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Review

Biofortification of Staple Crops to Eradicate Hidden Hunger: A Review

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ABSTRACT: There is a very close association between humans' beings and the enormous wealth of plants on this green planet. Amid the large floral diversity, numerous plants have been used for exclusive purposes, most notably the food. Though many staple crop plants and vegetables are rich sources of carbohydrates, proteins, and fats to meet hunger and require nourishment, they invariably lack some of the essential minerals and vitamins vital for the ideal growth of a human being. Globally, a large portion of the populace is facing 'hidden hunger' attributable to the deficit of certain minerals and vitamins in their routine diet because most of the staple food and fodder are deficient in any specific essential nutrients and vitamins. To meet this problem, people have used many approaches and developed new methods to improve staple crops. Biofortification is one such method which is used extensively by the researchers. In this attempt, various tactics of biofortification have been reviewed. The review also conferred that besides the attainment of a great success in many staple crops there are some limitation exist in the applicability of this advancement.

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1. INTRODUCTION

Predominantly, food crops exhibit deficiency in terms of their nutritional properties. It is tough to discover any such crop with enough nutrients to be used as an ideal and complete diet. Hence, the researchers have implemented their ideas to better the food crops through 'biofortification' (Bouis & Welch, 2010). In this approach, the nutrient concentration of food crops is augmented. In the past, it was achieved using conventional plant breeding, afterwards with improved agronomic practices and now through modern biotechnological methods without forfeiting any of the valuable characteristics of the preferred crops that are appreciated by consumers and farmers (Valença et al., 2017).

Though much work has been done in the past, and many attempts are still continuous, this particular aspect of crop improvement needs regular updates to a greater extent. It is a known fact that a considerable proportion of the human populace is suffering from 'Hidden Hunger". Hence this review is an effort in this direction that would enrich understanding the various causes and impacts of undernourishment and strategies used for biofortification to solve the problem.

2. METHODOLOGY

The present appraisal has been compiled with the help of various relevant works of literature that are liberally available on the internet via NCBI, Pub Med, Web of Science, Google Scholar, Scopus, etc.

3. MAJOR DEFICIENCIES IN PLANTS

Earlier, it was reported that the primary crops are usually deficient in Iron (Fe), calcium (Ca), vitamin A, and vitamin C. This deficiency causes nutritional disorders like anemia, osteoporosis, night blindness and scurvy, respectively (Agarwal et al., 2015; Debenoist et al., 2008; Fao, 2015; Heaney, 2000). For instance, deficiency of Zinc (Zn) was linked with stunting and hypogonadism (A.S. Prasad, 2013), while deficiency of Selenium (Se) was related to the problems of weak joints in humans (Sunde et al., 2010). Though numerous dietary supplements are obtainable to encounter these deficiencies, unfortunately, they are only accessible to rich people, and common people are usually away from these due to poverty in most countries (USNIH, 2017; Walker, 2014). Subsequently, in such countries, agronomic biofortification using chemical fertilizers is the most common approach economically friendly

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method, and they usually tend to neglect the ecological aspects of this (Valença et al., 2017).

The agronomic biofortification through chemical-based fertilizers was found reasonably practical and well established in the case of many crops worldwide (Smil, 2002). For instance, in India, Tandon (1994) reported the upsurge in rice harvest due to nitrogen supply was 27–28%, for wheat, it was 59%, in sorghum it was 68%, while for maize, it was 64% and 58% in case of pearl millet (Manwaring et al., 2016) . Likewise, Stewart et al. (2005) performed many field trials in the USA, and certain other nations reported that lack of nitrogen fertilizers caused a 41%, 27% and 16% reduction in the overall yield of maize, rice and wheat, respectively. Later, Erisman et al. (2008) also emphasized the finding of ammonia synthesis and its use in nitrogenous fertilizers. They also emphasized that almost 50% of the world populace would have suffered starvation without this. Whereas Synder et al. (2009) also mentioned the importance of nitrogen fertilizers for food availability to almost 40% of the world's population. According to Tillman et al. (2011), it is expected that to encounter the food scarcity for growing populace from 2005 to 2050, worldwide the farmers will have to harvest equally surplus food yearly as it happened in the last 2000 years. He estimated that about 250 million tons of nitrogen fertilizer will be needed yearly by 2050, i.e. more than the two fold consumed in 2005 (R. Prasad & Shivay, 2020).

