October 2021

Integrating nutrient-rich crops into food systems: A tool of change

pwc

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Foreword

As per the Global Hunger Index (GHI), more than two billion people worldwide suffer from hidden hunger or micronutrient insufficiency. Global food insecurity has slowly increased as well, from 22.6% in 2014 to 26.6% in 2019. The COVID-19 pandemic has had a severe impact on global food insecurity, resulting in around 768 million people facing hunger worldwide in 2020. This number is 118 million more than 2019 and nearly more than the previous five years combined. India is one of the highest contributors to the global problem of malnutrition and one of the 88 countries which is likely to miss the United Nations (UN) identified Sustainable Development Goal (SDG) targets under SDGs 1 (Zero Poverty) and 2 (Zero Hunger).[1]

Reversing the impact of years of poverty, the COVID-19 pandemic and other disruptions is only possible through nutrient-based strategies like biofortification. As per the World Health Organization (WHO), biofortification is a process of breeding staple crops to enhance their nutritional quality and profile. It is a relatively novel approach for nutrient enrichment and one of the most effective, efficient and sustainable ways of addressing the issue of hidden hunger amongst the masses, especially in developing nations.

The need for biofortification cannot be ignored, especially in a post-pandemic world where millions of people have been forced into poverty and hidden hunger is a widely prevalent phenomenon. Presently, biofortified pearl millet, rice, wheat, maize, finger millet, little millet, mustard, groundnut, yam, pomegranate, mustard, cauliflower and sweet potato are some of the crops available to farmers in India. These staple products are the primary target for nutrient enrichment as they are consumed as a part of daily diets.

Nutrient-enriched crops are highly beneficial for farmers. They are able to cultivate drought- and pest-resilient crops which fetch them higher prices in the market. Industry players can widen their product portfolio, thereby increasing their customer base and profits. Finally, consumers have access to nutrient-rich food which helps them achieve a healthy lifestyle. Moreover, biofortification stands out as a superior strategy when compared to dietary diversification, fortification, supplementation, etc. The strategy is aimed towards the rural poor to make nutrient-enriched crops available and accessible to them. Once biofortified varieties are developed, very minimal efforts are required for their maintenance, making them highly cost effective as only upfront investments are needed initially. The nutrient-enriched crops are future ready as most biofortified varieties are climate resilient.

At the global level, HarvestPlus is leading the efforts for advancing awareness, acceptance and commercialisation of biofortification. The Global Alliance for Improved Nutrition (GAIN) is also playing an integral role in mainstreaming biofortification. in the Government of India (GoI) has already taken a significant step in connecting agriculture and nutrition to biofortification. The incorporation of biofortified crops within food distribution and health schemes could help incentivise farmers in growing these crops and providing a ready market for their produce.

The incorporation of biofortified crops within these and other health schemes could help incentivise farmers to grow these crops and also provide a ready market for their produce. Private players could utilise this opportunity by creating the market for biofortified produce along with the Government by buying such produce directly from farmers and labelling/marketing their products appropriately for better consumer awareness and acceptance. A robust value-chain network of local-level nurseries, seed multiplication centres, seed sellers and farmers must be built to achieve availability and last-mile delivery for all. The introduction of fortified staples as an integral part of the ICDS and MDMS is a welcome step. Innovations and research and development (R&D) will also help in developing biofortified seeds (by conventional breeding in case of India), conducting efficacy studies, monitoring improvements in nutritional status of target populations and further researching crop improvement.

Though nutrient-enriched crops still have a long way to go before being accepted on a large scale, the trend of acceptance and demand is moving upward. To sum up, there is a need to foster global partnerships amongst governments, multilateral agencies, farmers, academia and the private sector (seed, grain and food industry). This could be done by integrating biofortification with the core global agenda of achieving SDGs 1 and 2 wherein all the stakeholders (governments, industries, farmers and academia) could play their respective roles in complete synergy with each other.

1 https://globalnutritionreport.org/reports/2020-global-nutrition-report/

Message from the Government of India

सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
सचिव, एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
SECRETARY & DIRECTOR GENERAL

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MESSAGE

It is my pleasure to note that the ASSOCHAM is bringing out a White Paper on **"Integrating Nutrient Rich Crops into Food Systems: A Tool of Change".** Biofortification of crop varieties is considered as the most sustainable and cost-effective approach where the nutrients can reach the target population in natural form. Biofortified varieties deliver required energy as well as essential nutrients for human growth and development. During the past five years, ICAR has developed and released 71 biofortified varieties in different crops. Seventeen of these varieties were dedicated to the nation by the Honourable Prime Minister on October 16, 2020. These crops are naturally biofortified with vitamins, minerals and amino acids and have reduced level of anti-nutritional factors to address hidden hunger and protein-energy malnutrition in the country. Adequate quantity of breeder seeds and their conversion to Foundation and Certified seeds is essential to increase area under biofortified crops. Preferential procurement and supply of biofortified grains thorough public distribution system and mid-day meal scheme, in a targeted manner, would go a long way in addressing malnutrition. The need of the hour is to utilize these biofortified varieties more effectively towards achieving 'Kuposhan Mukt Bharat'.

The ASSOCHAM, in association with Harvest Plus and GAIN, has created a platform to discuss the current scenario, challenges and the ways to promote biofortified crops to alleviate malnutrition. I sincerely appreciate their efforts and wish them all success.

(T. Mohapatra)

Date: 20th September 2021
Place: New Delhi-110 001

Message from PwC

Transforming food systems to focus on tackling pertinent issues like malnutrition and hunger – which have become a part of the global health priority list – has become a focal action point worldwide. With rising global population, climate change, economic disruptions and heightened susceptibility to a variety of diseases negatively influencing national socioeconomic structures, countries are increasingly trying to identify agricultural practices that can better equip them to fight the looming food crisis. The COVID-19 pandemic has further raised concerns of readiness, equity of resources (including food) and resilience of food systems. Thus, it is important to adopt manageable and sustainable solutions like biofortification that can help improve access to nutritional food.[3]

Agriculture has enormous potential to support improvements in nutrition. Previously, many agricultural policies have focused on boosting the productivity and area of cultivation of staple crops, resulting in increased availability and affordability for consumers. Although fortification, diet diversity and medical supplementation are all alternatives, biofortification of crop varieties is a promising, cost-effective, and long-term strategy for increasing vitamin and mineral availability to people whose diets are characterised by micronutrient-deficient staple food. Research has shown that this agro strategy of addressing vitamin deficit is extremely effective in combating malnutrition.

Globally, more than 20 million people belonging to agriculture in developing nations are producing and consuming biofortified food.[2] It has gained utmost importance ever since the SDGs were identified. However, all the stakeholders must work together to strengthen the biofortification value chain to make it more inclusive and successful. A successful value chain will be further aided by policies such as mainstreaming biofortification in national breeding programmes, followed by a coordinated campaign involving cluster demonstrations and a price premium for biofortified grains.

This report focuses on the significance of biofortification in fighting hidden hunger, food insecurity and malnutrition, current scenarios of biofortified and nutrient-enriched crops in the global and Indian contexts, and interventions undertaken by the involved organisations. It also discusses the value proposition for all the stakeholders in the Indian context and key evidence displaying the impact, issues, challenges and Government policy support for commercialisation of biofortified crops. It further provides key recommendations from farmer bodies, industry experts and policymakers to make biofortification a more adaptable and inclusive process.

Ajay Kakra
Executive Director
Management Consulting – Agriculture and Social
PwC India

2 https://www.sciencedirect.com/science/article/pii/S2211912417300068

Message from ASSOCHAM

Malnutrition poses profound socio-economic implications worldwide, more specifically in underdeveloped and developing countries. An inadequate balanced diet causes malnutrition leading to poor health, increased susceptibility to various diseases and significant loss of annual Gross Domestic Product. Children are the most affected due to malnutrition; as a result 151 million children under the age of five are stunted while 51 million do not weigh enough according to height.

Considering its widespread ramification, alleviation of malnutrition has been identified as one of the most critical steps for a hunger-free world. Of the 17 goals, SDG2 (Zero hunger) aims to end hunger through improved food and nutritional security. SDG3 (Good Health and Well-being) aims to ensure healthy lives and promote people's well-being at all ages. The development of biofortified varieties holds great promise for the health and well-being of the human population. Several studies have demonstrated the positive effects of biofortified crops on humans. Intensive efforts by public sector institutions and policy for intense promotional campaigns can effectively ensure a significant increase in the adoption and acceptance of biofortified crop varieties.

Recent initiatives of the government, like the Pradhan Mantri Matru Vandana Yojana maternity benefits program, POSHAN Abhiyan (National Nutritional Mission), and other schemes, namely, the Integrated Child Development Services, Mid-Day Meal Scheme, and the National Food Security Act, are well-intentioned and have been able to provide food to people to survive. However, the need of the hour is to go beyond only hunger and to solve the issue of hidden hunger. Here, biofortification offers a reasonable option.

With this background, I am pleased to present the White Paper on "Integrating Nutrient Rich Crops into Food Systems: A Tool of Change" which has been prepared in association with PwC with the support of HarvestPlus and GAIN.

I take this opportunity to congratulate all the experts associated with the report for their contribution and inputs.

Thank you.

Vineet Agarwal
President
ASSOCHAM

3 https://www.who.int/nutgrowthdb/2018-jme-brochure.pdf

Message from ASSOCHAM

India faces a development paradox – of being one of the fastest-growing global economies in the world and contrastingly approx. 14% of the population as undernourished.4 Furthermore, COVID-19 has worsened the malnutrition status of vulnerable communities in India weakening their immunity.

The emphasises calls for the fact that India needs to go beyond just stomach-filling or meeting calorie requirements. A malnutrition crisis requires the supply of food with the necessary nutrients (i.e. micronutrients). Solving hidden hunger requires a leap rather than focusing on just hunger. This issue requires that the policy focus shift from addressing hunger through supplements and providing food through public distribution systems and to improve the quality of food consumed.

