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Biofortification of Food Crops: An Approach towards Improving Nutritional Security in South Asia

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***Abstract:** Globally, over two billion people are suffering from micronutrient led malnutrition. A diverse diet composed of fruits, vegetables and animal products is needed to meet the nutritional and energy requirements. However, these diets are out of reach for most of the population, especially for people living in under-developed and developing countries. Major staple food crops consumed on a regular basis by the poor is generally low in nutritional content. This issue can be addressed by the process known as Biofortification, an approach of increasing the nutrient density (preferably, vitamins and minerals), and improve the quality dietary uptake and nutritional status of the major section of the society. With the advent of the biofortification, various breeding and agronomic techniques, modern biotechnological approaches have been developed that can successfully incorporate these body essentials in the major food sources. With malnutrition prevailing as major problem, it is a promising, sustainable and economical approach of delivering food rich in micronutrients to the people that have very limited access to diverse diets. This review summarises some important topics related to biofortification including, introduction, micronutrient deficient South Asian countries, different means of biofortification, limitations and future prospects.*
***Keywords:** Biofortification, Crops, Deficiency, Micronutrient, South Asia*

1. Introduction

'Hidden hunger' is a term referring to micronutrients, i.e. vitamins and minerals, deficiencies. Globally, micronutrient deficiencies affect an estimated two billion people that comprise almost one-third of the world's population (Thompson & Amoroso, 2014). Four micronutrients, Iodine, Iron, vitamin A and Zinc, deficiencies are of greatest public health concern worldwide because of their high pervasiveness and associated health and cognitive developmental consequences. Approximately 1 in every 3 children aged 6-59 months (children aged below 5 years) in low- and middle-income countries suffer from vitamin A deficiency (Stevens, *et al.,* 2015) and 18% of children below the age of 5 years are suffering from Iron-deficiency anaemia (Stevens, *et al.*, 2013). Likewise, worldwide 30% population suffer from inadequate iodine intake (Andersson, Karumbunathan, & Zimmermann, 2012) and 17% from insufficient Zinc intake (Wessells, Singh, & Brown, 2012).

The prevalence of micronutrient deficiencies are more severe and affect more people in poorer regions of the world. In 2013, around 1.7% of deaths among children aged below 5 years in low- and middle-income countries were attributable to vitamin A deficiency, with 95% of these deaths occurring in South Asia and sub-Saharan Africa (Stevens, *et al.*, 2015). Even though the pervasiveness of inadequate iodine intake in South Asia is comparable to the global average (32% compared with 30%) (Andersson, Karumbunathan, & Zimmermann, 2012), anaemia among 52 % of pregnant women and 58% of children aged below 5 years surpasses the global prevalence (38% and 43%,

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respectively), so does insufficient Zinc intake (at 30% versus the global average of 17%) (Stevens, *et al.,* 2013). This situation is of great concern for South Asia's future as it is related with significant health consequences that translate into huge economic losses. Regardless of recent growth across much of South Asia in terms of economic growth, agricultural output and exports, poverty reduction and even some indicators of improved child nutrition, the region's scenario of micronutrient deficiencies has improved little for several decades (Harding, Aguayo, & Webb, 2017).

To tackle this serious issue of micronutrient deficiencies, biofortification could be one of the alternatives. Biofortification in general may be put forward as the process of increasing nutritional content of food crops. It is comparatively economical and sustainable approach of improving nutritional status of food crops. This approach will help to improve the nutritional status of severely malnourished people. Also, biofortification could be one of the reasonable means of reaching malnourished population in rural areas who generally have restricted access to commercially marketed fortified foods and other supplements (Bouis, 2013).

The biofortification technique intends to incorporate micronutrient-dense traits to those varieties already having preferred agronomic traits, such as high yield. Unlike complementary interventions such as supplementation and fortification that begin in urban areas, marketed surplus of biofortified crops enter retail outlets, reaching rural population first. Biofortified food crops cannot deliver micronutrient per day in high levels as supplements or commercially fortified foods, however, they can help by improving the daily adequacy of micronutrient consumption among people throughout their life cycle (Bouis, Hotz, McClafferty, Meenakshi, & Pfeiffer, 2011).

2. Micronutrients deficiency in South Asia

2.1 Afghanistan

Deficiency of micronutrients are widespread in Afghanistan. About 46% of children under the age of 5 are vitamin A deficient. Approximately 23% of women of reproductive age were reported to have zinc deficiency and the majority of women (95%) are deficient in vitamin D (UNICEF, 2013).