4. SIGNIFICANT ISSUES IN THE NUTRITIONAL STATUS OF FOOD CROPS

The significant issues in the nutritional status of food crops generally include vitamin and mineral deficiencies. To address these issues related to malnutrition, Biofortification has been used to lessen the deficiencies of vitamins like pro-vitamin A, carotenoid, minerals deficiency like Zn, Fe, Se, etc. in many crops, viz., beans, cowpea, pearl millet, maize, rice, wheat, cassava, and sweet potato (Grusak & Penna, 1999; Miret & Munné-Bosch, 2014).

Apart from augmentation of vitamins and nutrients for a better nutritional profile, the other aspects of Biofortification include the easier bioavailability of micronutrients (Bouis & Welch, 2010), retention of nutrients and vitamins in cooked, processed and stored foods (Amarakoon et al., 2012; Hirschi, 2009) in comparison of non-biofortified foods. The primary aim is to provide biofortified staple crops that can improve micronutrient intake to those populaces where the diet is limited in any of the micronutrients/vitamins.

5. PROGRESS IN ATTAINING BIOFORTIFIED CROPS

Several attempts have been made in this direction considering the importance of proper nutrition. The obtained results are encouraging for iron-biofortified crops worldwide. The outstanding examples are (1) the Philippines, the moderately biofortified rice for Fe has upgraded the iron rations in reproductive-age women (Cao et al., 2019); (2) India, iron-biofortification was done in pearl millet which has augmented the iron level in children (Santos et al., 2017) and (3) Rwanda the iron-biofortified beans have upgraded the iron levels in the local women inhabitants (Kumar et al., 2019).

Regarding deficiency of vitamin, A evidence is available that orange-coloured sweet potatoes with pro-vitamin A biofortification lessens the vitamin A deficit children of especially in African nations (Kondwakwenda et al., 2018; Singh et al., 2013), while in Bangladesh, an attempt displayed augmented pro-vitamin A concentration without any improvement in the status of vitamin A as an exception (Lucca et al., 2006). However, an attempt with pro-vitamin A biofortified yellow cassava had shown an upsurge in vitamin A grade and a better augmentation in pro-vitamin A content in school children of Kenya (Talsma et al., 2016).

6. PRINCIPLE APPROACHES FOR BIOFORTIFICATION

In the recent past, supplementation of food remained the principal approach utilized for nutrition and vitamins fortification. However, this approach has some feebleness, together with the reduced bioavailability of some of the micronutrients after food release. Hence, biofortification has been taken into consideration as a prospect to provide executable program via (a) The agronomic tactic, (b) traditional plant breeding, and (c) gene engineering (Hirschi, 2009; White & Broadley, 2009).

6.1. Uptake and bioaccumulation of nutrients through vegetation

The plant species are usually capable of uptake, accumulate and translocate the minerals through their clear compartmentalization. However, these activities of plants also depend upon the ambient environmental and internal crosstalk amid various types of nutrients (Fageria, 2006; Rossi et al., 2004). For instance, Fe is a crucial nutrient both at micro and macro levels for the plant's metabolic process, overall progress, and growth (Briat et al., 1995). Fe may be absorbed through the roots in its Fe^{2+} form, subsequently oxidized to Fe^{3+}, then chelated through citrate, followed by its transport to the highest aerial point of the plant (Brown, 1978). Likewise, Zn is also a crucial mineral nutrient for plant progression and growth, which gathers ideally within the vacuoles of the epidermis of the leaf in the form of electron-dense forms (Vazquez et al., 1992, 1994).

Nonetheless, most of the staple crops have shown deficiency of minerals (Fe and Zn mainly) and vitamins A. Therefore, the local consumers have no option, and as a result, they remain deficient in metabolically essential components. Subsequently, many attempts were made through several tactics, and some of them were readily accepted, and the consumers did not accept some due to various concerns.

