STRATEGY PAPER 17

Biofortification to Address Malnutrition in India: Present Status and Way Forward

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Preface

'Health is wealth' – the age-old saying has assumed greater relevance in the wake of COVID-19 pandemic. It has reminded all of us about the importance of nutritious food. Balanced nutrition plays the central role in the growth and development of the mind and body, and contributes to the societal and economic well-being. Malnutrition, caused by the consumption of insufficient or unbalanced diet, has emerged as a major health-related problem worldwide, which affects people of all ages including infants, young children, adolescent girls, pregnant women, adult women and men, besides elderly people.

United Nations (UN) in 2015 set 17 Sustainable Development Goals (SDGs) where SDG 2 and SDG 3 emphasize on addressing hunger and malnutrition, and healthy living, respectively for promoting well-being of people. National Agricultural Research System under the leadership of Indian Council of Agricultural Research, Department of Agricultural Research and Education, Ministry of Agriculture and Farmers Welfare is committed to SDGs through development of high yielding biofortified crop varieties. As a result, since 2014, 87 biofortified varieties of 16 crops namely rice, wheat, maize, pearl millet, finger millet, small millet, lentil, groundnut, linseed, mustard, soybean, cauliflower, potato, sweet potato, greater yam and pomegranate have been developed with improved nutrients. The concentration of several anti-nutritional factors has also been significantly reduced in some of the cultivars. It has been estimated that alleviating malnutrition is one of the most cost-effective steps with every $1 invested in proven nutrition programme offering benefits worth $16.

In order to take full advantage of biofortified crops to address malnutrition in the country, it is essential to promote cultivation of such crop varieties and ensure availability of adequate produce for widespread consumption. To deliberate on this issue and define way forward, a strategy dialogue was organized by the academy on 26th March, 2021. The deliberations involving experts have been compiled in the form of this strategy document, which will help developing a roadmap for alleviating malnutrition through this sustainable, cost effective and widely adopted approach.

I am highly thankful to Dr U.S. Singh and Dr D.K. Yadava for convening this meeting and compiling the document. Useful comments and suggestions received from Dr P.S. Virk, HarvestPlus are duly acknowledged. My sincere thanks are also due to Dr P.S. Birthal and Dr Malavika Dadlani for their editorial support in preparing this document. I do hope that the suggested way forward will help define action plan for promoting biofortified crops in India.

December, 2022 — **(Trilochan Mohapatra)**
New Delhi — President

Biofortification to Address Malnutrition in India: Present Status and Way Forward

Malnutrition has emerged as a major health-related problem worldwide. It is caused by consumption of an unbalanced or insufficient diet (Yadava et. al. 2018). It affects most of the world's population at some point in their lifecycle during infancy to old age. Every country experiences one or the other form of malnutrition. It affects all geographies, age groups and people from rich to poor. Different forms of malnutrition are i) Undernutrition - Lack of proper nutrition caused by not having enough food, ii) Stunting - Low height as per age in children under five years of age due to limited access to food and health care, iii) Wasting - Thin for their height in children under five years of age because of acute food shortages or disease, iv) Micronutrient deficiencies - Suboptimal nutritional status caused by lack of intake, absorption or use of one or more vitamins or minerals, v) Moderate and severe thinness or underweight - A body mass index (BMI = weight in kg/height in m^2) <18.5 indicates underweight in adult populations, while a BMI <17.0 indicates moderate and severe thinness and vi) Overweight and obesity - Excessive weight as per height is classified as overweight and obesity in adults. BMI ≥25 is considered overweight, while ≥30 is treated as obesity (Global Nutrition Report, 2018).

United Nations (UN) in 2015 set 17 Sustainable Development Goals (SDGs) to chart a path for meeting current human needs without compromising the ability of future generations to meet their needs. At the core, SDGs aim to eliminate extreme poverty, hunger, and malnutrition; conserve environment and ensure that all people enjoy peace and prosperity by 2030. Twelve of the 17 goal indicators are related to nutrition and health.

Malnutrition contributes to increased morbidity, disability, stunted mental and physical growth, and reduced national socio-economic development. The status of malnutrition globally as well as in India is as under:

A. STATUS OF MALNUTRITION

Global scenario: The State of Food Security and Nutrition in the World 2021 published by FAO and other allied organization states that 2.37 billion do not have access to adequate food and 768 million people are undernourished. In Southern Asia, 30.7% and 14.1% of the children (<5 years) are stunted and wasted, respectively [FAO, IFAD, UNICEF, WFP and WHO. (2021)]. The data of Nutrition for Growth Tracker methodology indicates that in comparison to 2019, 118 million more people faced hunger in 2020 ((www.globalnutritionreport.org/ resources/nutrition-growth-commitment-tracking/methodology). As per the Global Nutrition Report (2021) on the state of global nutrition, 20.5 million newborns (14.6% of all live births) have a low weight at birth, 149.2 million (22.0%) children (<5 years) are stunted, 45.4 million (6.7%) children (<5 years) have wasting, 38.9 million (5.7%) children (<5 years) are overweight, 2.2 billion adults are overweight or obese (40.8% of women and 40.4% of men), 451.8 million (9.1% women and 8.1% men) adults are underweight, 570.8 million (29.9%) girls and women aged 15-49 years are anemic, 538.7 million (8.9% of women and 10.5% of men) adults have diabetes and 1.2 billion (19.9% of women and 24% of men) adult experience raised blood pressure. It further reports that overall, poor diets were responsible for >12 million avoidable deaths among adults. Out of the total deaths in adults, 20-25% have been associated with imbalanced diets (Mark HE, 2020 and WHO-Global Nutrition Targets 2025). As per the Global Hunger Index (2021), the average global hunger index (GHI) is 17.9 (moderate category) with a range of <5.0 to 50.8.

