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Biofortified Seeds in the Amelioration of Hidden Hunger: Current Status and Challenges

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ABSTRACT: Hidden hunger attributed as triple burden of malnutrition is a pessimistic situation currently affecting life globally. Expansion of high yielding but micronutrient deficient cultivars have further exacerbated the issue by exerting additional burden on poor people, children and pregnant women especially. Agricultural policies and its technological interventions possessed enormous potential in targeting hidden hunger through bio-fortification Bio-fortification enhance the nutrient uptake from soil, eradicates anti-nutritional factors thereby enriches the crop with micronutrients. Bio-fortified agri-foods are currently available worldwide but several challenges have restricted its approachability to mass population. The present review article is an attempt to propose mechanistic approach to combat hidden hunger with the help of 'Central Repository of Bio-fortified seeds' and to represent the approach standing panorama on grounds of plant breeding, genetic engineering etc. to provide bio-fortified seeds to farmers via collaborative efforts of Government of respective countries, WHO and agriculture research institutes to provide nutrient worldwide.

Keywords: Bio-fortification, Hidden hunger, Micronutrients, Plant breeding

INTRODUCTION

Bio-fortification can be defined as the process to enhance nutritional value of edible portion of plants by conventional agronomic interference or genetic alternation. Primary target in development of biologically fortified crops is to increase the bioavailable concentration of micronutrients, such as iron, iodine, zinc, calcium, selenium, folic acid, copper, molybdenum, cobalt, nickel, manganese, vitamin content, essential amino acids, fatty acids and elevated anti-oxidant concentration in edible portion of the crops (Hirschi *et al.*, 2009, White *et al.*, 2005, Prasad *et al.*, 2020). Comprehensive review of world's nutritional status highlighted the pessimistic prevalence of malnutrition. As per 2016 report, 11% of world's population which constitutes approximately 815 million people were observed to be underfed. Apart from health, malnutrition has also exhibited an adverse impact over the socio-economic development worldwide. It is likely to be predicted that malnutrition in every aspect could cost society up to an average of US$3.5 trillion per year, in which overweight and obesity alone constitutes a costing of US$500 billion per year. The most prevailing form of malnutrition which has bedevilled global population is 'micronutrient deficiency'. Micronutrients frailty is commonly referred as 'hidden hunger', at present which is disturbing life of more than 2 billion people (Fig. 1). The Indian government takes a two-step approach to reducing child malnutrition: a Public Distribution System makes food available at subsidized prices, and the Integrated Child Development Services (ICDS) provides nutritional supplements, bundled child and maternal services, and day-care facilities to targeted households (Bhoge, 2016).

Hidden hunger can be ascribed as triple burden of malnutrition comprising of under nutrition, micro-nutrient deficiency and the issue of being overweight or obese. The constant and boundless deprivation of micronutrients is a global food concern and can also be called as consequences of the alternatives which we have opted. Malnutrition negatively impacted people's productive ability and their prospect of accomplishing the goal of sustainable development for all (Ruel-Bergeron *et al.*, 2015). For instance, in Asia, Green Revolution concentrated on enhancing production of fewer crops often at the cost of production of broader range of food crops which could have been essential for local consumption. In last few decades, West Africans have favoured this scenario by making certain nutritious crop less accessible or relatively lesser pocket friendly thereby further contributing towards micronutrient deficiency. This possibly might be the reason because of which West African countries ranked last in uplifting the changes to overcome the situation (De Valença *et al.*, 2017). The present study is based on approach of plant breeding and genetic engineering for

provide the bio-fortified seeds globally as micronutrient concentration in our diet.

