Briefing Note for the Promotion of Biofortified Crops in India

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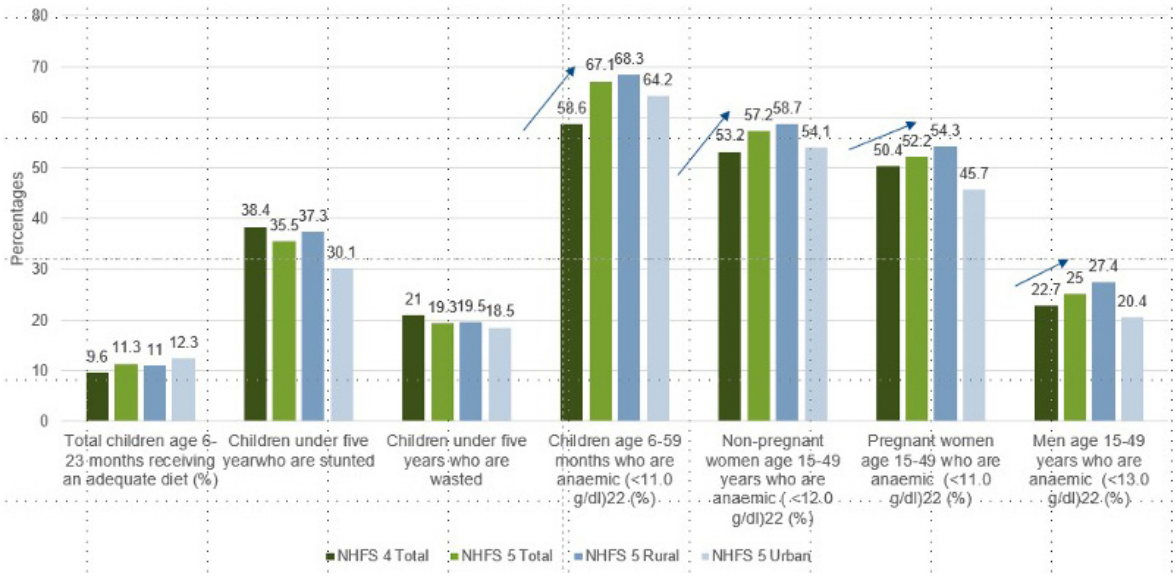
Background on Biofortification

More than 2 billion people are deficient in essential vitamins and minerals because they cannot afford or access a diverse, nutritious diet, fortified foods, or micronutrient supplementation. This "hidden hunger" can leave children stunted, vulnerable to disease, and with significantly impaired cognitive abilities, and can also increases a woman's risk of dying during childbirth.

India's burden of disease from hidden hunger is relatively high. According to the Global Nutrition Report (2020), India is lagging on global nutrition targets (WHO, 2021) for reductions in anaemia among women aged 15-49 (52% of Indian women are anaemic). According to India's Comprehensive National Nutrition Survey (2016-18), 41% of pre-schoolers, 24% of school-age children and 28% of adolescents were anaemic. Female adolescents had a higher prevalence of anaemia (40%) compared to their male counterparts (18%).

There are still significant lags, particularly in intake of zinc, the deficiency of which is a key contributor to stunting, increased risk for diarrhoea, and pneumonia among children; it is also a pathophysiology of diabetes and cardiovascular disease in adults. Nearly one-third (32%) of adolescents aged 10–19 years, nearly 19% of pre-school-age children, and 17% of school-age children aged 5–9 years were zinc deficient.[1] The recently released National Family Health Survey (NHFS-5) 2019-21 shows a decline in some malnutrition-related conditions over time, with increases in anaemia among most population segments (where iron deficiency is a significant risk factor) and initial improvements in stunting (where zinc deficiency is a key risk factor).

Figure 1: National Family Health Survey Trend Analysis



Source: Author's Own Analysis from National Family Health Survey, 2019

1. Comprehensive national nutrition survey (2016-2018): https://nhm.gov.in/index1.php?lang=1&level=2&sublinkid=1332&lid=713

Lockdowns related to the COVID-19 pandemic have reversed some of the initial progress in decreasing malnutrition, through three different pathways: 1) income losses due to decreases in available jobs, productivity and livelihood supports (WB, 2021; WFP 2020); 2) decreases in supply of nutritious perishables such as vegetables and meat, leading to price increases; and 3) disruption in social transfers such as school feeding programs or farm input distribution. This triple hurdle of increasing prices, declining livelihoods and disrupted safety nets requires a multi-level response with **food systems at the center** in order to ensure broad-based nutrition, health and economic gains in the medium and long term.