6.2. Use of Fertilizers for Biofortification

Earlier the use of fertilizers was considered appropriate to argue the nutritional status of many crops. However, in the recent past, the use of nitrogen fertilizers has been criticized by environmentalists. It is proved that nitrogen fertiliser use is accountable for environmental deprivation comprising (a). Release of N_2O accountable for the problem of global warming (Kroeze, 1994), (b). Ozone layer lessening (Ravishankara et al., 2009), (c). Nitrate accumulation of land and oceans (Caraco & Cole, 1999) resulting in algal blossoming, which is blamable for faunal death (Julio et al., 2005; Synder, 2008); and (d). Nitrate augmentation of surrounding groundwater is responsible for the blue baby syndrome (methemoglobinemia) (S.K. Gupta et al., 2000; Knobeloch et al., 2000; Lorna, 2004).

In recent times, phosphate fertilizers are also doubted for eutrophication of water bodies causing the "red tides" and associated with mortality of aquatic animals including (Williams, 2018).Such extraordinary rates of fertilizer use in many countries are alarming because their governments provide support to the manures manufacturing units to manufacture, carriage, storage and dissemination (Liu et al., 2014). Doering et al. (2018) considered China a best-case regarding the problematic strategy of excessive nitrogen fertilizers. The surplus use of fertilizers in many countries have brought a setback to the fertilizers.

A different setback to fertilizer's application has emerged from the awareness of organic food; consequently, many vegetables and fruits now prefer to be grown with organic manures devoid of chemical fertilizers according to the recommendations for organic production of fruits and vegetables (Coleman, 2012). Though the healthiness claims regarding organic foods are debatable (Baranski et al., 2017; Joel & Janet, 2012; Paull, 2011), they are preferred in developed countries. Hence, there is a need for a critical inspection of the consequence of manures on the overall potentials of plant-based food with a distinct focus on vitamins, minerals and other secondary metabolites beneficial to the healthiness of consumers. Concerning that the overall productivity of organic crops will make unable to match up with the production of crops supported with chemical fertilizers, it is presumable that it would not be readily available to the developing countries at an affordable price shortly (R. Prasad, 2005).

Through the characterization, these chemical nourishments are either naturally occurring or manufactured substances that hoard more than one indispensable nutrient. Also, the word is regularly used at large N, P, and K as the primary plant nutrients. However, resources that hoard secondary (Ca, S, Mg) and micro-nutrients (Fe, Zn, Mn, B, Cu, Mo, V, Cl, Ni, Se) have also come in the category of fertilizers. They have got pronounced consideration due to extensive insufficiencies of Sulfur Tandon (1994) and other micronutrients in soil (Alloway, 2008), which leads to complications in human well-being (Ritchie & Roser, 2019). Calcium is usually supplementary as a soil improvement as $CaCO_3$, especially on acid soils (Nwachuku & Loganathan, 1991; R. Prasad & Power, 1997) or as $CaSO_4$ (gypsum) on alkaline soils (Abrol et al., 1988) for getting soils near-neutral pH. For instance, Ca used as a fertilizer is used for groundnut (*Arachis hypogea*) at the hanging phase to meet the requirements of emergent pods (Radder & Biradar, 1973).

