stands out as one of the most cost-effective solutions to hidden hunger, providing a benefit worth 17 dollars for every dollar spent. Agronomical gains accompany biofortified varieties, enhancing growth and yield without incurring yield penalties. Ex-ante studies in India and other countries show high internal rates of return for iron, zinc, and vitamin A biofortification scenarios.

Over 290 varieties of 12 biofortified crops have been officially released in over 30 countries, including iron beans, pearl millet, vitamin A cassava, maize, and orange sweet potato, as well as zinc maize, rice, and wheat. India, through concerted efforts by institutions like the Indian Council of Agricultural Research (ICAR) and HarvestPlus, has released several biofortified crop varieties, addressing nutrient deficiencies and promoting nutritional health.

The commercialization of these crops, including iron-rich pearl millet hybrids and high-zinc and high-protein rice varieties, exemplifies the successful diffusion of biofortified crops in India. Ex-ante studies on zinc-enhanced rice show significant potential to reduce zinc deficiency cost-effectively. Various ICAR institutes continue to develop biofortified varieties, contributing to India's commitment to addressing malnutrition and hidden hunger. The release of 17 biofortified crop varieties by the Prime Minister of India on World Food Day 2020 underscores the country's dedication to harnessing biofortification to enhance nutritional outcomes.

4. Value chain development and the global experience

It's fascinating to see the intricate balance between consumer preferences, information dissemination, and the development of value chains for achieving SDG 2. The case of iron beans in Rwanda highlights the delicate trade-off consumers make between nutrition and consumption attributes.

Consumers' willingness to pay a significant premium when provided with information on the nutrition and health benefits of biofortified crops emphasizes the importance of awareness in driving demand. It's interesting that they lean towards international brands over local ones when making these choices.

This underscores the need for effective communication strategies to highlight the nutritional advantages of biofortified crops. It's not just about producing these crops but also about ensuring that consumers are well-informed about their benefits. This information can be a powerful driver for behavior change, positively impacting both consumer choices and, consequently, the value chains associated with these crops.

The dynamics you've outlined also highlight the global dimension of the issue, with consumers expressing a preference for international brands. This could have implications for market strategies and branding efforts aimed at promoting biofortified crops.

In summary, it's not just about the crops themselves but about shaping perceptions, providing information, and understanding consumer behavior to create robust value chains for micronutrient-rich foods.

Biofortified crop varieties are strategically developed to be adaptable and well-received by growers, as highlighted by Nestel et al. in 2006. Notably, in Bangladesh, the popularity of a shorter-duration zinc rice variety, coupled with improved submergence tolerance, has gained traction among farmers. In India, efforts to enhance the shelf life of high-iron pearl millet and enable cultivation in the cool season aim to enhance both production and the availability of nutritious food products (Bouis et al., 2017).

The success of introducing biofortified crops heavily relies on the vibrancy of seed markets and the chosen diffusion strategy. In various countries, a comprehensive approach involves collaboration with both the public and private sectors. Zambia, with its dynamic seed markets, exemplifies how engaging seed company networks can facilitate mass multiplication of biofortified crops (Simpungwe et al., 2017). This approach is mirrored in India, where active seed markets provide a conducive environment for the dissemination of biofortified varieties.

Specific initiatives by organizations like ICRISAT for pearl millet, HarvestPlus of IFPRI for zinc-fortified wheat, and ICAR for rice in regions like Odisha, Telangana, and Chhattisgarh showcase successful strategies within the vibrant seed markets. These initiatives demonstrate how targeted engagement with key actors in the seed value chain can propel the adoption of biofortified crops, contributing to the overarching goal of achieving Sustainable Development Goal 2 and addressing nutritional deficiencies on a broader scale.