Indian scenario: In India, 15.3% of the population are undernourished (WHO-Global Nutrition Targets 2025). As per the National Family Health Survey-5 (2019-21), the neonatal mortality rate (NNMR) is 24.9 per 1,000 births, infant mortality rate (IMR) is 35.2 per 1,000 births and child under five years mortality rate (U5MR) is 41.9 per 1,000 live births in Indian population .Under five-year age 35.5% children are stunted; 19.3% wasted, 7.7% severely wasted, 32.1% under-weight and 3.4% over-weight. Further, 18.7% women and 16.2% men possess BMI below normal (<18.5), 24.0% of women and 22.9% of men are overweight or obese (BMI ≥25.0). With regard to anaemia, 67.1% of the children (6-59 months), 57.2% of non-pregnant, 52.2% pregnant and 57.0% of women and 25.0% of men between 15-49 years, 59.1% of women and 31.1% of men between 15-19 years are anaemic. In addition, 13.5% of women and 15.6% of men possess high or very high blood sugar and 21.3% women and 24.0% men possess elevated blood pressure. As per the WHO-Global Nutrition Targets 2025, the GHI score of India is 27.5 (serious category) with rank at 101 among 116 countries in relation to GHI.

B. AVENUES FOR OVERCOMING MALNUTRITION

Nutritious diet is vital for proper growth and development in human. It helps preventing diseases, besides maintaining the body metabolism for physical- and mental- well being. Food provides energy, protein, essential fats, vitamins, antioxidants and minerals to meet our daily metabolic requirement (Yadava et al. 2018). Most of them cannot be synthesized in human body; therefore are to be supplemented through diet. Further, anti-nutritional factors present in edible parts of the food exert adverse affects on human health.Undernutrition causes ~45% death among children (<5 years) mainly in low and middle-income countries, and malnutrition in all its forms could cost society up to US$3.5 trillion per year (Global Nutrition Report, 2018). India loses over US$12 billion in GDP per year to vitamin and mineral deficiencies (https://www.harvestplus.org/where-we-work/india24-12-2021).The four major approaches being followed globally and in India to overcome the problem of malnutrition are as under (Yadava et al. 2021):

- ***Food fortification:*** It is a process of physically adding vital nutrients to the food in order to enrich it. For example, (i) iron, folic acid and vitamin B12 fortified wheat and rice flour, (ii) iron and iodine fortified salts, (iii) vitamin-A and vitamin-D fortified oil and milk, have been permitted by Food Safety and Standards Authority of India (FSSAI), Govt. of India.

- ***Medical supplementation:*** It is a process of providing vital nutrients through pills. Govt. sponsored programmes viz., (i) Weekly Iron Folic Acid Supplementation (WIFS) programme for school adolescent boys and girls (10-19 years) and out of school girls (10–19 years) in urban and rural areas, and (ii) Vitamin-A Supplementation (VAS) programme for children under five, are in place in India.

- ***Dietary diversification:*** It is a process of including diverse cereals, pulses, oilseeds, vegetables and fruits in the diet in order to enhance the nutritional status.

- ***Crop biofortification:*** It is a process of enhancing the nutritional quality of edible parts of the plants and animal products. For example, (i) iron and zinc rich wheat grains, (ii) protein and zinc rich rice grains, (iii) vitamin-A rich maize grains, (iv) milk, (v) eggs, and (vi) meat.The nutritional quality of food crops is improved through many approaches viz., agronomic practices, conventional plant breeding or modern biotechnology tools and dietary supplementation of animals.

Biofortification is one of the most practical approaches to address hidden hunger, which increases the vitamin and mineral content of staple foods grown and consumed by smallholder farmers. Biofortification is more a more sustainable approach for overcoming hidden hunger due to various merits:

- It provides nutrients in natural form; thus nutrients enter the body as part of natural food matrix.

- It is a cost-effective method to reach millions of people on a sustainable basis because people can afford the ‘biofortified food’ as it does not involve any additional price.

- ‘Biofortified varieties’ are as high yielding as ‘traditional varieties’, thus no loss is incurred to the farmers.

- It does not require elaborate infrastructure facility as required in ‘food fortification’.

- It does not need elaborate distribution system as required in ‘medical supplementation’.

- ✦ It does not involve additional cost on preparing the enriched food grains or dairy and poultry products like milk, meat and egg.

C. CROP BIOFORTIFICATION EFFORTS

Global scenario

HarvestPlus has made a significant contribution in leading the biofortification alliance of research centres and facilitating the release of more than 400 biofortified varieties of different crops and their upscaling in 40 countries across the globe. There are 14 million smallholder farmers who are growing these crops and 70 million people benefitting on farm and tens of millions have been reached off-farm as beneficiaries of these biofortified crops. The major crops biofortified for various traits addressed are (www.harvestplus.org):

(i) **Iron rich bean:** High yielding, virus resistant, heat and drought tolerant varieties developed by Bioversity/International Centre for Tropical Agriculture (CIAT). Provides upto 80% daily iron need.

(ii) **Iron rich pearl millet:** High yielding, mildew resistant and drought tolerant varieties/ hybrids developed by International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Provides 80% of daily iron needs.

(iii) **Zinc rich maize:** High yielding and virus resistant varieties/hybrids developed by International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA). Provides upto 70% of daily zinc needs.

(iv) **Vitamin A rich maize:** High yielding, disease and virus resistant varieties/ hybrids developed by CIMMYT and IITA. Provided up to 50% daily vitamin A needs.

(v) **Zinc rich rice:** High yielding, disease and pest resistant varieties developed by International Rice Research Institute (IRRI) and Bioversity/ CIAT. Provides upto 40% of daily zinc needs.

(vi) **Zinc rich wheat:** High yielding and disease resistant varieties developed by CIMMYT. Provides upto 50% of daily zinc needs.

(vii) **Vitamin A rich Cassava:** High yielding and virus resistant varieties developed by IITA and Bioversity/CIAT. Provides upto 100% of daily Vitamin A needs.