Likewise, the application of Sulphur (S) has now been considered compulsory in several soils because of the enhanced use of urea and NH_4NO_3 instead of $NH_4)_2SO_4$ and mono- and di-ammonium phosphate rather than usual superphosphate (Tandon, 2011). Zn shortage is prevalent (Alloway, 2008), and Fe insufficiencies are now problematic in many parts of the globe (Lucena & Hernandez-Apaolaza, 2017). The ingredients in a food product that have been acknowledged chiefly from the point of view of human nourishment comprise carbohydrate, protein and fat, which are recognized as macronutrients essential for an ideal human diet (Prentice, 2005), and most researches on consequences of manures refer to the quantity and yield of these essential macronutrients. Likewise, several nutritionists have acknowledged most vitamins as essential in this direction (Combs, 2007). Though, minerals are just described as residue and have not got appropriate consideration formerly. However, recently, the significance of minerals in human wellbeing has been acknowledged (Fortmann et al., 2013; R. Prasad & Shivay, 2020). From the perspective of the consequences of fertilizer on plant-based food composition concerning vitamins and minerals, their insufficiencies are most imperative and are accepted universally. Fertilizers use can also impact other plant food ingredients, which cause issues related to human health comprising sulfur-containing amino acids (SAAS), alliin and nitrates. Moreover, calcium insufficiencies leading to diseases like osteoporosis that the liming procedure can somewhat manage in acid soils.

6.3. The use of transgenic plants in mineral biofortification

Biofortification of plants with the help of contemporary cutting-edge biotechnology strategies has been explored in the recent past. Transgenic staple crops with the elevated buildup of critical minerals, viz., Fe, Zn, and Ca within the consumable/palatable tissue, have been created and tested with appreciable success. Concurrently, transgenic plants with decreased concentrations of anti-nutrients have been developed or under trial. For instance, a plant with reduced phytate content has been established to increase the bioavailability of essential minerals by avoiding the interference of phytate in their absorption through the gut (White & Broadley, 2009).

6.3.1 Biofortified Transgenic crops for Fe and Zn

Rice (*Oryza sativa*) is a well-researched cereal crop for nutrients biofortification. It is an indispensable crop for the massive fraction of the world's deprived populace, and invariably it is undersupplied in numerous vital micronutrients. Keeping this in view, transgenic rice has delivered a typical system to augment the level of bio-available Fe and Zn in the endosperm (seed). Researchers have revealed that the metal transporter proteins in various crop species can be utilized for several metal substrates, comprising Fe, Zn, and Cd. These metallic substrates can be taken up from the substrate through the root zone. It was instituted that forfeiture of these transporter proteins' function mutants resulted in uptake failure of the essential metals into the plant cells (Morrissey & Guerinot, 2009). Researchers have

Table 1

Some biofortified commonly used vegetable crops. (Chilimba et al., 2012; Dayod et al., 2010; Narayanan et al., 2015)

Element	Crop	Usual Concentration (mg kg^{-1} FW)		Typical Increase	The dose applied to leaves or roots (mg L^{-1})	
		Min	Max		Min	Max
Ca	Potato	144	245	0.7-fold	350	5200
Mg	Onion	652	1627	1.5-fold	0	150
I	Cabbage	0.1	2.5	34.4-fold	0.1	0.6
I	Cowpea	4	1566	>100-fold	0.7	15
I	Mustard	0	0.4	41-fold	0.7	1.1
Zn	Lettuce	2.2	30.4	12.8-fold	5.2	60
Se	Cucumber	0	0.2	7.6-fold	0	30
Se	Tomato	0.3	3.4	9.1-fold	5	20
Fe	Lettuce	2.3	4.3	0.9-fold	0.8	112
Fe	Sweet potato	185	253	0.4-fold	0	100
Cu	Spinach	0.5	3.0	4.5-fold	0	3
Si	Basil	41.2	293	6.1-fold	0	100

increased Fe and Zn buildup by increased iron uptake and its subsequent transport utilizing mugineic acid (the ferric iron chelator) (Masuda et al., 2013).

Similarly, transgenic crops were created and expressed the ferritin gene (SoyferH2) from *Glycine max* (soybean). These are compelled by the two promoters, which were endosperm-specific, also to the nicotianamine synthase gene (HvNAS1), two nicotianamine- aminotransferase genes (HvNAAT-A and HvNAAT-B), along with a mugineic acid synthase gene (IDS3) of barley were utilized to upsurge mugineic acid creation in transgenic rice. The engineered plants were found forbearing of iron-less topsoil and showed augmented iron buildup by almost 2.5-fold. Under the iron-rich circumstances, these transgenic rice lines augmented iron buildup by 4-fold, almost similar to those lines that had been nurtured in either commercially used refined soil (iron-sufficient conditions) or calcareous soil (iron-shortage circumstances).