A. Strategies for Mitigating Hidden Hunger

From 1990s, fortified micronutrients together with supplementation programs have gained popularity among the National and International health agencies to address the issue of micronutrient deficiency which leads to deficiency diseases such as kwashiorkor, anaemia, scurvy, inflammation, impotency, dermatitis, gastro-intestinal disorders and cardiac disorders in low and middle-income countries (Singh *et al.*, 2011; Etienne-Mesmin *et al.*, 2017; Mays, 2018; Beigi Harchegani *et al.*, 2020; Fitzpatrick *et al.*, 2021; Yusufu, 2021). Since that time, they are rapidly getting promoted at International and National level along with involvement of Country's respective Governmental agricultural agencies. Dietary supplementation, diversification, paradigm shift towards fortified and bio-fortified crop plants are the major adapted approaches for mitigating hidden hunger. Dietary diversification is generally adapted to bring changes in dietary habits with enriched bio-available iron and zinc content but the major limitation associated with this approach is its mass implementation which is highly difficult whereas supplementation means delivery of micro-nutrients orally either in form of tablets or syrups. Oral supplementation is supportive only in cases of chronic deficiency whereas in acute deficiency cases it can hinder the normal physiology of body (Fig. 2). Among numerous ways to combat iron and zinc deficiencies in human societies is food fortification (Sharifi-Soltani *et al.*, 2016). Bio-fortification deals at genetic level and thereby enhances the bio-availability of mineral content with the adage to tackle micronutrient deficiency in food crops (Amoroso *et al.*, 2016). Among all the above mentioned approaches bio-fortification has gained extensive importance.

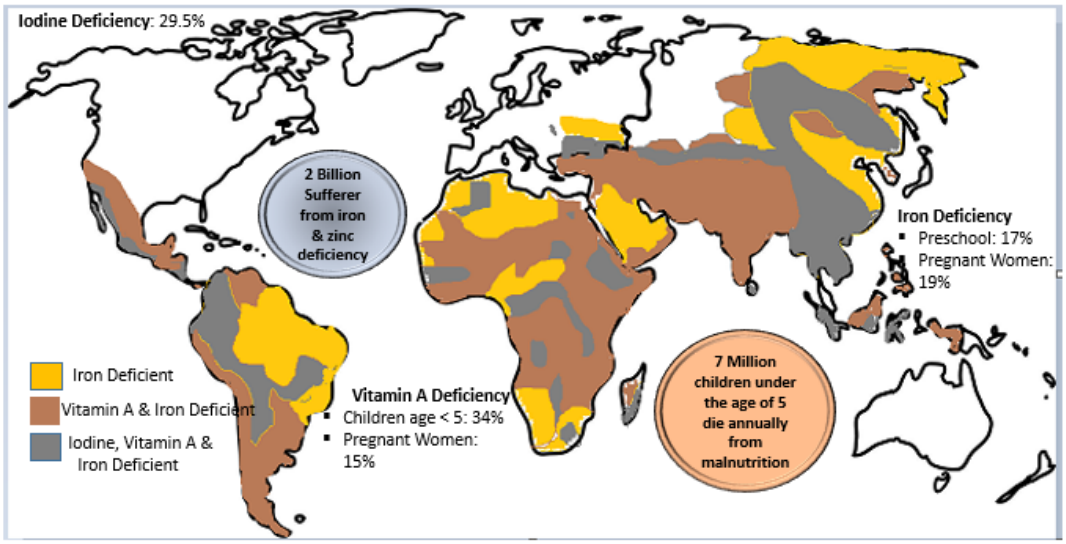

Fig. 1. Global scenario of hidden hunger.

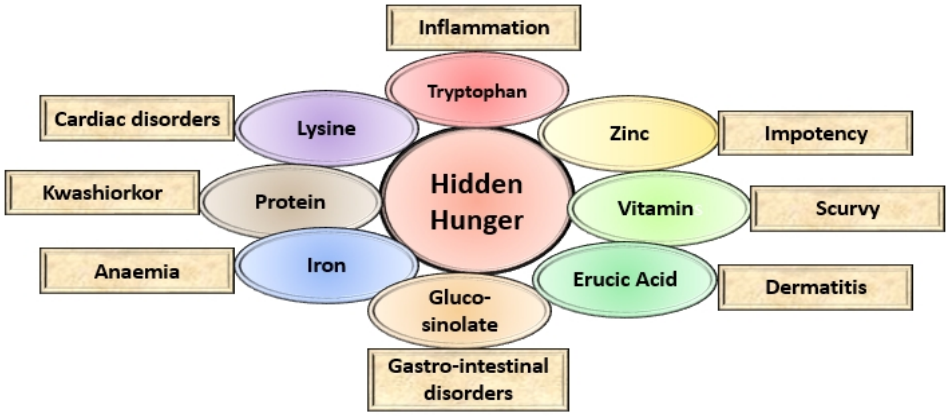

Fig. 2. Micronutrients and disease associated with their deficiency.

