## Biofortification: A pathway to strengthen food systems through nutrient-rich crops

July 2023





## Message from FICCI



**T R Kesavan** Chairman, FICCI National Agriculture Committee, and Group President, TAFE Ltd

Malnutrition has emerged as one of the most serious health issues worldwide. The consumption of unbalanced diet poor in nutritional quality causes malnutrition which is more prevalent in the underdeveloped and developing countries. It is a major health challenge which is being rightly addressed through the Sustainable Development Goals laid by the United Nations.

Nutritious food is central to a nation's growth, development, and prosperity. Though India has achieved record food grain production in recent past, widespread malnutrition in the country remains an area of concern. Deficiencies in key vitamins and minerals continue to pose a very serious constraint to human health and economic development. For India, the world's largest democracy and a fast-growing economy, the Government has set its vision to achieve 'Zero Hunger' by 2030 and 'Nutrition Targets' by 2025 under its commitment to Sustainable Development Goals (SDGs).<sup>1</sup>

Biofortification, an agriculture-based approach to the development and dissemination of micronutrient-rich crops, offers a viable option to mitigate malnutrition and hidden hunger. Biofortified crops have the advantage of reaching underserved rural population, who have limited access to nutrient-rich diets, commercially available fortified food, or other micronutrient interventions. Biofortification is an upcoming, promising, cost-effective, and sustainable technique of delivering micronutrients to a population that has limited access to diverse diets and other micronutrient interventions. The future of biofortification in India looks bright. The government is committed to promoting biofortification, and there is a growing demand for biofortified foods from consumers. With continued investment and support, biofortification has the potential to make a significant contribution to improving the nutritional status of the Indian population.

<sup>&</sup>lt;sup>1</sup> https://www.un.org/sustainabledevelopment/hunger/

## Message from Syngenta Foundation – India<sup>2</sup>



**Rajendra Jog** Country Director, Syngenta Foundation India

We are all aware that malnutrition has emerged as one of the most serious health issues worldwide. The consumption of unbalanced diet, diet based on single crop such as rice, wheat or maize does not provide adequate quantities of essential minerals and vitamins like iodine, iron, zinc, vitamin A, etc., leading to nutritional deficiency. This is more prevalent in underdeveloped and developing countries.

Globally around two billion people suffer from malnutrition. India loses over USD 12 billion in GDP per year to vitamin and mineral deficiencies. Considering the widespread impact of malnutrition, mitigation of malnutrition has been identified as one of the of the most important steps for achieving hunger free world.

To prevent malnutrition and reduce or eliminate the hidden hunger, several strategies such as dietary diversification, supplementation and industrial fortification of food products are available, however, biofortification of crop varieties in the food chain is considered as the most sustainable and cost-effective methodology to enrich the nutritional status of crops. Biofortification of crops would serve as a catalyst to achieve food and nutritional security in India and will help to remove malnutrition in all forms by 2030 as envisaged in the SDGs.

To overcome the issue of slow adoption of nutrient enriched crops, there is a need to create awareness across the value chain and consumers about the health benefits associated with biofortified crops. Capacity building of farmers to educate them about suitable agronomic practices to be followed to achieve good productivity of biofortified varieties is very critical. Aggressive marketing and promotional activities highlighting the value proposition associated with nutrient enriched crop is necessary to augment the acceptance and support across the value-chain.

While working as implementation partner of Gain and HarvestPlus, Syngenta Foundation India (SFI) has put in best efforts to create awareness by encouraging farmers in Rajasthan and Maharashtra for cultivation of iron fortified pearl millets and the farmers in UP for taking up production of zinc fortified wheat crop during last two years. SFI further took up various activities to educate millers and processors for creating a dedicated supply chain for the fortified products.

We hope to continue to work with Gain and Harvest Plus to promote this cause of national importance to help our country to address this hidden hunger (malnutrition) effectively.

<sup>&</sup>lt;sup>2</sup> The views, thoughts, and opinions expressed are by the industry partners of FICCI and do not reflect the views, opinions, policies, or position of PwC.

## Message from HarvestPlus<sup>3</sup>



Ravinder Grover Regional Coordinator-Asia HarvestPlus

The impact of COVID-19, geo-political conflict and climate on global food security has created unprecedented challenges, leading to food supply chain disruptions and increased food insecurity for vulnerable populations. The World Food Programme warns that up to 265 million people may face acute food insecurity due to these challenges, particularly in low- and middle-income countries where millions are struggling to access nutritious food. To address these challenges, biofortification is a crucial and cost-effective solution. By increasing the micronutrient content of staple crops, biofortification provides essential nutrition for those who rely on these crops for much of their diet.

HarvestPlus, a part of CGIAR, drives the advancement of biofortification and has developed over 400 nutrientrich crop varieties in partnership with national programs and partners. collaboration HarvestPlus and GAIN launched together the Commercialisation of Biofortified Crops program in 2018 to increase production and consumption of biofortified crops and foods.

The global community today recognises the crucial role of biofortification in addressing the food security challenges caused by the ongoing Covid, conflict and climate crisis and improving the diets of vulnerable populations. By supporting the scaling up of biofortification, everyone can have access to nutritious food for a healthy and productive life. This report highlights biofortification as a crucial tool for securing food and nutrition for millions impacted by malnutrition, especially in Asia.

Biofortification is a game changer in the fight against malnutrition and food insecurity. It empowers communities with the power of better nutrition, simply by enhancing the nutrient content of the food they already eat. No longer do they need to rely on costly, external sources of nutrition, but can find it in their staple crops. Join us in revolutionising the way we tackle malnutrition and food insecurity and be a part of the biofortification movement that is changing lives and communities for the better.

<sup>&</sup>lt;sup>3</sup> The views, thoughts, and opinions expressed are by the industry partners of FICCI and do not reflect the views, opinions, policies, or position of PwC.

## Message from PwC India



Shashi Kant Singh Partner and Leader – Agriculture and Food Sector PwC India

Nutrition is important for human development; however, it was not until 2008 when it was considered a priority and a High-Level Task Force on Global Food and Nutrition Security was established by the UN Secretary-General and the first Lancet series on 'Maternal and Child Undernutrition' highlighting evidence around nutrition interventions was published.<sup>4</sup> The United Nations (UN) Sustainable Development Goals (SDGs) have also laid emphasis on better and nutritionally rich food to end hunger by 2030. However, eliminating malnutrition remains a major challenge which has been further aggravated by the COVID-19 pandemic.

The Green Revolution in India in the 1960s was responsible for increasing the agricultural productivity as well as the overall food production in the country. As a result, India had a surplus stock of cereals for the first time ever with a focus on providing calorie support to all people, especially those from the lower income groups. Despite this remarkable feat, the rate of malnutrition in India remains stubbornly high. Moreover, India is now dealing with a 'triple burden' of malnutrition where undernutrition and micronutrient deficiencies co-exist with rising rates of people being overweight and obese. Given that the economic cost of micronutrient malnutrition is estimated between 0.8–2.5% of the GDP,<sup>5</sup> India's aim to become a USD 5 trillion economy cannot afford to bear the cost of malnutrition.

Huge investments have been made by the government to tackle the issue of malnutrition by implementing multiple national and state programmes through nutrition specific and nutrition sensitive interventions including supplementation of vitamin A, iron, and folic acid, promoting dietary diversity, food fortification, etc. Biofortification as an approach is one of the most practical and sustainable pathways to address 'hidden hunger'. As Indian diet is rich in staple cereals, an incremental improvement in the nutrition content of the cereal crops is bound to have direct impact towards addressing micronutrient malnutrition in the country. Furthermore, addressing micronutrient malnutrition through crop biofortification is economic as well as it provides micronutrients in their natural form with no requirement for infrastructural change or need a separate distribution channel.

However, there is a need to design a detailed strategy to generate awareness about biofortification and to ensure the availability of biofortified crops for consumption for the population of the country. Though measures such as programmes conducted by Indian Council of Agricultural Research (ICAR) and agreements with seeds companies have been taken to popularise biofortified seeds and increase the availability of the crops for the farmers, there is much more that can be done for the adoption of biofortified seeds and biofortified food. This report is an attempt to demystify the misconceptions related to biofortification and to present a detailed overview of the benefits of biofortification.

<sup>&</sup>lt;sup>4</sup> https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/NutritionPrimer\_layout\_WEB\_v5.pdf#page=7

<sup>&</sup>lt;sup>5</sup> https://www.firstpost.com/business/economy/by-2030-malnutrition-will-cost-india-more-than-125-billion-825499.html

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## **Executive summary**

Over the last few decades, the burden of malnutrition has drawn significant attention in India at the national and state levels, leading to a shift in focus from ensuring food security to nutrition security. In order to fulfill the nutritional requirements of the population, the agriculture sector is gradually shifting from being production-centric to ensuring that the production of nutrient-enriched food crops is in sufficient amounts. The central and state government is implementing multiple programs contributing to improved nutrition outcomes. Substantial progress has been achieved on production enhancement and diversification, and steps are being taken to promote nutri-cereals.

Among the various strategies which have been adopted to address malnutrition, biofortification has emerged as an effective strategy to improve the nutritional status of human beings without changing existing dietary patterns. Biofortification tends to approach the issue of micronutrient malnutrition by enhancing the micronutrient content in food crops that form the most acceptable diet of the vulnerable population and varieties that are high-yielding or profitable for the farmers.

The market trend for biofortification is increasing owing to the rising demand for nutrient-enriched food. Globally, the market size for biofortification is valued at USD 100.84 million in 2022, which is projected to grow at a CAGR of 8.9% from 2023 to 2030 reaching a value of USD 217.21 million by 2030.<sup>6</sup> The rising biofortification market is expected to be fuelled by increasing consciousness of consumers towards health and growing investments in agricultural technology.

The Government of India has identified and advocated nutrient-enriched crops as one of the effective pathways for tackling micronutrient malnutrition and is also implementing multiple programmes to address micronutrient malnutrition such as provision of supplementary food through ICDS, mid-day meal programme, National Nutrition Mission, and prophylactic supplementation of iron, vitamin A, and folic acid. Furthermore, with the proofs of concept provided by private players in the field of biofortification, several organisations in India initiated research and development projects in the 2000s towards biofortified cereals funded through national and international agencies.<sup>7</sup> The Indian Council of Agricultural Research (ICAR) is playing a critical role in providing necessary impetus in the domain of crop research and development for food grain production in India. ICAR has improved the nutritional quality in high yielding varieties of cereals, pulses, oilseeds, vegetables, and fruits using breeding methods.

The public sector plays a vital role in providing an enabling environment for enhanced uptake of biofortified crops both at supply and demand side of the food system. Further, conducive policy environment is crucial for enhancing the outreach of nutrient-enriched crops so that the benefit of consuming such food gets translated to the vulnerable population.

Biofortification as a strategy for tackling micronutrient malnutrition is not a mutually exclusive approach. In the presence of various other approaches to reduce micronutrient deficiencies in the population, it is pertinent to explore the probabilities of complementing strategies that augments the delivery of necessary micronutrients to the vulnerable population without being resource intensive. In this context, the possibility of combining biofortification with large-scale food fortification (LSFF) may be employed as a strategy for reaching out to a large population with essential micronutrients that are deficient in the diet.