Transgenic plants having biosynthetic genes expressing ferritin and mugineic acid both displayed tolerance against the usual Fe-deficiency in calcium-rich soil, and the Fe content in the polished generation of seeds (T3), and this augmentation was around 4 and 2.5 times, respectively, related to the non-transgenic plants grown in regular and calcium-rich soil (Hefferon, 2020).

In continuance with these attempts, Li et al. (2019) have recognized a Zn transporter protein family (ZIP) to accept divalent cation in crops. They revealed that ZmZIP5 protein overexpression consequently augmented Fe and Zn levels in seeds (endosperms) of rice.

Likewise, Beasley et al. (2019) performed constitutive expression of the nicotianamine synthase 2 (OsNAS2) gene of *Oryza sativa* in *Triticum aestivem*. The modification resulted in the up-regulation of nicotianamine (NA) and 2′-deoxymugineic acid (DMA), imperative for Fe and Zn transport. As a result, the transgenic bread wheat hoarded higher concentrations of Fe and Zn in endosperm and bioavailability of Fe was also augmented in transgenic from field-grown CE-OsNAS2 grain.

In another attempt, R. Sharma and Yeh (2020) used a mutant for ethyl methanesulfonate (EMS) in Arabidopsis, adapted to iron-poor soil and confirmed the buildup of 4–7 times higher iron content than the wild-type counterparts in the root, shoot, and seeds. This mutant offered an overriding phenotype, “Metina”, which triggers the Fe controlling way by enhancing Fe homeostasis constitutively, and thus may be worthwhile in the direction of Fe biofortification. In the same way, Qiao et al. (2019) established that the gene of wheat encrypting the cell number regulator (CNR) protein displayed superior forbearance to Zn and overexpression of TaCNR5 in Arabidopsis increased translocation of Zn, Cd, and Mn from root to shoot. This specifies that heavy metal forbearance features can be used as a tool for the biofortification of important cereal grains with desirable micronutrients (Table1).

Since a similar molecular mechanism is operated for transferring Fe and Zn into plants, augmenting Fe level in rice also facilitates augmented Zn buildup. For instance, Aung et al. (2013) created a common rice transgenic line, especially in Myanmar, where around 70% of the population is iron-poor regarding their nourishment. This line was capable of over-expressing the nicotianamine synthase gene (HvNAS1) to improve iron transport, the Fe(II)-nicotianamine transporter gene (OsYSL2) to transfer Fe to the endosperm and the Fe storage protein gene (SoyferH2) to upsurge iron buildup in the endosperm of the seeds. These rice plants displayed enhanced accumulation of over 3.4-fold higher concentrations of Fe; furthermore, about 1.3-fold higher Zn concentrations were also reported compared to traditional, non-transgenic rice lines. The obtained results were beneficial to address the deficiency of these two micronutrients for the populace of Myanmar.

Paul et al. (2014) created transgenic better performing Indica rice in which the soybean-origin ferritin gene was expressed. Even in the fourth generation, the resultant transgenic rice yielded more than 2.6-fold elevated levels of ferritin than the non-transgenic equivalents. When milled, the transgenic grains delivered about 2.50-fold and 1.50-fold proliferations in Fe and Zn content, separately. Likewise, the iron transporter gene (MxIRT1) attained from apple was used by Tan et al. (2018) to produce transgenic rice plants that showed an upsurge in Fe and Zn of 3-fold, as well as a decrease in Cd concentration, was also observed. Cd is supposed to contest with Fe and Zn for transportation and buildup in the rice endosperm and, therefore, lower levels of Cd can reduce the harmfulness in the seed.