Biofortification is an agriculture-based method used to develop and disseminate micronutrient-rich crops, providing a viable option to reduce malnutrition and hidden hunger. This method provides the necessary micronutrients in the staple crops, thus reducing people's nutritional vulnerability.

The Government of India has already taken an important step in linking agriculture and nutrition with biofortification. Prime Minister Narendra Modi has given a strong endorsement to staple crop biofortification as a sustainable and cost-effective solution to alleviate malnutrition. He dedicated17 recently-developed biofortified seed varieties of eight local and traditional crops, including wheat and paddy rice, that are being made available to Indian farmers.

Despite taking the first step towards this viable option, India needs a comprehensive and integrated plan to expand the development and consumption of biofortified crops to ensure the nutritional security of its citizens.

I am happy to note that ASSOCHAM in association with PwC with the support of HarvestPlus & GAIN is coming out with a White Paper on "Integrating Nutrient Rich Crops into Food Systems: A Tool of Change.

I am sure that this paper will provide valuable insights, and I sincerely hope the recommendation provided in this report will help the policymakers.

Deepak Sood
Secretary General
ASSOCHAM

4 https://www.tribuneindia.com/news/nation/indias-14-population-undernourished-157337

Message from GAIN

The Global Alliance for Improved Nutrition (GAIN) is a Swiss-based foundation launched at the UN in 2002 to tackle the human suffering caused by malnutrition. GAIN is driven by a vision of a world without malnutrition, in which all people have access to and consume nutritious and safe food. GAIN's mission is to advance nutrition outcomes by improving the consumption of nutritious and safe food for all people, especially the most vulnerable to malnutrition. We plan to reach a billion people by 2022, while targeting major improvements to food systems that drive healthier eating.

We work to understand and deliver specific solutions to the daily challenge of food and nutrition insecurity faced by poor people. By understanding that there is no "one-size-fits-all" model, we develop alliances and build programmes using a variety of models and approaches that involve governments, local and global businesses, and civil society, to deliver sustainable improvements at scale.

GAIN along with HarvestPlus launched the Commercialisation of Biofortified Crops (CBC) Programme in 2019 to address widespread hidden hunger in Africa and Asia by significantly expanding the reach of foods and food products made with biofortified staple crops. Biofortified staple crops, foods, and food products can be affordable and natural sources of nutrition for billions of people. The CBC Programme works with commercial value chain actors – including seed producers, farmers, aggregators, and processors – to catalyse commercial markets for biofortified seeds, grains, and food products.

Our work is guided by the Sustainable Development Goals, especially SDG2: zero hunger; it will contribute to SDG 2.1, the elimination of hunger and malnutrition worldwide, and to SDG2.2 on the goals set internationally for wasting and stunting for children under 5 years, and the nutritional needs of adolescents, pregnant and breastfeeding women, and the elderly.

The programme will also support in a) reducing poverty and social inequality through a focus on supporting local food production, improving local food supply, and promoting the consumption of healthy food in order to combat malnutrition in a sustainable manner, and b) promoting sustainable and inclusive growth through working with local small and medium enterprises to get nutritious biofortified foods to consumers.

Recognizing the importance of climate action, we will also explore how our biofortified crops can best be used to combat climatic stress.

Tarun Vij
Country Director
GAIN India

Message from HarvestPlus

The UN Food Systems Summit, held in September 2021, brought strong commitments from countries around the world to make food systems more nutritious, equitable, environmentally sustainable, and resilient. A key near-term objective is to help achieve the Sustainable Development Goals (SDGs) by 2030, particularly those relating to ending hunger and malnutrition (SDG 2), and ensuring good health and well-being (SDG 3).

Several countries attending the summit officially included staple crop biofortification in their national strategies for transforming food systems—specifically, to help address a predominant form of malnutrition: micronutrient deficiency, or hidden hunger.

Biofortification complements other hidden hunger responses such as industrial food fortification, supplementation, and the promotion of greater dietary diversity. It is particularly relevant for the hundreds of millions of rural families who mostly eat what they grow themselves. It puts more vitamins and minerals in the crops these families know, grow, and eat every day, harvest after harvest.

Hidden hunger, beyond its serious health and developmental impacts, has consequences for countries and their economies as a result of lost human productivity. For example, the World Bank estimates that hidden hunger in India lowers the country's GDP by USD 12 billion annually.5

This report focuses on identifying key strategies to improve accessibility and availability of biofortified crops in India, highlighting the roles of different stakeholders, policymakers, and business leaders therein. It provides key recommendations for national governments, policy makers, development partners, NGOs, industry leaders and decision makers to ensure inclusion of biofortification in national and regional policies and programs.

For our part, HarvestPlus is working with a broad range of public and private partners in India who are committed to increasing production and consumption of nutrient-enriched staple crops, including iron pearl millet, zinc rice, and zinc wheat. By the end of 2020, more than 600,000 smallholder farming families were growing these crops, but many millions more families would stand to benefit from them.

HarvestPlus is committed to helping the national government and other partners to rapidly scale up biofortification in India and reach these families as well as low-income urban consumers. This includes collaborations on the crop development and production side with national agricultural research centres, global agricultural research partners, and seed companies. Through the Commercialisation of Biofortified Crops Programme, a partnership with the Global Alliance for Improved Nutrition (GAIN), we are also accelerating the use of biofortified crops through the food value chain. And we are supporting policy engagement efforts to integrate biofortification fully in key programmes and policies.

This report is intended to help add to the growing momentum for biofortification in India, and we look forward to welcoming new committed partners to the movement.

Arun Baral
CEO
Harvest Plus

5 https://www.hindustantimes.com/analysis/value-addition-to-common-foods-can-fight-india-s-hidden-hunger/story-sW5Cd4AJiWLZTFdyF-DrCPO.html

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1.

Context

1.1. Background

Food security had a different global definition in the past. The emphasis was more upon staving off hunger by focusing on calorie intake rather than the qualitative metrics. The 1996 World Food Summit organised by the Food and Agriculture Organization (FAO) defined food security as all the people having physical and economic access to sufficient, safe and nutritious food at all times to meet their dietary needs and food preferences for an active and healthy life.[6] The four main dimensions of food security are identified as physical availability of food, economic and physical access to food, food utilisation and stability of the other three dimensions over time.

As the essence and intensity of undernutrition have become more evident in the recent decades, the global health community has worked towards remodelling the concept of nutrition security by emphasising more on the balanced intake of nutritious food rather than food that only provides calories.

The World Health Organization (WHO) defines undernutrition as a form of malnutrition caused by the deficiencies or imbalances in a person's intake of energy or/and nutrients. Stunting (less height for age), wasting (low weight for height), underweight (low weight for age) and other micronutrient deficiencies or insufficiencies are all manifestations of undernutrition. Overweight, obesity and diet-related non-communicable diseases could be categorised as other effects of malnutrition.[7]

Malnutrition is one of the major causes of deaths of children aged under five years.[8] It puts children at heightened risks of impaired physical and cognitive development, poor physical growth, increased morbidity from infectious diseases and lower adult-work productivity.

The 2020 Global Nutrition Report assessed malnutrition on the basis of three parameters, namely anaemia (a condition of iron deficiency), stunting and wasting, and overweight.[9] As per WHO, 1.62 billion people worldwide are anaemic, of which 47.4% are children aged under five years and 30.2% are non-pregnant women.