B. Strategic interventions to support bio-fortification

Developed and developing countries are focusing on monotonous diet enriched with rice, wheat, maize and additionally supplements their diet with fruits and vegetables whereas rural poor people are deprived of these benefits and constitutes a major proportion of hidden hunger population. Lamentably, the accessible food grains do not provide micronutrients which are essential for healthy life. Bio-fortification mainly concentrates over starchy staple crops for example rice, wheat, sorghum, etc., since they dominate in dietary habit worldwide, more commonly those groups who are afflicting with hidden hunger. Genetic engineering and adaptation of conventional breeding techniques are the major approaches for accession of bio-fortification. For the implementation, few steps need to be marked such as increased nutrient uptake from soil, amplification of nutrient transport towards grains, enhanced sequestration of mineral towards endosperm comparatively to husk and aleurone, scale down anti-nutritional factors existing in grains and enhance promotors responsible for mineral availability (Shekhar *et al.*, 2013).

C. Agricultural policies to target hidden hunger through bio-fortification

Agriculture is the prime source of production of food grains thus acts as a key factor in ensuring a sustainable life but its current policies and technological interventions are primarily concentrating in fetching profit from farms and agro-industries rather than focusing on enhancing nutritional status of food grains. Current agricultural system is primarily focussing on enhancing yield and crop productivity. This approach has led to abrupt increase in micronutrient deficiency in food grains ultimately deteriorating health of millions which needs to be considered on priority basis to avoid further damage. Emphasizing the prevalent issue of hidden hunger, agriculture can play an enormous role in uplifting the nutritional status of food grains by focussing on production of bio-fortified crops. Now a day, scientists have diverted their focus on breeding those crops whose edible portion can have better nutritional value. Malnourished communities have started choosing bio-fortified crops to combat the issue. If consumed regularly, these crops can restore micronutrients in human beings. This strategy may lead to overall elimination of hidden hunger but for the triumph of the goal various strategies at global level need to be initiated. Three major methodologies named as transgenic, crop breeding and fertilization were observed to be the potent techniques to implement the same. Staple crops have been majorly targeted by these approaches and it was identified that the practical grounds of bio-fortification can be amplified by use of transgenic along with breeding methods. The considerable benefit associated with this approach is, if a functional gene is once discovered then it can be employed many a times to achieve several targets. For example, phytoene and nicotinamide synthase, carotene desaturase and ferritin are multi-purpose genetically modified products. Transgenic wheat, barley, sorghum, soybean, lupines, potato, etc. are the successful example of this approach (Fig. 3). But inspite of vast abundance of bio-fortified food grains and vegetables, the hidden hunger rate has not declined upto a significant rate and still a major section of global population is affected with micronutrient deficiency (Hunger *et al.*, 2012, Yadava *et al.*, 2017).