Table 1: Progress in the release of biofortified crop varieties in India

Crop	Variety/Hybrid	Improved vitamin/ mineral/amino acid	Developer
Pearl millet	ICTP 8203 ICMH 1201 HHB 299, AHB 1200	Iron Iron and zincIron	Harvest Plus Indian Council of Agricultural Research Chaudhary Charan Singh-Haryana AgriculturalUniversity and ICRISAT Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani under AICRIP of Indian Council of Agricultural Research
Rice	DRR Dhan 45,	Zinc	Indian Institute of Rice Research, Hyderabad
	DRR Dhan 49 CR Dhan 310	Protein	National Rice Research Institute, Cuttack
	CR Dhan 311	Protein and zinc	National Rice Research Institute, Cuttack
Wheat	BHU 3 and BHU 6	Zinc	Harvest Plus
	WB 02	Zinc and iron	Indian Institute of Wheat and Barley Research,Karnal
	HPBW 01	Iron and zinc	Punjab Agricultural University, Ludhiana
	Pusa Tejas,Pusa Ujala	Protein, iron, and zinc	ICAR-Indian Agricultural Research Institute,Regional Station, Indore
	MACS 4028	Protein, iron, and zinc	Agharkar Research Institute, Pune
Sweet potato	Orange fleshed Sweet Potato	Vitamin A	Harvest Plus
	Bhu Krishna	Anthocyanin	Indian Council of Agricultural Research
Maize	Pusa Vivek QPM9 Improved	Provitamin A, lysine, and tryptophan	Indian Agricultural Research Institute, New Delhi
	Pusa HM4 Improved	Tryptophan and lysine	Indian Agricultural Research Institute, New Delhi

	Pusa HM8 Improved	Tryptophan and lysine	Indian Agricultural Research Institute, New Delhi
	Pusa HM9 Improved	Tryptophan and lysine	Indian Agricultural Research Institute, New Delhi
Lentil	PusaAgeti Masoor IPL 220	Iron Iron and zinc	Indian Agricultural Research Institute, New Delhi Indian Institute of Pulse Research, Kanpur
Soybean	NRC-127	KTI-free	Indian Institute of Soybean Research, Indore
Mustard	Pusa Mustard 30	Low erucic acid	Indian Agricultural Research Institute, New Delhi
	Pusa Double Zero Mustard 31	Low erucic acid and low glucosilates	Indian Agricultural Research Institute, New Delhi
Cauliflower	Pusa beta Kesari 1	Beta carotene	Indian Agricultural Research Institute, New Delhi
Potato	Bhusona	Beta carotene	Central Tuber Crops Research Institute, Trivandrum
Pomegranate	Solapur lal	Iron, zinc, and vitamin C	National Research on Pomegranate, Pune

Source Adapted from Yadava et al., (2018)

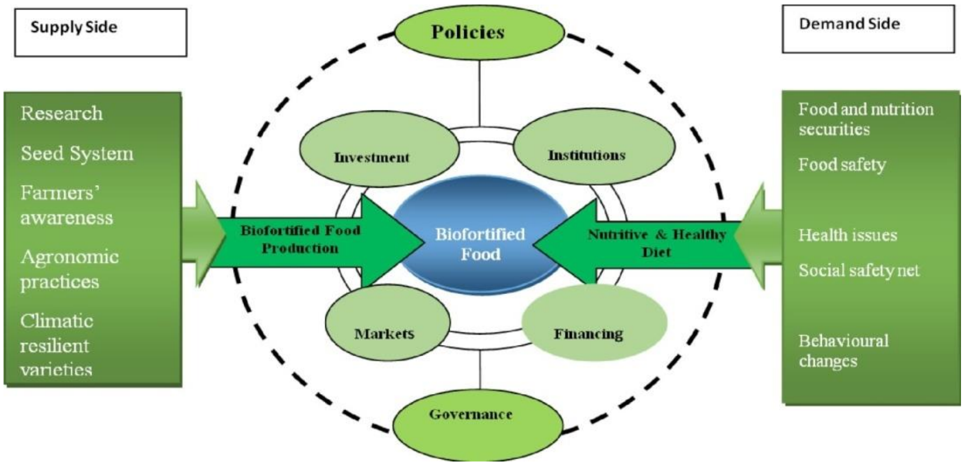
Farmers' willingness to cultivate biofortified food crop varieties hinges on their ability to command better prices than older counterparts, leading to improved production and income, as discussed by Nuthalapati et al. in 2020. Additionally, access to processing techniques and processors, as emphasized by Low et al. in 2017, plays a crucial role in influencing farmer adoption. These factors must be at the forefront when considering the biofortification of food crop varieties and promoting cultivation. Strategies such as utilizing demonstration plots by agricultural extension personnel, leveraging public service radio programs, and employing social marketing techniques akin to those used by food companies, as highlighted by Bouis et al. in 2017, are instrumental in this regard.