2.2 Bangladesh

In Bangladesh, children are affected from high rates of micronutrient deficiencies, mostly for vitamin A, iron, iodine and zinc. Bangladesh has made significant progress in reducing vitamin A deficiency (VAD) among preschool children over the past 15 years; however, consumption of vitamin A rich foods is still low, suggesting that the underlying causes of VAD require further attention and support. Anaemia is also highly prevalent among children in Bangladesh and few programs have been initiated to improve their iron status (FAO, 2010)

2.3 Bhutan

Although they may not be visible to the naked eye, vitamin and mineral deficiencies are widespread in Bhutan, as shown in Figure 2. Approximately, 22% of preschool aged children and 17% of pregnant women are vitamin A deficient (WHO, 2009).

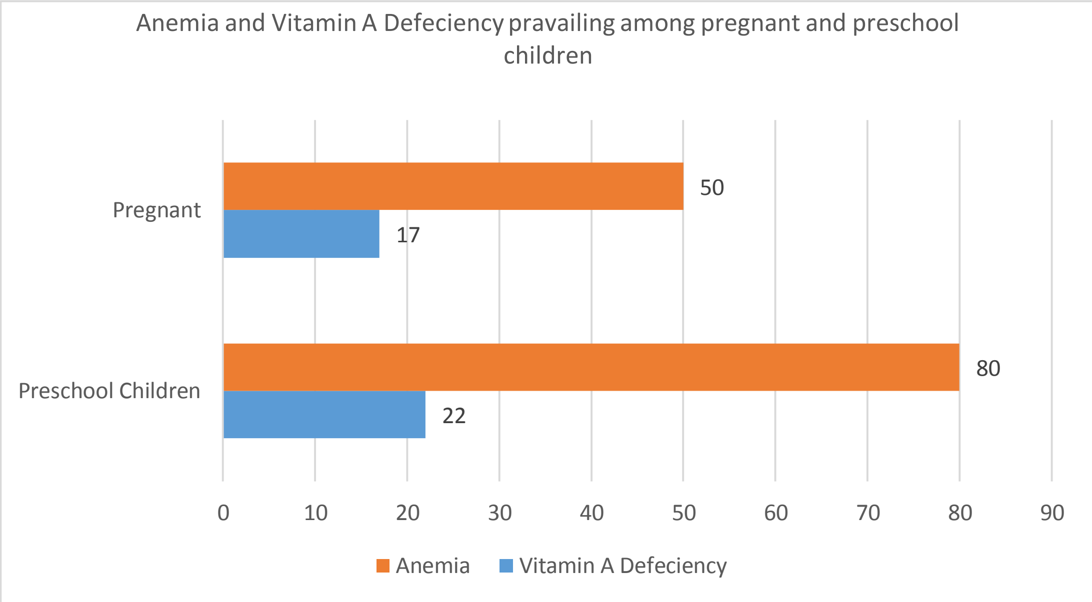

***Chart-I**: Pregnant and preschool children under the deficiency of iron and Vitamin A.*

Also, 80% of preschool aged children and 50% of pregnant women are anaemic shown in **Chart-I** (WHO, 2008).
To tackle iodine deficiency, currently 96% of households in Bhutan consume iodized salt (UNICEF, 2009).

2.4 India

The survey conducted by the Union Ministry of Health and Family Welfare (MHFW), Government of India reported that 19% of pre-school children and 32% of adolescents were found to be zinc deficient. 23% of pre-school children and 37% of adolescents were folate deficient. Also, the deficiencies of Vitamin A, Vitamin D and Vitamin B12 is between 14 to 31% for pre-school children to adolescents (Bhuyan, 2019). Iron, zinc, and vitamin B6 could be considered to be targeted deficiencies with 41, 25, and 6% of the population potentially falling below estimated average requirements, respectively. The other key micronutrients assessed - calcium, vitamin A, B12 and folate – all indicate a widespread risk of deficiency, with 94, 89, 89, and 81% of the population deemed at risk, respectively (Ritchie, Reay, & Higgins, 2018).
In India, anaemia is one of the major public health problems. According to National Family Health Survey (NFHS4) conducted by the Ministry of Health and Family Welfare reported the prevalence of anaemia as 58.6% among children aged 6-59 months, 53.1% among women aged 15-49 year, 50.4% among pregnant women aged 15-49 year and 22.7% among men aged 15-49 year (MHFW, 2017).