Rural areas overall are most burdened by nutritional deficiencies due to lack of affordability of diverse diets. High levels of agricultural productivity are not strong predictors of micronutrient sufficiency. States like Punjab, Haryana, Maharashtra and Gujarat are highly productive in staples as well as sub-sectors such as dairying and horticulture. However, these also suffer from high-to-very high rates of micronutrient deficiencies. For example, Punjab and Haryana have the highest prevalence rates of iron deficiency (above 60%) among children aged 1-4. (Comprehensive National Nutrition Survey, 2018).

Additionally, climate volatility is poised to affect nutrition through overall decreases in yield as well as declines in the micronutrient content of crops. A significant number of biofortified varieties are early maturing and tolerate variability both in rainfall and different soil conditions. Therefore, new investments in research and development, specifically biofortification, are needed to ensure agriculture technologies can go beyond productivity to simultaneously address malnutrition and climate volatility.

In recognition of this, the Indian Council on Agriculture Research (ICAR) and HarvestPlus have made strong advances in the basic research, development and release of nutrient enriched staple crops. A key technology for nutritionally enhanced staples is called "biofortification" and uses conventional breeding to enrich commonly consumed staple crops like wheat, pearl millet, and maize with micronutrients like iron, zinc, and vitamin A. The CGIAR HarvestPlus program—the global leader and pioneer of biofortification—has reached over 64 million people across the world with biofortified seeds and foods, and aims to benefit one billion people by 2030. To reap and spread these benefits in rural India, smallholder farmers need improved inputs (i.e., biofortified seeds, fertilizer) which simultaneously offer enhanced nutrition and yields. Biofortification is a critical complement to other nutrition strategies like fortification and supplementation to ensure the long-term health of rural populations.

Biofortification has seen significant initial policy support in India. In 2018, ICAR established minimum levels of iron and zinc to be bred into national varieties of pearl millet, mandating that all newly released hybrid pearl millet seed must be biofortified to a minimum standard of 42 parts per million (PPM) iron (zinc minimum is pending).

In 2020, ICAR declared that 10 percent of ICAR's Frontline Demonstrations (FLDs) of crops would now include zinc biofortified wheat and rice varieties.[2]

On World Food Day 2020, during a ceremony to mark the 75th anniversary of the United Nations Food and Agriculture Organization (FAO), the Prime Minister of India officially recognized specific biofortified varieties and recommended strong linkages across national nutrition programs and farmer producer organizations to develop markets for biofortified crops.[3] Translating this shared vision into scale will depend on coordinated policy actions for a highly multisectoral area, cutting across nutrition, agriculture, and women and child development.

2. https://www.harvestplus.org/knowledge-market/in-the-news/seeds-future-india's-agriculture-research-system-helps-promote
3. https://www.harvestplus.org/knowledge-market/in-the-news/world-food-day-india-pm-modi-endorses-biofortification-address

Biofortification: An Impactful and Cost-Effective Food Systems Based Approach

Over the last fifteen years, research conducted by HarvestPlus and its partners has demonstrated the efficacy, cost-effectiveness, and impact of biofortified crops to capture and share lessons learned to catalyse scale up.[4] This robust body of evidence highlights biofortification's efficacy in addressing hidden hunger, including assessments of biofortified crop consumption by women, adolescent girls, and children to measure nutritional status and functional outcomes, such as cognitive and physical performance. This research has demonstrated that:

- Conventional crop breeding can increase nutrient levels in the plant without compromising yield and other traits preferred by farmers and consumers;
- Additional nutrients in crops improve health, micronutrient status, and cognitive abilities;
- Farmers are willing to grow biofortified crops and consumers are willing to eat them.

The biofortified crops currently promoted in India —iron pearl millet, zinc wheat, zinc rice, and iron lentil—help alleviate micronutrient deficiencies when eaten regularly. Below is a summary of the evidence most relevant to the Indian context.