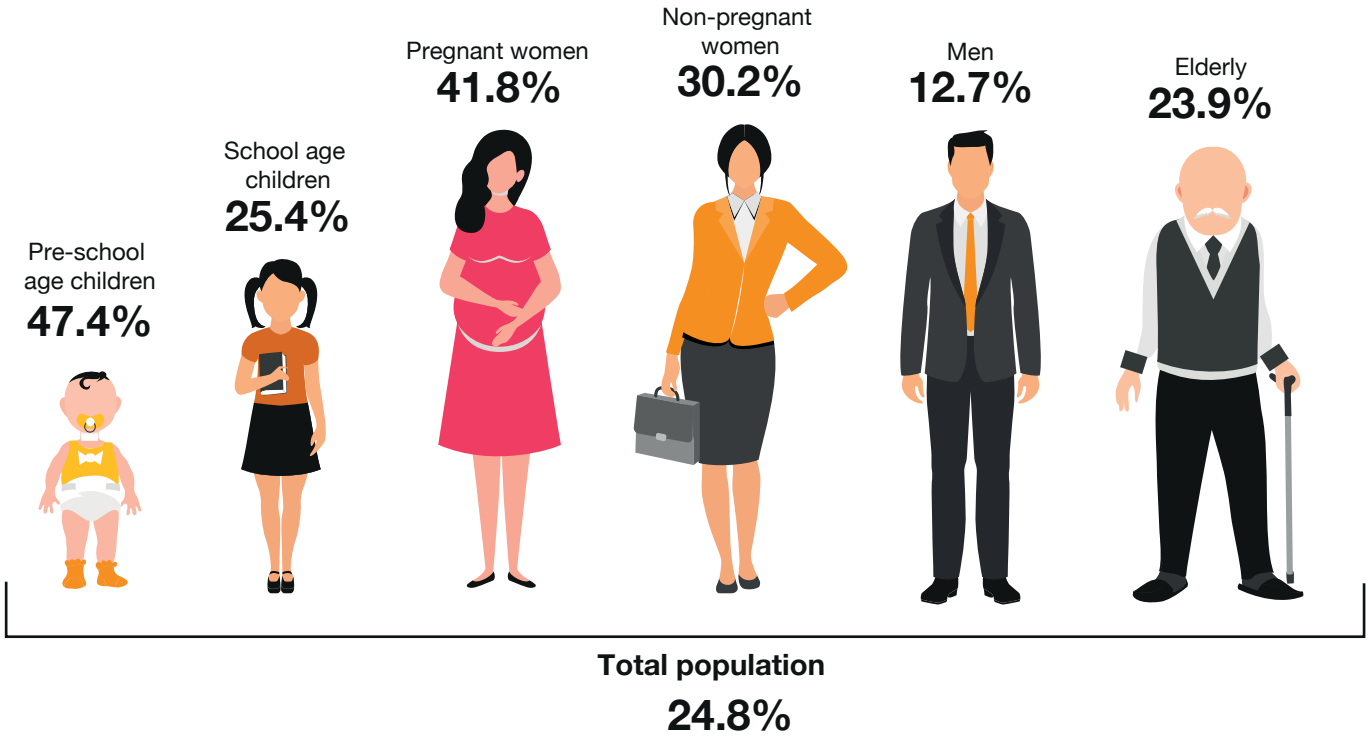
6 http://www.fao.org/wfs/index_en.htm

7 https://www.who.int/health-topics/malnutrition

8 https://www.who.int/news-room/fact-sheets/detail/children-reducing-mortality

9 https://globalnutritionreport.org/reports/2020-global-nutrition-report/

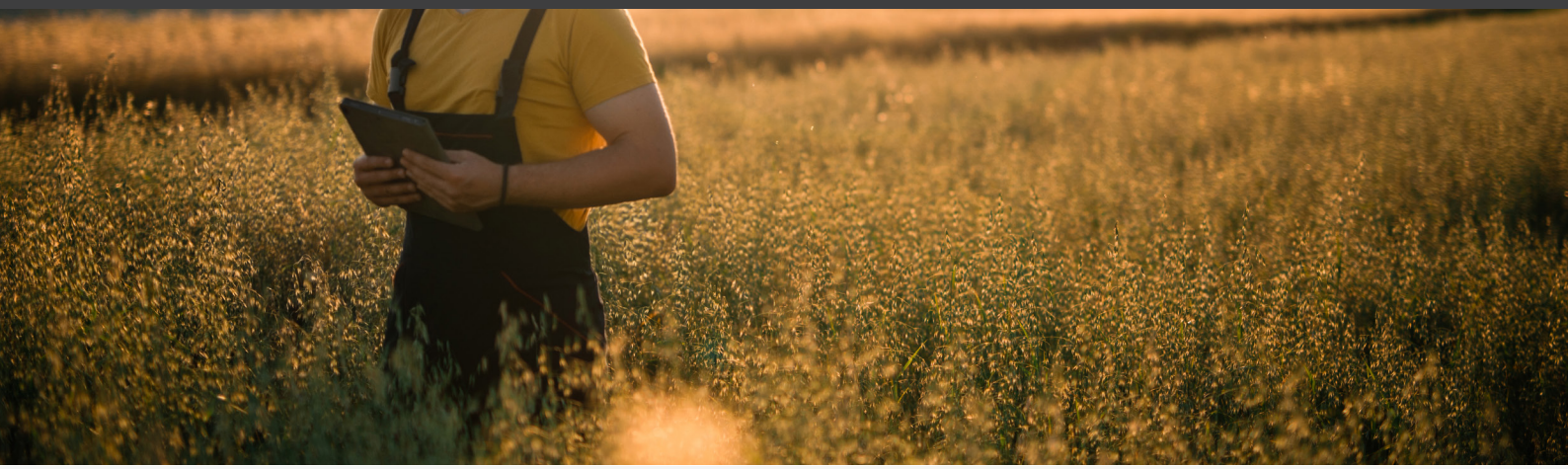
Prevalence of anaemia in various segments of the global population



Source: WHO

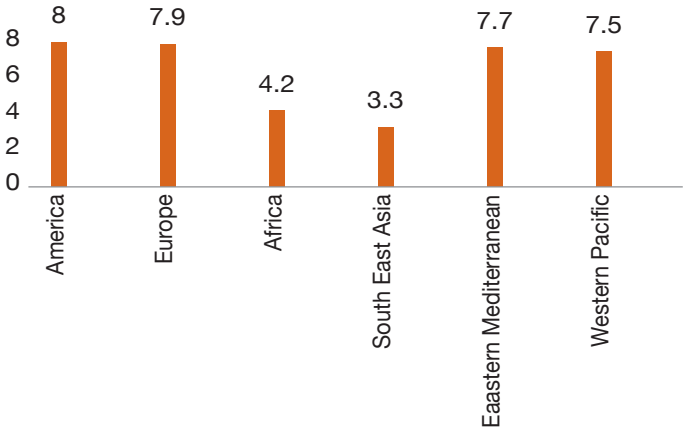
Prevalence of stunting in children under the age of five years in Southeast Asia

40.9% Afghanistan	**38.4%** India	**38%** Pakistan	**36.1%** Bangladesh
36% Nepal	**35%** South Asia	**21.2%** Bhutan	**17.3%** Srilanka



Globally, 150 million children are stunted and 50 million children are wasted. South Asia has the highest rate of stunting and wasting with around 33.3% and 15.3% of the children under the age of five years affected respectively compared to the global average of 22.2% and 7.5%. As per WHO, around 1.9 billion adults and 38.9 million children under the age of five years worldwide are overweight.[10]

Overweight prevalence among children under the age of five years (in %)



Source: WHO

As per the Global Hunger Index (GHI), more than two billion people suffer from hidden hunger or micronutrient insufficiency, with nearly half of them living in India.[11] Hidden hunger is a type of malnutrition that occurs when the intake and absorption of vitamins and minerals are insufficient to maintain optimal health and development. Hidden hunger is most prevalent in countries in Sub-Saharan Africa, India and Afghanistan, with stunting, iron deficiency and vitamin A insufficiency being common among pre-school children. There are 18 countries in Sub-Saharan Africa and two countries in Asia – India and Afghanistan – with the highest Hidden Hunger Index scores.[12]

COVID-19 increased world hunger in 2020. After a five-year period of relative stagnation, the Prevalence of Undernourishment (PoU) rose by 1.5 percentage points extending up to 9.9%, making it difficult to achieve the Zero Hunger SDG by 2030. Around 768 million people faced hunger worldwide in 2020 due to the pandemic, which is around 118 million more compared to 2019.[13] The pandemic has pushed more people into poverty, thereby forcing them to buy cheaper staples and exacerbating malnutrition and hidden hunger.

Climate unpredictability, economic depression and inefficient food supply chains are all key drivers of food poverty and malnutrition, and result in a combined effect on nutrition status. These drivers are making nutritious food expensive and particularly inaccessible to people below the poverty line. Thus, the increased prevalence of undernutrition is particularly evident in these segments of the population. An efficient and integrated food system combining all the requisite strategies is necessary to address this situation.

1.2. Strategies to tackle food insecurity and malnutrition

Transformation with pronounced flexibility is essential to build a sustainable and inclusive food system which can provide affordable and healthy diets, thereby alleviating all forms of malnutrition and food insecurity.

FAO in its 'The State of Food Security and Nutrition in the World 2021' report identified the following six measures that could be undertaken for transforming food systems.

Integrating humanitarian, development and peacebuilding policies in conflict-affected areas

Scaling up climate resilience across food systems

Strengthening the resilience of the most vulnerable to economic adversity

Intervening along the food supply chains to lower the cost of nutritious food

Strengthening food environments and changing consumer behaviour to promote dietary patterns with positive impacts on human health and the environment

Tackling poverty and structural inequalities, and ensuring that interventions are pro poor and inclusive

Source: FAO

10 https://www.who.int/health-topics/malnutrition

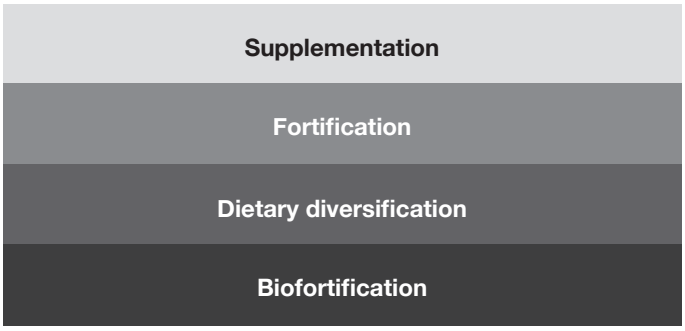
11 https://reliefweb.int/report/world/2020-global-hunger-index-one-decade-zero-hunger-linking-health-and-sustainable-food#:~:text=The%20global%20level%20of%20hunger,progress%20is%20even%20being%20reversed.

12 https://reliefweb.int/report/world/global-hidden-hunger-indices-and-maps-advocacy-tool-action

13 http://www.fao.org/publications/sofi/2021/en/

Many types of interventions can be deployed individually or together to prevent and address the widespread vitamin and mineral deficiencies. Integrative implementation of all the strategies is necessary to tackle the existing global hunger and malnutrition status. These include short-term supplementation and medium-term food fortification with a major focus on long-term dietary diversification and biofortification.

Areas of investment to combat malnutrition



Supplementation: Supplementation has been a significant intervention in the fight against vitamin deficiency in recent decades, especially vitamin A. It's also a cost-effective technique for increasing child survival rates. Vitamin A supplementation programmes are frequently incorporated into national policies since they have proved to lessen the risk of all-cause mortality and diarrhoea. The United Nations Children's Emergency Fund (UNICEF) recommends that at least 70% of the children aged between six months–five years should receive vitamin A supplements every six months to reduce infant mortality rates.[14] Providing other micronutrient supplements on a widespread scale is less prevalent. Iron supplements are prescribed to pregnant women in some cases to combat anaemia, though the coverage of such prescriptions and compliance with them are low. Children can benefit from home fortification using micronutrient powders or lipid-based supplements rich in iron and zinc.