Various strategies have been adopted across the globe for scaling up for biofortified food grain to address prevailing condition of malnutrition in the underdeveloped and developing world. We propose the **marketing-supply-policy support-institutional strengthening (MSPI)** strategy to achieve the goal of scaling up biofortification.

The adoption of biofortification on a large scale would require robust policies from the Government ensuring market drive for sustainable growth and a continuous and effective supply drive. **Convergence** of various health and food supply programmes, **policy monitoring** to review improvements achieved, **incentivisation** through subsidised seeds, better prices, etc., **capacity building** and **catalysing and enabling partnerships** along the staple crop value chains to replace non-biofortified seeds, grains, ingredients, and foods with their biofortified counterparts, are some of the policy dimensions to overcome the bottlenecks.

<sup>&</sup>lt;sup>6</sup> https://www.verifiedmarketresearch.com/product/biofortification-market/

<sup>&</sup>lt;sup>7</sup> https://currentscience.ac.in/Volumes/123/03/0271.pdf

Market drive for sustainable growth is also critical and can be achieved through **direct farm gate purchase**, **increase consumer awareness**, **proper labelling and packaging**, while the supply drive can be strengthened through **improving farmer acceptance and awareness**, **developing a robust value chain** and **umbrella branding** through an unified logo.

India is going through a major shift in its nutrition status with an increasing population facing micronutrient malnutrition irrespective of geography or socio-economic strata. As discussed in this report, biofortification is an evidence-based, cost-effective, and sustainable strategy for fighting micronutrient malnutrition. However, the existing agricultural policies in their current state are insufficient to address both conditions as policy orientation is still majorly skewed towards maximising macronutrients through production and consumption of staple crops. With adequate reserves of rice and wheat and focus shifting from food security to income security, a designed diversification from crop-centric farming to nutrient-enriched crops is the appropriate way to tackle micronutrient gaps in consumption and to reach the optimum potential of biofortification in tackling micronutrient malnutrition, there is need for collaborative efforts amongst the agri-value chain actors.





## 1. Biofortification

### 1.1. Understanding the what, why and how of biofortification

### What is biofortification?

The human body needs more than 40 nutrients in adequate amounts to sustain a healthy and productive life. The agricultural system, however, focuses more on enhancing the yield and productivity of the crops. In recent times, the focus of the agricultural sector is gradually shifting from being yield-centric to producing nutrient-enriched food crops. Among the various strategies employed by the Government of India and the private sector to embark on this path, biofortification has emerged as an effective strategy to improve the nutritional status of human beings without changing the existing dietary patterns.

The World Health Organization defines biofortification as the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology. Biofortification differs from conventional fortification as it aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops.<sup>8</sup> Biofortification is the process of developing nutrient-enriched crops which have a greater quantity of micronutrients like zinc, iron, and vitamins in comparison to conventional food crops. Consumption of these nutrient-enriched crops can enhance the quantity of essential micronutrients in the human body. Crops such as wheat, maize, rice, millet and cassava, which are the staple food for a majority of the world's population, are not a rich source of vitamins and micronutrients. Therefore, staple crops, especially cereals, are the most targeted food crop for biofortification. The process of biofortification aims to:

- increase the nutritional value of food by enhancing the quantity of protein, zinc, iron, vitamin A, vitamin C, calcium, anthocyanin, lysine and tryptophan in the crop. These nutritional factors are essential for the normal functioning of the human body.
- reduce antinutritional factors such as glucosinolates, erucic acid and Kunitz trypsin inhibitor that are present in the edible part of the food crops, the consumption of which can cause adverse effect on human health.

### The need for biofortification

Various approaches ranging from food-based approaches such as dietary diversification, biofortification, fortification of food and supplementing essential nutrients based on direct consumption of nutrient-enriched food to generating awareness about nutrition-based foods, prioritising national health and nutrition programmes and strategies, and feeding programmes for the vulnerable population have been identified to solve the complex issue of micronutrient malnutrition.

Parameters	Biofortification	Food fortification	Dietary diversification	Supplementation
Dosage	Low	Low	Low	High
Intervention type	Preventive	Preventive	Preventive	Preventive, treatment
Potential coverage	Wide (staple food consumers)	Moderate (limited to consumers having access to fortified food)	Narrow (participants in promotion programmes)	Narrow (supplement recipients)

### Figure 1: Strategies to combat micronutrient malnutrition

<sup>&</sup>lt;sup>8</sup> https://cdn.who.int/media/docs/default-source/anaemia/areacop-webinar---24-september-2020/areacop-webinar-kristinamichauxpresentation.pdf?sfvrsn=45bc32a3\_6

Parameters Biofortification		Food fortification	Dietary diversification	Supplementation
Dosage	Low	Low	Low	High
Target reach	General	General (mostly urban)	Regional focal points (mostly rural)	Risk populations
Infrastructure Seed distribution channels		Supply chain channels	Extension and education system	Health system
Change agents Researchers, farmers		Processors	Extension workers	Health workers
Funding timeframe	One-time	Continuous	Long-term	Continuous
Intervention required for the target population	None (inclusive within the usual diet)	Partial (change in form, colour, taste)	Yes (change of diet and customs)	Partial (compliance in taking supplements)

Among these interventions, biofortification emerges as a promising approach to tackle micronutrient malnutrition due to the following reasons:

**Reach among target population:** Biofortification has the capacity to reach the vulnerable sections of the population since most of the nutrient-enriched crops are staple crops which form a major part of the dietary intake of the poor. Since staple crops are consumed regularly by most of the family members of lower income households, using biofortified crops-based food is sufficient and minimises the need for any additional intervention within the target population.

**Cost-effective:** Biofortification emerges as a beneficial approach for combating micronutrient malnutrition as it is cost-effective both in terms of intervention investment as well as costs per disability-adjusted life years (DALYs) saved.<sup>9</sup> This holds true especially in South Asian countries and Africa, where the seed distribution system is highly effective. Moreover, biofortified crops developed for one geographical region or country can be evaluated for their performance and adaptation to other agroecological conditions, thereby augmenting the output from initial investment and the saving time and investment required to develop new variants.

**Food-system based approach:** The approach aims to distribute biofortified crops which already exist within the present food-system, thereby fostering a self-sustaining value-chain that does not bank on creating an additional system for delivering essential nutrients.

<sup>&</sup>lt;sup>9</sup> A public health intervention is expected to reduce the number of DALYs lost, and the extent of such a reduction is a measure of the benefit of the intervention. DALYs lost are the sum of years of life lost (YLL) and the years lived with disability (YLD). The YLL represents the numbers of years lost because of the preventable death of an individual, while the YLD represent the numbers of years spent in ill-health because of a preventable disease or condition: DALYs lost = YLL + YLD

### The biofortification process

To achieve sustainable and significant micronutrient levels in the product, different approaches such as genetic engineering and conventional plant breeding have been employed. Let us look at some of these approaches in detail.

### Figure 2: Biofortification approaches



Source: Adapted from Assessment of Biofortification Approaches Used to Improve Micronutrient-Dense Plants That Are a Sustainable Solution to Combat Hidden Hunger (https://link.springer.com/article/10.1007/s42729-021-00663-1)

**Conventional plant breeding:** The basic principle to produce a nutrient-enriched crop variety is to identify and transfer the desirable traits from the donor to the recipient parental line. This can be achieved through conventional plant breeding techniques where plant breeders utilise the genetic variability in crops. Breeders effectively utilise germplasms which belong to primary, secondary, and tertiary gene pools for the identification of essential genes as a prerequisite for development of biofortified varieties. Conventional methods such as the production of Zn- and Fe-enriched rice and wheat with a higher yield can be used to achieve multiple gains. This approach is widely used for development of nutrient-enriched crops, for example, quality protein maize (QPM) is accepted by farmers. However, the major limitation of conventional breeding method is that the approach is time-consuming and dependent on the genes which are already present in the crop gene pool.

**Transgenic breeding:** Another genetic engineering approach towards biofortification – transgenic breeding – is employed to transfer and overexpress the desired traits from an unrelated plant species to a staple crop. The donor organism or species may or may not be related to the taxonomic or evolutionary aspects of the staple crop. Genetic engineering remains a preferred option in the absence or limited availability of genetic diversity related to essential nutrients in the existing germplasm. However, a successful genetic engineering approach requires various key factors like reliable tissue culture and regeneration methods, development of gene constructs with suitable promoters, efficient transformation methods, and multiplication and characterisation of transformed plants for the traits introduced by conventional breeding methods.<sup>10</sup>

<sup>&</sup>lt;sup>10</sup> http://oar.icrisat.org/4788/1/GenomicsandCropImprovement\_392-407\_2011.pdf

**Agronomic biofortification:** Agronomic biofortification is primarily based on techniques like surface spraying or external application of mineral fertilisers, particularly iron and zinc, to increase the solubility and micronutrient content in the soil or in the foliage. The principle behind this approach is that the external application of micronutrients to soil or leaves of the crop will enhance the concentration of essential nutrients in the edible parts of the plant. This method includes the use of synthetic fertilisers, biofertilisers, organic manures, as well as seed priming through soil or foliar application. In low- and middle-income countries, agronomic biofortification is considered to be the fastest and easiest strategy for developing nutrient-enriched crop which can be used to biofortify any staple crop with multiple micronutrients without affecting the yield.

### 1.2. Biofortification as a strategy for tackling malnutrition

### Current scenario of malnutrition in India

Malnutrition is a problem which arises due to a complex number of factors such as the impact of poverty, conditions like poor awareness about nutrition and behavioural practices, low access to nutrition, poor affordability, lack of availability at the immediate geography and gender exclusion in consumption. The Government has set its vision to achieve Zero Hunger by 2030 and Global Nutrition Targets by 2025 under its commitment to the United Nation's (UN) Sustainable Development Goals (SDGs). While conscious efforts including convergence, have led to wider recognition and efforts between central and state governments of various countries have been taken to address nutrition vulnerability, the challenges still remain. However, as per the Global Nutrition Report 2022, three out of six global maternal, infant, and young children nutrition (MIYCN) targets to address stunting, wasting, anaemia, low birth weight and childhood obesity are off track for India. At the same time, the global nutrition target to combat the growing prevalence of non-communicable diseases (NCDs) is also off track. The recently published factsheets from NFHS-5 and the findings from Comprehensive National Nutrition Survey 2016 also highlight similar observations with negligible improvement in symptoms of malnutrition like stunting, wasting and anaemia.