Iron pearl millet

Iron pearl millet was demonstrated to be an efficacious approach to improve iron status in adolescent children through a six-month randomized controlled efficacy study conducted in rural Maharashtra, India. After only four months, iron deficiency was significantly reduced, and serum ferritin and total body iron were significantly improved in secondary school children who consumed iron pearl millet flat bread twice daily. Children who were iron deficient at the beginning of the study were 64 percent more likely to resolve their deficiency by the end of the six months.[5] Results from the same trial indicate that iron-biofortified pearl millet consumption also improved the children's performance in attention and memory tests.[6]

Zinc wheat

A large randomized controlled efficacy study including over 3,000 mother-child pairs was conducted in New Delhi, India to understand the impact of zinc wheat. The study demonstrated that when preschool children aged four to six, consumed agronomically biofortified (i.e., treated with zinc fertilizer) zinc wheat for six months, morbidity outcomes were significantly reduced: children spent 17 percent fewer days sick with pneumonia and 40 percent fewer days vomiting than children who consumed foods prepared with conventional wheat. Mothers (non-pregnant, non-lactating) who consumed foods prepared with zinc-biofortified wheat spent significantly fewer days (9 percent) with fever than mothers in the control group.[7]

Zinc rice

A zinc absorption trial is in progress in Bangladesh where a randomized controlled efficacy study is also underway to determine the impact of zinc-biofortified rice consumption on the nutrition outcomes of young children aged 12-36 months. An earlier study compared the absorption of zinc from a biofortified rice variety to commercially fortified rice in 16 healthy adults; the findings indicated that rice biofortification is as good a source of bioavailable zinc as postharvest zinc fortification.[8]

4. https://www.harvestplus.org/evidence-document
5. Julia L Finkelstein, Saurabh Mehta, Shobha A Udipi, Padmini S Ghugre, Sarah V Luna, Michael J Wenger, Laura E Murray-Kolb, Eric M Przybyszewski, Jere D Haas, A Randomized Trial of Iron-Biofortified Pearl Millet in School Children in India, *The Journal of Nutrition*, Volume 145, Issue 7, July 2015, Pages 1576–1581, https://doi.org/10.3945/jn.114.208009
6. Samuel P Scott, Laura E Murray-Kolb, Michael J Wenger, Shobha A Udipi, Padmini S Ghugre, Erick Boy, Jere D Haas, Cognitive Performance in Indian School-Going Adolescents Is Positively Affected by Consumption of Iron-Biofortified Pearl Millet: A 6-Month Randomized Controlled Efficacy Trial, The Journal of Nutrition, Volume 148, Issue 9, September 2018, Pages 1462–1471, https://doi.org/10.1093/jn/nxy113
7. Sazawal, S., Dhingra, U., Dhingra, P. *et al.* Efficacy of high zinc biofortified wheat in improvement of micronutrient status, and prevention of morbidity among preschool children and women - a double masked, randomized, controlled trial. *Nutr J* 17, 86 (2018). https://doi.org/10.1186/s12937-018-0391-5
8. Brnic M, Wegmuller R, Melse-Boonstra A, et al. Zinc absorption by adults is similar from intrinsically labeled zinc-biofortified rice and from rice fortified with labeled zinc sulfate. *The Journal of Nutrition*, 2016 Jan;146(1):76-80. https://doi.org/10.3945/jn.115.213421

Biofortification is also considered a cost-efficient strategy because:

- An upfront investment allows the development of biofortified seeds which are naturally nutritionally enriched and once adopted by farmers do not need high recurrent costs.

- The germplasm (the living tissue from which plants can be grown) can be shared globally, which makes it a more-sustainable approach compared to recurring investments needed for large scale fortification and supplementation programs.

- Since farmers largely consume what they grow, biofortification as an agriculture-based and low-cost intervention ensures daily access to micronutrients for low-income rural families who may otherwise be excluded fromsupplementation and fortification programs.