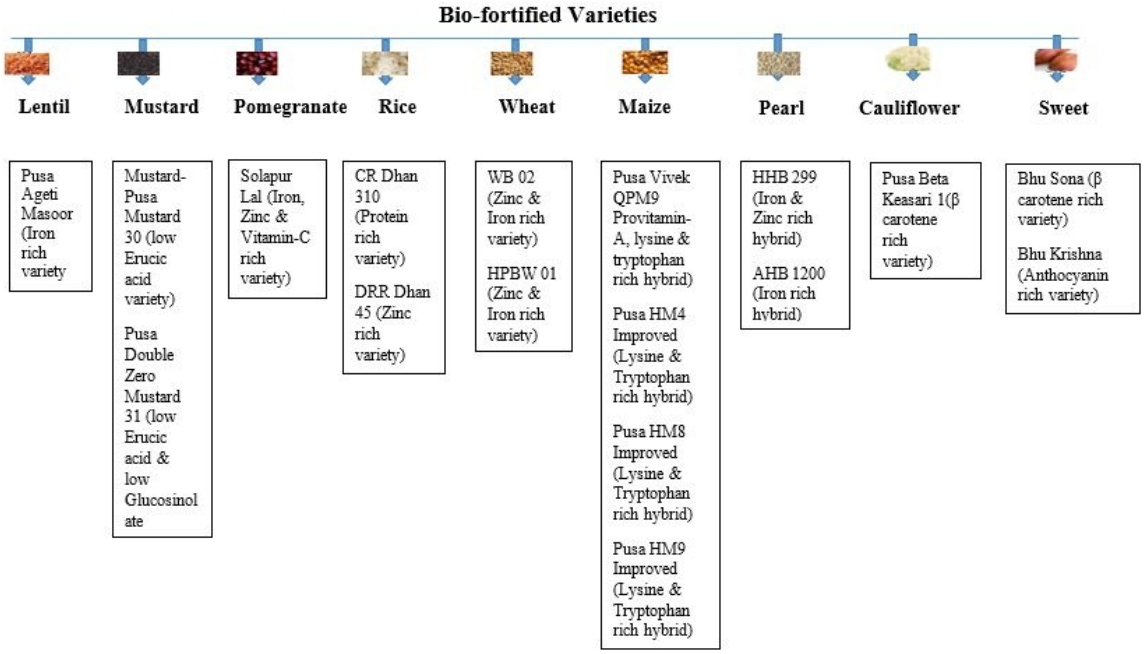

Fig. 3. Micronutrient enriched bio-fortified varieties.

D. Limitations and Challenges associated with bio-fortification

There are many factors which are limiting the accessibility of bio-fortified products and success rate in achieving the complete solution of hidden hunger. Two major behavioural issues are also associated with bio-fortification: one is related to farmer and another with consumer. Farmers are fascinated in planting those varieties which are agronomically better than the current one, for example cultivars which are drought resistant, tend to have better yield or is lesser prone to diseases. Crops which are exhibiting profound micronutrient concentration but is revealing adverse agronomic performance is directly rejected by farmers. Therefore, it can clearly have predicted that the bio-fortified varieties which are agronomically superior and micro-nutrient enriched can only compete in present scenario (Murgia *et al.,* 2012).

Global implementation of bio-fortification needs a paradigm shift and few of such limitations have been highlighted below:

1. Plant breeder's needs to work in close proximity with the nutritionists to achieve breeding targets to accomplish the objective of overcoming micronutrient deficiency. Currently agricultural science and nutrition, both these branches are not running these programs hand in hand which is an emergent need of the hour.
2. Bio-fortified products will be widely accepted only if the products will be able to prove its efficacy of comprising more nutritional level. Most of the products are still standing in developmental pipeline. Till now only few staple crop could have been released such as orange/ orange-fleshed or sweet potato for naming a few.
3. Nutrient enrichment is more prominent in cases of fortification or oral supplementation rather than the bio-fortification in which micro-nutrients are genetically bred into the crops.
4. Nutritionists have diverted their focus on 9-24 months' age group to reduce the chances of micronutrient deficiency in infants. Rather infants consumes lesser amount of staple food crops but no such attention is given to pregnant ladies.

Enhancing the efficacy of bio-fortified crops to overcome hidden hunger needs to be prioritized by agriculture institutes. There is an emergent need to identify and discover those genes which can:

→Facilitates the translocation of nutrients from soil to seed ultimately ensuring the best produce