### Figure 3: Status of critical nutrition indicators of India

Source: National Family Health Survey (NFHS) data

Furthermore, the State of Food Security and Nutrition in the World 2022 reports that in 2020, 70.5% of India's population was unable to afford a healthy diet which was marginally lower in 2019 (69.4%). The report highlights that although the number of undernourished people in India has declined in the last 15 years to 224.3

million in 2019–2021, there are now more obese and anaemic women in the country. Moreover, there is a growing gender gap in food insecurity which has worsened in the last two years.<sup>11</sup>

#### Status of micronutrient malnutrition in India

#### Figure 4: Severity of micronutrient malnutrition



Source: Muthayya et al 2013

Malnutrition is not only caused by the lack of adequate and nutritious food, but due to many other factors, including frequent illness, poor care practices, and lack of access to health and other social protection services. Another form of malnutrition called 'hidden hunger' or micronutrient deficiency is affecting women and children especially those from the poor households. Research has shown that the highest contributors to hidden hunger are iron deficiency, anaemia, zinc deficiency, vitamin A deficiency and iodine deficiency.<sup>12</sup> India accounts for nearly half of the global population which suffers from micronutrient deficiencies, reporting a widespread (more than 80% total Indian population) risk of deficiencies in vitamin A, calcium, B12 and folate, with a more localised deficiency of zinc, iron, and vitamin B6. It is alarming to note that more than two-thirds of children



<sup>11</sup> https://globalnutritionreport.org/resources/nutrition-profiles/asia/southern-asia/india/

<sup>13</sup> https://main.mohfw.gov.in/sites/default/files/NFHS-5 Phase-II 0.pdf

<sup>&</sup>lt;sup>12</sup> https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8770653/





Source: Maggini, S., Pierre, A., Calder, P.C. Immune Function and Micronutrient Requirements Change over the Life Course. Nutrients 2018, 10, 1531. https://doi.org/10.3390/nu10101531

#### Exploring biofortification as a strategy to address malnutrition

Nutrition is not an outcome of a single factor but a combination of determinants grouped under food, health, and care. Concerns related to nutrition require responses from a range of sectors like food security, public health, water, sanitation and hygiene, and social protection. The vulnerability of a household to food and nutrition insecurity is determined by several factors that are categorised according to their relationship to the four dimensions of food and nutrition security: **availability, access, affordability, and absorption of food**. Let us take a look at them in detail.

### Figure 6: Dimensions of food and nutrition security



#### Source: PwC analysis



**Availability of biofortified food:** Biofortification tends to resolve the issue of micronutrient malnutrition by enhancing the micronutrient content in food crops that form the most acceptable diet of the vulnerable population and varieties that are high-yielding or profitable for the farmers. Biofortified crops have the advantage of reaching underserved rural population, who have limited access to nutrient-rich diets, commercially available fortified food or other micronutrient interventions. Globally, around 10 million farming households are growing biofortified crops, while more than 48 million farming households are potentially benefitting from biofortification in over 30 countries.<sup>14</sup> In India, the Indian Council of Agricultural Research (ICAR), under the National Agricultural Research System, has developed 87 cultivars of cereals, millets, vegetables, fruits and oilseeds through plant breeding who's grain yield is at par with the traditional varieties in terms of yield.<sup>15</sup>

Accessibility to biofortified food: The primary target for the supply and consumption of biofortified food are vulnerable groups such as young children, adolescent girls, and women who usually do not have access to a nutrient rich diet in the family although these groups have relatively higher need for micronutrients. These needs often remain unmet due to cultural norms, dietary habits, lack of access to micronutrient-enriched food, etc., which can further increase their biological vulnerability to diseases and infections. Delivering micronutrients through nutrient-enriched staple crops can ensure equitable intra-household distribution of food since, unlike vegetables, fruits, and animal-sourced food, staple food forms the primary diet of each member in the family and therefore, through biofortified food, young children, adolescent girls, and women within the family have access to micronutrient-dense food.

**Affordability:** Biofortification has proven to be one of the most cost-effective strategies for combating micronutrient malnutrition. The Copenhagen Consensus ranked interventions that reduce micronutrient deficiencies, including biofortification, among the highest value-for-money investments for economic development. For every dollar invested in biofortification, as much as USD 17 of benefits can be gained.<sup>16</sup> Biofortification requires one-time investment in the development of nutrient-enriched varieties, once the seeds of biofortified cultivars are present in the supply system, the nutrition traits remain stable in the crop gene pool. Therefore, repeat investment or additional costs for scaling-up biofortified varieties is marginal. In addition to being nutrient-enriched, biofortified crops tend to be resilient to diseases, pests, climate extremities, and are high yielding which makes them cost-effective and sustainable.

**Absorption of biofortified food in the body:** One of the basic concerns about the consumption of biofortified food is to have enough nutrient bioavailability in order to impact an individual's micronutrient status. Biofortification is not the only solution which can combat micronutrient deficiencies, however, the approach can complement other steps like fortification and supplementation which have been taken to reduce micronutrient malnutrition. Several studies have proven the efficacy of nutrient-enriched staple food crops which are produced through biofortification in enhancing the levels of micronutrients in the body. Most studies on iron biofortified crops have shown a considerable improvement in the iron status of the people who suffered from iron deficiency at the start of the study. Cultivating high-iron staple crops such as pearl millet and common beans can help alleviate the prevalence of iron deficiency which is commonly caused by inadequate intake of iron-rich foods, particularly in the population of developing countries.<sup>17</sup> Another set of studies concluded that biofortified staples can play a significant role to combat the increasing Vitamin-A deficiency among young children. Another study showed that zinc absorbed from fortified food did not differ significantly from zinc biofortified crops. This shows that biofortification can be a cheaper alternative for delivering zinc to the most vulnerable population such as children under the age of five years.<sup>18</sup>

<sup>&</sup>lt;sup>14</sup> https://www.cast-science.org/wp-content/uploads/2020/10/CAST\_IP69\_Biofortification-1.pdf

<sup>&</sup>lt;sup>15</sup> Devendra Kumar Yadava, Partha Ray Choudhury, Firoz Hossain, Dinesh Kumar, Tilak Raj Sharma and Trilochan Mohapatra (2022). Biofortified Varieties: Sustainable Way to Alleviate Malnutrition (Fourth Edition). Indian Council of Agricultural Research, New Delhi. 106 p.

<sup>&</sup>lt;sup>16</sup> http://www.copenhagenconsensus.com/sites/default/files/Hunger+and+Malnutrition.pdf

<sup>&</sup>lt;sup>17</sup> https://www.hilarispublisher.com/open-access/biofortified-crops-can-alleviate-micronutrient-deficiencies-review-ofevidence-fromrandomized-feeding-trials-2376-1318-1000154.pdf

<sup>18</sup> https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3151017/

2. Understanding the biofortification landscape in India



### 2.1. Biofortification value-chain and the role of ecosystem actors

The value chain for producing and delivering nutrient-enriched crops (NEC) comprises various steps from agricultural research to making biofortified food available in the market. Though the value chain for biofortified food is not very different from the conventional value chain, there are a few additional steps at the beginning of the system in which the researchers develop nutrient-rich crops before they are ready for supply. Let us look at the three stages of the value chain.

#### Figure 7: Agri-value chain for delivery of nutrient-enriched crops



Source: PwC analysis

**Crop research and development:** In the crop research phase, nutritionists, plant breeders, and food technologists establish a nutritional breeding target for the crops based on factors such as food consumption pattens of the target population, estimated nutrient losses during storage and processing, and nutrient bioavailability. While traditional crop improvement approaches focus on value-added traits that are attractive for existing markets and provide superior crop and marketing options to the farmers; biofortification enhances the nutrient content to augment the product profiles for biofortified staple crops. This entails setting of target nutrition levels or standards based on contribution of the traits to the crop's nutrition status. Simultaneously, coordinated marketing research should be conducted to ensure that value propositions and requirements for all value chain actors are incorporated in the product profiles. Once the nutrient-enriched crop is developed and the variety is released, multiplication of crop propagation materials is undertaken by engaging with private seed companies, particularly for crops that are commercially viable such as pearl millet, maize, wheat, and rice. Crops which do not attract investment from the private sector are multiplied by partnering with NGOs, farmer organisations, etc.

**Production and post-harvest handling of crops:** Biofortified seeds can have the desired impact when they reach the agricultural system for mass consumption and when farmers have access to the propagation material. Currently, seeds/vines are available to farmers either through direct purchase from agri-dealers, as demonstrative packages which are distributed as a part of an on-going intervention, or through fellow farmers. At this stage, crop production of the biofortified variety is undertaken by the farmers which also makes farming households a point of consumption. Several interventions and programmes encourage the farming community to consume the harvested, nutrient-enriched produce as many farming households are micronutrient deprived and utilise the surplus produce for sale. The inclusion of biofortified components in processed foods is expected to not only help food systems deliver enhanced nutrient content but is also seen as a 'demand pull' strategy to encourage the adoption and production of biofortified crops at the farmer level. The post-harvest handling process involves aggregation of the biofortified produce and supplying the aggregated harvest to the millers and processors for primary processing towards consumption or food product development.

**Utilisation of biofortified crops:** The consumption of food products is affected by availability, affordability and sticky factors like taste, preferences, socio-cultural norms and desirability. However, the consumption of nutritious food is governed by the interplay between income and the food environment (food availability, accessibility, affordability, properties, marketing, and regulation). Therefore, biofortified crops need to be acceptable as per the cooking quality requirements for greater adoption. Consumption of nutrient-enriched food depends on branding and advertising which in turn helps in providing proper information and influencing the consumer.

### Multiple actors are engaged in delivering nutrient-enriched crops to the consumers through the agrivalue chain

Step	Activity	Value chain actors
Agriculture research	<ul> <li>Defining nutritional breeding targets</li> <li>Identification of appropriate methodology for crop development</li> <li>Targeted breeding</li> <li>Testing of developed variety for desired traits and adaptation</li> </ul>	Agronomists, nutritionists, food technologists, research institutions, etc.
Varietal release	Local or regional release of tested variety for commercial use	Research institutions, government, etc.
Multiplication of seed	<ul> <li>Foundation of seed multiplication led by agricultural research institutions or other government entities</li> <li>Involvement of private seed companies for scale production of seeds</li> <li>Engagement of identified farmer-based organisations such as farmer producer organisations/farmer producer companies, progressive farmers, for production of certified seeds</li> </ul>	Agricultural research institutions or other government entities, private seed companies, farmers

#### Figure 8: Biofortification delivery channel and value chain actors

Step	Activity	Value chain actors
Agri-input supply	<ul> <li>Private seed companies produce and market certified seeds</li> <li>Non-conventional seed dissemination and seed sharing among fellow farmers</li> </ul>	Private seed companies, farmers
Cultivation of crop	Cultivation of biofortified variety by farming households	Farming households
Post-harvest handling and primary processing	<ul> <li>Aggregation of harvested surplus produce into commercial quantities</li> <li>Protection of crop variety identity (traceability)</li> </ul>	Local aggregators, millers, etc.
Secondary processing	<ul> <li>Food product development by food processing companies/units</li> <li>Maintaining traceability of nutrient-enrich food products</li> </ul>	Food processing companies, local processors, etc.
Retailing	<ul> <li>Consumer marketing and dissemination of information around nutrient-enriched food products</li> <li>Retaining biofortified food products at local food market</li> </ul>	Retailers, local shops, etc.
Consumption	<ul><li>Through public health and nutrition intervention programmes</li><li>Through local market</li></ul>	National/regional/local feeding programmes or interventions, commercial food retailers

### Strengthening the value-chain for biofortification

The effectiveness of biofortification as a strategy to reduce micronutrient malnutrition has been wellestablished, however, to achieve the optimum potential of the approach, there is a need to strengthen different nodes in the biofortification value-chain by employing different strategies. Let us look at the some of the ways in which biofortification value chain can be enhanced:

**Generating awareness:** One of the major reasons for the slow adoption of nutrient enriched crops is the lack of awareness among the value chain actors and consumers about the health benefits of biofortified crops. Furthermore, participation of farmers in informative demonstration trials are critical to eliminate the apprehensions around yield capacity of biofortified varieties and other agronomic practices. Additionally, strong connections with agri-food processors should be established and information regarding the use of nutrient enriched crops as ingredients for a healthy diet should be disseminated. Financial and enterprise development support may be extended to enable small and medium-scale enterprises to take-up biofortification. Marketing and promotional activities highlighting the benefits of nutrient-rich biofortified crop should also be conducted to promote the crop and increase its adoption.