2.5 Maldives

Several national reports and surveys show high levels of stunting, wasting and micronutrient deficiencies in Maldives. The Micronutrient survey conducted in 2007 showed that more than half of the children between 6 months to 5 years are vitamin A deficient (5.1% severely and 50.1% moderately deficient). Anaemia prevalence among children aged 6 months to 5 years is 26.3%, while more than half of the children (57.3%) are iron deficient. Zinc and iodine deficiency are also at significant levels with 16.0% of children zinc deficient and 19% iodine deficient (MoH, 2016).

Anaemia is a chronic health problem among women in the Maldives. In 2001, the Multiple Indicator Cluster Survey reported that 51% of women of reproductive age were anaemic and that the rate was at 56% among pregnant women. The National Micronutrient Survey 2007 showed that overall, 15.4% women of reproductive age were anaemic to some degree; 0.3% severely anaemic and 15.1% moderately anaemic. While 2007 survey indicated to a dramatic reduction in the proportion of women with anaemia, it found that overall, 38% of women were iron deficient. Among women, 26.8% were found to have zinc deficiency and 4.7% women and 39.3% women have severe and moderate vitamin A deficiency respectively (MoH, 2016).

2.6 Nepal

The Nepal National Micronutrient Status Survey (NNMSS) assessed micronutrient status among representative populations in Nepal, including specifically the status of vitamins A, iron, folic acid, iodine, zinc and the condition of anaemia. The prevalence of anaemia assessed by haemoglobin concentration was 27 percent among pregnant women of 15-49 years, 21 percent among adolescent girls aged 10-19 years, 20 percent among non-pregnant women aged 15-49 years, 19 percent among children of 6-59 months and 11 percent among adolescent boys 10-19 years. Iron deficiency anaemia assessed by low haemoglobin and low ferritin was 11 percent among children 6-59 months, eight percent among non-pregnant women 15-49 years, seven percent among adolescent girls 10-19 years, five percent among pregnant women 15-49 years and one percent among adolescent boys 10-19 years.

Around 21 percent among children aged 6-59 months and 24 percent among non-pregnant women aged 15-49 years were Zinc deficient. Zinc deficiency among both groups meets the criteria of a public health problem (greater than 20 percent) in the country. Zinc deficiency was more prevalent among children 6-59 months in rural areas (UNICEF, 2016).

Micronutrients	Deficiency prevalence
Iron	35% of women (15–49 years of age) and 46% of children (under five years)
Iodine	22.0–27.9% (urinary iodine <100 μg/L)
Zinc	87.3% in children; 61.0% in pregnant women
Folate	6.2% in children; 12.0% in pregnant women
Vitamin A	8.5% in children; 7.0% in pregnant women
Vitamin D	17.2% in children; 14.0% in pregnant women
Vitamin E	17.9% in children; 25.0% in pregnant women
Vitamin B2	33.0% in pregnant women
Vitamin B6	43.1% in children; 40.0% in pregnant women
Vitamin B12	18.1% in children; 28.0% in pregnant women
Selenium	59.0% in children

Table: Prevalence of micronutrients deficiency in Nepal (Bhandari & Banjara, 2015)

2.7 Pakistan

According to National Nutrition Survey-2018 conducted by UNICEF Pakistan, Approximately, 53.7% of Pakistani children are anaemic and 5.7% are severely anaemic. Around 41.7% and 18.2% of women of reproductive age (WRA) are anaemic and iron deficient, respectively.