In the production and dissemination of micronutrient-dense biofortified foods, behavioral change communication, a common practice in health sector interventions, takes center stage, according to Meenakshi et al. in 2010. The diversity among consumers necessitates communication strategies that are segmented and targeted. Banerji et al. in 2016 suggest that concise messages are more impactful and cost-effective. Social marketing strategies, as demonstrated in a randomized trial by Cornell University in Maharajganj, Uttar Pradesh, catalyze the diffusion and consumption of biofortified crops, as noted by Uchitelle-Pierce and Ubomba-Jaswa in 2017, and supported by Merckel's findings in 2019. The study concludes that information and knowledge must be curated and made accessible to the target population physically, culturally, and in a timely manner.

The experience of diffusing high-iron varieties of pearl millet in India, as revealed by Karandikar et al. in 2018, underscores challenges in the rabi crop. Unsuitable varieties, invisible traits, non-segregated grains, and poor shelf life present hurdles. Overcoming these challenges requires the development of brand building and detection kits, in addition to creating biofortified pearl millet varieties suitable for rabi with an improved shelf life.

Multinational companies show slow interest, but small and medium-sized companies can generate demand for biofortified grains and food even before supplies reach scale. As production and supply become sufficient, small and medium-sized processing companies, capable of nutrient detection and certification, play a pivotal role in developing and distributing food products with desirable consumption attributes. Private sector participation is essential for creating sustainable markets for biofortified seeds and foods, while NGOs continue to be important in delivering nutrition information to vulnerable households. The partnership between World Vision and HarvestPlus, as illustrated by McDonald et al. in 2017, exemplifies this collaboration.

In India, ICAR has set a groundbreaking global standard by stipulating the minimum iron content for pearl millet hybrids. Additionally, ICAR has established a Consortia Research Platform for biofortification research, conducting studies on enhancing the nutritional content of rice, wheat, maize, pearl millet, sorghum, and minor millets. Government initiatives, such as declaring millets with high nutritive value as nutricereals and their inclusion in the public distribution system (PDS), contribute to the distribution of iron-rich pearl millet.



Source Adapted from Joshi (2018)

Fig 1: Value chain development of biofortified food crops

Biofortification has garnered support as a public health strategy against hidden hunger from esteemed organizations such as the World Bank, World Food Programme, Bill and Melinda Gates Foundation, USAID, UKAID, various UN bodies, donor agencies, and national and subnational governments. Notably, the State of Food Security and Nutrition in 2020 marked a significant milestone by endorsing biofortified foods as a means to combat micronutrient deficiency, with backing from FAO, IFAD, UNICEF, WFP, and WHO.

Several countries, including India, actively endorse and incorporate biofortification into their national nutrition strategies. However, there's a pressing need for concerted efforts to produce these innovative crops, stimulate demand, and facilitate consumption.

Up until now, biofortification efforts have primarily focused on encouraging the cultivation of orange-fleshed sweet potatoes. This preference stems from the recent commercialization of biofortified varieties of other crops. The development of value chains for biofortified crops is a relatively recent phenomenon. Market research by Harvest Plus reveals consumer hesitancy in mixing regular sweet potatoes with the orange-fleshed variety, citing concerns about softness and mushiness. To effectively promote consumption, a nuanced approach tailored to different age groups is essential.

The dynamics within adopting farmer communities contribute to challenges in information dissemination. Some adopting farmers may withhold information from potential growers due to fears of losing their niche. Despite this, there is a contagion effect, as noted by Uchitelle-Pierce and Ubomba-Jaswa in 2017.

Developing strategies for the delivery of biofortified food crops in any country or region requires a thoughtful consideration of these factors, necessitating further research. It's crucial to address consumer preferences, tackle concerns about the texture and mixing of biofortified crops, and navigate the intricate dynamics within farming communities. As biofortification gains prominence in global nutrition strategies, tailoring interventions to overcome these challenges will be instrumental in realizing the full potential of biofortified crops in fighting micronutrient deficiencies.

5. Conclusions

Despite consistent and robust economic growth and agricultural production, the persistent challenge of malnutrition and hidden hunger necessitates a paradigm shift in the food system towards prioritizing nutrition, as formalized by SDG 2. Biofortification emerges as a promising strategy to alleviate malnutrition, offering sustained cost-effectiveness as incremental costs diminish after the initial breeding investment.