(viii) **Vitamin A rich Orange Sweet potato**: High yielding, virus resistant and drought tolerant varieties developed by International Potato Center (CIP). Provides up to 100% of daily vitamin A requirement.

Indian scenario

National Agricultural Research System under the leadership of Indian Council of Agricultural Research (ICAR) has improved the nutritional quality in high yielding varieties of cereals, pulses, oilseeds, vegetables and fruits using breeding methods. Special efforts were initiated during 12th Plan with the launching of a Consortium Research Platform on Biofortification. Crop based ICAR institutes and some of the State Agricultural Universities mounted efforts independent of the Consortium to develop biofortified crop varieties. All these initiatives and efforts have led to the development of 87 varieties of rice (8), wheat (28), maize (14), pearl millet (9), finger millet (3), small millet (1), lentil (2), groundnut (2), linseed (1), mustard (6), soybean (5), cauliflower (1), potato (2), sweet potato (2), greater yam (2) and pomegranate (1) (*Annexure-I*) (Yadava, et al. 2022). In addition, a large number of advance elite materials are in the pipeline and will be released in due course of time. These biofortified varieties assume great significance to achieve nutritional security of the country.

D. BIOFORTIFICATION OF ANIMAL AND POULTRY PRODUCTS

To address malnutrition, biofortified egg and meat are available in global market. There also exists tremendous scope for milk biofortification. Changing the feed composition and/ or feeding strategies to animals lead to biofortified animal food products. Biofortified animal foods are similar in appearance to conventional foods. The amount of intake and form of biofortified animal food is also same as it is normally expected, but contain additional biologically active component beyond basic nutrients. Milk from goat fed on green fodder has higher levels of Vitamin A and selenium. Buffalo milk has been biofortified with Conjugated Linoleic Acid (CLA) by feeding oil seed cake and mustard oil. Mustard oil feeding also narrows ω-6/ω-3 ratio from 3.29 to 1.19 in milk.

Including flax seed, fish oil and spirulina (biomass of Cyanobacteria) in poultry feed increases the Omega- 3 fatty acid in eggs. Combining 0.02% Atorvastatin, 0.25% EDTA, 375 mg/kg Niacin, 250 mg/kg tochopherol and 1.5% fish oil in feed reduces total egg yolk cholesterol by 19%. Combination of chromium (1000 µg/kg) and spirulina (2 g/ kg) along with α-tochopherol (250 mg/kg) and fish oil (1.5%) also has similar effect in reducing total cholesterol. Besides, addition of copper at 100-150 ppm in feed has been found to decrease egg yolk cholesterol in poultry. Carotene enrichment of poultry egg has been possible by feeding fortified cassava. Like human, poultry also cannot synthesize Vitamin A, however, they can store the provitamin obtained from feed. Beta carotene biofortified poultry eggs are available world-wide, even in many cities in India. Vitamin K biofortified eggs were produced by increasing the Vitamin K3 (Synthetic Vitamin K) in poultry feed. Yellowness of yolk, fed with fortified feed is higher by27-45%. Consumption of an average-sized (60g) Vitamin K fortified egg contributes an additional 35µg Vitamin K, meeting 56% of total RDA. Vitamin K fortified eggs are available in the market in US, England, Germany, Ireland, Japan, China and also in India. “Super egg”, “England best egg” and “Smart eggs” are available in the USA, Europe, China, Japan and other parts of western Europe. Selenium-enriched eggs remain fresh for a longer period. Only Eggland’s Best hens are fed with proprietary all-vegetarian feed which makes the eggs more nutritious. In India, micronutrients, Omega-3, Vitamin D & DHA enriched eggs are available in Delhi, Panipat, Mumbai, Pune, Kolkata, Vijayawada, Mysore, Chennai, Bangalore, Coimbatore, Trivandrum and Cochin. Selenium enriched meat is also available in global market. Selenium enriched yeast, produced by growing *Saccharomyces cerevisiae* in Se rich media is an established source of organic selenium. The new cream-on-top-style yogurts are made with milk from grass-fed cows that enjoy a diet of organic grass and no grains, yielding milk that is high in omega-3 fatty acids.

E. IMPACT OF BIOFORTIFIED VARIETIES

Many studies have been published on the impact of feeding on biofortified varieties in India as well as in other countries. Some of the impact-study findings are as under:

1. Feeding orange fleshed sweet potatoes to South African school children aged 5-10 years showed a favourable response in the children’s vitamin-A status compared to traditional white variety (van Jaarsveld et al., 2005).

2. In Mozambique, children possessed significantly higher serum retinol concentrations when fed with orange-fleshed sweet potato over the two-years compared to non-intervened children (Low et al., 2007).

3. Children experienced fewer sick days when fed with porridge made from QPM compared to normal maize. Infants and young children experienced 12% higher rate of growth in weight and 9% in height when fed with QPM (Gunaratna et al., 2010).

4. Consumption of 100g QPM was required for children to maintain adequate levels of lysine resulting in a reduction in normal maize consumption by 40% (Nuss and Tanumihardjo, 2011).

5. In Mexico, zinc absorption was enhanced in adult women when biofortified wheat was served as food (Rosado et al. 2009).

6. In India, children of 12-16 years of age were fed with *‘bhakri’* made from iron-rich and conventional pearl millet grains. Feeding iron-rich pearl millet was an efficacious approach to improve iron status in school-aged children (Finkelstein et al. 2015).

7. Biofortified wheat flour consumption provides nearly 30% more Zn than commercial conventional wheat irrespective of whether the flour is white or brown (whole wheat flour) (Signorell et al, 2015).

8. The consumption of sweet potatoes in Europe has increased 365% over the past decade and supermarkets are catering to this trend. The United Kingdom and the Netherlands are responsible for most of the European import of sweet potatoes. More than 80% of the supply to Europe comes from the United States, with Covington and Beauregard being the dominant varieties (CBI, EU, 2017).