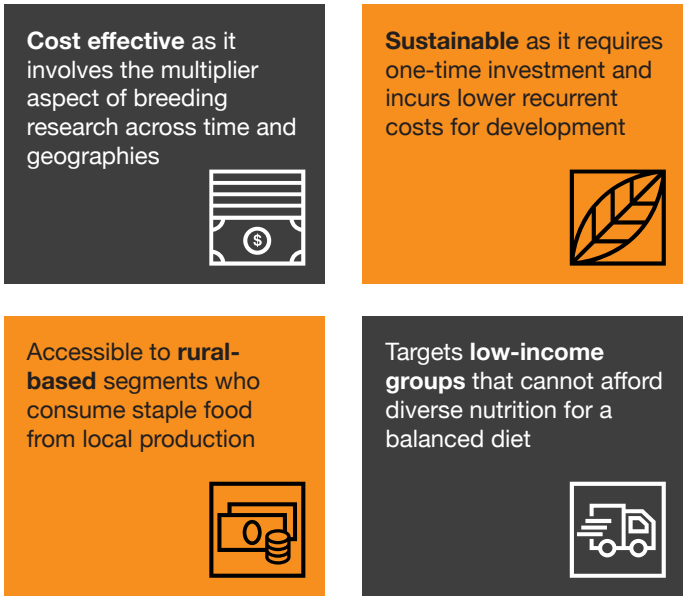
Dietary diversification: One of the most effective and long-term approaches to minimise hidden hunger is to increase dietary diversity. In the long run, dietary diversification ensures a nutritious diet with a balanced macro and micro nutrient base along with the inclusion of other food-based components. Most people can obtain enough nutrition from various food sources while specific groups, such as pregnant women, are required to take supplements. Effective approaches to encourage dietary diversity, such as growing kitchen gardens and building awareness among parent communities about food habits of newborn and growing children, food preparation and storage procedures to reduce nutrition loss, should be incorporated.

Fortification: Commercial food fortification which involves addition of micronutrients to staple food by processing is one of the alternative methods of ensuring food and nutrition security. Providing access to iodised salt is one of the most sustainable and cost-effective societal health strategies. Around 88% of the world's population has access to iodised salt.[15] Other examples of fortification include addition of iron and/or zinc to wheat flour and addition of vitamin A to cooking oil and rice. Fortification is particularly effective for urban consumers buying commercially processed food.

Biofortification: Biofortified food could provide a sustainable source of essential vitamins and minerals to all the segments of society. Biofortification focuses on rural households where food production is based and large-scale fortification is non-accessible. It involves the identification of crop varieties that naturally contain high densities of certain micronutrients. Plant breeders use these varieties to develop new, productive and biofortified crop lines for farmers to grow, market and consume.

Biofortified material was grown by around 9.7 million agri households and reached about 48.5 million people globally in 2020. Consuming biofortified varieties has significantly impacted individual nutrient status and cognitive performance on multiple occasions. For example, biofortified iron pearl millet in the form of bhakri and sev improved the iron status, serum ferritin levels and cognitive skills related to memory, attention and perception in children aged between 12–16 years in Maharashtra. Another research conducted in Delhi showed decreased levels of morbidity and pneumonia in children aged between 4–6 years who consumed zinc biofortified wheat varieties.[16]

Advantages of biofortification



Source: PwC analysis

14 https://data.unicef.org/topic/nutrition/vitamin-a-deficiency/#:~:text=The%20World%20Health%20Organization%20has,Asia%20(44%20per%20cent).

15 https://data.unicef.org/topic/nutrition/iodine/13 http://www.fao.org/publications/sofi/2021/en/

16 https://www.sciencedirect.com/science/article/pii/S2352385919300180

2.

Biofortification: Global and Indian perspectives

As per WHO, **nutrient enrichment of crops** or biofortification is a process of breeding staple crops to enhance their nutritional quality and profile. Unlike other forms of fortification, in which vitamins and minerals are added to food manually post harvest, nutrient-enriched crops are cultivated to have a higher nutrient content. This is achieved through agricultural practices or plant breeding. As stated earlier, unlike food fortification, biofortification is a pre-harvest process where the plant/crop assimilates nutrients from the environment and is closely aligned with the natural growth cycle of a plant rather than addition during processing. Biofortification has the following advantages:

- cost effective as it does not require behaviour change, can reach the poorest sections of society, and supports local farmers
- the nutrient enrichment strategy is more sustainable as once the seed is developed, its distribution and delivery do not lead to any further losses of nutrients or do not need any additional interventions for improvement of bio-efficacy of the nutrients added
- has a wider reach as the rural and impoverished population could be specifically targeted
- reduces the risk of over/underdose as the nutrient addition is closely aligned to the natural growth cycle of a crop
- biofortified crops are also often more resilient to pests, diseases, higher temperatures and drought, and provide a higher yield.

2.1. Global scenario

The need for biofortification cannot be understated, especially in a post-pandemic world where millions of people have been forced into poverty and hidden hunger is a widely prevalent phenomenon. Hidden hunger is also known as micronutrient malnutrition. The purpose of biofortification is not only to address the issue of calorie deficit but also sustain the vitality of human health through a balanced diet with the requisite essential nutrients in adequate quantities. As per 'The State of Food Security and Nutrition in the World 2021' report prepared by FAO, International Fund for Agricultural Development (IFAD), UNICEF, World Food Programme (WFP) and WHO, low- and middle-income countries have been affected the most by the COVID-19 pandemic.

Over half of the world's undernourished live in Asia (418 million) and around one-third live in Africa (282 million). Compared to 2019, 46 million more people in Africa, 57 million in Asia and 14 million in Latin America and the Caribbean were pushed into hunger in 2020.[17]

Sustainable, food-based strategies to address malnutrition must be adopted as currently, approximately three billion people worldwide are facing hunger and many more are at the risk of becoming micronutrient malnourished. In this context, evidence-based and mass-targeted interventions like biofortification have an increasingly significant role to undo the losses incurred due to the pandemic and expedite the recovery process.

The global market for biofortification stood at around USD 72 million in 2017 and is predicted to reach up to USD 117 million within the next few years, growing at a compound annual growth rate (CAGR) of 8.6%.[18] Increasing demand for high nutritional content food along with improvement in technology in the agriculture sector are driving this growth.

Biofortification

Meat free

Plant-based food with the essential nutrients, iron, zinc and vitamin A

Clean label

No genetically modified organism (GMO), no addition of additives

Natural

Natural source of vitamins and minerals

Ethical

Good for me and good for the world

2.2. Indian scenario

India is one of the world's leading producers of agricultural commodities and by virtue of having the second largest population size, also runs some of the world's largest food security programmes like Targeted Public Distribution System (TPDS), National Food Security Act (NFSA), Midday Meal Scheme (MDM), and Integrated Child Development Services (ICDS). The

country's vast agroclimatic diversity allows farmers to grow a variety of crops. Despite such efforts on behalf of the Government, India remains one of the highest contributors to the global burden of malnutrition.[19] FAO estimates that around 14% of India's current population (approximately 194.4 million people) is undernourished.

Malnutrition is also a major cause of child deaths in India as it accounts for approximately 68% of the total under-five deaths and 17% of the total disability-adjusted life years (DALY). Nearly one in three children in the world and every second wasted child lives in India.[20]

The GHI 2020 ranks India as 94 out of 107 countries. The score India received was 27.2, putting it at a serious level of hunger. This score is majorly attributed to the globally highest wasting rate of approximately 20.8% and a very high stunting rate of 37.4%.

In such a scenario, reversing the impact of years of poverty, COVID-19 and other disruptions in a populous country like India is only possible through nutrient-based strategies like biofortification. Biofortification is a highly sustainable, natural and cost-effective method of reaching the masses in less time and not as resource intensive as other food-based strategies.

Some of the popular staple varieties developed by the Indian Council for Agricultural Research (ICAR) are rice – CR Dhan 310 (protein-rich variety), wheat – WB 02 (zinc- and iron-rich variety), maize – Pusa Vivek QPM9 Improved (provitamin A, lysine- and tryptophan-rich hybrid), pearl millet – HHB 299 (iron- and zinc-rich hybrid), mustard – Pusa Mustard 30 (low erucic acid variety), and sweet potato Pusa Mustard 30 Bhu Sona (β-carotene rich variety). Currently, biofortified pearl millet, rice and wheat are available to farmers in India.

17 http://www.fao.org/state-of-food-security-nutrition

18 https://www.marketsandmarkets.com/Market-Reports/biofortification-market-38080924.html

19 https://globalnutritionreport.org/reports/2020-global-nutrition-report/

20 http://www.fao.org/countryprofiles/index/en/?iso3=IND

2.3. Need for biofortification in India

As per FAO, India is one of the world's largest producers of milk and pulses, and ranks as the second-largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruits and cotton.[21] Despite the status, an estimated 927,606 'severely acute malnourished' children aged between six months to six years were identified across the country till November 2020 by the Ministry of Women and Child Development.[22] Also, 53.1% of women aged between 15–49 years are anaemic.[23] These metrics are indicative of chronic malnourishment in women, girls and children in India.

The deterioration of our country's food and nutrition system is due to the continuous focus on calories and lack of understanding of nutritional components of food. Three of the GHI's four indicators, which are used to rank countries, are related to nutrition. These indicators encompass a well-balanced diet that includes all nutrients and micronutrients. Malnutrition is the underlying issue in India and not food shortages. The goal is to eliminate hidden hunger and not just hunger. The problem necessitates a policy shift away from measures that address hunger through supplements, food distribution through public distribution networks, etc., towards improving the quality of food consumed.

Biofortification, a farming-based approach to developing and disseminating micronutrient-rich crops, is a promising solution for reducing malnutrition and hidden hunger. It is primarily aimed at poor and rural people who have no access to fortified food. With a one-time research and development (R&D) investment, biofortified seeds can spread through the existing seed distribution systems in the country. Farmers, even with limited resources and market access, can grow biofortified crops since they do not need to repeatedly purchase seeds year after year and use planting material from season for cultivation.