As part of a comprehensive approach, biofortification has the potential to provide 35–50% of the daily estimated average requirement of micronutrients, particularly benefiting the rural poor. Consumers demonstrate a willingness to pay a premium of 21.6–23.7% for high iron pearl millet and high zinc wheat, leading to the development of various food products from these crops. However, the challenge lies in mainstreaming nutrient traits across all relevant crop pipelines, requiring careful consideration of minimum micronutrient levels during the varietal release stage. This strategic integration is crucial for maximizing the impact of biofortification in addressing nutritional deficiencies and contributing to the broader goal of enhancing global food security and health.

A significant challenge lies in generating demand for biofortified crops, necessitating collaboration between agriculture and health ministries with various government organizations and stakeholders. Educating both producers and consumers about the nutritional benefits of biofortified varieties becomes imperative. Social marketing methods and behavioral change communication can play pivotal roles in promoting the consumption of these nutrient-rich crops.

Incentivizing the seed sector is crucial for fostering adoption and production. Evidence from the adoption of orange-fleshed sweet potato in Africa suggests that initial diffusion may require subsidies, as highlighted by Low et al. in 2017. Encouraging farmer producer organizations to cultivate biofortified varieties and establishing linkages with private sector entities for branding and packaging can be instrumental. Certification and product labeling are essential components for developing a robust value chain for both biofortified grains and processed foods. Detection kits become indispensable for easily and cost-effectively determining the micronutrient levels in food products.

Efforts to persuade processors and private retailers to carry biofortified foods, coupled with inclusion in government schemes such as the Mid-Day Meal Scheme and PDS, are vital for scaling up. Extensive research is needed to identify biofortified food products that would attract urban consumers, along with appropriate labeling strategies and niche development. The Food Safety and Standards Authority of India could play a role in promoting processed biofortified foods and mandating their inclusion as a certain share of fortified foods, aligning with several states' governmental mandates.

However, utilizing biofortification to combat hidden hunger has its limitations. The progress beyond orange-fleshed sweet potato to other crops is in its early stages, with limited data on consumer acceptance and willingness, primarily focusing on a few crops like sweet potato and cassava. Long-term nutritional security hinges on achieving dietary diversity through increased incomes and well-functioning markets. Research becomes imperative to understand the impact of consuming multiple biofortified crops on nutrient intake, total nutrient absorption, nutrition, and health across various age and gender groups, including infants, over extended periods.

In summary, overcoming the challenges of biofortification requires a multi-faceted approach involving collaboration among ministries, stakeholders, and the private sector. Incentives, subsidies, and strategic partnerships are essential components to drive adoption and production. The integration of biofortified foods into existing government schemes and market channels, coupled with robust research on consumer preferences and long-term health impacts, is pivotal for the successful utilization of biofortification in addressing hidden hunger.

References

[1] Allen, S and Ade Brauw. 2018. Nutrition sensitive value chains: theory, progress, and open questions. Global Food Security 16 (March): 22–28. https://dx.doi.org/ 10.1016/j.gfs.2017.07.002

[2] Banerji, A, E Birol, B Karandikar, and J Rampal. 2016. Information, branding, certification, and consumer willingness to pay for high-iron pearl millet: evidence from experimental auctions in Maharashtra, India. Food Policy 62 (July): 133–41. https://dx.doi.org/ 10.1016/j.foodpol.2016.06.003

[3] Birol, E, J V Meenakshi, A Oparinde, S Perez, and K Tomlins. 2015. Developing country consumers' acceptance of biofortified foods: a synthesis. Food Security 7: 555–68. https://dx.doi.org/10.1007/s12571-015-0464-7

[4] Bouis, H E, A Saltzman, and E Birol. 2019. Improving nutrition through biofortification, in (eds) S Fan, S Yosef and R Pandya-Lorch, Agriculture for improvednutrition: seizing the momentum, 47–57, CAB International.

[5] Dizon, F, A Josephson, and D Raju. 2021. Pathways to better nutrition in South Asia: evidence on the effects of food and agricultural interventions. Global Food Security 28 (100467): 1–13. https://dx.doi.org/10.1016/ j.gfs.2020.100467

[6] Jitendra. 2013. India loses up to $46 billion to malnourishment. Down to Earth. 29 May. https:// www.downtoearth.org.in/news/india-loses-up-to-46- billion-to-malnourishment-41181

[7] Joshi, P K. 2018. Agricultural transformation in India: challenges and opportunities. Paper presented at the Annual Conference of the Indian Society of Coastal Agriculture, Dr Balasahib Swant Kokan Krishi Vidyapeeth, Dapoli, Maharashtra.