Other methods have also done enhancements in Fe and Zn biofortification. For instance, Trijatmiko et al. (2016) established that plants were containing soybean ferritin (SferH-1) and rice nicotianamine synthase (OsNAS2) genes infatuated augmented content of Fe and Zn in the endosperm. A Caco-2 cellular assay showed that transgenic rice's augmented Fe and Zn content was bio-available at a good strength. Transgenic plants created by Banakar et al. (2017) showed elevated levels of nicotianamine and 2′-deoxymugenic acid (DMA) and were capable of accruing up about 4-fold more Fe and 2-fold more Zn endosperm, with lower levels of Cd compared to their wild-type rice plants.

Besides the members of the family Poaceae, other important members of the family Fabaceae have also been studied for Fe and Zn biofortification using transgenic approaches. In one such attempt, Tan et al. (2018) upgraded Fe levels in *Cicer arietinum* L. (chickpea) by enhancing iron transport and accumulation by creating a merger of Cicer arietinum nicotianamine synthase 2 (CaNAS2) and Glycine max ferritin (GmFER) genes. Transgenic plants of Cicer arietinum over-expressed these genes, demonstrated a 2-fold increase in Na concentration, signifying an upsurge in Fe bioavailability (**Table 1**).

6.3.2 Calcium-biofortified transgenic plants

The calcium level of crops has also been augmented through transgenic approaches. The developments pivot on upgraded information of how the soluble form of calcium ions existed in the loam are conveyed and hoard in various tissues of plant (Doyad et al., 2010). Ca performs a meaningful role in overall cell signalling and can affect the dietary status of animals and human beings. Park et al. (2009) have produced transgenic plants, viz., potato, tomato, carrots, and lettuce expressing elevated levels of Ca transporters. There is a short cation exchanger (sCAX1) among the Ca transporters, which can escalate Ca transport into the vacuoles of the plant cell (Connolly, 2008). Improved Ca absorption was already confirmed in animal models that were fed on transgenic plants.

Likewise, researchers have observed that the usually neglected finger millet would be a good candidate in biofortification as it has high calcium content through the knowledge of strategies behind Ca uptake, its transportation, and finally, the buildup in grain. It was stated that change in the environment might adversely affect mineral buildup in diverse plants; this could minimize their further ease of access from food crops to both human beings and animals (Martínez-Ballesta et al., 2010).

7. VITAMINS BIOACCUMULATION IN CROPS

Some vitamins, viz., folic acid and β-carotene, are vital for everyday health. The progress of microbial biochemistry enabled better knowledge of the biosynthetic pathways responsible for vitamin production in plant species. Plants manufacture almost all vitamins essential in the diet with the exemption of vitamin C (ascorbic acid), which is precisely manufactured by cells (Ishikawa et al., 2006; Miret & Munné-Bosch, 2014; Smith et al., 2007). Invariably the biosynthesis is compartmentalized inside different organelles. Due to the better understanding of the metabolism in vitamin production, many transgenic plants can be generated with the elevated buildup of essential vitamins.

7.1. Transgenic biofortification strategies for vitamins buildup

Transgenic technology has a prospective to lessen the global affliction of under-nourishment and unseen starvation. Vitamin-or mineral-enriched transgenic biofortified food products are supposed to be the successive cohort of transgenic foods. Non-transgenic biofortified foods have been generally developed and sell at markets; however, the practical conservative breeding techniques may be insufficient for crops with a truncated level or devoid of definite micronutrients (Beyer, 2010).

8. BIOFORTIFICATION AND PHYTOREMEDIATION

In contemporary agricultural practices, the eventual objective is to produce wholesome and harmless foodstuff in sufficient amounts with a sustainable environment. By incorporating conventional and modern strategies, appreciable success has been achieved in the augmentation of crop yields; however, an increase in the mineral contents has become imperative since a large portion of the global population is in the misery of malnutrition in this regard. Biofortification of many trace minerals can be attained through composting, crop breeding and/or agricultural biotechnology. Conversely, soils polluted with metals/ metalloids possibly cleaned up using phytoremedial approaches, viz., phytoextraction that unites hyperaccumulation with high biomass manufacture (P.K. Gupta et al., 2021). However, several advancements have been made in recognizing the inter-specific and intra-specific deviations in the buildup of trace elements and mechanistic perceptive regarding the cellular transportation of these trace nutrients and subsequent homeostasis in plants. However, the applicability of Phytoremediation in biofortification remains to be explained. Hence this particular area is a credible prospect to be explored.