Cost-effectiveness and impact

The Copenhagen Consensus ranked interventions that reduce micronutrient deficiencies, including biofortification, among the highest value-for-money investments for economic development. As per their analysis, for every USD $1 invested in biofortification, as much as USD $17 of benefits may be gained.[9]

In "Biofortification", a Best Practice Paper for the Copenhagen Consensus Center, J.V. Meenakshi[10] examined the costs and benefits of providing zinc-dense rice in Bangladesh, iron-dense beans in Rwanda, and pro-vitamin A maize in Kenya, and found that benefits were between 20 and 200 times higher than the costs, when all of the effects on a community's health were taken into account. This does not include economic returns due to improved yield and climate tolerance which would further improve the cost-benefit ratio of biofortification. The study also suggests that with biofortified crops, the cost per Disability-Adjusted Life Year (DALY) saved is highly cost effective (i.e., USD $15 to $20).

Inflection Point for Scaling

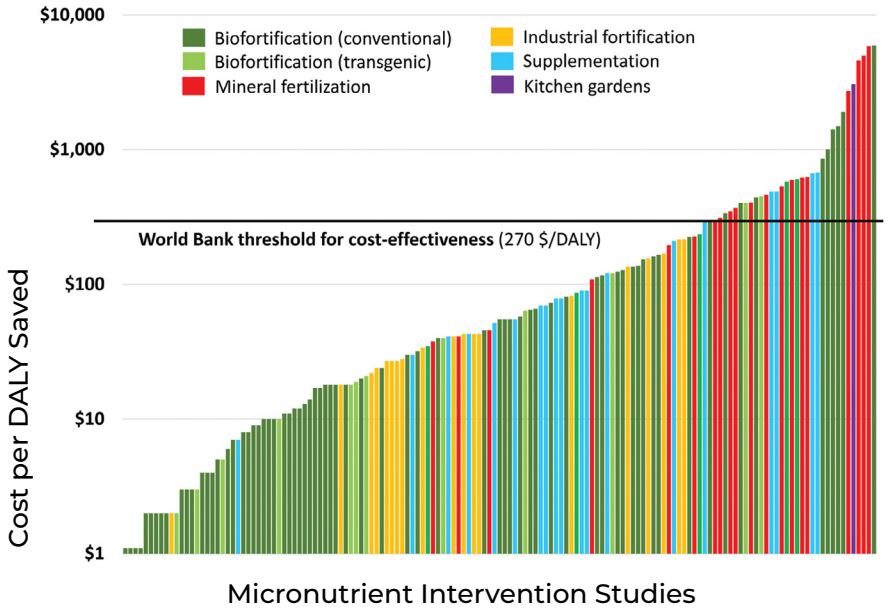
Biofortified crops can reach scale effectively in India, particularly among rural communities where year-round diverse diets, commercially fortified foods, or micronutrient supplements are often inaccessible, unaffordable, or both. Having proven the efficacy and effectiveness of biofortified crops, HarvestPlus has since 2019 brought in a stronger focus on scaling biofortification, both through existing public policies in agriculture and nutrition and increased commercialisation. Four critical enabling measures can exponentially expand the propagation and consumption of biofortified products, and also ensure the impact of nutritionally enriched staples for priority segments of the population such as rural low-income households, women and girls and populations in tribal areas:

- **Establish a national accelerator program for nutrition-smart agriculture technologies** by supporting research and development, adequate supply of early generation seed, and technical assistance for the public and private sector to multiply biofortified seed.
- **Recommend biofortification as a priority investment in aspirational districts**, both for promoting agencies of farmer-producer companies and in sustainable agriculture and livelihoods projects supported by the government, and include the demonstration of biofortified varieties in the National Food Security Mission.
- **Prioritize the inclusion of biofortified grain such as iron pearl millet, zinc wheat and zinc rice in public procurement** for school feeding, the public distribution system and the Integrated Child Development Scheme on a preferential basis through a price premium.
- **Enable financing as well as traceability and certification** for biofortified seed-to-grain value chains.