The impact of biofortified crops, i.e. the improvement in iron and serum ferritin levels was observed in iron-deficient young boys and girls in Maharashtra who consumed biofortified pearl millet flat bread twice daily for four months. Such results can pave the way for expansion and adoption of the initiative. The Government of India (GoI) is promoting biofortification as well. Prime Minister Narendra Modi recently endorsed the biofortification of regionally cultivated crops as a long-term and cost-effective solution to malnutrition.

Meanwhile, the state government of Bihar, India's third-most populated state with one of the lowest per capita incomes and the highest rate of stunting, has pledged to increase zinc-wheat seed production through public seed firms. To promote these nutrient-rich types, the state government of Bihar has established a 'nutritional village' that will farm only biofortified crops using organic methods.

In Rajasthan, a localised food initiative by the Uttari Rajasthan Cooperative Milk Union Ltd (URUMUL) Trust in collaboration with HarvestPlus promoted and distributed biofortified zinc wheat varieties among the desert regions to help farmers with small landholdings to survive the lockdown during the pandemic. Farmers grew good-quality wheat grain compared to the traditional variety.

Several biofortified crops such as iron pearl millet, zinc wheat, zinc rice, zinc sorghum and iron/zinc lentil are already available in India and treat micronutrient shortages by increasing iron and zinc levels in the diet. As per a report by HarvestPlus, zinc wheat was grown by 442,000 Indian households and iron pearl millet was grown by 238,000 households in 2019. Additionally, zinc wheat was consumed by an estimated 2.2 million people and iron pearl millet was consumed by almost 1.2 million people in the same year.[24]

Though steps have been taken to expand and commercialise this viable choice, India needs an integrated and comprehensive policy support and plan to meet the nutritional requirements of its inhabitants. A multi-year integrated approach is required to build a well-functioning biofortification ecosystem.

21 http://www.fao.org/india/en/

22 https://www.thehindu.com/news/national/927-lakh-severely-acute-malnourished-children-identified-till-november-last-year-rti/article34743642.ece

23 https://www.who.int/data/gho/indicator-metadata-registry/imr-details/4552

24 https://www.harvestplus.org/knowledge-market/in-the-news/seeds-future-india%E2%80%99s-agriculture-research-system-helps-promote

2.4. Key crops for nutrient enrichment in India

The joint effort by ICAR and the state agricultural universities (SAUs) to make India self-sufficient in food production is commendable. From producing 50.82 metric tonnes (MT) in 1950–1951, Indian food production has reached up to 296.65 MT in 2020-21. Similarly, the production of horticultural crops has also increased from 96.56 MT in 1991–1992 to 326.6 MT in 2020–21.[25] The creation and implementation of high-yielding cultivars and heterotic hybrids – efforts undertaken during the Green Revolution – have allowed for a massive increase in yield potential. However, nutritional quality was not given enough consideration during the yield augmentation process and as a result, the bulk of these cultivars lack the nutritious content that is required. ICAR has recognised the prime significance of nutritional quality and conducted research towards developing a number of staple and nutrient-enriched crops through the All India Coordinated Research Projects (AICRPs). Varieties have been developed in major crops such as rice, wheat, maize, pearl millet, lentil, mustard, soya bean, cauliflower, sweet potato and pomegranate for incorporating iron, zinc, protein and provitamin A levels.[26]

25 https://www.ibef.org/industry/agriculture-india.aspx#:~:text=Principal%20agricultural%20commodities%20export%20for,2021%20was%20US%24%2032.12%20billion.&text=The%20Economic%20Survey%20of%20India,285.21%20million%20tonnes%20in%20FY19.

26 https://icar.org.in/files/BiofortifiedEnglish_.pdf

Wheat

Wheat is one of India's staple crops along with rice. It is produced in an area of 31.45 million hectares (ha) across the country and accounts for more than half of the calories consumed in north India's diet. Wheat production touched an all-time record of 107.59 million tonnes in 2020 with an average yield of 3.4 tonnes/ha.[27] Wheat, like many other staple grains, has relatively low levels of iron and zinc which can lead to delayed brain development and child mortality. Substituting normal wheat cultivars with biofortified wheat types results in significant increase of zinc intake. Biofortified wheat has a higher zinc absorption rate than regular wheat with lower zinc content.

ICAR identified 22 biofortified varieties of wheat till date which received positive responses from farmers across the country. Out of the 17 biofortified varieties notified by Prime Minister Narendra Modi on World Food Day 2020, five contain higher zinc levels compared to traditional varieties.[28]

Some of the varieties notified by ICAR are:

Sr. no.	Biofortified variety	Nutritional content (ppm)	Recommended states	Developed by
1	WB-02	Zinc–42 Iron–40	Punjab, Haryana, Delhi, Rajasthan, Western Uttar Pradesh, Una district of Himachal Pradesh and the Tarai region of Uttarakhand	Developed by ICAR-Indian Institute of Wheat and Barley Research under ICAR-AICRP on Wheat and Barley
2	HPBW-01	Zinc–40.6 Iron–40	Punjab, Haryana, Delhi, Rajasthan, Western Uttar Pradesh (except Jhansi division), Jammu and Kathua district of Jammu and Kashmir, Paonta Valley and Una district of Himachal Pradesh, and Tarai region of Uttarakhand	Developed by the Punjab Agricultural University under ICAR-AICRP on Wheat and Barley
3	Pusa Tejas	Protein–12% Zinc–42.8 Iron–41.1	Madhya Pradesh, Chhattisgarh, Gujarat, Rajasthan (Kota and Udaipur Division) and Uttar Pradesh (Jhansi Division)	Developed by ICAR-Indian Agricultural Research Institute, Regional Station, Indore
4	Pusa Ujala	Protein–13% Iron–43 ppm	Maharashtra and Karnataka	Developed by ICAR-Indian Agricultural Research Institute, Regional Station, Indore
5	MACS 4028	Protein–14.7% Zinc–40.3 Iron–46.1	Maharashtra and Karnataka	Developed by Agharkar Research Institute, Pune, under ICAR-AICRP on Wheat and Barley

Source: ICAR

Public-private partnerships (PPPs) are also gaining momentum in India's seed sector and allowing for fast-track commercialisation, and reaching out to millions of farmers benefitting from zinc biofortified wheat varieties. The state government of Bihar is promoting the production and consumption of biofortified wheat by releasing a variety called Rajendra-Gehu-3 developed by the Rajendra Prasad Central Agricultural University. It is also encouraging the use of other prevailing varieties such as BHU-31 and BHU-25 launched by seed companies in Bihar.[29]

27 https://agricoop.nic.in/sites/default/files/Web%20copy%20of%20AR%20%28Eng%29_3.pdf

28 ICAR

29 https://www.harvestplus.org/knowledge-market/in-the-news/zinc-wheat-events-bihar-attract-hundreds-farmers

Pearl millet

India is the largest producer of millets in the world and known for the variety of millets it produces. Pearl millet is the most widely grown type of millet in India. Rajasthan accounts for 90% of India's pearl millet acreage, followed by Maharashtra, Gujarat, and Uttar Pradesh.[30] It is one of the most remarkable staple food items in India and primarily consumed in the form of bread, porridge and puffs. Long valued for its nutritional importance by rural Indians, pearl millet is referred to as a nutri cereal for its energy and protein content, a more balanced amino acid profile than maize or sorghum, and comparatively higher iron and zinc densities.

The ICAR-AICRP on Pearl Millet is developing iron biofortified pearl millet varieties to tackle widespread iron deficiency. As per a research survey, these millets have had significant nutritional impact on adolescent boys and girls in Maharashtra.[31]

Some of the varieties developed by ICAR are:

Sr. no.	Biofortified variety	Nutritional content (ppm)	Recommended states	Developed by
1	HHB-299	Iron–73 Zinc–41	Kharif season in Haryana, Rajasthan, Gujarat, Punjab, Delhi, Maharashtra and Tamil Nadu	CCS-Haryana Agricultural University, Hisar, in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) under ICAR-AIRCP on Pearl Millet
2	AHB-1200 (Fe)	Iron–73	Kharif season in Haryana, Rajasthan, Gujarat, Punjab, Delhi, Maharashtra and Tamil Nadu	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, in collaboration with ICRISAT under ICAR-AICRP on Pearl Millet
3	Phule Mahashakti	Iron–87 Zinc–41	Kharif season in Maharashtra	Mahatma Phule Krishi Vidyapeeth, Dhule, under ICAR-AIRCP on Pearl Millet on Pearl Millet
4	AHB-1269 (Fe)	Iron–91 Zinc–43	Kharif season in Gujarat, Haryana, Punjab, Delhi, Maharashtra, Telangana and Tamil Nadu	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, under ICAR-AIRCP on Pearl Millet

Source: ICAR

In 2012, HarvestPlus partner Nirmal Seeds commercialised ICTP-8203-F, an improved version of the existing variety with 15% higher yield and 11% higher iron content, in Maharashtra.[32] Varieties developed by ICAR in rice include CR Dhan 310 with high protein content for Odisha, Madhya Pradesh and Uttar Pradesh, and DRR Dhan 45 and DRR Dhan 49 with higher zinc quantities for the central and southern parts of India.[33] Varieties developed by ICAR in maize include Pusa Vivek QPM9 improved, Pusa HM4 improved, and Pusa HM8 and HM9 improved containing high levels of provitamin A, tryptophan and lysine. Varieties in cauliflower and sweet potato, namely Pusa Beta Kesari and Bhu Sona, have also been developed by ICAR by processing high beta-carotene levels.[34]

30 http://www.aicpmip.res.in/aboutus.html

31 https://www.sciencedirect.com/science/article/pii/S2352385919300180

32 https://www.harvestplus.org/sites/default/files/Biofortification_Progress_Briefs_August2014_WEB_0.pdf

33 https://icar.org.in/files/BiofortifiedEnglish_.pdf

34 Ibid.

2.5. Government support

The GoI is encouraging biofortification amidst rising interest in nutrient-enriched crops to combat micronutrient deficiencies. Biofortified staple crop varieties can be included in midday meals for school children from low-income rural households.