9. BEHAVIORAL CONCERNS ASSOCIATED WITH BIOFORTIFICATION

There are two main behavioral concerns associated with biofortification at the farmers and consumers' levels, respectively. On the one hand, the farmers are concerned about planting those varieties with superior agronomical traits than the current varieties of their preferred crops, viz., varieties tolerant to drought and other common diseases (Fan, 2016). Invariably, farmers neglect the crops having upgraded concentration of micronutrients if they have any vigorously growing varieties (A. Sharma & Verma, 2019). Therefore, biofortified varieties must have other traits of interest and high mineral contents to win the preference of the local farmers.

Likewise, biofortified crops usually exhibit different coloration in comparison to the usual crops, which possesses a hindrance at consumer's end, for instance, Pro-vitamin A carotenoid gives distinct color to foods; therefore, motivation of consumers to revolutionized their purchasing and consumption habits from white- to orange-fleshed foods, viz., cassava, maize, sweet potato, etc. (Ye et al., 2000). Apart from the color in few crops, the taste of foods is also pretentious due to the improved concentration of pro-vitamin A, hence not preferred. Therefore, general acceptability has to be promoted through beneficial information related to the health of the food/food products (Shwetha et al., 2020).

10. DISCUSSION

With increasing populations, especially in developing and under-developed countries, the scarcity of food crops and malnutrition exist simultaneously. The hardly available food to them can fulfil their daily diet, but it is evident that the majority of such populace is facing hidden hunger as they are not getting nutritious food and are prone to various infectious entities. Since the understanding of this hidden hunger, researchers have started to counter this challenge initially by using chemical fertilizers and afterwards through transgenic biofortified crops. Later on, organic farming also seems to be a possible approach in this direction. All three possible methods have their benefits and drawbacks that have been discussed in the recent past. However, keeping all the points along with the major problem of hidden malnutrition, there is an acute need to encourage the use of transgenic biofortified crops so that desirable nourishment can be delivered to the needy populace globally.

Though the deficiency of nutrients like Fe, Zn, and pro-vitamin A is prevalent in the developing world, staple crops like rice, wheat, and few lentils are consequently majorly transformed. Nevertheless, many other micronutrients exist scarcely in other food crops and there is a need to create transgenic vegetables to provide better nourishment to the populace than the existing non-transformed forms.

Now the time has come to solve the ethical, social, and environmental concerns regarding transgenic biofortified crops' safe and economical use. Phytoremediation should also be a consideration for the sustainability of the environment during the use of various fortification approaches. Likewise, technology transfer is another issue that must be sorted out among the developed and developing world, considering humanity and moral background.

11. CONCLUSION

Agronomic and transgenic biofortification of food crops can be used to increase human nutrition for needy populaces. There are few practical approaches by which biofortification can be done. The conventional approach seems well enough in this direction if we neglect the environmental concerns. Organic farming is another way to get biofortified crops, but it also has the issue of high cost therefore hard to attain for the poor but needy people. The transgenic approach is a perfect answer to all the environmental concerns, but it also has few limitations, like several ethical concerns and availability in the developing world. However, the existing situation presents signs of changes with the agreement on the 'Golden Rice' in many nations. Also, the applicability of phytoremediation and biofortification has to be evaluated for a sustainable environment for better used in the future. It is expected that other transgenic biofortified food crops will quickly get authorization from various regulatory bodies, and therefore support to lessen malnutrition or hidden hunger worldwide. Therefore, governments of different countries must form a policy in which all the issues can be settled by mutual consent and the hidden hunger can be eliminated from this planet.

CONFLICTS OF INTEREST

The authors declare no competing interests.

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AUTHOR CONTRIBUTIONS

This work was carried out in collaboration among all authors. AA has conceptualized the topic. K, AS, and FB collected all available literature. IE wrote the first draft of the manuscript. CB critically reviewed the study. All authors read and approved the final manuscript.

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