9. As per the USDA (2017) report, sweet potato production in the America has increased 57% in the last decade. National sweet potato production in the USA increased by an average of 6.1 percent per season since 2000, with a record high production in 2016 valued at $705 million. In the USA, per capita availability rose from 1.9 kgs in 2000 to 3.4 kgs in 2016.

10. Consumption of provitamin-A-rich maize by Zambian children significantly improved their serum β-carotene concentrations compared with traditional maize (Sheftel et al., 2017; Palmer et al., 2018).

11. Sazawal et al., (2018) while studying the efficacy of high zinc biofortified wheat in improvement of micronutirent status, and prevention of morbidity among pre-school children and women reported that children (4-6 years) in India when fed with high zinc flour from biofortified wheat varieties had a 17% and 40% reduction in days with pneumonia and vomiting, respectively over the group fed with low zinc wheat flour.

F. EFFORTS TOWARDS MAINSTREAMING BIOFORTIFIED PRODUCTS

Special efforts are being made to popularize these biofortified varieties among masses. Quality seeds of biofortified varieties are being produced and made available for commercial cultivation. Extension Division of ICAR has also launched special programmes viz. Nutri-sensitive Agricultural Resources and Innovations (NARI) and Poshan Vatika for up-scaling the biofortified varieties through its Krishi Vigyan Kendras (KVKs).

CIP has made significant contributions to R&D through strong collaboration with the Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram. CIP provided seeds of Jewel population in 2009 and in 2016 and two of CIP lines have been released in India. State Government of Odisha is financing the CIP-led project GAINS for the development of OFSP value chains.

For ensuring regular supply of quality seeds of biofortified varieties, ICAR has included all the biofortified varieties of different crops in the breeder seed production chain.

Possible efforts are being made by inclusion of biofortified varieties in the state seed rolling plans. Some of the regular efforts being made by National Agricultural Research System under aegis of ICAR are listed below:

1. Unprecedented awareness and demand of seed of biofortified varieties was created with two programmes by Hon'ble Prime Minister on 16 October, 2020 and 28 September 2021, where 17 biofortified and 35 trait specific varieties including 12 biofortified varieties of different crops were dedicated to the nation.

2. ICAR is ensuring seed availability of biofortified varieties. Since 2016-17, total 43 biofortified field crop varieties out of 79 have been included in the seed chain and a total of 18323 q breeder seed has been produced and made available to the seed producing public and private sector seed agencies for their downstream multiplication to foundation and certified seed prior to cultivation by the farmers. During 2022-23, breeder seed indents of wheat comprised more than 33% biofortified varieties breeder seed demand.

3. More than 300 private seed companies have come forward and signed more than 1215 Memorandum of Agreement (MoA) for taking license of biofortified crop varieties for their seed production and marketing.

4. Large quantities of planting material and seed/tubers of biofortified horticultural crop varieties was distributed viz., potato: 222.70 q, sweet potato: 206.30 lakh cuttings, pomegranate: 19.90 lakh planting material, and greater yam: 115 q.

5. ICAR has launched a progam 'Nutri-Sensitive Agricultural Resources and Innovation' (NARI) through its 100 KVKs, focusing on popularization of biofortified varieties and development of their value added products.

6. During past two years 2020-21, around 500 demonstrations of biofortified varieties have been conducted through KVKs.

7. Under NFSM program, the state governments have been advised to use at least 30% of biofortified/ stress-tolerant varieties in the latest crop production technology demonstrations for rice and wheat on farmers' fields.

8. Under CLFLDs of pulses, 92375 demonstrations have been allocated and ATARIs have been requested to organize at least 10% of the CFLDs on biofortified varieties of pulses as per the availability of seed in the district with high burden of malnutrition.

9. Under FLD on Pulses, Coarse Cereals, and Nutri Cereals, 2869 FLDs have been allocated to ICAR Institutes in which atleast 10% of the FLDs to use biofortified varieties of pulses as per the availability of seed in the districts with high burden of malnutrition.

10. Bulletins and pamphlets have been prepared both in physical and digital forms and shared with various agencies of state and central departments of agriculture, public sector undertakings, farmer producer organizations and non-governmental organizations. Special efforts are being made to popularize these biofortified varieties among masses through All India Radio, Doordarshan, Social Media etc. In addition, the literature is being distributed among farmers during field days, kisan melas and training programs.
11. Details of biofortified varieties with package of practices are being shared on the websites of the public institutes.
12. Efforts are being made for inclusion of biofortified grains/ products under the various government schemes like Public Distribution System, Integrated Child Development Scheme, National Food and Nutrition Security Mission (NFSM), Rastriya Krishi Vikas Yojna (RKVY) etc.
13. The activities for upscaling of biofortified varieties are being undertaken by converging the activities of other ministries/ departments of Govt. of India.
14. Pearl millet cultivar testing and release policy has included minimum standards for grain iron and zinc since 2018.
15. During 2021-22, more than 5.5 m ha area was under biofortified varieties of different crops including wheat (4.5 m ha), rice (1.00 lakh ha), pearl millet (5.0 lakh ha), lentil (0.50 lakh ha) and mustard (5.0 lakh ha).

G. WAY FORWARD

The way forward is summarised in the Figure 1. The following points need consideration for developing specific action plan by the concerned stakeholders:

- Convergence of activities of different Ministries/Departments/Organizations for mainstreaming the biofortified grains and their products can bring a sea change in nutrition outcomes in the country. Biofortified grains should be preferentially procured and supplied through PDS and other government programs to promote their consumption. Collaboration among industry partners, State Rural Livelihood Missions, Civil Bodies, Famer Producer Organizations (FPO), Non-Governmental organizations (NGO), Self Help Groups (SHG), Startups etc. has to be systematically ensured for scaling up the supply and distribution of biofortified grains and food products.
- Modern tools including Block Chain and Artificial Intelligence technology are to be employed for tracking and tracing biofortified grains and their bio-products for quality

control. Integration of handy tools for rapid detection of quality traits is required for segregating and incentivizing biofortified grains under government procurement scheme.