→Leads to synthesis of essential vitamins in seed

More of such strategies can exhibit a profound effect in it and they require a substantial support at global and respective country's level (Hefferon *et al.,* 2016, Rawat *et al.,* 2013). Currently adopted techniques for implementation of bio-fortification are primarily focusing on enhancing mineral and vitamin content in crops whereas breeding of prebiotics can also enhance the absorption and utilization of micronutrients through the body thus helps in acquiring 100% benefit from the diet which we are consuming on the regular basis. Bio-fortification does not focus only on production of nutrients enriched crops rather it has diverse advantages which can complement other traditional approaches as well to eliminate hidden hunger from the society. Bio-fortification can emerge out as an efficient agriculture based strategy which can help to overcome nutritional desires of malnourished communities at global level (Yadava *et al.,* 2018). Despite of prevailing efforts made by the research community, the success rate is confined to the limited section of the society. In order to implement it and to procure the maximum benefit of the tactic we need a digitalized approach which can bring down all the initiatives at one platform to avail maximum output of it. In the next section of article, we will be discussing more about the digitalized mechanistic approach to overcome hidden hunger (Ludwig *et al.,* 2019, Harding *et al.,* 2018).

E. Digitalized mechanistic approach to overcome hidden hunger: A hypothetical approach

Digitalization in agriculture and health sector are the major tools to attain this goal. Innovatory techniques such as plant breeding and genetic engineering have fundamentally changed the shape of agricultural product in terms of both quality and quantity. These two parameters have enriched capacity to overcome health issues by combating micronutrient deficiency. Now with the help of these two interventions we have the chance to take the next leap forward via digitalized monitoring of 'Central Repository of Bio-fortified seeds' (Fig. 4). Innovations generally arise from necessity which has led to the establishment of research institutes which are day and night involved in production of bio-fortified seeds. Globally, agriculture research institutes have initiated production of several bio-fortified seeds of rice, wheat, maize, lentil, sweet potato and many more with enriched iron, zinc, Vitamin-C, carotene etc.

These products have the potential to eradicate the issue of hidden hunger from the society if consumed on regular basis but the major limitations associated in availing the benefits out of these products is their worldwide distribution. Mostly, in all corners of globe these interventions are flourishing but only a minor section of the society is able to fetch benefit out of it. Therefore, these assistance needs to be provided at world level by establishing central repository.

Major aim of this organization will be to work in collaboration with world agricultural research institutes and WHO. Bio-fortified seeds developed in research labs will be analysed in central repository along with the preparation of more of such products. Once analysed regarding quality and safety parameters inclusive of harmful chemical constituents and its capability to replace the currently available seeds available in public and private sector, with the consent of WHO it will be shared with the agriculture ministry of respective country. In the initial phase, expenses of venture could be bear by Government of respective country not only to promote the product but with the motto of complete eradication of hidden hunger from their place. From the ministry's hand the product will be handled over to agriculture research institutes from where it will be provided to the farmers with its complete implementation guidelines. Quality of seeds

will also be analysed in research institutes and its entire information will be shared with central repository and WHO. As guided by central repository, farmers will be instructed to grow that particular crop. At each step of production and processing, a complete transparency will be maintained between the repository, Government and farmers. Ultimately these bio-fortified food grains, vegetable and fruits will be supplied to the wholesaler then retailer and finally to the end consumer. Despite of exhibiting enormous benefits, it has certain limitations as well. Few sections of the society did not agree with the concept of bio-fortified food stuff.