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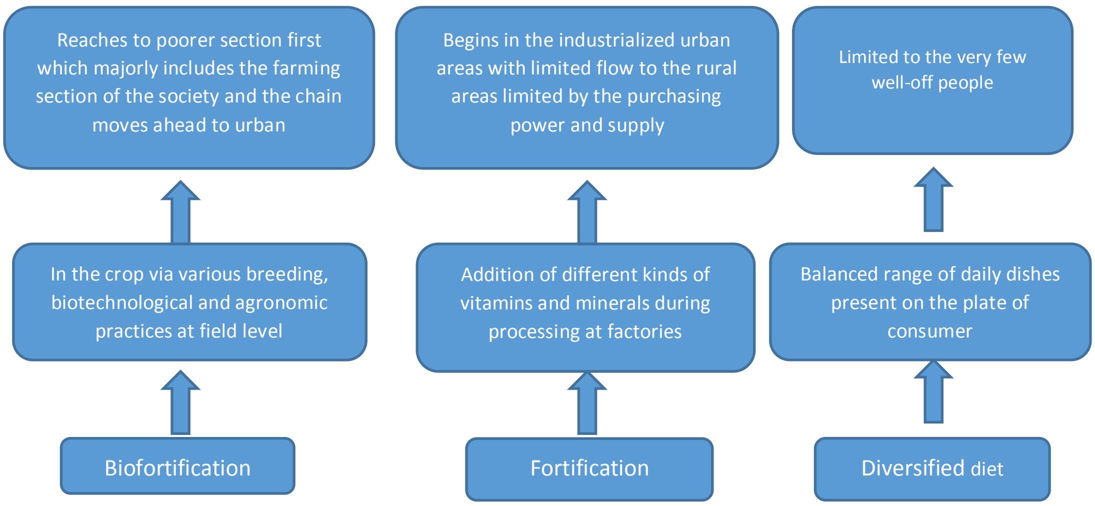
The prevalence of Zinc deficiency is 18.6%, with rural children having slightly higher prevalence (19.5%) than those in urban areas (17.1%).
About 51.5% of children are vitamin A deficient, of whom 12.1% have a severe deficiency. Likewise, around 27.3% of WRA are vitamin A deficient, with 22.4% experiencing moderate and 4.9% severe deficiency.
A high prevalence of vitamin D deficiency at approximately 62.7% was recorded, with 13.2% of children having severe deficiency. The majority of WRA (79.7%) are affected by vitamin D deficiency, with 54% experiencing moderate and 25.7% experiencing severe deficiency. Vitamin D deficiency is more common in urban (83.6%) than in rural settings (77.1%) (UNICEF, 2018).

2.8 Sri Lanka

Currently, Sri Lanka is experiencing the double burden of over- and undernutrition. Although considerable evidence is available regarding macronutrient deficiency in Sri Lanka, there is little published information regarding Micronutrients Deficiency. The highest prevalence of anaemia (34 percent) was found during 6–11 months of age and then the second year of life (24 percent). In a recent nutrition survey (2015), 31.8 percent of women were found to be anaemic. Other micronutrient deficiencies are also a significant concern, especially vitamin A and calcium (Jayatissa, Gunathilaka, Herath, & Fernando, 2014; Weerahewa, Wijetunga, Babu, & Atapattu, 2018).

3. How Biofortification can help to tackle micronutrients deficiency?

Biofortification is the process of increasing the nutritional content in a crop through conventional plant breeding, or using modern biotechnology, or agronomic practices (Bouis H. E., 2018). The plants translocate the minerals from the soil to the seeds (more precisely, the edible portion of the crop), and/or synthesize the vitamins in the seeds before harvest—at the initial point in the value chain—while short-term, gap filling interventions are implemented at points further down the value chain (as shown in the figure above). In the long run, increasing earnings and the production of crops rich in micronutrients and improving dietary diversity will considerably reduce micronutrient malnutrition. In the near-to-medium term, consumption of biofortified food can help in addressing micronutrient malnutrition by increasing the daily adequacy of vitamins and minerals intake among the people throughout their lifecycle (Bouis H. E., 2018).



4. Different Approaches of Biofortification

Biofortified food crops can be developed through transgenic approach, conventional plant breeding or agronomic practices. In a review, Monika Garg and her team documented list of all the crops and type of biofortification (Garg, et al., 2018). A brief summary on percentage coverage by each of the improvement strategies for each of different set of products is shown in **Chart II** below.