- Basic research on genetics and different metabolic pathways is to be strengthened in order to understand the nutrition traits. Biotechnology tools like genomic selection and genome editing are to be employed urgently, supported by adequate funding and state-of-art research infrastructure, for development of micronutrient-rich multi-trait varieties without compromising the yield in different field and horticultural crops. Crop wild relatives and farmers' varieties, rich in different essential nutrients, are to be identified and utilized in breeding programs.
- Minimum targets of nutrient and vitamin levels in edible parts/grains are to be defined in the ICAR-All India Coordinated Research Project trials, particularly in the main staple food crops namely, rice and wheat, and variety release policy is to be prescribed accordingly to encourage development of nutrient-rich varieties in India. Similarly, all hybrids in maize are to be biofortified for release. This will have a significant impact on the feed industry, as 75 per cent of maize grain is used in poultry industry.
- A robust seed production system should be put in place through strong public-private partnership for supply of quality seeds to the farmers including organically produced seeds of biofortified varieties.
- Agronomic management plays an important role in determining the level of micronutrients in the edible parts of the plant, hence good agricultural practices (GAPs) are to be standardised and recommended for biofortified crops.
- For biofortification of milk, meat, chicken, pork and eggs, a national research program needs to be initiated on feeding of biofortified grains and other edible plant parts, and impact of nutrient-dense feed ingredients on the quality of the products.
- Affordability, access and absorption (AAA) are three key determinants for success of biofortified varieties for which cheaper prices, sufficient quantity of biofortified products and nutrient availability to the body should be the fundamental principle. Elaborate bioavailability studies are therefore required for optimizing the quantity of biofortified food for meeting the body requirement for good health.
- For promoting both cultivation and consumption of biofortified food, massive awareness campaigns on "Nutrition Literacy" highlighting the benefits of biofortified crops and their products need to be undertaken through school programmes, food and seed fares, folk songs, tales for children, advertisements in local languages, radio and television regional channels, commercial advertisements, social media, online newsletters etc.

- In order to rapidly spread such varieties, large scale demonstrations, field days, farm fairs and trainings, establishment of nutri-smart villages/ Poshan Vatika, and creation of Nutrition Sakhi (Poshan Mitra) at village/ ward levels demand immediate attention of the concerned agencies.

- Partnership, particularly at global level, with institutions/centres of excellence/ programs such as HarvestPlus, for capacity building and infusion of new knowledge, technology and elite plant material has to be developed/strengthened to make faster progress and meet standards of nutritional traits and breeding pipelines along with monitoring of efficacy.

- Price incentive to farmers for growing biofortified varieties is to be considered by the government till such time when all the biofortified varieties become as high yielding as the highest yielding variety of the respective crop for a specific ecology. Logically, the Minimum Support Price (MSP) should be decided not only by considering C2 plus 50 per cent but by the nutrient content of the produce.

- A proactive approach should be followed from seed to fork by developing value chains; packaging, appropriate labelling based on scientific evidences published in peer reviewed international journals of repute, branding, advertising and demand creation through various agencies will be required.

REFERENCES

FAO, IFAD, UNICEF, WFP and WHO. (2021). The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO.

Finkelstein J.L., Mehta S., Udipi S.A., Ghugre P.S., Luna S.V., Wenger M.J., Murray-Kolb L.E., Przybyszewski E.M. and Haas J.D. (2015). A randomized trial of iron-biofortified pearl millet in school children in India. J. Nutr. 145: 1576-81.

Global Food Policy Report (2016). Washington, DC: International Food Policy Research Institute

Global Hunger Index (2021): Hunger and Food Systems in Conflict Settings. Bonn: Welthungerhilfe; and Dublin: Concern Worldwide.

Global Nutrition Report (2018). Shining a light to spur action on nutrition. Bristol, UK: Development Initiatives.

Global Nutrition Report (2021): The state of global nutrition. Bristol, UK: Development Initiatives.

Gunaratna, N.S., De Groote, H., Nestel, P., Pixley, K.V. and McCabe, G.P. (2010) A meta-analysis of community-level studies on quality protein maize. Food Policy 35: 202-210.

Low J.W., Arimond M., Osman N., Cunguara B., Zano F.., Tschirley D. (2007). A food-based approach introducing orange-fleshed sweet potatoes increased Vitamin A intake and serum retinol concentrations in young children in rural Mozambique. J. Nutr. 137: 1320-1327.

Mark H.E., Dias da Costa G, Pagliari C., Unger S.A. (2020). Malnutrition: the silent pandemic. British Medical J. 371: m4593

National Family Health Survey-5 (2019-21). Ministry of Health and Family Welfare, Govt. of India.

Nuss E.T. and Tanumihardjo S.A. (2011). Quality protein maize for Africa: closing the protein inadequacy gap in vulnerable populations. Advances in Nutrition 2: 217-224.

Nutrition for Growth Tracker methodology (www.globalnutritionreport.org/resources/nutrition-growth-commitment-tracking/methodology).

Palmer A.C., Craft N.E., Schulze K.J., Barffour M., Chileshe J., Siamusantu W. and West K.P. (2018). Impact of biofortified maize consumption on serum carotenoid concentrations in Zambian children. European J. Clin. Nutr. doi: 10.1038/s41430-017-0054-1.

Rosado J.L., Hambidge M, Miller LV, Garcia OP, Westcott J, Gonzalez K, Conde J, Hotz C, Pfeiffer W., Ortiz-Monasterio I. and Krebs N.F. (2009). The quantity of zinc absorbed from wheat in adult women is enhanced by biofortification. J. Nutr. 1920-1925.