**Nurturing an enabling environment:** The absence of a clear plan which outlines the framework for multisectoral associations at different levels and defines the institutional roles and responsibilities for the implementation of biofortification value chain has contributed to the limited scope of biofortification interventions in the country. Therefore, identifying and nurturing advocates of biofortification across the value chain and engaging with local officials to develop an supportive environment for the adoption of nutrient-enriched crops is an important part of adopting biofortification as an agronomic practice. Fostering synergies between both the public and the private sector as well as NGOs will help in ensuring that the supply and demand is seamless and the outcomes of programmes to curb micronutrient malnutrition are successful. Establishing technical working groups involving stakeholders across the value-chain for providing strategic inputs to augment adoption and on-ground application and leveraging public-private partnerships for developing rural infrastructure are some of the other steps which can be undertaken to address the challenge of the availability of biofortified crops/seeds. To protect the farmers from factors related to climate change, price discovery, storage and logistics, the sector needs more investments and innovation which can be provided by the private sector. Furthermore, better coordination and collaboration among various stakeholders across scientific and policy-related aspects of biofortification can further strengthen the local food system.

**Policy support:** As the strategy to implement biofortification gains momentum and a number of nutrientenriched crops are developed, it is critical to have regulations and quality standards for each step of the process. For instance, quality parameters need to be defined in order to consider a specific crop as biofortified. Without quality checks, crops with inadequate levels of micronutrient may exist in the value chain and the positive impact of the adoption of biofortified food may not be achieved. It could also lead to a loss of investment and adoption even though the Government is implementing various national and state programmes to improve the nutrition-related outcomes through nutrition-specific and nutrition sensitive interventions but the endeavours might not yield the desired outcome. Though substantial progress has been made in areas such as production enhancement and diversification, and steps are being taken to promote nutrition enriched crops, there is a need to strategically position biofortification, so that new regulations can be incorporated within the implementation process.

### 2.2. Current scenario of biofortification – global and national trends

### **Global trends**

The trend for biofortification is increasing in the global market due to the rising demand for nutrient-enriched food. Globally, the market size for biofortification is valued at USD 100.84 million in 2022, which is projected to grow at a compound annual growth rate (CAGR) of 8.9% from 2023 to 2030 and reach USD 217.21 million by 2030.<sup>19</sup> The growing biofortification market is fuelled by the increase in the awareness of the consumers towards healthy foods and growing investments in agricultural technology. On the basis of geography, Asia-Pacific is estimated to dominate the global biofortification market, while the biofortification market in Africa is expected to grow with the highest CAGR.<sup>20</sup>

Consortium of International Agricultural Research Centers (CGIAR) reports that between 2004 and 2019, more than 350 biofortified varieties have been released, along with hundreds more which are currently in their testing phase and more than 50 million people in smallholder farming families in 41 countries now benefit from biofortified crops.<sup>21</sup>

The first biofortified crop variety – a vitamin A fortified sweet potato – was released for farmers in Uganda in 2007.<sup>22</sup> One of the leading private players in the biofortification sector reports that more than 12.8 million people (64 million household members) are now growing and eating one or more of the 12 crops biofortified with vitamin A, iron, or zinc – micronutrients which have been identified by the World Health Organization. More than one billion people are expected to benefit from biofortified foods by 2030.<sup>23</sup> Till now, 422 biofortified varieties of 12 biofortified, climate-smart staple crops have been developed. Out of 422 varieties, 278 varieties have been released in African countries, followed by 79 in Asian countries and 65 in Latin American countries.

<sup>&</sup>lt;sup>19</sup> https://www.verifiedmarketresearch.com/product/biofortification-market/

<sup>&</sup>lt;sup>20</sup> https://www.databridgemarketresearch.com/infographic/global-biofortification-market-1

<sup>&</sup>lt;sup>21</sup> https://www.cgiar.org/innovations/crops-bred-to-improve-nutrition/

<sup>&</sup>lt;sup>22</sup> https://www.harvestplus.org/about/history

<sup>&</sup>lt;sup>23</sup> https://www.harvestplus.org/harvestplus-biofortified-crops-map-and-table-updated-with-2020-data/

The table below contains the list of biofortified crop varieties which have either been released or are in their testing phase as of 2020.24,25

Figure 9: List of biofortified crop vari	ties which have eithe	r been released or a	re in their testing
phase as of 2020			

No.	Name of the crop	Countries where the varieties have been released	Countries where the varieties have been tested	Crop specific information i.e. nutritional benefit, important traits, and other information		
1	Iron bean	Panama, Nicaragua, Honduras, Guatemala, El Salvador, Colombia, Brazil, Bolivia, Tanzania, Rwanda, Kenya, Democratic Republic of Congo, Burundi, Uganda, Zimbabwe	Haiti, South Sudan, Ethiopia, Malawi	When eaten regularly it provides up to 80% of daily iron needs for women of reproductive age and children	Heat and drought resistant, high yielding, resistant to pests and virus resistant	
2	Iron lentil	Syria, Nepal, Bangladesh, India	Lebanon, Morocco, Ethiopia, Pakistan		Early maturing, high yielding 12 varieties of iron lentils have been released	
3	Iron pearl millet	Togo, Niger, India	Zambia, Tunisia, Tanzania, South Sudan, Senegal, Mali, Madagascar, Kenya, Ghana, Eritrea, Burkina Faso, Benin, Uganda, Zimbabwe, Malawi, Gambia, Nigeria	When eaten regularly it provides up to 80% of daily iron needs for women of reproductive age and children	10 varieties have been released in India and one variety released In Africa (Niger)	
4	Iron-zinc cowpea	Brazil, Zimbabwe, India	Nigeria			
5	Vitamin A banana/ plantain	Democratic Republic of Congo Burundi	Tanzania, Rwanda, Guinea, Cote d'Ivoire, Cameroon, Uganda, Nigeria			

<sup>24</sup> 

https://www.harvestplus.org/wp-content/uploads/2022/11/Biofortified-Crops-Around-the-World.pdf https://www.researchgate.net/publication/318426701\_Biofortified\_Crops\_Can\_Alleviate\_Micronutrient\_Deficiencies\_Review\_of \_Evidence\_from\_Randomized\_Feeding\_Trials 25

No.	Name of the crop	Countries where the varieties have been released	Countries where he varieties have been released been tested		Crop specific information i.e. nutritional benefit, important traits, and other information		
6	Vitamin A cassava	Brazil, Sierra Leone, Ghana Democratic Republic of Congo, Cameroon Nigeria	Panama, Mexico, Haiti, Guatemala, Colombia, Zambia, Tanzania, Swaziland, Senegal, Niger, Mozambique, Liberia, Kenya, Guinea, Gambia, Gabon, Ethiopia, Cote d'Ivoire, Chad Central African Republic, Benin, Uganda, Malawi	When eaten regularly it provides up to 100% of daily vitamin A needs for women of reproductive age and children	Grows well even in poor soil conditions, high yielding and virus resistant		
7	Vitamin A maize	Brazil, Zambia, Togo, Tanzania, Rwanda Mali, Ghana, Democratic Republic of Congo, Cameroon, Zimbabwe, Malawi, Nigeria	Panama, Mexico, South Africa, Sierra Leone, Senegal, Kenya Ethiopia, Eritrea, Egypt Burkina Faso, Benin, Uganda, Angola, Pakistan, China, Haiti Colombia, Nepal, South Sudan, Niger, Mozambique, Liberia, India	When eaten regularly it provides up to 50% of daily vitamin A needs for women of reproductive age and children	Drought tolerant, high yielding, resistant to diseases and viruses		
8	Vitamin A orange sweet potato	Peru, Panama, Nicaragua, Guatemala, Colombia, Brazil, South Korea, Indonesia, Timor- Leste, Zambia, Tanzania, South Africa, Rwanda, Mozambique, Madagascar, Kenya, Ghana, Ethiopia, Cote d'Ivoire, Burundi, Burkina Faso, Uganda, Nigeria, Angola, Malawi, Bangladesh, China, India	Honduras, Haiti, South Sudan, Senegal, Niger, Morocco, Mali, Zimbabwe	When eaten regularly it provides up to 50% of daily vitamin A needs for women of reproductive age and children	Drought tolerant, high yielding, resistant to diseases and viruses		

No.	Name of the crop	Countries where the varieties have been released	Countries where the varieties have been tested	Crop specific inforn nutritional benefit, i other information	op specific information i.e. tritional benefit, important traits, and ner information	
9	Zinc maize	Nicaragua, Honduras, Guatemala El Salvador, Colombia, Bolivia	Panama, Mexico, Haiti, South Africa, Egypt, Nigeria	Provides up to 70% of daily zinc needs	Drought tolerant, high yielding, resistant to diseases and viruses	
10	Zinc rice	Nicaragua, El Salvador, Colombia, Indonesia, Bangladesh, India	Haiti, Guatemala, Brazil, China, Myanmar, Cambodia, Madagascar	When eaten regularly it provides up to 40% of daily zinc needs for women of reproductive age and children	-	
11	Zinc wheat	Mexico, Brazil, Bolivia Nepal, Bangladesh, Pakistan, India	Philippines, Bhutan, Afghanistan, Zambia, Ethiopia, Zimbabwe, China	-	-	
12	Zinc-iron sorghum	India	South Sudan, Mali, Uganda, Nigeria	-	-	
13	Iron-zinc Irish potato	-	Peru, Bolivia, Nepal, Bhutan, Rwanda, Kenya, Ethiopia, Uganda, Malawi, China, India	-	-	



### Biofortification priority index (BPI): A tool for data-driven decision-making for scaling up biofortification

BPI is a data-driven decision-making tool for scaling up biofortification in a particular country. It is the most acceptable interactive tool and identifies the crop combinations through which biofortification can have the maximum impact on reducing the micronutrient deficiencies and improve the quality of the diet.



Source: HarvestPlus

The BPI is a composite crop-specific index. It accounts for the degree of production and consumption of each biofortifiable crop in a given country and the deficiency level for the micronutrient with which the specific crop can be enriched. The BPI ranks 128 countries in Africa, Asia, and Latin America and the Caribbean for each of the 13 biofortified staple crops based on the degree of production and consumption of each biofortified crop in a given country and the deficiency level for the micronutrient with which the specific crop can be enriched.

The countries which are at the top of the index are based on the production and consumption of biofortified food by which micro-nutrient deficiency would be impacted.