9. Horton S J, Alderman H, Rivera JA. Hunger and Malnutrition: Copenhagen Consensus Challenge Paper, 2008.
10. Meenakshi, J. & Johnson, Nancy & Manyong, Victor & De Groote, Hugo & Javelosa, Josyline & Yanggen, David & Naher, Firdousi & González, Carolina & García, James & Meng, Erika. (2010). How Cost-Effective is Biofortification in Combating Micronutrient Malnutrition? An Ex ante Assessment. World Development. 38. 64-75. 10.1016/j.worlddev.2009.03.014.
11. Bailey RL, West Jr.KP, Black RE. The Epidemiology of Global Micronutrient Deficiencies. *Ann Nutr Metab*.2015;66 (suppl 2): 22-33, doi: 10.1159/000371618

Figure 2: Cost-Effectiveness of Different Micronutrient Interventions

(columns show estimated cost in US$ per disability-adjusted life year saved, each based on a different study).



Source: Council for Agricultural Science and Technology (CAST). 2020. Food Biofortification—Reaping the Benefits of Science to Overcome Hidden Hunger— A paper in the series on The Need for Agricultural Innovation to Sustainably Feed the World by 2050. Issue Paper 69. CAST, Ames, Iowa

A Critical Role for Public Policy

Countries worldwide are starting to target support for biofortification. In 2021, Indian Prime Minister Shree Narendra Modi gave a strong endorsement to staple crop biofortification as a sustainable and cost-effective solution to alleviate malnutrition. On World Food Day 2020, he dedicated to the nation 17 recently developed biofortified seed varieties of local and traditional crops, including rice and wheat, that are being made available to Indian farmers.

At an event in Jakarta, Indonesia in December 2018 to celebrate the release of a new zinc rice variety, an advisor to Indonesian President Joko Widodo recognized the key role biofortification can play in addressing childhood malnutrition: "Zinc rice can be a solution that allows Indonesia to move more quickly to achieve its long-term goals on stunting," he said.[12] The Government of Indonesia has now targeted to cover 100,000 hectares for zinc rice production in 2022 and committed significant investment in this area with HarvestPlus as a technical assistance partner.

In Bangladesh, the Public Food Distribution System (PFDS) is now piloting guidance at the district level to prioritize procurement of biofortified zinc rice.

Both the World Bank and the Asian Development Bank have started to recognize biofortification as a critical nutrition-smart agriculture strategy and recognize the centrality of this food-based approach for India and other countries which face continued micronutrient deficiency challenges. A World Bank meta-analysis stated, "Within the already limited agricultural R&D, the share of research on the variety of foods needed for addressing nutritional deficiencies in existing diets is low—but some high-quality examples exist such as biofortification." (World Bank, 2019).

At an African Union Summit meeting in early 2022, leaders of the 55 AU member states formally adopted a declaration on biofortification and fortification which calls on member state governments to advance scaling of biofortified crops

12. https://www.harvestplus.org/knowledge-market/in-the-news/launch-high-zinc-rice-indonesia-could-help-stem-childhood-stunting

and foods. The declaration will underpin advocacy for pro-biofortification policies and programs at the country level.

In Africa, Dr. Akinwumi Adesina, the President of the African Development Bank (AfDB) and World Food Prize Laureate, has been a champion of biofortification for many years, predicting that "biofortified crops are going to be game-changers in dealing with the issue of malnutrition in our world today." Biofortification is now an explicit strategy within AfDB's institutional lending policy. Dr. Adesina's support was crucial to the adoption and expansion of biofortified crops in his native Nigeria when he led his country's agriculture ministry. Since then, the government of Nigeria has incorporated biofortified crops in its Growth Enhancement Support Scheme, with an aim to reach 2.5 million farming households and significant public investment for expanding biofortification initiatives as part of the Agriculture Sector Food and Nutrition Security Policy (ASFNS, 2016-2025).

Like Nigeria, Zambia has introduced biofortified varieties of cassava and maize rich in vitamin A. In Rwanda, through government support, about half a million farmers are growing biofortified varieties of beans rich in iron. Farmers using these varieties are harvesting more yield per hectare and earning more income selling the surplus.[13] The Government of DR Congo has also allocated significant investment in biofortification with support from the World Bank.

High Level Roadmap for Scaling Biofortification in India

Biofortification is a multisectoral intervention cutting across the agriculture, nutrition, health, women and child development, and social protection sectors. HarvestPlus seeks to partner with NITI Aayog to facilitate multisectoral coordination and public investment, leverage existing platforms and programs, and rapidly scale biofortified crops in the country. This will involve starting with jointly expanding biofortification projects in aspirational districts with a coordinated approach among various government agencies.