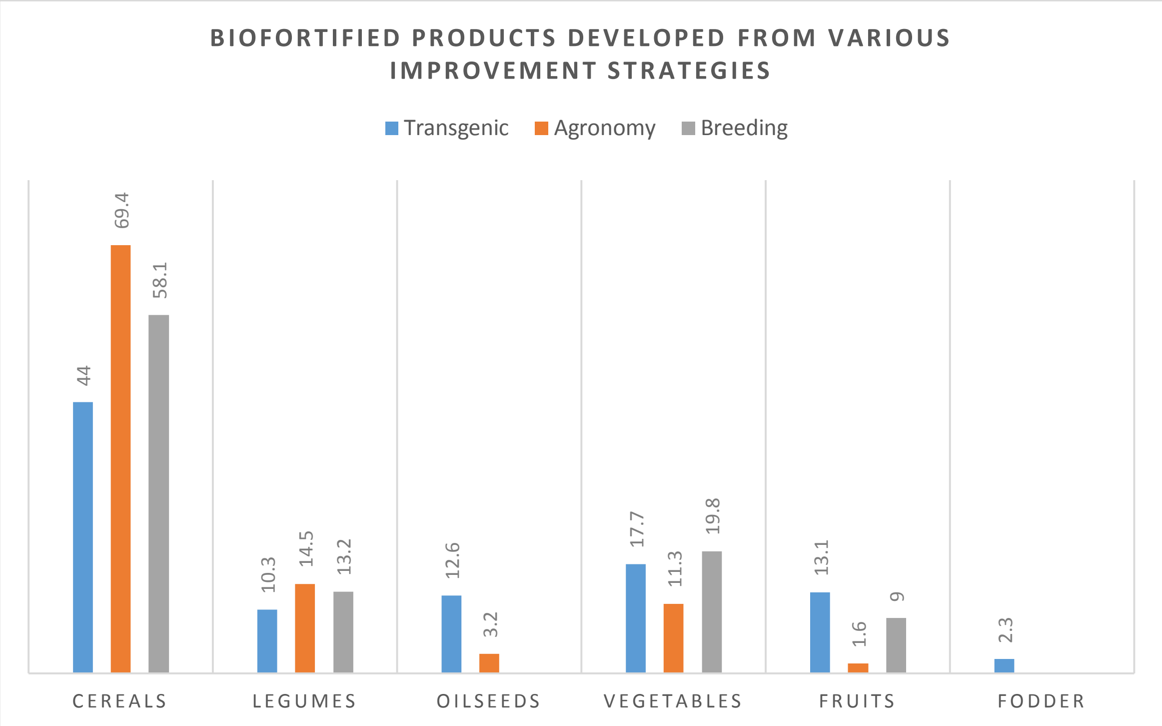


Chart II: *Percentage coverage of biofortified materials under various improvement strategies.*

4.1. Biofortification via Transgenic Techniques

Plant varieties having limited or no genetic variation in nutrient content are biofortified through transgenic means (Zhu, *et al.,* 2017). It relies on the access to the unlimited genetic pool for the transfer and expression of gene of interest from one crop variety to another which is independent of their evolutionary and taxonomic status. Also, when a particular vitamin or mineral is naturally absent in crops, transgenic means remain the only feasible choice to fortify these crops with the particular nutrient (Pe´rez-Massot, *et al.*, 2013).

Transgenic techniques can also be applied for incorporating genes which are involved in enhancing micronutrient content, their bioavailability and reducing anti-nutrients concentration which limit the nutrient bioavailability in crop plants. Additionally, modification of genes can be done to redistribute nutrients between plant tissues, improve micronutrient content in the edible parts of crops, thereby, increasing the biochemical pathways efficiency in edible tissues (Shewmaker, Sheehy, Daley, Colburn, & Yang Ke, 1999; Agrawal, Kohli, Twyman, & Christou, 2005). Initially, during research and development stage, the process is time and labour intensive and requires considerable amount of investment, but in the long-term, it is a cost-effective and sustainable method, in contrast to nutritionbased organizational and agronomic biofortification programs (Hefferon, 2016; White & Broadley, 2005). Additionally, there is no any taxonomic limitations in modern biotechnology and even synthetic genes can be constructed and used. Transgenic crops with improved micronutrient concentration can help in combating micronutrient malnutrition (Hirschi, 2009). Many crops have been developed with improved nutritional content through transgenic method such as high unsaturated fatty acid soybean, high lysine maize, iron-rich cassava and provitamin A-rich Golden rice (Garg, *et al.,* 2018).

4.2. Biofortification via Agronomic Practices

Biofortification via agronomic approach involves temporary improvement of nutritional status of staple food crops through physical application of fertilizers (Chankmak & Kutman, 2017). As compared to inorganic mineral forms, organic minerals are more available for a human, as they are easily absorbed and less excreted (Daniels, 1996) and their toxicity symptoms are less intensive (DRI 2000). It commonly depends on the physical application of nutrient-rich fertilizers or/and increase in their solubilisation or/and mobilization from the soil to the edible tissues of plants.