Name of the crop	Тор	High	Medium	Low	Νο	India's position in global ranking	Status of research (released/testing) and number of varieties released
Iron bean						25/123 countries	Activities status: N/A No. of variety released: 0
Iron Irish potato						21/126 countries	Activities status: testing No. of variety released: 0

### Figure 10: India's crop ranking based on BPI<sup>27</sup>

<sup>26</sup> https://bpi.harvestplus.org/about.html

<sup>27</sup> https://bpi.harvestplus.org/country\_charts.html

Name of the crop	Тор	High	Medium	Low	No	India's position in global ranking	Status of research (released/testing) and number of varieties released
Iron lentil						3/119 countries	Activities status: released No. of variety released: 1
Iron pearl millet						10/117 countries	Activities status: released No. of variety released: 10
Vitamin A banana						44/112 countries	Activities status: NA No. of variety released: 0
Vitamin A cassava						51/123 countries	Activities status: NA No. of variety released: 0
Vitamin A maize						46/128 countries	Activities status: testing No. of variety released: 0
Vitamin A orange sweet potato						53/119 countries	Activities status: released No. of variety released: 6
Zinc maize						53/128 countries	Activities status: NA No. of variety released: 0
Zinc rice						12/128 countries	Activities status: released No. of variety released: 1

Name of the crop	Тор	High	Medium	Low	No	India's position in global ranking	Status of research (released/testing) and number of varieties released
Zinc sorghum						27/116 countries	Activities status: released No. of variety released: 1
Zinc wheat						3/128 countries	Activities status: released No. of variety released: 9

#### National trends

#### **Biofortification in India**

In addition to implementing multiple programmes to address micronutrient malnutrition such as providing supplementary food through Integrated Child Development Services (ICDS), mid-day meal programmes, National Nutrition Mission, and the preventive supplementation of Iron, vitamin A, and folic acid, the Government has identified and advocated a few nutrient-enriched crops as one of the effective pathways for tackling micronutrient malnutrition. Furthermore, with the proofs of concept provided by private players in the field of biofortification, several organisations in India have undertaken research and development projects towards biofortified cereals funded through national and international agencies.<sup>28</sup>

#### Figure 11: Major biofortified varieties developed in India



Source: Biofortified Varieties: Sustainable Way to Alleviate Malnutrition, 4th Edition by Indian Council of Agricultural Research

<sup>&</sup>lt;sup>28</sup> https://currentscience.ac.in/Volumes/123/03/0271.pdf

The Indian Council of Agricultural Research (ICAR plays a critical role in providing the necessary impetus in the domain of crop research and development for food grain production in India. ICAR has pioneered in improving the nutrition content of high yielding varieties of cereals, pulses, oilseeds, vegetables, and fruits using breeding methods. Special efforts were taken during the twelfth plan with the initiation of a special project on consortium research Platform on Biofortification. The National Agricultural Research System (NARS) in collaboration with other national and international initiatives has led to the development of 16 biofortified crops of which 87 varieties of different crops have been improved. Among various crops categories namely cereals, legume, oil seeds, fruits and vegetables, the highest number of biofortified varieties have been developed for cereal crops (wheat–28).<sup>29</sup>

### Figure 12: Trait-wise biofortified cultivars developed through breeding

### Figure 13: Year-wise release of biofortified cultivars developed through breeding in India







<sup>29</sup> Biofortified Varieties: Sustainable Way to Alleviate Malnutrition, 4th Edition by Indian Council of Agricultural Research

### Focus on the production of millets

Millets are considered to be superfoods. They are food grains with high nutritional value and health benefits and require less amount of water for their cultivation. In 2019, India produced more than 170 lakh tonnes (80% of Asia's and 20% of global production) millets. Between 1950–55 and 2015–2020, India has witnessed a 56% decline in the area under millets since 1950s, due to change in consumption patterns, conversion of irrigated areas for wheat and rice cultivation, unavailability of millets, low yield, and less demand due to dietary habits. Before the Green Revolution, the share of millets was 20% of the total food grain basket whereas, at present, it is confined to a mere 6% of India's food basket. Average yield of millets in India is 1239 kg/ha which is comparatively higher than the global average of 1229 kg/ha.

To further enhance the nutritional quality of millets, ICAR has thus far developed nine biofortified varieties of pearl millet, three varieties of finger millet and one variety of small millet.<sup>30</sup>

					Pearl millet				
Variety	HHB 299	AHB 1200Fe	AHB 1269Fe	ABV 04	Phule Maha- shakti	RHB 233	RHB 234	HHB 311	HHB 67 Improved 2
Micro- nutrients and Yield (Q/Ha.)	Iron (73.0 ppm) Zinc (41.0 ppm) 32.7 Q/ha	Iron (73.0 ppm) 32.0 Q/Ha	Iron (91.0 ppm) Zinc (43.0 ppm) 31.7 Q/Ha	Iron (70.0 ppm) Zinc (63.0 ppm 28.6 Q/ha	lron (87.0 ppm) Zinc (41.0 ppm) 29.3Q/Ha	Iron (83.0 ppm) Zinc (46.0 ppm) 31.6Q/Ha	Iron (84.0 ppm) Zinc (46.0 ppm) 31.7 Q/Ha	lron (83.0 ppm) 31.7 Q/Ha	Protein (15.5 %) Iron (54.8 ppm) Zinc (39.6 ppm) 20.0Q/Ha
Finger millet				Little millet					
Variety	VR 929 (Vegavathi)	CFMV1 (Indravati)	CFMV 2			Variety	CLMV 1		
Micro- nutrients and Yield (Q/Ha.)	Iron (131.8 ppm) 36.1Q/Ha	Calcium (428mg/ 100g) Iron (58.0 ppm) Zinc (44.0 ppm 31.1Q/Ha	Iron (39.0 ppm) Zinc (25.0 ppm) Calcium (454 mg/ 100g) 29.5Q/Ha			Micro- nutrients and Yield (Q/Ha.)	lron (59.0 ppm) Zinc (35.0 ppm) 15.8Q/Ha		

Source: Biofortified Varieties: Sustainable Way to Alleviate Malnutrition, 4th Edition by Indian Council of Agricultural Research

### 2.3. Mapping evidence for biofortification initiatives

Biofortification is being considered as one of the most effective strategies to address micronutrient malnutrition, however, there are many misconceptions around adoption of biofortified staple foods. A number of studies and trials have been conducted to develop evidence around biofortification and primarily address three broad areas:

- Is crop breeding effective in increasing the nutritional content of crops without compromising on other desirable traits such as yield?
- Will the enhanced nutrient content of the biofortified crops will be bioavailable and assimilated sufficiently by the body?
- Is biofortification a cost-effective strategy to tackle micronutrient malnutrition?

<sup>&</sup>lt;sup>30</sup> Biofortified Varieties: Sustainable Way to Alleviate Malnutrition, 4th Edition by Indian Council of Agricultural Research

While the responses to these questions have been discussed in the earlier sections of the report, let us look at few cases which further demonstrate the evidence for the benefits of biofortification.<sup>31,32</sup>

- A study in Maharashtra, India, showed significant improvement in the iron status of 12–16 years children on consumption of iron biofortified pearl millet snack 'bhakri' at midday and evening. The effect of iron biofortified pearl millet was found to be greater among children who were Fe-deficient at the baseline.
- Another study on consumption of Vitamin A sweet potato/orange-fleshed sweet potato in Uganda and Mozambique among children, led to increase in serum retinol and significant reduction in incidences of diarrhoea among children under five years of age.
- A randomised control trial (RCT) for agronomically biofortified zinc wheat conducted on mother-child pairs in New Delhi, India, revealed that children aged 4–6 showed significantly reduced signs of morbidity with lesser sick days. Further, mothers who consumed Zn wheat experienced significantly fewer days with fever.
- In Zambia, the results of a study on zinc biofortified maize highlighted that feeding biofortified maize can meet zinc requirements and provide an effective dietary alternative to regular maize for this vulnerable population.
- Regular intake of biofortified Fe-beans by iron deficient women between the age group of 18–27 years in Rawanda have shown a significant increase in ferritin, haemoglobin and total iron content in the body.
- A meta-analysis on assessing the nutritional impact of quality protein maize (QPM) indicated that consumption of QPM instead of conventional maize leads to a 12% increase in the rate of growth in weight and a 9% increase in the rate of growth in height in infants and young children with mild to moderate undernutrition from populations in which maize is the major staple food.<sup>33</sup>

The above cited studies on iron, vitamin A and zinc biofortified crops have consistently shown that these nutrients are bioavailable to the body in significant quantities in comparison to non-biofortified varieties. Further, the research trials have substantiated that increased consumption of iron, vitamin A and zinc through biofortified food positively affects the functional health status of undernourished children and women including improved physical performance and cognitive capacity and reduced morbidity. The trials have further shown that biofortified food are comparatively more effective in certain cases, e.g., conditions such as infections and inflammations are detrimental to efficacy of micronutrient interventions, high content of phytic acid in food reduces bioavailability of iron.



<sup>&</sup>lt;sup>31</sup> https://www.researchgate.net/publication/318426701\_Biofortified\_Crops\_Can\_Alleviate\_Micronutrient\_Deficiencies\_Review\_of Evidence from Randomized Feeding Trials

- <sup>32</sup> https://www.harvestplus.org/wp-content/uploads/2021/12/Biofortification\_The-Evidence.pdf
- <sup>33</sup> https://www.stat.purdue.edu/~mccabe/MetaAnalysis/QPMMetaAnalysis.pdf

## 2.4. Developing a holistic environment for agricultural policy for biofortification in India

A conducive policy environment is crucial for enhancing the outreach of nutrient-enriched crops to a larger section of the population. The increasing demand for nutritious food can be managed by reorienting agricultural policies to enhance investments in the allied sectors for improving productivity and efficiency in the value chain. The public sector plays a vital role in providing an enabling environment for enhanced adoption of biofortified crops both at supply and demand side of the food system. Substantial progress has been made in producing nutrient-enriched crops in India and steps are being taken to promote such nutrient-enriched cereals. The Government further mandated the inclusion of millets in the public distribution system (PDS). Inclusion of iron pearl millet as well as zinc wheat and zinc rice in the PDS may help increase the nutrition component of the subsidised food programme and deliver much-needed micronutrients to a large segment of the population. The extension division of ICAR has also launched two special programmes – Nutri-sensitive Agricultural Resources and Innovations (NARI) and Value Addition and Technology Incubation Centres in Agriculture (VATICA) for up-scaling the biofortified varieties through its Krishi Vigyan Kendras (KVKs).

At the state level, government of Bihar included biofortification in its third Agriculture Roadmap (2017–22).<sup>34</sup> In 2020, the first zinc-biofortified wheat variety (Rajendra-Gehun-3) was released for cultivation in Bihar and the Chief Minister Rapid Seed Extension Programme now offers a 50% subsidy on zinc wheat seeds.

The Department of Food and Nutrition at Dr Rajendra Prasad Central Agricultural University, Bihar, and the Ministry of Women and Child Development are collaborating on developing a nutri-mix product line. Nutri-mix products (e.g., balshakti, paushtik laddu, sattu laddu) are health supplements made with biofortified crops (zinc wheat, zinc rice, and iron lentils) along with locally available nutrient-rich foods, which are developed to, complete the nutritional requirements of children between the age of 1–6 years, and women of reproductive age.