Scaling biofortification in India requires a concerted effort across both the public and private sectors. A recent policy review led by HarvestPlus indicated the following initial areas for intervention:

1) Establish a national accelerator program for nutrition-smart agriculture technologies by supporting research and development, adequate supply of early generation seed, and technical assistance for the public and private sector to multiply biofortified seed.

Early Generation Seed: Strengthening the seed value chain to produce and supply high-quality seeds is an important step for the popularization of biofortified varieties of different crops. Biofortification involves selective breeding to enhance naturally occurring traits such as high micronutrient content, high yield and climate resilience. Agriculture R&D policy can mainstream micronutrients as a standard for varietal testing and release procedures. A strong example is iron pearl millet where micronutrient content standards are already in place. Zinc rice standards have been developed and will be released with appropriate support from the Central Varietal Release Committee. A specific percentage of released varieties should be earmarked for micronutrient enrichment every year. A specific funding allocation should be made for varietal development and breeder seed multiplication with agriculture universities, and state and national seed corporations under the aegis of ICAR. A biofortified seed certification training program should be conducted with the state seed certification agencies so that they are able to identify, track and certify biofortified varieties in partnership with HarvestPlus. State-level demand planning and production plans should incorporate biofortification, while private sector companies and cooperatives involved in early generation seed should receive special technical assistance to help maintain the quality of biofortified seed.

13. https://www.un.org/africarenewal/magazine/august-2014/biofortification-offers-hope-africa%E2%80%99s-malnourished

2) Recommend biofortification as a priority investment in aspirational districts, both for promoting agencies of farmer-producer companies and in sustainable agriculture and livelihoods projects supported by the government, and include the demonstration of biofortified varieties in the National Food Security Mission.

Biofortification offers strong linkages with livelihoods support, both through improving health and productivity (especially for women) and directly increasing yields and economic returns for farmers. Biofortified seeds and crops and related value addition can be an important multiplier for impact in government livelihood programs.

Seed Multiplication: The Government of Bihar is providing a model on how to scale biofortified seed production through the state seed authority and the Bihar Rural Livelihoods Promotion Society (JEEViKA) initiative, where farmer producer organizations are being trained by HarvestPlus to replicate seed. These models are ready for scaling across priority states with coordinated technical and financial support. Providing initial subsidized seeds and other inputs in select states will allow farmers to test and learn from new varieties and would further contribute to the rapid dissemination of nutritionally improved cultivars among small-scale farmers. Assurance of a remunerative price, through a minimum support price and/or premium price for biofortified grains in the market, will also encourage farmers to grow biofortified crops. (See section on food systems policy for a detailed recommendation).

Adoption and Extension: Furthermore, the integration of biofortification in the national agriculture extension system would be a critical step to support widespread adoption of biofortified inputs. Targeting extension experts such as KVK experts, ATMA personnel, and private seed companies will help facilitate increased adoption by farmers. This integration will be particularly effective if accompanied by special campaigns to generate nutritional awareness—for example, nutrition education and training through community food and nutrition extension units.

3) Prioritize the inclusion of biofortified grain such as iron pearl millet, zinc wheat and zinc rice in public procurement for school feeding, the public distribution system, and the Integrated Child Development Scheme on a preferential basis through a price premium.

Food Systems Policy and Government Programs: The National Nutrition Strategy unveiled in 2017 by the NITI Aayog, Government of India envisages alleviation of malnutrition in the country through food-based solutions. Inclusion of these biofortified cereals in different government-sponsored programmes (such as National Food Security Mission, Poshan Abhiyaan, Integrated Child Development Services (ICDS) program, Mid-Day Meal Scheme, and others) would help provide much-needed nutritious food to the most vulnerable people. HarvestPlus in India has already launched a partnership on the Mid-Day Meal Scheme with Akshay Patra and the Indian Institute of Science. We are looking forward to piloting the integration of biofortified crops with other key procurement schemes as well. The inclusion of biofortified products in these government distribution channels will especially benefit children, pregnant women, and elderly people, and will both trigger demand for these nutritious grains and improve nutritional outcomes.