Micronutrients such as Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Iodine (I), Selenium (Se), Molybdenum (Mo), Cobalt (Co), and Nickel (Ni) are found in varying proportions in the edible parts of certain crop plants which are generally absorbed from the soil. Physical application of such nutrients as fertilizers can improve the soil micronutrient status which can contribute in reducing micronutrient malnutrition in humans (Cakmak, 2007). Soils, in which crops are grown, if deficient in nutrients, are not able to translocate minerals to the edible tissues. In such case, soluble inorganic fertilizers are directly applied to the plant roots or leaves. Foliar application of fertilizers with micronutrients often stimulates more nutrient uptake and efficient allocation in the edible plant parts than soil fertilization, especially with cereals and leafy vegetables (PG Lawson, 2015). Besides fertilizers, soil microorganism which promote plant growth can be used to improve the mobility of nutrients to edible plant parts and enhance their nutritional. Moreover, soil microorganisms belonging to different species of genera *Pseudomonas, Bacillus, Azotobacter, Rhizobium*, etc. can also be used to increase nutrient availability to plants (Rengela, Batten, & Crowley, 1999; Smith & Read, 2008).

4.3. Biofortification via Conventional Plant Breeding

Biofortification through conventional breeding is the most accepted approach by common people. It is a sustainable, economical method as compared to biofortification by transgenic and agronomic means. For conventional plant breeding to be feasible, sufficient variation of genotype in desired trait becomes essential. This variation can be utilized to increase micronutrient content in crops. In this method, plants having high nutrient content are crossed with plants with low nutrient content but desirable agronomic traits (such as high yield) over multiple generations to produce plants having desired agronomic and nutrient traits. However, breeding strategies have to sometimes depend on the restricted genetic variation present in the gene pool. In some cases, this can be overcome by crossing with distant relatives and thus moving the trait slowly into the commercial cultivars. Alternatively, new traits can be incorporated directly into commercial varieties by mutagenesis (Garg, et al., 2018).

The Consultative Group for International Agricultural Research (CGIAR) along with the International Centre for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI) have initiated the HarvestPlus program to produce biofortified staple food crops. It is focussed at using plant breeding as an intervention strategy to address micronutrient malnutrition by producing staple food crops with enhanced levels of essential minerals and vitamins that will have measurable impact on improving the micronutrient status of target populations, mainly resource-poor people in the developing world (Bouis & Welch, 2010).

5. Limitations of Biofortification

- In agronomic biofortification, success is highly variable due to the differences in mobility and accumulation of minerals among different species of plant, soil compositions in a particular geographical location of each crop (Ismail, Heuer, Thomson, & Wissuwa, 2007). For instance, a study which involved diverse rice genotypes showed that, in the phosphate deficient soils, there were 20 times differences in the phosphate uptake among the genotypes. It was due to decrease in root biomass (Wissuwa & Ae, 2001).
- Biofortification through conventional breeding may be sustainable and economical in the long run; nevertheless, there are some limitations such as amount of genetic variability in the plant gene pool. This method is also time and labour intensive, for example, improving Selenium concentration in wheat grains (Lyons, Ortiz-Monasterio, Stangoulis, & Graham, 2005) and enhancement of oleic, linoleic, and linolenic fatty acid content in soybean (Oliva, *et al.*, 2006).
- In case via transgenic techniques, it is less accepted by the consumers. Also, different regulatory processes have been implemented by different countries for the acceptance and commercialization of the crops developed via transgenic approach. Furthermore, these regulatory processes are very costly and time consuming (Watanabe, *et al.,* 2005).

6. Future Prospects

To effectively ensure a significant increase in the adoption and acceptance of biofortified crops, intensive efforts by public sector institutions and policy for intense promotional activities are required. Reinforcing the seed chain to produce and supply good quality seeds is one of the important steps for promoting biofortified crops. The maintenance of genetic purity is very important for keeping the quality trait intact; therefore, special seed production areas need to be recognised. Providing subsidized seeds along with other inputs would further contribute to the rapid dissemination of nutritionally improved cultivars among the farmers. To encourage the farmers to grow more biofortified crops, guaranteed premium remunerative price through minimum support price for biofortified grains in the market should be ensured. Government should invest more on extension activities in order to make the farmers, industry and consumers aware of the availability and benefits of biofortified crops (Yadava, Hossain, & Mohapatra, 2018).