The GoI has already taken significant steps for connecting agriculture and nutrition to biofortification. Prime Minister Narendra Modi has strongly advocated for the adoption of biofortification as a long-term sustainable strategy to curb malnutrition in all forms.[35]

Bihar, which has highest rate of stunting among children in the country, committed to rapidly scale up the production of zinc-wheat seeds by leveraging the capacity of Bihar State Seed Corporation as well as local agricultural universities and farm schools. The main objective is to reach low-income families and children affected by stunting due to zinc deficiency. The state government's Rural Development Council partnered with HarvestPlus to establish a model nutritional village in Kukribigah, Patna, for cultivating only biofortified crops using organic methods.[36]

Additionally, the ICAR-Central Tuber Crops Research Institute in Arunachal Pradesh is encouraging the consumption of biofortified tuber crops to curb vitamin A deficiencies.[37]

In 2018, ICAR notified the minimum levels of iron and zinc to be bred in national varieties of pearl millet, thereby providing a strong regulatory push for the development of biofortified varieties. Additionally, a memorandum of understanding (MoU) was signed between ICRISAT and the Indian Institute of Millet Research (IIMR) to jointly coordinate for the Smart Food Initiative in India.[38] ICAR has also launched the Nutri Sensitive Agricultural Resources and Innovations (NARI) programme to promote nutritious farming by establishing nutria-smart villages and Krishi Vigyan Kendra (KVK) developed location-based nutrition garden models to increase awareness and boost the initiative.

Furthermore, The Food Safety and Standard Authority of India (FSSAI) has introduced the +F logo for fortified staple food products to enable easier identification of nutrient-rich foods and formulated a defined set of standards for fortification under five categories of wheat flour, rice, milk, edible oil and double fortified salt.[39]

As biofortification is a complementary strategy to fortification and is supported by the GoI and state governments, authorities are committed to addressing widespread malnutrition and its subsequent health and livelihood consequences. With a strong push to mainstream nutrition in the public food distribution system and other governmental measures, India has the potential to significantly increase the breeding, release, production, and consumption of naturally nutritious crops, and develop healthier food systems for future generations.

35 https://icar.org.in/files/BiofortifiedEnglish_.pdf

36 https://www.harvestplus.org/knowledge-market/in-the-news/bihar-state-india-promote-biofortified-crops-address-nutrition-security

37 https://arunachaltimes.in/index.php/2021/03/10/awareness-prog-on-bio-fortified-tuber-crops-held/

38 https://www.icrisat.org/pan-india-strategies-to-promote-millet-products-internationally/

39 https://fssai.gov.in/cms/fortified-food.php

2.5.1. Organisations involved and interventions undertaken

The GoI has entered into partnerships with private players and multilateral agencies like FAO, WHO, WFP and UNICEF to play a key role in the last-mile delivery of food-based strategies as described in the following figure:

Sr. no.	Initiative	Implementing agency	Interventions under the initiative
1	ICDS	Ministry of Women and Child Development	Six services, namely supplementary nutrition, pre-school non-formal education, nutrition and health education, immunisation, health check-up and referral
2	NHM	Ministry of Health and Family Welfare	Rural and urban health services like reproductive-maternal-neonatal-child and adolescent health (RMNCH+A), and treating communicable and non-communicable diseases
3	MDMS	Centrally sponsored scheme under the Ministry of Education	World's largest school meal programme to provide cooked meals for children aged between 6–14 years who enrol in and attend schools
4	Rajiv Gandhi Scheme for Empowerment of Adolescent Girls (RGSEAG), namely SABLA	Ministry of Women and Child Development	Improving the health status, skills and knowledge base of adolescent girls aged between 11–18 years and providing them with information on health and family welfare, hygiene and guidance on existing public services
5	Mother and Child Protection Card	Jointly by the Ministries of Health and Family Welfare, and Women and Child Development	Helps in timely identification, referral and management of complications during pregnancy, childbirth and the post-natal period as well as provide complete immunisation to infants, early and exclusive breastfeeding, complementary feeding and monitoring their growth
6	Weekly Iron and Folic Acid Supplementation (WIFS) Programme	Ministry of Health and Family Welfare	Meet the challenges of high prevalence and incidence of iron-deficiency anaemia among adolescents

At the global level, HarvestPlus leads efforts to advance biofortification and is working with the Global Alliance for Improved Nutrition (GAIN) to expand the commercialisation of biofortification. GAIN is a Swiss foundation working under the UN since 2002 and aiming at enhancing food and nutrition security by transforming food systems globally. HarvestPlus is a part of the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH) working with GAIN for improving access to biofortified seeds, grains and food worldwide.

2.6. Impact of biofortification in India

Many intervention studies have been conducted to analyse the impact of biofortification on public health. While the majority of the evidence comes from developing nations, biofortification could have an impact on public health in developed countries as well, which would necessitate further modelling and research.

As per a study conducted on adolescents in Maharashtra for six months, the consumption of biofortified pearl millet significantly improved iron levels. A significant increase in the total iron body and serum ferritin level along with improved cognitive performance were observed in economically distressed adolescents aged between 12–16 years in Maharashtra who were fed with biofortified iron pearl millet bhakri and sev. A consumer acceptance study conducted in rural Maharashtra also indicated that consumer willingness and acceptability to pay increased prices when nutritional information is included.

In August 2020, ICAR took the initiative to scale up production and consumption of biofortified crops, and announced the inclusion of zinc biofortified wheat and rice varieties in its frontline demonstrations. It has also set the benchmark for minimum iron and zinc levels for national pearl millet varieties which will be used in MDM schemes for pregnant and lactating women, and the ICDS school feeding programme.

Zinc wheat has also proven to be useful for improving public health. According to a research conducted in New Delhi involving more than 3,000 mother-child pairs, children aged between four–six years experienced 17% fewer sick days when affected with pneumonia and 40% fewer sick days when affected with vomiting after consuming zinc biofortified wheat, along with decreased morbidity levels. Mothers who consumed zinc biofortified wheat experienced 9% lesser feverish days than normal.

As per an International Food Policy Research Institute (IFPRI) study, the potential for introducing biofortified rice and wheat through the PDS, a state-funded programme that provides staples and other essential commodities to the poor at reduced prices, was explored in Bihar and Odisha. PDS accounts for nearly 20–40% of the iron and zinc consumed through grains (mostly rice and wheat) in rural Bihar and Odisha. Zinc consumption from rice might increase by approximately 60% if the amount of regular rice consumed from PDS in these states is replaced with biofortified varieties. Similarly, switching from PDS wheat to a biofortified variety could boost iron and zinc intake by more than 30%.[40] Replacing PDS staples with biofortified variants could result in significant improvements in maintaining the nutritional security for India's poorest and most vulnerable citizens.

According to a study on zinc biofortified rice varieties, the percentage of zinc intake of recommended dietary allowance (RDA) accounted for 24% for males and 29% for females when they consumed traditional varieties of rice. However, with the consumption of zinc biofortified rice varieties, the zinc intake could go up to 38–47% of the RDA for males and 46–57% of the RDA for females.[41]

2.7. Analysis of nutrient enrichment as a practice

Biofortification is steadily gaining global and national importance, and its advantages over other nutrient enhancement techniques could be future areas of interest in India and worldwide. These opportunities should be leveraged while considering the strengths and weaknesses of this practice. Also, different techniques associated with biofortification may have different risk profiles. Hence, understanding the disadvantages is also pertinent before any pragmatic and policy-level inclusions.

SWOT analysis of biofortification in India

Strengths

- Cost effective and more sustainable
- Wider reach and replicable over a large scale
- Improved bioavailability and efficacy
- Nutrients embedded naturally
- More resilience to pests, diseases and droughts, and higher yield

Weaknesses

- Difficult implementation in India due to marginal farming
- Low awareness among masses

Opportunities

- Growing demand from commercial/non-commercial segment
- Since process costs are minimal, supply chain effiiency is paramount
- Integration in ongoing social initiatives and government schemes
- Propostion for the health-conscious consumer segments
- Product diffrentiator for food companies

Threats

- Opposition for implementation because of the perceived risk around biotechnologically engineered crops.
- Adulteration due to lack of traceabiliy in the value chain
- Non-availability of biofortification standards to facilitate grain trade
- Lack of adequate nutirient testing laboratories and infrastructure

40 https://www.ifpri.org/news-release/biofortified-staples-may-hold-key-indias-rural-malnutrition-reuters

41 https://www.frontiersin.org/articles/10.3389/fnut.2020.00026/full

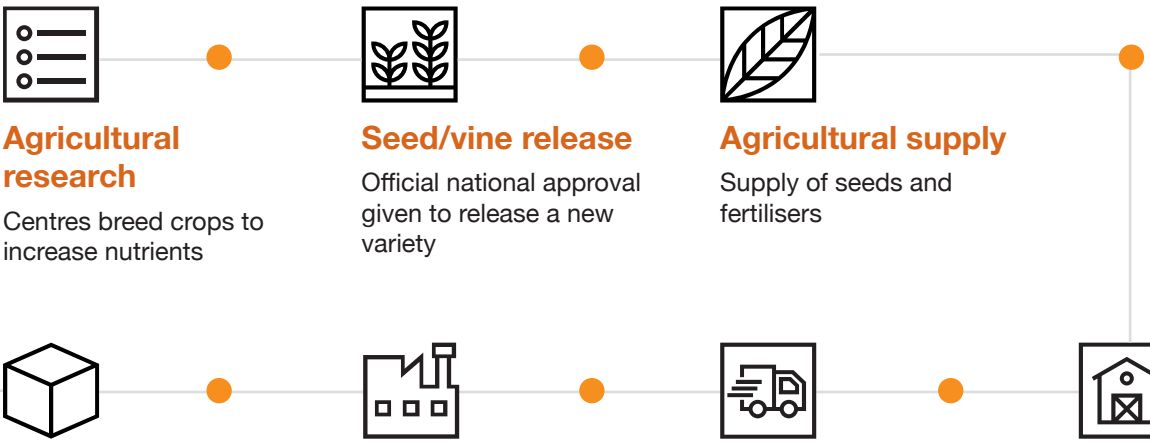
3.