Sazawal S., Dhingra U., Dhingra P., Dutta A., Deb S., Kumar J., Devi P. and Prakash A. 2018. Efficacy of biofortified wheat in improvement of micronutrients status, and prevention of morbidity among preschool children and women – a double masked, randomized, controlled trial. Journal of Nutrition: 17-86. Https://doi.org/10.1186/s12937-018-0391-5

Sheftel J., Gannon B.M., Davis C.R. and Tanumihardjo S.A. (2017). Provitamin A-biofortified maize consumption increases serum xanthophylls and 13C-natural abundance of retinol in Zambian children. Experimental Biol. Medicine 1-7 doi: 10.1177/1535370217728500.

Signorell, C. et al. 2015. Evaluation of Zinc Bioavailability in Humans from Foliar Zinc Biofortified Wheat and from Intrinsic vs. Extrinsic Zn Labels in Biofortified Wheat. European J. Nutr. Food Safety 5(5): 863-864 van Jaarsveld P.J., Faber M., Tanumihardjo S.A., Nestel P., Lombard C.J. and Benade A.J.S. (2005). Beta-carotene-rich orange-fleshed sweet potato improves the Vitamin A status of primary school children assessed with the modified-relative-dose-response test. Am. J. Clin. Nutr. 81: 1080-1087.

Yadava D.K., Hossain F. and Mohapatra T. (2018). Nutritional security through crop biofortification in India: Status & future prospects. Indian J. Medical Research. 148: 621-631. DOI: 10.4103/ijmr.IJMR_1893_18.

Yadava D.K., Choudhury P.R., Hossain F., Kumar D., Sharma T.R. and Mohapatra T. (2022). Biofortified Varieties: Sustainable Way to Alleviate Malnutrition (Forth Edition). Indian Council of Agricultural Research, New Delhi. 107p.

WHO. Global Nutrition Targets 2025. Policy Brief Series.

https://www.harvestplus.org/where-we-work/india. (Accessed on 24-12-2021).

Annexure-I

List of Crop-wise Biofortified Varieties Developed in India

S. No.	Variety	Year	Salient features
			Rice
1.	CR Dhan 310	2015	Rich in protein (10.3%) in polished grains in comparison to 7.0-8.0% in popular varieties
2.	DDR Dhan 45	2015	Rich in zinc (22.6 ppm) in polished grains in comparison to 12.0-16.0 ppm in popular varieties
3.	DDR Dhan 48	2018	Rich in zinc (24.0 ppm) in polished grains in comparison to 12.0-16.0 ppm in popular varieties
4.	DDR Dhan 49	2018	Rich in zinc (25.2 ppm) in polished grains in comparison to 12.0-16.0 ppm in popular varieties
5.	Zinco Rice MS	2018	Rich in zinc (27.4 ppm) in polished grains in comparison to 12.0-16.0 ppm in popular varieties
6.	CR Dhan 311 (Mukul)	2018	Rich in protein (10.1%) and zinc (20.1 ppm) in polished grains in comparison to 7.0-8.0% protein and 12.0-16.0 ppm zinc in popular varieties
7.	CR Dhan 315	2020	Rich in zinc (24.9 ppm) in polished grains in comparison to 12.0-16.0 ppm in popular varieties
8.	CR Dhan 411	2021	Rich in protein (10.1%) in polished grains in comparison to 7.0-8.0% in popular varieties
			Wheat
1.	WB 02	2017	Rich in iron (40.0 ppm) and zinc (42.0 ppm) in comparison to 28.0-32.0 ppm iron and 30.0-32.0 ppm zinc in popular varieties
2.	HPBW 01	2017	Rich in iron (40.0 ppm) and zinc (40.6 ppm) in comparison to 28.0-32.0 ppm iron and 30.0-32.0 ppm zinc in popular varieties

S. No.	Variety	Year	Salient features
3.	PusaTejas (HI 8759) durum	2017	Rich in protein (12.0%), iron (41.1 ppm) and zinc (42.8 ppm) in comparison to 8-10% protein, 28.0-32.0 ppm iron and 30.0-32.0 ppm zinc in popular varieties
4.	PusaUjala (HI 1605)	2017	Rich in protein (13.0%) and iron (43.0 ppm) in comparison to 8-10% protein and 28.0-32.0 ppm iron in popular varieties
5.	HD 3171	2017	Rich in zinc (47.1 ppm) in comparison to 30.0-32.0 ppm in popular varieties
6.	HI 8777 (durum)	2018	Rich in iron (48.7 ppm) and zinc (43.6 ppm) in comparison to 28.0-32.0 ppm iron and 30.0-32.0 ppm zinc in popular varieties
7.	MACS 4028 (Durum)	2018	Rich in protein (14.7%), iron (46.1 ppm) and zinc (40.3 ppm) in comparison to 8-10% protein, 28.0-32.0 ppm iron and 30.0-32.0 ppm zinc in popular varieties
8.	PBW 752	2018	Rich in protein (12.4%) in comparison to 8-10% in popular varieties
9.	PBW 757	2018	Contains high zinc (42.3 ppm) in comparison to 30.0-32.0 ppm zinc in popular varieties
10.	Karan Vandana (DBW 187)	2018	Rich in iron (43.1 ppm) in comparison to 28.0-32.0 ppm in popular varieties
11.	DBW 173	2018	Rich in protein (12.5%) and iron (40.7 ppm) in comparison to 8-10% protein and 28.0-32.0 ppm iron in popular varieties
12.	UAS 375	2018	Rich in protein (13.8%) in comparison to 8-10% in popular varieties
13.	Pusa Wheat 3249 (HD 3249)	2019	High zinc content (42.5%)
14.	PBW 771	2019	High zinc content (41.4 ppm)
15.	DDW 47	2019	High protein 12.7% and high iron content (40.1 ppm.) in grain