#### **Distribution of fortified rice**

The supply of fortified rice has been approved by the Government through the Targeted Public Distribution System (TPDS) under the National Food Security Act (NFSA) and in few other government welfare schemes in all states and union territories (UTs) in a phased manner. The allocation of fortified rice started during the second quarter of FY 2021–22 under the Saksham Anganwadi and Poshan 2.0 (erstwhile Integrated Child Development Scheme), and from the third quarter of FY 2021–22, all the states and UTs were allocated 100% fortified rice. Subsequently, during FY 2021–22 7,31,962 MTs of fortified rice had been allocated to all the states and UTs and 6,34,079 MTs of the same during FY 2022–23 (up to second quarter). Similarly, the Government intends to scale up the production of biofortified crop varieties and integrate them in government support programmes such as midday meals for school children, and other welfare schemes to reach the most vulnerable population groups.<sup>35</sup>

### Policy intervention for millet development

Millets are more nutritious than rice and wheat as their grains have higher levels of proteins, essential vitamins, minerals and amino acids. Millets are recommended for the well-being of infants, lactating mothers, the elderly, and convalescents due to their rich nutritive value. In 2018, The Government of India had proposed to the United Nations that 2023 should be declared as the International Year of Millets (IYOM). India's proposal was supported by 72 countries and United Nation's General Assembly (UNGA) declared 2023 as the International Year of Millets on 5 March 2021. The Department of Agriculture and Farmers Welfare has taken a proactive multi-stakeholder engagement approach engaging all the central government ministries, states/UTs, farmers, start-ups, exporters, retail businesses, hotels, Indian embassies, etc., to achieve the aim of IYM 2023 and taking Indian millets to the global market.

Several states have included millets in the public distribution system after the Prime Minister announced the inclusion of millets in the welfare programme in July 2017. Some of the initiatives taken by the states are briefly summarised below.

<sup>34</sup> https://www.harvestplus.org/bihar-and-odisha-nutrition-initiative-tackles-malnutrition-in-two-vulnerable-indian-states/

<sup>&</sup>lt;sup>35</sup> https://pib.gov.in/PressReleaselframePage.aspx?PRID=1846133

Karnataka	<ul> <li>Initiatives for millets as 'The Food of the future' (incentive to farmers INR 10,000/ha for cultivation of millets).</li> <li>Distribution of millets through PDS where in the grains are sourced and distributed locally.</li> <li>Procuring ragi and jhowar by giving a bonus of 20–25% above the MSP from farmers.</li> </ul>
Kerala	<ul> <li>Millet Village Scheme launched by Government of Kerala to promote the cultivation of cereals such as millet, ragi, bajra and maize by setting up a millet village.</li> <li>Project aimed at protecting seeds of traditional varieties of millets and ensures food security and livelihood for tribals.</li> </ul>
Maharashtra	Promoting millets through Project on Climate Resilient Agriculture.
Odisha	<ul> <li>Launched Odisha Millet Mission with an aim to increase acreage under millet production and bring millets back to food table.</li> <li>Financial subsidy of INR 9,500 per ha over a three-year period is being given to farmers to shift to millet cultivation.</li> </ul>
Telangana	Promotion of millets through Farmer Producer Organisations.



### 2.5. Biofortification and large-scale food fortification

Biofortification as a strategy to tackle micronutrient malnutrition cannot work exclusively. It is important to explore the probabilities of complementing strategies which can augment the delivery of necessary micronutrients to the vulnerable population without being resource intensive. In this context, the possibility of combining biofortification with large-scale food fortification (LSFF) can be employed as a strategy for reaching out to a large population with essential micronutrients that are deficient in the diet.

### Large-scale food fortification

Large-scale food fortification, also known as mass or industrial fortification, involves addition of one or more micronutrients to the staple foods at the time of processing. This generally encompasses a production capacity of more than 50 metric tonnes referring to the reach of a fortified product and is usually mandated and regulated by the Government as a response to micronutrient deficiencies in a population or subpopulation.

### Figure 14: Chronological development of LSFF in India



### Large-scale food fortification

Many food items such as salt, oil, milk, wheat flour, rice, and maize flour have been fortified due to mandates and these fortified items have been produced at scale. Globally, iodine deficiency has been considerably controlled due to the consumption of iodised salt. With 110 iodine deficient countries in 1993, the world has move to now only 19 deficient countries.<sup>36</sup> Although around 30% of low- and middle-income countries households are still deprived of iodised salt, reducing iodine deficiency through iodised common salt is considered as one of the most effective public health nutrition interventions. The Government initiated the focus on food fortification in the 1950s when they recognised that the Indian diet is commonly deficient in iodine, vitamin A, and iron. Fortification of margarine with vitamin A was mandated by the Government in 1953, followed by mandatory fortification of salt with iodine in 1962.

Although the basic premise and the ultimate goal of both LSFF and biofortification is the same – combating micronutrient deficiencies through enhancing micronutrient content in staple food – the delivery channel and entry points for the approaches differ. The LSFF delivery model requires an additional step at the processing stage where specific micronutrients are added to the food before packaging. On the other hand, the biofortification delivery model follows the existing supply chain with an additional step at the initial stage where nutrient-enriched crops are developed through various methods which have been discussed in the earlier sections.

Though natural complementarities do exist between the two approaches implementing only one of the two approaches in isolation may not be enough as food consumption patterns and the need for essential micronutrients vary across population, geography, and socio-economic status. For instance, LSFF may not be the best approach where staple crops are primarily consumed without processing or are processed through dispersed supply chain nodes such as small-scale processors with limited fortification skill or capacity. In such cases, ensuring the availability of nutrient-enriched staple crops may address the lack of micronutrients in the staple food. Alternatively, in instances where the target population for each micronutrient interventions are different, overlapping of approaches can be a feasible and effective approach.

Although there is limited evidence which can prove the efficacy and cost-effectiveness of LSFF combined with biofortification for fighting micronutrient deficiencies, some studies have explored the potential of the complementary nature of the two approaches. A study in Zambia which explored the optimal intervention portfolio for fighting vitamin A deficiency found that fortifying cooking oil with vitamin A oil was the most cost-effective intervention but having both vitamin A-biofortified maize and vitamin A-fortified oil increased coverage (especially in rural areas) without a significant increase in the costs.<sup>37</sup> A similar analysis was undertaken in Cameroon to identify the most cost-effective combination of vitamin A interventions for children. The study highlighted that in certain regions of the country (e.g., in the southern parts of the country and in urban areas), fortification had the potential to eliminate vitamin A deficiency, while taking vitamin A supplements and vitamin A-biofortified maize would be needed to tackle vitamin A deficiency in the northern regions where the population predominantly consumes maize.<sup>38</sup>

To establish a robust proof of concept, there is need to gather evidence by conducting implementation, compliance and impact studies that demonstrate the performance and efficacy of the combination of LSFF and biofortification while also quantifying the impact of these strategies in micronutrient uptake.

<sup>&</sup>lt;sup>36</sup> https://www.ign.org/cm\_data/IGN\_Global\_Scorecard\_AllPop\_and\_PW\_May2017.pdf

https://www.ign.org/cm\_data/IGN\_Global\_Scorecard\_AllPop\_and\_PW\_May2017.pdf

<sup>2003&</sup>amp;rfr\_id=ori:rid:crossref.org&rfr\_dat=cr\_pub%20%200pubmed https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7187426/

3. Strategy for scaling biofortified seeds, grains, and food products Various strategies have been adopted across the globe for scaling up for biofortified food grain to address malnutrition in underdeveloped and developing nations of the world. One of the strategies we propose is the **Marketing supply policy support and institutional strengthening (MSPI)** strategy to achieve the goal of scaling up biofortification. Let us look at the four steps of this strategy in detail.



### A Marketing strategies

Biofortification may be promoted through **umbrella branding**, creating a single brand to cover multiple biofortified products. One of the ways in which this can be done is by creating a unique identity for all the biofortified products under a standard logo.

**Awareness campaign and promotions** to generate awareness can further drive the acceptance of the biofortified products amongst a larger audience and build trust in the products. For example, National Egg Coordination Committee's 'Sunday ho ya Monday, Roz khao anday' campaign was aimed to drive the acceptance of the consumption of eggs by informing the people about the benefits of the product.<sup>39</sup>

### B Strengthening the supply

The **supply chain of biofortified seeds** need to be strengthened through comprehensive planning, and **access and availability** of the seeds need to be made easier for the producers. The Government is making dedicated efforts for scaling biofortified varieties The National Food Security Mission (NFSM) promotes usage of at least 30% biofortified or stress-tolerant varieties of rice and wheat in the crop production technology demonstrations at the farmers' fields.<sup>40</sup> A number of other field demonstration being conducted for pulses and coarse cereals under government programmes have allocated use of biofortified varieties especially in the high burden districts. The year 2018 was declared the 'Year of Millets by the Government of India,' and an appeal was made to the farmers to grow 'nutri-cereals' for improving food and nutrition security. In the same year, Indian Council of Agriculture Research (ICAR) made a significant stride by establishing minimum levels of iron (42 ppm) and zinc (32 ppm) for all released pearl millet varieties.<sup>41</sup> To ensure regular supply of quality biofortified seeds, ICAR has incorporated biofortified varieties in its breeder seed production programme. As stated in the earlier section, various state governments have also made major commitments to scale up production and consumption of biofortified grains. Private seed companies have also come forward for taking license for production and marketing of biofortified seeds.

<sup>&</sup>lt;sup>39</sup> https://brandequity.economictimes.indiatimes.com/news/advertising/neccs-egg-ceptional-campaign-and-the-story-bts/93221527

<sup>40</sup> https://agriportal.cg.nic.in/sameti/PDF/English/Annual%20Plan/Document.pdf

<sup>41</sup> https://www.icrisat.org/committed-to-alleviating-malnutrition-india-declares-minimum-levels-for-iron-and-zinc-in-pearl-millet/

### C Policy support

End-to-end **policy support** in the biofortified product value chain can drive both the demand and supply for nutrient-enriched food. The central government may consider developing an overarching **national biofortification policy** as a guiding document for the states across the country. This policy document can bring uniformity and balance in the agricultural sector and also streamline the process to facilitate coordination between the public and the private sector. The policy can also include plans to conduct programmes, schemes and other initiatives to promote biofortified products. **A conducive policy environment** can help the country in the production, promotion and acceptance of biofortified crops.

The central and state governments can also set a **higher price for biofortified products** as part of Minimum Support Price (MSP). Further, biofortification can be made **part of ongoing initiatives like National Food Security Mission, National Mission for Sustainable Agriculture** taken by the central government. Developing a supportive policy environment can encourage and empower value chain actors, public sector, private companies and NGOs to scale up biofortification interventions both within their domain and as a collaborative endeavour.

### D Institutional strengthening

The policy support can be further driven through strong institutional research and development, and implementation. A separate division in the **Ministry of Agriculture and Farmers' Welfare (MoA&FW)** can ensure a focused approach for biofortification and provide policy and implementation support for the end-to-end stages of biofortified products' value chain. Convergent efforts to promote consumption of biofortified crops maybe planned with Ministry of Health and Family Welfare and Ministry of Women and Child Development through the suggested division under MoA&FW. **Institutional structuring at the state or regional level** can lead to better implementation of national initiatives and help in effective monitoring and evaluation of the outcomes and the impact of the programmes.

To further strengthen the research and development along with production of biofortified crop, a dedicated **national research centre** under the ICAR can provide a strong research base while **a centre of excellence** for biofortified products can facilitate the production of biofortified crops.