Commercialisation of biofortified crops

The commercialisation of biofortified crops is essential to address widespread malnutrition and hidden hunger in developing and less-developed nations. The process is initiated by expanding the reach of food and food products developed by imparting nutrient-enriched properties. It involves all the stakeholders of the value chain, namely seed producers, government bodies, farmers, aggregators and processors to catalyse commercial markets for biofortified seeds.

3.1. Value proposition

To increase the demand and adoption of biofortified varieties, specifically defined value propositions for each stakeholder in the value chain is necessary.



Agricultural research

Centres breed crops to increase nutrients

Seed/vine release

Official national approval given to release a new variety

Agricultural supply

Supply of seeds and fertilisers

Farming

Targeting smallholder farmer families in developing countries

Aggregation

Staple crops are collected from small-scale farmers

Milling

Crops undergo basic processing and flour is milled

Processing

Food manufactures of any size make the crop into a finished ready-to-eat food product

Retailing

Shops of all sizes from roadside vendors to global retailers

Value proposition for producers

- The prominent value imparted to the farmers cultivating biofortified varieties is the higher grain quality and better yield of developed varieties when compared to conventional ones. Farmers belonging to Rajasthan's Bikaner and Jodhpur districts cultivated high-quality zinc biofortified wheat varieties which are rich in nutrients compared to traditional varieties. This initiative not only helped them survive the pandemic but also encouraged more farmers to cultivate biofortified crops in surrounding districts. Biofortified rice was introduced in Bangladesh in 2013 with a 30% higher zinc content. The rice matures faster and has zinc in the endosperm, which is not compromised with during polishing, thereby helping in meeting the zinc requirements of the population.
- Biofortified crops are often more resilient to pests, diseases, higher temperatures and droughts, and can provide higher yields. In Rwanda, the cultivation of iron-fortified beans addressed the widespread iron deficiency in children and women, and provided to be beneficial for farmers for multiple reasons. The iron-fortified beans have improved tolerance to virus, heat and drought, and the yields of the farmers increased by 17–22%, generating additional profit of USD 57–78 per hectare.
- In the wake of increasing consumer awareness regarding nutritional requirements and balanced diet, the cultivation of nutrient-rich crops can increase demand through a widened consumer base and fetch better prices. Many countries in Africa have potato as a staple food item in their diets. Orange flesh sweet potato, which has higher levels of beta-carotene, has very high consumer acceptability, leading to eight different African countries releasing 31 new varieties of the crop.
- Many biofortified planting material or seeds from the previous season can be reused by farmers. Therefore, they don't have to incur any other cost except the initial investment. The nutrients that get included in the staple crops remain present in the seeds and the cost of production becomes sustainable. In Nigeria, once the benefits of biofortified cassava were realised and accepted, more than 500,000 farmers planted the crop.
- Biofortification is a step that can be implemented at global and national levels. Hence, farmers and producers can get support from governments through different initiatives. Several biofortified varieties of traditional staple crops have been released in India with improved traits, and regulations set up to establish minimum levels of iron and zinc in iron biofortified varieties of pearl millet. The Government of Nigeria has created a new regulatory and legal framework to support the seed industry, and develop a multiplication programme to provide increased access of biofortified cassava stems and orange sweet potato vines to more than 80 million Nigerians in the future. In Zambia, orange maize is cultivated which has high beta-carotene traits. The Government of Zambia has included biofortification in its food and nutrition strategy, actively promoting these improved maize varieties and encouraging farmers to move towards growing nutrient-enriched crops.

Value proposition for industry

The biofortified seed industry includes manufacturing seed organisations, government bodies, private companies engaged in seed multiplication, private dealers and sub-dealers, millers and processors.

- Increased scope of profitability for manufacturing and distributing seed companies along with dealers due to enhanced consumer interest in nutrient-enriched foods produced through sustainable means.
- Biofortification can be a unique selling proposition (USP) for processors and millers due to increased health consciousness, recognition and acceptance, similar to large-scale food fortification among urban population and the growing market trend towards nutritious food. An increased consumer base in the processing sector can lead to the expansion of the product portfolio. For example, flakes or puffs can be made from iron pearl millet to provide healthy alternative snacks. Extended support from development partners and government incentives can help the sector flourish in the long term.
- Partnerships and collaboration with international and public sector institutions by private sector companies for inclusion and biofortification development programmes can lead to sustainable and cost-effective outcomes, and improve visibility. The Government of Nigeria has been promoting private-sector involvement in the production, processing and marketing of biofortified cassava stems and orange flesh sweet potato vines.

Value proposition for consumers

- Intake of nutrient-enriched food can help increase immunity and improve overall health aided by minimal lifestyle changes as consumers increasingly understand the importance of a balanced diet with all the essential micronutrients.
- Biofortified crops help in providing increased vitamins and minerals, and curb zinc, iron or vitamin A deficiencies in a sustainable and cost-effective manner. In Rwanda, the presence of widespread iron deficiency led to anaemia which affected 38% of the children aged under five years and 19% of the pregnant women.[42] The consumption of iron biofortified beans by children, non-pregnant women and lactating mothers helped them obtain 80% of their daily average iron requirements.
- Iron biofortified varieties help in improving cognitive skills associated with perception, memory and attention. As per a survey, a group of adolescents in Maharashtra aged between 12–16 years consumed biofortified pearl millet bhakri or sev for six months, resulting in significantly improved cognitive skills related to perception, attention and memory.[43]

42 https://www.researchgate.net/publication/319233044_Prevalence_of_Iron_Deficiency_and_Iron_Deficiency_Anemia_in_the_Northern_and_Southern_Provinces_of_Rwanda

43 https://www.sciencedirect.com/science/article/pii/S2352385919300180

3.2. Challenges

There are a few prominent challenges in the commercialisation of nutrient-enriched crops which can restrict widespread adoption amongst farmers, traders, processors, millers, private seed companies and end consumers.

1. **Lack of awareness among farmers:** Most farmers are used to cultivating traditional varieties of crops and unlikely to switch to biofortified ones due to the fear of low yields, high input cost and potential crop loss. Lack of communication and marketing activities for biofortified seeds by local bodies can likely result in farmers being slow in switching to nutrient-enriched crops.

2. **Lack of awareness among industry players:** A majority of the industry players play key roles in developing varieties of crops featuring prime desirable characteristics related to yield, resistance to diseases, pests and other climatic variations with low focus upon nutritional traits. Better awareness and inclusion initiatives can escalate the development of nutrient-enriched crops.

3. **Low capacity of regional seed companies and lack of government incentives:** Securing a sufficient volume of breeder seeds to multiply new varieties can be a challenge for local bodies due to limited access to resources, capacity and incentives to reach market demand. They may incur costs related to R&D, adaptive breeding, maintenance breeding and dissemination. The provision of remarkable incentives for investments in R&D can encourage local bodies to develop biofortified crops

4. **Lack of differentiative features:** A majority of biofortified crops lack distinctive phenotypic characteristics such as appearance or different grain size compared to traditional ones. So, it may be challenging to convince farmers and traders about the qualitative features of the developed grain compared to traditional grains.

5. **Misconception about price:** Misinformation about the prices of nutrient-enriched grains can discourage farmers from cultivating biofortified crops as the majority of producers comprise smallholder farmers who are highly price sensitive.

6. **Change in appearance:** In some cases, nutrient enrichment can change the colour of the grain or produce. For example, in case of sweet potato biofortified with beta carotene for higher levels of vitamin A, the final produce is orange in colour instead of traditional white fleshed sweet potato. This could be an impediment for consumers as they might think the produce is either deformed or diseased.

7. **Short post-grain shelf life:** Shorter shelf life of some biofortified grains, especially pearl millet, can be a barrier to product development by processing as developing/implementing solutions to increase shelf life can result in high cost and lead to increased product prices.

8. **Forms of consumption:** Processing biofortified crop varieties only to cater to limited forms can reduce the potential of an addressable market size. For example, pearl millet is mostly consumed as freshly baked bread, puffs or cookies which have limited acceptance in rural areas.

4.