Lack of awareness on the health benefits of biofortified crops is one of the major factors for slow adoption of biofortified crops. Essential factors for generating awareness are: educational background of the household head and the extent of farmers' participation in demonstration trials and field days (Gregory & Sewando, 2013; Zuma, Kolanisi, & Modi, 2018)

7. Conclusion

Biofortification can improve the nutritional content of the staple food crops which are consumed on a regular basis by poor people in South Asia as well as other developing countries. It provides a comparatively inexpensive, cost-effective, sustainable, long-term means of delivering more micronutrients to the poor. Biofortified crops contain adequate levels of micronutrient which is frequently lacking in diets of under-developed and developing countries. Biofortified crops should not have any changes in the taste, flavour and other quality attributes that may lead to the rejection of the product among the consumer. A good fortified food is one having enhanced nutrition with unaltered rheological properties of the food. These biofortified food apart from enhancing the nutritional status, also have reduced anti-nutritional component of the food. So time has come to shift our focus towards nutritional and micronutrients sufficiency along with enhanced production. Therefore, government should invest more in research in this particular area to improve the nutritional status of the people living in South Asia as large section of the people in this region has limited access to other fortified foods and nutritional supplements characterized by low income, limited awareness and non-uniform distribution, and access of these materials. So enhancement of nutritional status of staple food crops seems to be an effective way out towards reaching this goal of malnutrition free South Asia in particular, and whole world in general.

References

Agrawal, P., Kohli, A., Twyman, R., & Christou, P. (2005). Transformation of plants with multiple cassettes generates simple transgene integration patterns and high expression levels. *Molecular Breeding*.

Andersson, M., Karumbunathan, V., & Zimmermann, M. (2012). Global iodine status in 2011 and trends over the past decade. *Journal of Nutrition*.

Bhandari, S., & Banjara, M. R. (2015). Micronutrients deficiency, a Hidden Hunger in Nepal: Prevalence, Causes, Consequences, and Solutions. *Hindawi*, 2.

Bhuyan, A. (2019, October 8). *Government Surveys Micronutrient Deficiency Among Children for the First Time*. Retrieved from The Wire: https://thewire.in/health/government-surveys-micronutrient-deficiency-among-children-for-the-first-time

Bouis, H. (2013). *Biofortification: Evidence and lessons learned linking agriculture and nutrition.* FAO and WHO.

Bouis, H. E. (2018). Biofortification: An Agricultural Tool to Address Mineral and Vitamin Deficiencies. In M. V. Mannar, & R. F. Hurrell, *Food Fortification in a Globalized World* (pp. 69-81). Academic Press.

Bouis, H. E., Hotz, C., McClafferty, B., Meenakshi, J., & Pfeiffer, W. H. (2011). Biofortification: A new tool to reduce micronutrient malnutrition. *Food and Nutrition Bulletin*.

Bouis, H., & Welch, R. (2010). Biofortifi cation—A Sustainable Agricultural Strategy for Reducing Micronutrient Malnutrition in the Global South. *Crop Science*.

Cakmak, I. (2007). Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant and Soil*.

Chankmak, I., & Kutman, U. (2017). Agronomic biofortification of cereals with zinc: a review. *European Journal of Soil Science*.

Daniels, L. A. (1996). Selenium Metabolism and Bioavailability. *Humana Press.*

FAO. (2010). *Nutrition country profiles - Bangladesh*. Retrieved from Food and Agriculture Organizatioin.

Garg, M., Sharma, N., Sharma, S., Kapoor, P., Kumar, A., Chunduri, V., & Arora, P. (2018). Biofortified Crops Generated by Breeding, Agronomy, and Transgenic Approaches Are improving Lives of Millions of People around the world. *Frontiers in Nutririon*.

Gregory, T., & Sewando, P. (2013). Determinants of the probability of adopting quality protein maize (QPM) technology in Tanzania: A logistic regression analysis. *International Journal of Development and Sustainability*.

Harding, K., Aguayo, V., & Webb, P. (2017). Hidden hunger in South Asia: a review of recent trends and persistent challenges. *Public Health Nutrition*.

Hefferon, K. L. (2016). Can Biofortified Crops Help Attain Food Security? *Current Molecular Biology Reports*.

Hirschi, K. D. (2009). Nutrient Biofortification of Food Crops. *Annual Review of Nutrition*.

Ismail, A. M., Heuer, S., Thomson, M. J., & Wissuwa, M. (2007). Genetic and genomic approaches to develop rice germplasm for problem soils. *Plant Molecular Biology*.

Jayatissa, R., Gunathilaka, M., Herath, P., & Fernando, D. (2014). *National Nutrition and Micronutrient Survey, Part II. Iron, Zinc, Calcium Deficiency among Children Aged 6–59 Months.* Colombo: Ministry of Health and UNICEF Sri Lanka.

Lyons, G., Ortiz-Monasterio, I., Stangoulis, J., & Graham, R. (2005). Selenium concentration in wheat grain: Is there sufficient genotypic variation to use in breeding? *Plant and Soil*.