Public Private Partnership for Integrated Agriculture Development (PPPIAD) has been conceived as an alternative mode of implementation under the Rashtriya Krishi Vikas Yojna (RKVY), where biofortified products can be promoted under a PPP model by leveraging the technical capabilities of the private sector. This model can also facilitate knowledge sharing and learning among stakeholders and encourage discussions based on scientific evidence and promote collaboration and learning.





Identifying the challenges to biofortification in India



There is increasing demand for biofortified produce and products from market players who see the value and importance of these products for their business as well as for customers and the nation. Small working groups are trying to explore opportunities for biofortified produce and products for consumers and markets. However, there are various challenges and barriers as expanding the market reach of biofortified produce would involve a unique blend of marketing, sales and development of stakeholder and public relations in order to meet consumer preferences and overcome challenges on the demand and supply side.

Other obstacles include maintaining the integrity of the supply chain, the absence of published standards for biofortified grains, developing consumer value propositions, and effectively communicating the benefits of biofortification to industry players, supply chain actors, farmers and consumers.





Source: PwC analysis

### 4.1. Barriers on the supply side of the value chain

**Awareness among farmers:** Farmers have been cultivating traditional crops for a very long time and switching to biofortified crops leads to various apprehensions among them. These include a fear of low yields, misconceptions about price, high input cost and changes in the appearance of the final product. The fears can be attributed to lack of awareness among farmers regarding biofortified crops. For instance, misinformation about the prices of nutrient-enriched grains can discourage farmers from growing biofortified crops as most of the cultivators comprise smallholder farmers who are affected by high input costs. Lack of communication and market opportunities from local bodies, market players and the Government can lead to reluctance as well as a slow transition to biofortified crops.

**Awareness of industry partners:** Industry players prefer crop varieties that are resistant to diseases, pests and climatic variations, and yield maximum quantity with minimum expense, thus allowing them to maximise their profits. Nutritional value is of less importance when taking production decisions. There is a lack of awareness and inclusion initiatives related to the development of nutrient-enriched crops.

Low capacity of regional seed companies and absence of Government incentives: One of the barriers on the supply side of the value chain is the low capacity of regional seed companies and lack of Government incentives to support these companies.

Further, local bodies are unable to acquire sufficient volumes of seeds to multiply new varieties of biofortified crops due to limited capacity and access to resources as well as lack of incentives to reach the market. Lack of budget for R&D, maintenance breeding,<sup>42</sup> adaptive breeding<sup>43</sup> and dissemination are additional challenges which hamper the production of biofortified seeds and crops.

**Lack of visible differentiating features:** It has been observed that most of the biofortified crops lack 'phenotypic characteristics' in comparison to traditional crops – for example, a difference in the colour of leaves or grains and grain size. Apart from biofortified sweet potato – which appears orange in colour instead of white – other biofortified staples do not possess such distinguishing features. Therefore, it becomes a challenge to convince farmers and traders about the benefits of producing biofortified crops.

**Quality assurance:** Quality is of utmost importance for any product and biofortified varieties are no different. The end-use quality is an important factor while improving any grain crop quality trait as the acceptability by the consumers is hugely dependent on the final quality of the product in terms of appearance, texture, taste, aroma, nutrient-content, etc.

Quality assurance of the biofortified products and produce can become a challenge if safety methods are not put into place. There is also a possibility of substandard, spurious, falsely labelled, falsified or counterfeit products flooding the market in case demand grows, thus increasing health problems. Therefore, it becomes very important to maintain the quality of biofortified products at every step to ensure that the final product that reaches consumers is of good quality. Quality assurance will help in building consumer trust in these products.

**Affordability:** The reach of the biofortified crops and products also depends on their affordability. Manufacturers play a crucial role in setting the right price for consumers, thus ensuring equitable distribution and accessibility of products.

<sup>&</sup>lt;sup>42</sup> Maintenance breeding refers to germ plasm improvement for overcoming diseases, improving grain quality or eliminating other defects that may constrain production and grain marketability

<sup>&</sup>lt;sup>43</sup> It refers to the selection of crops that grow well under unfavourable conditions.

### 4.2. Barriers on the demand side of the value chain

**Lack of awareness regarding micronutrient deficiency:** People are not very well versed with the concept of micronutrient malnutrition. The concept of 'hidden hunger' is not well understood because of lack of visible traits. Micronutrient malnutrition is not only prevalent in rural areas but also in urban areas and in families who have adequate resources due to lack of knowledge on nutrition. The demand for biofortified products will not increase unless people are made aware of micro-deficient malnutrition and its effects on the body.

Lack of awareness regarding biofortified products: There is very little awareness among the population regarding biofortified products and their benefits. In addition, cultural factors as well as income constraints contribute to lack of dietary diversity and restrict the consumption of nutrient-rich foods even if they are available and accessible. In the present scenario, the potential customer of biofortified crops is generally uninformed and confused about the health advantages of biofortified crops, which limits the purchase of these crops even if there is willingness to pay a higher price for them. Adoption of biofortified products is also significantly influenced by the household head's educational status as they primarily take household decisions on purchase of goods and are the main food providers of the family.

The importance of consuming biofortified crops is increasing as they have the capacity to address various nutritional problems. However, even if the supply of fortified products is adequate, they may not be given the required priority as their attributes are not top of mind for targeted customers.

**Consumer preferences:** The consumer is ultimately responsible for deciding whether or not to adopt biofortified crops, and several factors, including a difference in colour which is visible in certain cases, can affect their purchase decision. Golden Rice from the Philippines is a good example of how consumer attitudes towards biofortified produce can be changed. Research has shown that the effect of negative information can be overcome by highlighting the nutritional benefits of biofortified food.<sup>44</sup>

However, the success of Golden Rice and other nutritionally enhanced crops in the pipeline will crucially depend on two factors: (i) how these crops are integrated into national nutrition strategies; and (ii) how consumers manage to incorporate them into their daily lives in their efforts to achieve 'golden diets'.<sup>45</sup> India could learn from the 'golden rice' case study and incorporate biofortification in the food systems of the country in a more effective way.

A few more examples of crops whose colour is altered due to increased beta carotene content are listed below.

Produce	Colour of traditional produce	Colour of biofortified produce	Regions/countries
Maize	White/yellow	Orange	Southern/Eastern/ Central Africa
Cassava	White	Yellow	Nigeria

To increase acceptance of these vitamin biofortified crops, it is necessary to create greater consumer awareness through public campaigns.

**Acceptability:** The contribution of biofortified crops to improved nutrition and health outcomes depends on case-specific circumstances in developing countries.

<sup>&</sup>lt;sup>44</sup> https://www.sciencedirect.com/science/article/abs/pii/S0958166917300344

<sup>&</sup>lt;sup>45</sup> https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8907858/

Various factors influence acceptability, including technology efficacy, coverage and local dietary patterns. The acceptability of biofortified crops depends on local dietary patterns, and not taking this into account before targeting a particular species or variety of crop can have implications. Biofortification can be more effective when the selected crop is an essential local staple food which is consumed on a daily basis and in large quantities. Therefore, crop selection may vary from region to region. Coverage, defined as the share of biofortified varieties in the total quantity of consumption, is mainly a function of farmer adoption and consumer acceptance. Consumer acceptance also influences farmer adoption decisions, as low acceptance would translate into lower market prices.

**Affordability:** Willingness and ability to pay higher prices for biofortified products even if they are slightly more expensive than non-fortified products remain a challenge especially for the poor, who bear the brunt of micronutrient malnutrition.

Another challenge is personal preference in terms of taste, texture and visual appearance. Even if biofortified products are available at the same prices as non-biofortified products, the decision to adopt them is based on the visible attributes rather than non-visible ones such as a higher concentration of zinc or iron. Consumers are more likely to adopt biofortified products if their taste and texture resemble those of traditional crops.

**Shorter post-grain shelf life:** The short post-grain shelf life of biofortified produce makes a challenge for consumers to store these products and for market players to process it in some other form. For example, the shorter shelf life of pearl millets, coupled with weak supply chains, has emerged as a major hindrance for processing and packaged product development. Although a few packaging solutions do exist, shelf-life enhancement needs to be looked into to expand the potential market size in both rural and urban areas.



5. Strategic actions to overcome bottlenecks and the way forward



The success of biofortification will depend on the strategies adopted to eliminate the bottlenecks discussed in the previous chapter. The adoption of biofortification on a large scale would require robust policies from the Government, ensuring a market drive for sustainable growth, and a continuous and effective supply drive.

### 5.1. Policy dimensions to support biofortification

Scheme convergence with health and food supply programmes: To increase the adoption and consumption of biofortified crops and foods and incentivise investments in biofortification, there is a need for evidence-based, context-specific delivery strategies that are replicable, cost-effective and scalable. Such strategies should consider the complex local, regional, and national policies, market environments, sociocultural factors and food systems to supply biofortified food to those who need it the most. The close linking of agriculture to nutrition and health while formulating agricultural, nutritional and health policies would provide sustainable solutions to the issues of hidden hunder and wide nutritional gaps. The biofortification movement intricately links the food mandates of different ministries, including agriculture, health and nutrition, and the environment, and therefore a 'whole-of-government approach' becomes very essential. Multiple stakeholders are involved in biofortification - for instance, new varieties of biofortified seeds are developed by the Indian Agricultural Research Institute, provision of biofortified seeds to farmers at subsidised rates is the responsibility of the National Seeds Corporation, produce procurement is done by the Food Corporation of India and distribution of biofortified produce is done through government schemes such as PDS, Mid-Day Meal and anganwadi. This showcases the roles of various departments/organisations within various ministries. Therefore, scheme convergence across the Ministry of Consumer Affairs, Food and Public Distribution, Ministry of Agriculture and Farmers Welfare as well as health and food supply programmes becomes important to address the challenges of nutrient deficient malnutrition and strengthen the role of biofortification in the country. One of the examples of convergence of various schemes/programmes is POSHAN Abhiyaan, a multi-ministerial initiative to reduce the level of undernutrition and enhance the nutritional status of children in the country. It is a conjunction of various schemes/programmes including the Pradhan Mantri Matru Vandana Yojana (PMMVY). anganwadi services. Scheme for Adolescent Girls under the Ministry of Women and Child Development (MoWCD), the National Health Mission (NHM) of the Ministry of Health and Family Welfare, the Swachh Bharat Mission of the Ministry of Drinking Water and Sanitation (MoDW&S), the Public Distribution System (PDS) of the Ministry of Consumer Affairs, Food and Public Distribution (MoCAF&PD) under the Ministry of Panchayati Rai (MoPR), the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) of the Ministry of Rural Development (MoRD) and other urban local bodies through relevant ministries.

At the same time, it is critical that at the level of society, various stakeholders are brought together on a common platform as diet-related diseases and nutrition-related illnesses cut across all age groups and sections of the population. Such a 'whole-of-society' approach would involve public authorities, families, communities, religious institutions, civil societies, academia, and media for the development of integrated programmes.<sup>46</sup>

**Policy monitoring to review improvements achieved:** Monitoring, evaluation, research and learning (MERL) plays a significant role in all aspects, be it the adoption of biofortified varieties by farmers or the consumption of biofortified foods by consumers. MERL can help in assessing the policy implications and understanding the success and failures of various interventions to increase outreach of biofortified products. Based on the learnings, suitable changes can be made to the policies to achieve desirable outcomes. In terms of MERL, it is necessary to focus on the following:

- i. **Monitoring:** Monitor and review the efficacy of biofortification interventions and share achievements with communities to build their trust and confidence.
- ii. **Evaluation:** Conduct more consumer and market research and assess health and nutrition impacts to establish a better understanding of the market and impact of biofortified produce and products by the food industry.
- iii. Research and learning: Research the efficacy and effectiveness of biofortified crops in terms of micronutrient status and health outcomes. The establishment of strong linkages between research-level interventions and the agri and food industry and health will thus be important.