Way forward

Biofortification, a relatively novel approach for nutrient enrichment, is one of the most effective, efficient and sustainable ways of addressing hidden hunger amongst the masses, especially in developing nations. Fostering global partnerships between governments, multilateral agencies, farmers, academia and the private sector is a prerequisite for ensuring last-mile delivery. This could be done by integrating biofortification with the core global agenda for achieving SDGs 2 (Zero Hunger) and 3 (Good Health and Well-being) wherein all the stakeholders (governments, industries, farmers and academia) could play their respective roles in complete synergy with each other. A few key recommendations for each stakeholder towards becoming both nutrition and food secure are given below:

Directly impacting SDG targets

- Providing access to nutritious food
- Ending all forms of malnutrition, specifically stunting and wasting of children
- Increased productivity and income for smallholder farmers
- Sustainable agricultural practices

- Reduced global maternal mortality
- Reduced mortality of children under five years and newborns
- Reduced premature mortality

Indirectly impacted SDGs

Supply-side interventions

Farmers play a central role in shaping the supply dynamics of biofortified crops. Their acceptance of biofortified seeds determines the future coverage of the population being supplied with nutrient-enriched meals. Therefore, it is necessary in a country like India to spread awareness, especially amongst farmers, about the relative advantages of using biofortified seeds for improved acceptance. Agricultural research institutions like ICAR have already developed many staple crop varieties which are biofortified with various nutrients like iron, zinc, anthocyanins and erucic acid. A robust value-chain network of local-level nurseries, seed multiplication centres, seed sellers and farmers must be developed for ensuring the availability and last-mile delivery of biofortified crops. Using good pre- and post-harvest management practices will ensure minimum crop losses in the long run. Promoting farm income enhancement by awarding remunerative prices for biofortified crops could also encourage farmers to use such seeds. Furthermore, providing subsidised farm inputs for efficient distribution and adoption of improved cultivars, and promoting the adoption of the 'seed village' model of cultivation can increase the interest of farmers to cultivate biofortified crops. Undertaking strong promotional extension activities like field demonstration could go a long way in resolving hunger- and health-related issues. Designing a knowledge repository on related best practices, case studies and interventions will help in sustainable and cost-effective scale-up. Lastly, establishing strong linkages with the agri food processing industry will help in better dissemination of biofortified crops.

Demand-side interventions

The GoI's initiatives to introduce fortified staples as an integral part of the ICDS and MDM programmes is a welcome step. The incorporation of biofortified crops in health schemes could help incentivise farmers, encourage them to grow these crops and provide a ready market for their produce. Private players could help in creating a market for biofortified crops by buying biofortified produce directly from farmers and labelling/marketing their products appropriately for better consumer awareness and acceptance.

In this context, umbrella branding under a unified logo could be a step in the right direction. For example, the +F logo is being used as an umbrella logo for all fortified food. The same approach could be adopted for biofortified produce or products. Simultaneously, using digital platforms for marketing and consumer awareness campaigns could play a key role in stimulating demand for biofortified crops while having a mass outreach. Also, improving the foothold in retail would help the stakeholders understand the right pricing strategy and identify target customers as well as the B2B/B2C engagements for processors or sellers of biofortified crops.

Policy-level interventions

Biofortifying a specific nutrient in food supply and distribution schemes should be backed by health data which suggests a deficiency of that particular nutrient in the target population. Therefore, reviewing nutrition statuses at national and local levels could be a guiding step for implementing the right policy at the right place. Besides, national food safety and quality regulatory bodies like the FSSAI could promote biofortified food products through specific labelling and nutrition rating practices to increase demand. Additionally, in the domain of biofortified packaged food and food imports, the development and adoption of standards for biofortification could help facilitate trade. We would also need to integrate biofortification in global, national, and regional policies and programmes such as ICDS and MDM. The establishment of an independent department under the Ministry of Agriculture for the growth and scaling up of biofortification, and handling all related issues could be beneficial. Catalysing and facilitating partnerships between plant breeders, nutrition scientists, genetic engineers, molecular biologists and subject matter experts to replace conventional seeds and ingredients with biofortified alternatives should be explored. Incentivising investments by governments, the private sector, and society at large to address biofortification as a strategy to combat hidden hunger could help in the long run.

Research-level interventions

Academia and the knowledge industry could perform their imperative role by framing policy-level guidelines and engaging in agri-extension activities. The key components of this role include developing biofortified seeds, conducting efficacy studies, monitoring improvements in nutritional statuses of target populations and researching on crop improvement. Further, at a global level, research convergence will be required for designing country-specific theories of change for impact-assessment studies. Efforts should be undertaken to initiate research to breed alternative varieties/staples and enable synergy among subject specialists – breeders, biotechnologists, biochemists, seed technologists, agronomists and post-harvest technologists across various sectors. Research should be promoted for strengthening the seed value chain to produce and supply good-quality seeds to popularise biofortified varieties of crops. Further, conducting large-scale trials to help establish the efficacy and benefits of biofortified crops and seeds will be a positive approach. There should be concentrated efforts to explore existing barriers in adopting digital solutions and integrating the necessary equipment to develop biofortified varieties. Stakeholders should also look to create platforms and plan for events to address the myths and misconceptions associated with fortification and biofortification. They should provide training associated

with new product development with biofortified ingredients, retaining micronutrients during processing, packaging, transportation and storage, ensuring traceability (i.e. supply chain integrity), and maintaining food safety and quality as well as capacity building in marketing, nutrition labelling, etc.

The above recommendations are summarised below:

Supply-side interventions

- Improving farmer awareness and acceptance
- Robust value-chain network between nurseries, seed multiplication centres, seed sellers and farmers
- Good pre- and post-harvest management practices
- Seed purchase incentivisation

Demand-side interventions

- Scheme convergence for providing a ready market
- Direct farm gate purchase of biofortified produce for processing and labelling/marketing accordingly by private players
- Online marketing and consumer awareness campaigns
- Umbrella branding
- Choosing the right pricing and target customer

Policy-level interventions

- Scheme convergence with health and food supply programmes
- Policy monitoring to review improvements achieved
- Labelling and packaging incentivisation for private players by regulatory authorities

Research-level interventions

- Scheme convergence with health and food supply programmes
- Policy monitoring to review improvements achieved
- Labelling and packaging incentivisation for private players by regulatory authorities

Scaling up biofortification requires expanding existing relations and developing capacity, and providing technical assistance and linking organisations, institutes and other private entities for them to increasingly take the lead and ensure appropriate on-ground delivery.

Different stakeholders such as national governments, policymakers and decision takers must ensure the inclusion of biofortification in global, national, and regional policies and programmes such as ICDS and MDM. At the same time, they should establish standards and regulatory frameworks to facilitate easier promotion and marketing of biofortified food. Public and private sector breeding partners and food processors must mainstream biofortification across their product lines as it is central in developing the food-product value chain for biofortified crops. Micro, small and medium enterprises (MSMEs) and SMEs also push up the demand for biofortified food. Training and capacity building associated with developing nutrient-enriched crops and healthy food using biofortified ingredients, retaining micronutrients during processing, packaging, transportation, and storage, ensuring traceability (i.e. supply chain integrity) and maintaining food safety and quality for millers, farmers, consumers, and several other partners across the supply chain are essential to increase the impact of biofortified crop varieties.

Development partners and NGOs play a significant role in delivering this nutrition intervention to the vulnerable sections of society. The existing partnership between GAIN and HarvestPlus is an example of how development partners can come together and integrate biofortified crops into their existing agricultural schemes and programmes, linking them to health and nutrition initiatives. Academia/institutes/research centres/ universities can also focus on initiating research to breed alternative varieties/staples and enable better coordination and collaboration among various subject specialists – breeders, biotechnologists, biochemists, seed technologists, agronomists and post-harvest technologists across various sectors, and strengthen the seed chain to produce and supply good-quality seeds to popularise biofortified varieties of crops. Biofortification will help in achieving SDG 2 (Zero Hunger) only through a collaborative effort that reaches across the value chain involving different partners.

About ASSOCHAM

The Knowledge Architect of Corporate India

Evolution of Value Creator

ASSOCHAM initiated its endeavour of value creation for Indian industry in 1920. Having in its fold more than 400 Chambers and Trade Associations, and serving more than 4,50,000 members from all over India. It has witnessed upswings as well as upheavals of Indian Economy, and contributed significantly by playing a catalytic role in shaping up the Trade, Commerce and Industrial environment of the country.

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ASSOCHAM is seen as a forceful, proactive, forward looking institution equipping itself to meet the aspirations of corporate India in the new world of business. ASSOCHAM is working towards creating a conducive environment of India business to compete globally.

ASSOCHAM derives its strength from its Promoter Chambers and other Industry/ Regional Chambers/Associations spread all over the country.

Vision

Empower Indian enterprise by inculcating knowledge that will be the catalyst of growth in the barrierless technology driven global market and help them upscale, align and emerge as formidable player in respective business segments.

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As a representative organ of Corporate India, ASSOCHAM articulates the genuine, legitimate needs and interests of its members. Its mission is to impact the policy and legislative environment so as to foster balanced economic, industrial and social development. We believe education, IT, BT, Health, Corporate Social responsibility and environment to be the critical success factors.

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ASSOCHAM represents the interests of more than 4,50,000 direct and indirect members across the country. Through its heterogeneous membership, ASSOCHAM combines the entrepreneurial spirit and business acumen of owners with management skills and expertise of professionals to set itself apart as a44 Chamber with a difference.

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ASSOCHAM derives its strengths from the following Promoter Chambers: Bombay Chamber of Commerce & Industry, Mumbai; Cochin Chambers of Commerce & Industry, Cochin: Indian Merchant's Chamber, Mumbai; The Madras Chamber of Commerce and Industry, Chennai; PHD Chamber of Commerce and Industry, New Delhi.

Together, we can make a significant difference to the burden that our nation carries and bring in a bright, new tomorrow for our nation.

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About HarvestPlus

HarvestPlus is a part of the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH). HarvestPlus improves nutrition and public health by developing and promoting biofortified food crops that are rich in vitamins and minerals, and providing global leadership on biofortification evidence and technology.

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About GAIN

The Global Alliance for Improved Nutrition (GAIN) is a global, Swiss-based foundation launched at the United Nations in 2002 to tackle human suffering caused by malnutrition. GAIN's work to improve the consumption of nutritious and safe foods is based on three strategic objectives: increase consumer demand for nutritious and safe foods; increase accessibility to nutritious and safe foods; strengthen the enabling environment for designing, implementing, and scaling up effective programs.

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About PwC

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Acknowledgements

Editorial support
Saptarshi Dutta
Design support
Kirtika Saxena

pwc.in

Data Classification: DC0 (Public)

KS/September 2021-M&C 15113