S. No.	Variety	Year	Salient features
16.	Pusa Wheat 8802 (HI 8802)	2019	High protein content (13.3%)
17.	Pusa Wheat 8805 (HI 8805)	2019	High protein content (12.4%) and iron content (40.4 ppm)
18.	MACS 4058 (durum)	2020	Rich in protein (14.7%), iron (39.5 ppm) and zinc (37.8 ppm) in comparison to 8-10% protein, 28.0-32.0 ppm iron and 30.0-32.0 ppm zinc in popular varieties
19.	HD3298	2020	Rich in iron (43.1 ppm) and grain protein (12.12%) in comparison to 28.0-32.0 ppm iron and 8-10% protein in popular varieties
20.	HI1633	2020	Rich in iron (41.6 ppm), zinc (41.1 ppm) and grain protein (12.4%) in comparison to 28.0-32.0 ppm iron, 30.0-32.0 ppm zinc and 8-10% protein in popular varieties
21.	DBW303	2020	Rich in grain protein (12.1%) in comparison to 8-10% protein in popular varieties
22.	DDW48	2020	Rich in grain protein (12.1%) in comparison to 8-10% protein in popular varieties
23.	DBW 332	2021	Rich in protein (12.2%) and zinc (40.6 ppm) in comparison to 8-10% protein and 30.0-32.0 ppm iron in popular varieties
24.	DBW 327	2021	Contains high zinc (40.6 ppm) in comparison to 30.0-32.0 ppm zinc in popular varieties
25.	HI 1636	2021	Contains high zinc (40.4 ppm) in comparison to 30.0-32.0 ppm zinc in popular varieties
26.	HI 8823	2021	Rich in protein (12.1%) and zinc (40.1 ppm) in comparison to 8-10% protein and 30.0-32.0 ppm zinc in popular varieties
27.	HUW 838	2021	Contains high zinc (41.8 ppm) in comparison to 30.0-32.0 ppm zinc in popular varieties
28.	MP (JW) 1358	2021	Rich in protein (12.1%) and iron (40.6 ppm) in comparison to 8-10% protein and 28.0-32.0 ppm iron in popular varieties

S. No.	Variety	Year	Salient features
			Maize
1.	Vivek QPM 9	2007	Rich in lysine (4.19% in protein) and tryptophan (0.83% in protein) in comparison to 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
2.	Pusa Vivek QPM9 Improved	2017	Rich in provitamin-A (8.15 ppm), lysine (2.67% in protein) and tryptophan (0.74% in protein) in comparison to 1.0-2.0 ppm provitamin-A, 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
3.	Pusa HM4 Improved	2017	Rich in lysine (3.62% in protein) and tryptophan (0.91% in protein) in comparison to 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
4.	Pusa HM8 Improved	2017	Rich in lysine (4.18% in protein) and tryptophan (1.06% in protein) in comparison to 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
5.	Pusa HM9 Improved	2017	Rich in lysine (2.97% in protein) and tryptophan (0.68% in protein) in comparison 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
6.	Pusa HQPM-5 Improved (APQH5)	2019	High Provitamin A (6.77 microgram/g) (1.02 in normal maize); High lysine 4.25% and tryptophan 0.94% (Normal maize <0.6% tryptophan <2.5% lysine)
7.	Pusa Vivek Hybrid-27 Improved (APH27)	2019	Improved Provitamin A 5.49 microgram/g
8.	Pusa HQPM-7 Improved (APQH7)	2019	Hgh provitamin A 7.10 microgram/gram High lysine 4.19% and tryptophan 0.93%
9.	IQMH 201 (LQMH 1) (IMHQPM 1530) (Hybrid)	2020	High lysine (3.03%), tryptophan (0.73%) in protein as compared to 1.5-2.0% lysine and 0.3-0.4% tryptophan content in popular hybrids
10.	IQMH 202 (LQMH 2)	2020	High lysine (3.04%), tryptophan (0.66%) in protein as compared to 1.5-2.0% lysine and 0.3-0.4% tryptophan content in popular hybrids
11.	IQMH 203 (LQMH 3)	2020	High lysine (3.48%), tryptophan (0.77%) in protein as compared to 1.5-2.0% lysine and 0.3-0.4% tryptophan content in popular hybrids

S. No.	Variety	Year	Salient features
12.	Malviya Swarn Makka-1	2021	Rich in lysine (3.89% in protein) and tryptophan (0.97% in protein) in comparison 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
13.	Pusa HQPM 1 Improved	2021	Rich in provitamin-A (7.02 ppm), lysine (4.59% in protein) and tryptophan (0.85% in protein) in comparison to 1.0-2.0 ppm provitamin-A, 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
14.	Pusa Biofortified Maize Hybrid-1	2021	Rich in provitamin-A (6.60 ppm), lysine (3.37% in protein) and tryptophan (0.72% in protein) in comparison to 1.0-2.0 ppm provitamin-A, 1.5-2.0% lysine and 0.3-0.4% tryptophan in popular hybrids
			Pearl Millet
1.	HHB 299	2018	Rich in iron (73.0 ppm) and zinc (41.0 ppm) in comparison to 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popular varieties/hybrids
2.	AHB 1200	2018	Rich in iron (73.0 ppm) in comparison to 45.0-50.0 ppm in popular varieties/hybrids
3.	AHB 1269 Fe	1st 2018	Rich in iron (91.0 ppm) and zinc (43.0 ppm) in comparison to 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popular varieties/hybrids
4.	ABV 04	1st 2018	Rich in iron (70.0 ppm) and zinc (63.0 ppm) in comparison to 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popular varieties/hybrids
5.	RHB 233 (MH 2173)	2019	High iron (83 ppm) and high Zn (46 ppm)
6.	RHB 234 (MH 2174)	2019	High iron (84 ppm) and high Zn (41 ppm)
7.	HHB 311 (MH 2179)	2019	High iron content (83 ppm)
8.	Phule Mahashakti	2018	Rich in iron (87.0 ppm) and zinc (41.0 ppm) in comparison to 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popular varieties/hybrids
9.	HHB 67 Improved 2	2021	Rich in protein (15.5%), iron (54.8 ppm) and zinc (39.6 ppm) in comparison to 8.0-9.0% protein, 45.0-50.0 ppm iron and 30.0-35.0 ppm zinc in popular varieties/hybrids