<sup>&</sup>lt;sup>46</sup> World Health Organization. Glossary: Whole-of-government, whole-of-society, health in all policies, and multisectoral. World Health Organization, 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9344990/

Incentivisation: It is important to introduce incentives at various levels:

- i. Provision of seeds and other resources at subsidised rates/free: Providing subsidised seeds and other agricultural inputs to farmers would be helpful for rapid dissemination of nutritionally improved cultivars. One example of incentivisation is the Seed Village Programme, through which implementing agencies (State Departments of Agriculture, State Agricultural Universities, Krishi Vigyan Kendras, State Seeds Corporations, National Seeds Corporation, State Farms Corporation of India (SFCI), State Seed Certification Agencies, Department of Seed Certification) provide seeds at 50% of the cost to identified farmers of a seed village.<sup>47</sup> These farmers then distribute certified seeds at 50% of the seed cost for cereal crops and 60% for pulses, oilseeds, fodder and green manure for up to one acre per farmer to other farmers.
- ii. Better price for produce/minimum support price/direct purchase: Unless farmers get a premium price for premium produce, adoption will be low. Farmers can be encouraged by providing assured premium remunerative prices through minimum support price for such high micronutrient varieties.
- iii. Free training and workshops: Non-monetary incentives in terms of capacity building through the provision of free training and workshops to farmers may also be considered.

**Capacity building and strengthening:** Capacity building of various stakeholders will play an important role in enhancing the outreach of biofortified products. Investments are required to support capacity development at all levels:

- i. **Individual level:** Various agriculture research and management training institutions and universities should be looped in for training farmers on various aspects, including those related to technological developments in this area. For instance, farmers could be trained in 'good pre- and post-harvest management practices' that would help them increase product quantity and quality.
- ii. **Institutional/organisational level:** The objective of capacity building at the institutional/organisational level should be to have sound policies, structures, effective management and methods in place.48 The target institutions/organisations would be research institutes, development partners, farmers organisations, civil societies and government departments.

**Catalysing and facilitating partnerships:** There is a need to catalyse and enable partnerships along the staple crop value chains to replace non-biofortified seeds, grains, ingredients and foods with their biofortified counterparts.

A multi-sectoral approach that brings together public and private sector partners across the value chain and includes all concerned stakeholders such as researchers, policymakers, businesses, farmers and civil society organisations is the need of the hour. Partnerships can be built in various areas such as knowledge sharing, technology and supply chain. There is also a need to establish a network at the local level – i.e. seed sellers, local-level nurseries, seed multiplication centres and farmers – to ensure availability and consistency in the value chain. An example of such a partnership is the 'Nutritional Village' in Bihar where the Rural Development Council (RDC) and the Government of Bihar have, with the support of a private player (in the biofortification sector), developed a holistic farming model which optimises nutrition for farming families and promotes ecological resilience.

<sup>&</sup>lt;sup>47</sup> This model includes a trained group of farmers in a village who are involved in the production of seeds of various crops in order to cater to their own needs and those of fellow farmers in terms of timely provision of seeds at an affordable cost.

<sup>&</sup>lt;sup>48</sup> Aamna S. Khan International Journal of Agricultural Extension (2014). 05-11 International Conference – Emerging Horizons of Agricultural Extension for Sustainable Rural Development

Case study: Bihar's 'Nutritional Village'

Bihar is India's third most populous state and has the country's highest rate of stunting. It has recently committed to rapidly scaling up the production of zinc wheat seeds (as zinc deficiency is a major cause of stunting) to reach vulnerable farming families. One of the steps in this direction is the establishment of a Nutritional Village by the state government.<sup>49</sup> This village comprises 475 households of Kukri Bigha, Dulhin Bazar, in the district of Patna which will cultivate biofortified crops using the following farming model:

- · providing biofortified zinc wheat seeds to farmers
- · providing organic pesticides and insecticides to farmers
- utilising organic farming methods.

Other states can take similar steps to increase the outreach of biofortified crops by catalysing and facilitating partnerships.

### 5.2. Market drive for sustainable growth

**Direct farm gate purchase:** Direct farm gate purchases from farmers would boost the continuity and affordability of biofortified products by facilitating direct procurement of agricultural produce from the farmer's doorstep by food processing companies, exporters and wholesalers. Farmers would thus not need to bring their produce to the marketplace for sale.

**Greater consumer awareness:** Clear value propositions must be established for each crop to generate demand for biofortified foods. Consumer preferences are also influenced by extrinsic factors<sup>50</sup> such as consumption trends and advertisements. Therefore, there should be equal focus on advertising the benefits of biofortified products.

**Proper labelling and packaging:** Credence goods are those products whose quality and safety cannot be verified and evaluated even after the purchase and consumption process. These products face high levels of uncertainty due to the lack of relevant information. Biofortified products fall under the category of credence goods. Therefore, there is a need for proper labelling and packaging of these products.

Branding and labelling mechanisms can help consumers differentiate biofortified crops from non-biofortified varieties.

For example, a study was conducted to identify the influence of branding on the acceptance of iron pearl millet.<sup>51</sup> Two types of brands of iron pearl millet are available in India:

- international brand (iron content is certified by an international health agency)
- local brand (certification by a state-level health authority).

The study revealed that consumers, especially female consumers, preferred international branding to statelevel certification, thus highlighting the importance of branding in enhancing the adoption and consumption of biofortified products.<sup>52</sup>

Consumers with limited, imperfect or contradictory information may not be able to make choices consistent with their preferences, especially in the case of biofortified products whose benefits are visible in the long term. Therefore, regulation of health claims must be refined, and efforts must be made to reduce the information asymmetry between producers and consumers. Industry players could play a role here by labelling and marketing products bought directly from the farmer appropriately before selling them to the end user.

<sup>&</sup>lt;sup>49</sup> https://www.harvestplus.org/bihar-state-in-india-to-promote-biofortified-crops-to-address-nutrition-security/

<sup>&</sup>lt;sup>0</sup> Basmann, R.L. A theory of demand with variable consumer preferences. Econometrica 1956, 24, 47–58

<sup>&</sup>lt;sup>51</sup> https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/129106/filename/129317.pdf

<sup>&</sup>lt;sup>52</sup> https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/129106/filename/129317.pdf

### 5.3. Supply drive

**Improving farmer acceptance and awareness:** Acceptance by farmers is a key determining factor for the future of biofortified crops. It is crucial to spread awareness among farmers and thus clear myths and misconceptions regarding biofortified crops for improved acceptance and better outcomes. A farmers' decision to choose a biofortified variety depends on the key factors listed below. Each factor needs to be considered while developing strategies.



#### Figure 16: Key factors affecting farmers' decision to choose a biofortified variety

In the case of end-use quality, a large-scale demand-creation campaign was led by Nirmal Seeds in 2012 for iron pearl millet which included training of farmers and the establishment of demonstration plots at multiple locations to display the superior agronomic traits of biofortified pearl millet. Similar workshops and campaigns can be organised to increase farmer outreach. At the same time, digital platforms can be used to increase outreach to consumers. Positive feedback or experiences of stakeholders with respect to the consumption of biofortified food products can be widely shared with others farmer groups to enhance their confidence in biofortified produce and products.

**Robust value chain:** The success of a value chain can be ensured through last-mile delivery, starting from the development of biofortified seeds to the final step of product delivery to consumers. Ensuring supply chain integrity, meeting manufacturing product standards and developing strategic messaging for consumers are some of the promising pathways for strengthening the value chain of biofortified produce.

**Umbrella branding:** A common logo for umbrella branding would be another useful tool. For example, the symbol '+F' is being used to brand all processed food.<sup>53</sup> The same approach can be adopted for unprocessed products and agricultural biofortified produce. Standardisation of the logo will have a direct impact on the uptake of biofortified produce and products by consumers by building awareness and trust.

<sup>&</sup>lt;sup>53</sup> India, F. S. (2022, May 31). Retrieved from https://ffrc.fssai.gov.in/assets/file/SOP\_Advisory\_on\_+F\_endorsement.pdf





India is going through a major shift in its nutrition status, with an increasing share of the population facing micronutrient malnutrition irrespective of geography or socio-economic status. This report has presented biofortification as an evidence-based, cost-effective and sustainable strategy for fighting micronutrient malnutrition. However, the existing agricultural policies are insufficient to address malnutrition as they are still skewed towards maximising macronutrients through the production and consumption of staple crops. With adequate reserves of rice and wheat and the focus shifting from food security to income security, a designed diversification from crop-centric farming to nutrient-enriched crops is the appropriate way to tackle micronutrient gaps in consumption.

This calls for **devising and implementing scale-up strategies for biofortification** backed by **conducive policy-level interventions**. Scaling of biofortification demands a shift from pilot-level interventions and piecemeal approaches to expanding existing partnerships and building new ones. Additionally, the **established and evidence-enabled engagements** need to be maintained and nurtured with increased partner capacity. Further, the Government must ensure that **biofortification is included in the national nutrition agenda** as a pathway to combat micronutrient malnutrition and that sufficient resources are made available to research institutions to drive further innovations in this space. Public and private sector actors should work towards **mainstreaming biofortified trait across their product lines** and **promoting nutrient-enriched seeds** through marketing and promotional techniques. **Food processors** in the agri value chain must have the required input and information to **include nutrient-enriched produce in their product basket**. And finally, **consumers should be made aware of the advantages of consuming nutrient-enriched food** and given **easy access** to these products. Therefore, to realise the potential of biofortification in tackling micronutrient malnutrition, there is a need for collaborative efforts amongst the agri value chain actors.



## About FICCI

Established in 1927, FICCI is the largest and oldest apex business organisation in India. Its history is closely interwoven with India's struggle for independence, its industrialisation, and its emergence as one of the most rapidly growing global economies.

A non-government, not-for-profit organisation, FICCI is the voice of India's business and industry. From influencing policy to encouraging debate, engaging with policy makers and civil society, FICCI articulates the views and concerns of industry. It serves its members from the Indian private and public corporate sectors and multinational companies, drawing its strength from diverse regional chambers of commerce and industry across states, reaching out to over 2,50,000 companies.

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## About PwC

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# About PwC's Agriculture and natural resources team

PwC India has a dedicated, highly experienced team working in the agriculture and natural resources sector which provides advisory services related to agriculture and agribusiness management, long-term transformational project implementation, food processing, agricultural credit, agri policy, impact assessment, performance improvement, commodity trading, integrated resource management, farm inputs and agri infrastructure. The team comprises professionals who have an extensive experience in various aspects of agriculture, including advisory in the agriculture and food domain, supply chain management, public private partnerships, policy advocacy, agri economics, agri retail, agri marketing, farm inputs and banking.

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Data Classification: DC0 (Public)

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GG - July 2023 - M&C 29937

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