[8] Karandikar, B, M Smale, E Birol, and M Tedla-Diressie. 2018. India's pearl millet seed industry: prospects for high iron hybrids. HarvestPlusWorking Paper 2018, No 28. https://www.cabdirect.org/cabdirect/abstract/20183391222

[9] MacDonald C, B Hilton, and R Dove. 2017. Integrating biofortified crops into community development programs. African Journal of Food, Agriculture, Nutrition and Development 17 (2): 12063–2077. https://dx.doi.org/10.18697/ajfand.78.HarvestPlus12

[10] Menon P, A de Wagt, V Reddy, K Reddy, C S Pandav, R Avula, P Mathews, S Kaur, S Pawar, S Ranjan, S Sharma, and R Sankar. 2021. Supporting efforts toaddress malnutrition in the contextof the COVID-19 pandemic in India: an emergency need. Medical Journal of Dr D Y Patil Vidyapeeth 14 (4): 369–73. https://dx.doi.org/10.4103/ mjdrdypu.mjdrdypu_338_21

[11] Meenakshi, J V, N L Johnson, V M Manyong, H DeGroote, J Javelosa, D R Yanggen, F Naher, C Gonzalez, J García, and E Meng. 2010. How cost-effective is biofortification in combating micronutrient malnutrition? an ex ante assessment.World Development 38 (1): 64–75. https://dx.doi.org/10.1016/j.worlddev.2009.03.014

[12] Nirmala, B, V R Babu, C N Neeraja, W Amtul, P Muthuraman, and D S Rao. 2016. Linking agriculture and nutrition: an ex ante analysis of zinc biofortification of rice in India. Agricultural Economics Research Review 29 (conference): 171–77. https://dx.doi.org/ 10.5958/0974-0279.2016.00044.6

[13] Nuthalapati, C S R, R Sutradhar, T Reardon, and M Qaim. 2020. Supermarket procurement and farmgate prices in India. World Development134 (105034): 1–14. https://dx.doi.org/10.1016/j.worlddev.2020.105034

[14] Pingali, Prabhu and N Sunder. 2017. Transitioning toward nutrition-sensitive food systems in developing countries. Annual Review of Resource Economics 9: 439–59. https://dx.doi.org/10.1146/annurev-resource-100516-053552

[15] Qaim, M, A J Stein, and J V Meenakshi. 2007. Economics of biofortification. Agricultural Economics 37 (S1):119–33. https://dx.doi.org/10.1111/j.1574- 0862.2007.00239.x

[16] Sazawal, S, U Dhingra, P Dhingra, A Dutta, S Deb, J Kumar, P Devi, and A Prakash. 2018. Efficacy of high zinc biofortified wheat in improvement of micronutrient status, and prevention of morbidity among preschool children and women—a doublemasked, randomized, controlled trial. Nutrition Journal 17. https:// dx.doi.org/10.1186/s12937-018-0391-5

[17] Sharma, M, A Kishore, D Roy, and K Joshi. 2020. A comparison of the Indian diet with the EAT-Lancet reference diet. BMC Public Health20: 1–13. https:// dx.doi.org/10.1186/s12889-020-08951-8

[18] Suri, S and KKapur. 2020. POSHAN Abhiyaan: fighting malnutrition in the time of a pandemic. ORF Special Report No 124, Observer Research Foundation. https://www.orfonline.org/wp-content/uploads/2020/12/ ORF_SpecialReport_124_Poshan.pdf

[19] Talsma, E F, A Melse-Boonstra, and I D Brouwer. 2017. Acceptance and adoption of biofortified crops in low- and middle-income countries: a systematic review. Nutrition Reviews 75 (10): 798–829. https://dx.doi.org/10.1093/nutrit/nux037

[20] Yadava, D K, F Hossain, and T Mohapatra. 2018. Nutritional security through crop biofortification in India: status and future prospects. Indian Journal of Medical Research 148 (5): 621–31. https://dx.doi.org/10.4103%2Fijmr.IJMR_1893_18