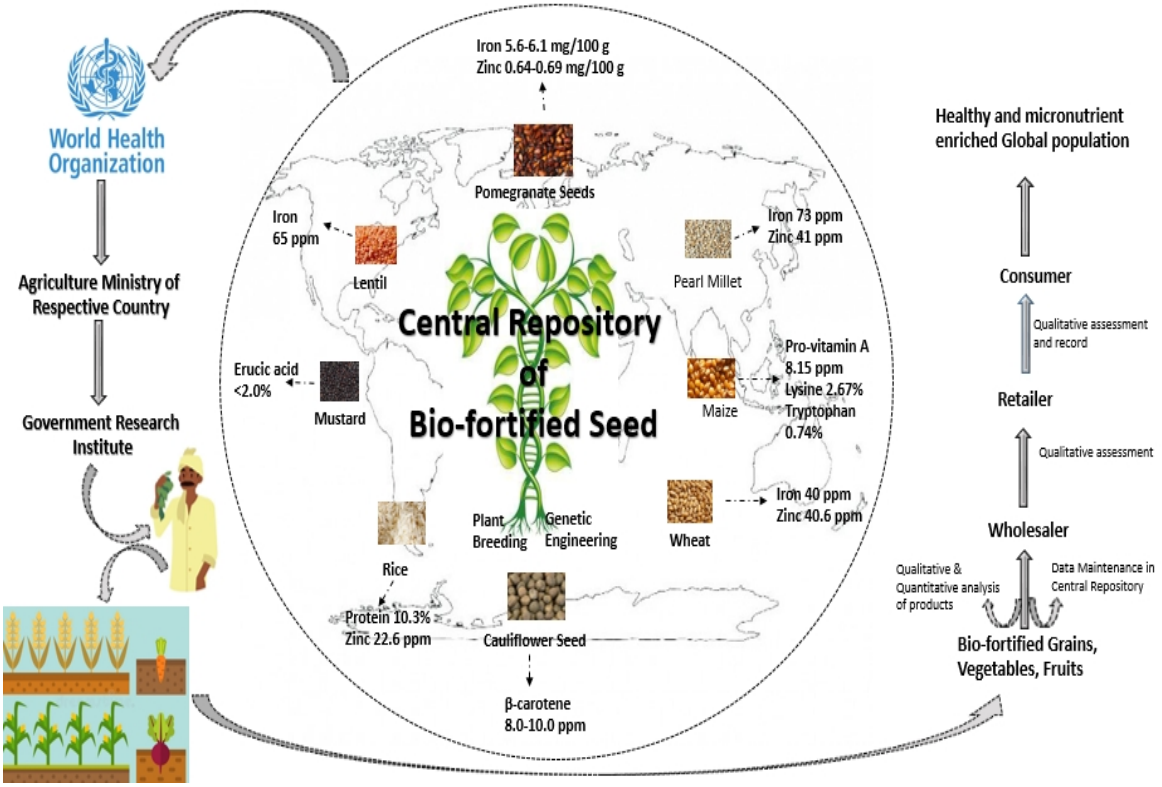

Fig. 4. A hypothesized 'Central Repository of Bio-fortified seeds' to provide bio-fortified seeds worldwide.

Infants and young children are very less dependent on food grains hence they cannot acquire much benefit out of this approach. In Africa, nutrient supplementation to the current crop is currently in demand whereas nutrient trait supplementation at the beginning of plant breeding work has obtained reluctant reviews from the population. In this scenario implementation of 'Central Repository of Bio-fortified seeds' will not be an easy task but with WHO and Government's support it can attain its desire aspirations.

The potential involvement of agricultural tool in combating hidden hunger is broad spectrum. The work encompassed by many research institutes including Patanjali Research Institute has examined the complex interaction between agriculture and hidden hunger, not only in terms of yield but even at the seed level which has acquired the best traits as a result of genetics and plant breeding tool, production of bio-fortified crops through the bio-fortified seeds have already established its grounds in various research institute. Efforts are in progress around the world to generate demand for bio-fortified food crops and to produce micro-nutrient enriched food products to provide benefit to consumers at both farmer and non-farmer level.

CONCLUSION AND FUTURE PERSPECTIVES

Prevailing importance of micronutrients in human diet is a matter of utmost concern due to increase ratio of undernourished population. Genetic engineering and plant breeding are two such fundamental approaches which can reshape the micronutrient concentration in our diet. Based upon these methodologies 'Central Repository of Bio-fortified seeds' can produce bio-fortified seeds and with the help of WHO and agricultural ministry of respective country it can be provided to farmers for the betterment of agricultural products. Although phenotypic traits of bio-fortified seeds will remain same because of which it may be hard to convince research institutes and farmers regarding enriched micronutrient status in the beginning but once initiated it exhibits vast potential to completely eradicate hidden hunger worldwide. Research community, policy makers and WHO needs to focus on this intervention to overcome growing issue of hidden hunger.

Conflict of Interest. The authors declare no conflict of interest.

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