MHFW. (2017). *National Family Health Survey (NFHS-4).* Mumbai: International Institute for Population Sciences.

MoH. (2016). *Maldives Health Profile.* Malé: Planning and International Health Division.

Oliva, M., Shannon, J., Sleper, D., Ellersieck, M., Cardinal, A., Paris, R., & Lee, J. (2006). Stability of Fatty Acid Profile in Soybean Genotypes with Modified Seed Oil Composition. *Crop Science*.

Pe´rez-Massot, E., Banakar, R., Go´mez-Galera, S., Zorrilla-Lo´pez, U., Sanahuja, G., Arjo, G., . . . Yuan, D. (2013). The contribution of transgenic plants to better health through improved nutrition: opportunities and constraints. *Genes Nutr*.

PG Lawson, D. D. (2015). Soil versus foliar iodine fertilization as a biofortification strategy for field-grown vegetables. *Frontiers in Plant Science*.

Rengela, Z., Batten, G., & Crowley, D. (1999). Agronomic approaches for improving the micronutrient density in edible portions of field crops. *Field Crops Research*.

Ritchie, H., Reay, D. S., & Higgins, P. (2018). Quantifying, Projecting, and Addressing India's Hidden Hunger. *Frontiers in Sustainable Food Systems*.

Shewmaker, C., Sheehy, J., Daley, M., Colburn, S., & Yang Ke, D. (1999). Seed-specific overexpression of phytoene synthase: increase in carotenoids and other metabolic effects. *The Plant Journal*.

Smith, S., & Read, D. (2008). *Mycorrhizal Symbiosis.* London: Academic Press.

Stevens, G., Bennett, J., Hennocq, Q., Lu, Y., De-Regil, L., Rogers, L., . . . Ezzati, M. (2015). Trends and mortality effects of vitamin A deficiency in children in 138 low-income and middle-income countries between 1991 and 2013: a pooled analysis of population-based surveys. *Lancet Global Health*.

Stevens, G., Finucane, M., Maria De-Regil, L., Paciorek, C., Flaxman, S., Branca, F., . . . Ezzati, M. (2013). Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995–2011: a systematic analysis of population-representative data. *Lancet Global Health*.

Thompson, B., & Amoroso, L. (2014). *Improving Diets and Nutrition: Food-Based Approaches.* Rome and Walling : FAO and CABI.

UNICEF. (2009). *Tracking progress on child and maternal nutrition.*

UNICEF. (2013). *National Nutrition Survey Afghanistan.*

UNICEF. (2016). *Nepal National Micronutrient Status Survey.* Ministry of Health and Population, Government of Nepal.

UNICEF. (2018). *National Nutrition Survey.* Islamabad: Nutrition Wing, Ministry of National Health Services, Regulations and Coordination, Government of Pakistan.

Watanabe, K., Sassa, Y., Suda, E., Chen, C., Inaba, M., & Kikuchi, A. (2005). Global political, economic, social and technological issues on transgenic crops—review. *Plant Biotechnology Journal*.

Weerahewa, J., Wijetunga, C. S., Babu, S. C., & Atapattu, N. (2018). *Food Policies and Nutrition Transition in Sri Lanka.* International Food Policy Research Institute.

Wessells, K., Singh, G., & Brown, K. (2012). Estimating the global prevalence of inadequate zinc intake from national food balance sheets: effects of methodological assumptions. *PLoS One*.

White, P. J., & Broadley, M. R. (2005). Biofortifying crops with essential mineral elements. *Trends in Plant Science*.

WHO. (2008). *Worldwide prevalence of anaemic.*

WHO. (2009). *Global prevalence of vitamin A deficiency in populations at risk.*

Wissuwa, M., & Ae, N. (2001). Genotypic variation for tolerance to phosphorus deficiency in rice and the potential for its exploitation in rice improvement. *Plant Breeding*.

Yadava, D. K., Hossain, F., & Mohapatra, T. (2018). Nutritional security through crop biofortification in India: Status & future prospects. *Indian Journal of Medical Research*.

Zhu, C., Naqvi, S., Gomez-Galera, S., Pelacho, A. M., Capell, T., & Christou, P. (2017). Transgenic strategies for the nutritional enhancement of plants. *Trends in Plant Science*.

Zuma, M., Kolanisi, U., & Modi, A. (2018). The Potential of Integrating Provitamin A-Biofortified Maize in Smallholder Farming Systems to Reduce Malnourishment in South Africa. *International Journal of Environmental Research and Public Health*.