S. No.	Variety	Year	Salient features
			Finger Millet
1.	Vegavathi (VR 929)	82nd 2019	High in grain Zn content (199.1%). It is high in Fe, Ca, protein content, dietary fibre and low in Tannin content.
2.	CFMV 1 (Indravathi)	2020	Rich in Ca (428 mg/100 g), Fe (58 mg/kg) and Zn (44 mg/kg) in comparison to Ca (200 mg/100 g), Fe (25 mg/kg) and Zn (16 mg/kg) in popular varieties
3.	CFMV 2	2020	Rich in protein (6.41%), Ca (654 mg/100 g), Fe (39 mg/kg) and Zn (25 mg/kg) in comparison to Ca (200 mg/100 g), Fe (25 mg/kg) and Zn (16 mg/kg) in popular varieties
			Little Millet
1.	CLMV 1	2020	Rich in protein (14.4%), Fe (59 mg/kg) and Zn (35 mg/kg) in comparison to Fe (25 mg/kg) and Zn (20 mg/kg) in popular varieties
			Linseed
1.	TL 99	2019	Linolenic acid (<5%) (normal varieties (>40%)
			Lentil
1.	Pusa Ageti Masoor	2017	Rich in iron (65.0 ppm) in comparison to 45.0-50.0 ppm in popular varieties
2.	IPL 220	2018	Rich in iron (73.0 ppm) and zinc (51.0 ppm) in comparison to 45.0-50.0 ppm iron and 35.0-40.0 ppm zinc in popular varieties
			Mustard
1.	Pusa Mustard 30	2013	Low in erucic acid (<2.0% in oil) in comparison to >40.0% in popular varieties
2.	Pusa Double Zero Mustard 31	2017	Country's first Canola Quality Indian mustard variety Low in erucic acid (<2.0% in oil) and glucosinolates (<30.0 ppm in seed meal) in comparison to >40.0% erucicacidand >120.0 ppm glucosinolates in popular varieties

S. No.	Variety	Year	Salient features
3.	Pusa Mustard 32	2020	Low in erucic acid (<2.0% in oil) in comparison to >40.0% in popular varieties
4.	Pusa Double Zero Mustard 33	2021	Low in erucic acid 0.58% in oil) and glucosinolates (15.17 ppm in seed meal) in comparison to >40.0% erucic acid and >120.0 ppm glucosinolates in popular varieties
5.	RCH 1	2021	Low in erucic acid 0.09% in oil) and glucosinolates (19.49 ppm in seed meal) in comparison to >40.0% erucic acid and >120.0 ppm glucosinolates in popular varieties
6.	PGHS 1699 (GSH 1699)	2021	Low in erucic acid 1.49% in oil) and glucosinolates (20.34 ppm in seed meal) in comparison to >40.0% erucic acid and >120.0 ppm glucosinolates in popular varieties
			Soybean
1.	NRC 127	2018	Country's first Kunitz Trypsin Inhibitor (KTI) free variety. Free from KTI in comparison to 30-45 mg/g of seed mealin popular varieties
2.	NRC 132	2020	Null Lipoxygenase 2 (Less beany flavour, suitable for making soybean milk and other products)
3.	NRC 147	2020	High Oleic Acid (42.0%)
4.	NRC 142	2021	Country's first double null variety for Kunitz Trypsin Inhibitor (KTI) and lipoxygenase-2 (Lox-2)
5.	MACSNRC 1667	2021	Free from KTI in comparison to 3045 mg/g of seed meal in popular varieties
			Groundnut
1.	Girnar 4 (ICGV 15083)	2020	Oleic acid 78.5% and linoleic acid 4.8% in comparison to 45-52% oleic acid in conventional popular varieties
2.	Girnar 5 (ICGV 15090)	2020	Oleic acid 78.4% and linoleic acid 4.6% in comparison to 45-52% oleic acid in conventional popular varieties

S. No.	Variety	Year	Salient features
			Cauliflower
1.	Pusa Beta Kesari1	2015	Country's first provitamin-A rich cauliflower, rich in provitamin-A (8.0-10.0 ppm) in comparison tonegligible content in popular varieties
			Potato
1.	Kufri Manik	2020	Kufri Manik
2.	Kufri Neelkanth	2020	Rich in anthocyanin (1.0 ppm) in comparison to negligible content in popular varieties
			Sweet Potato
1.	Bhu Sona	2017	Rich in provitamin-A (14.0 mg/100 g) in comparison to 2.0-3.0 mg/100 g in popular varieties
2.	Bhu Krishna	2017	Rich in anthocyanin (90.0 mg/100 g) in comparison tonegligible amount in popular varieties
			Greater Yam
1.	Da 340	2020	Rich in anthocyanin (141.4 mg/100 g), iron (136.2 ppm) and calcium (1890 ppm) in comparison to negligible anthocyanin, 70-120 ppm iron and 800-1200 ppm calcium in popular varieties
2.	Sree Neelima	2020	Rich in anthocyanin (50.0 mg/100 g), crude protein (15.4%) and zinc (49.8 ppm) in comparison to negligible anthocyanin, 2.7% crude protein and 22-32 ppm zinc in popular varieties
			Pomegranate
1.	Solapur Lal	2017	Rich in iron (5.6-6.1 mg/100 g), zinc (0.64-0.69 mg/100 g) and vitamin-C (19.4-19.8 mg/100 g) in fresh arils in comparison to 2.7-3.2 mg/ 100 g iron, 0.50-0.54 mg/100 g zinc and 14.2-14.6 mg/100 g vitamin-C in popular variety

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