Safety net programs such as the Targeted Public Distribution System are an important vehicle for low-income households to access vital micronutrients. HarvestPlus internal analysis for one state—Rajasthan—demonstrated that the substitution of iron pearl millet (bajra) for either wheat or rice currently used in the Food

14. Yadava DK, Hossain F, Choudhary PR, Kumar D, Singh AK. Biofortification of crops: A sustainable tool for nutritional security in India. Indian Farming 2018; 68: 37-42

Subsidy program would provide more-nutritious food rich in iron to an impoverished target population, while at the same time save substantial government resources. The total fiscal savings for the government are estimated at USD 25.5 million dollars if the ration is comprised of 50% bajra and 50% wheat and rice in their current proportion. An estimated 13,746 DALYs[15] would be saved with a 50% bajra subsidy.[16]

Biofortified grains and foods could initially be integrated into public procurement and distribution programs on a pilot basis. For example, allowing local procurement officials to prioritize biofortified grain, both millets and wheat, can be an important market signal for farmers and seed companies for the demand for such produce. However, to ensure broad nutritional impact, such a demand pull would need to be complemented with supply-side support. The cost-effectiveness of millets in PDS demonstrate that incentivizing both seed companies and farmers to expand biofortified product lines, can result in strong gains both economically and in terms of health benefits for farmers directly provided they are given a premium price for iron millet sales into the PDS system.

4) Enable financing as well as traceability and certification for biofortified seed-to-grain value chains.

Private Sector Involvement: Private sector actors, including start-up enterprises, should be incentivized to enter biofortified seed, grain and food product markets. Innovative financing should be encouraged for promoting entrepreneurs across biofortified value chains, especially with a focus on gender inclusion. There is a very strong opportunity to work closely with apex financing institutions such as NABARD to design a specialized scheme focusing on nutrition-smart agriculture that will provide banks and farmer producer organizations a clear support mechanism to finance and facilitate the scale of biofortified seed and grains.

Traceability: Traceability plays a critical role in aggregation and segregation of biofortified crops. Some pilot initiatives, like the "biofortified village model" based on the concept of aggregation clusters, have been piloted by HarvestPlus in Bihar in partnership with the Government of Bihar. However, there is enough opportunity to integrate digital technology in the biofortified value chain so that segregation can be done at a low cost in the farmers' fields and simultaneously build the confidence of procurement agencies. Startup India and ATAL Innovation Mission can play an important role in identifying, testing, and scaling up block chain and traceability tool in the value chain.

Certification: Certification of biofortified crops will build the confidence of buyers and consumers. Similar to Organic and India GAP certification, a dedicated certification scheme could be initiated by agencies like APEDA. The Ministry of Agriculture can provide a subsidy to growers for individual and group certification in the initial stage to generate interest among the producers. HarvestPlus has developed standards for biofortified crop grains in partnership with the British Standards Institute, and HarvestPlus is deeply engaged with FSSAI to develop post-harvest standards for biofortified crops for food industry players. This initiative can be scaled up by providing incentives to corporates for the initial few years.

15. DALYs refers to 'Disability Adjusted Life Years'. According to WHO One DALY represents the loss of the equivalent of one year of full health. DALYs for a disease or health condition are the sum of the years of life lost to due to premature mortality (YLLs) and the years lived with a disability (YLDs) due to prevalent cases of the disease or health condition in a population.

16. Unpublished mimeo

Conclusion and Opportunities for Collaboration

Coupled with a strong push to mainstream nutrition in the public food distribution system and other policy initiatives, there is potential for greatly increasing the breeding, release, production, and consumption of naturally nutritious crops in India to help ensure healthier generations to come. Strong policy support and investment from the government would enable the increased adoption and acceptance of biofortified crops.

The time for a comprehensive, food-based nutrition response is now, as highlighted by Honorable Prime Minister Narendra Modi on World Food Day 2020 when he gave a strong endorsement to staple crop biofortification as a sustainable and cost-effective solution to alleviate malnutrition. Working together in partnership, HarvestPlus and NITI Aayog can accelerate access to these nutritious crops to boost food and nutrition security and improve lives.