A REVIEW ON BIOFORTIFICATION – APPROACHES AND LIMITATIONS

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ABSTRACT:

Due to poor dietary intake of micronutrients, particularly zinc and iron, micronutrient malnutrition is thought to affect more than half of the country's population and is one of the most serious global challenges facing humanity. Biofortification, or increasing the bioavailability of vital components in plant edible portions through agronomic intervention or genetic selection, could be beneficial. The Consultative Group on International Agricultural Research has been investigating the genetic potential of boosting bioavailable zinc and iron in staple food crop plants such as rice, wheat, maize, pearl millet, and others. According to efficacy and effectiveness research, as well as recent distribution successes, biofortification is a potential platform for counteracting secret hunger. This study focus on biofortification methods and a few biofortified crops.

Key words: Biofortification, approaches, biofortified crops, advantages, limitations.

Introduction:

Farming technology strive to promote the nutritional status and thus the health of the poor in developing countries. Traditionally, the topic of nutrition has been associated with outright hunger in impoverished countries, which is defined as a shortage of nutritional energy intake (FAO 2010). In turn, the argument over how to tackle the world food problem is dominated by the debate of whether hunger is a technical problem of food production or a social problem of food distribution. This is a particularly important problem since agricultural biotechnology is employed to improve crop yields. While the fact that there are approximately one billion hungry people in the world is a huge concern, micronutrition malnutrition, often known as "hidden hunger," is a big issue that often goes unrecognised (Kristof 2009; Hidden Hunger 2011; Micronutrient Initiative 2011a). Although malnutrition caused by insufficient energy intake is felt immediately by those who are hungry and is easily noticed by others because it results in waste and hindrance, a lack of trace elements in people's diets has no direct visible but potentially serious effects on the health and welfare of those affected. Micronutrient deficiencies can result in fatigue, impaired physical and mental issues, morbidity, blindness, and premature death due to increased sensitivity to infectious diseases.

Even when inadequate dietary intakes are recognised as the major cause of micronutrient deficiencies—that is, even when "hidden hunger" is known as a food-related issue—micronutrient deficiencies are often treated as health issues. WHO'S website has a section devoted to micronutrient deficiencies, which reflects this viewpoint (WHO 2011f). The most common resemblance to controlling vitamin and mineral deficiency in this context are fortification or addition (e.g., WHO 2011f; UNICEF 2011; GAIN 2011; Micronutrient initiative 2011b). A complementary solution has arisen, including to these approaches, as micronutrient malnutrition persists: breeding basic food crops for more micronutrient content. Given that micronutrient shortages are primarily a food-related problem, the concept of supplementing people's diets with what they're missing is not new; it's already been done via fortification. However, upto late 1990s, when the Consultive category on International Agricultural Research launched the "Micronutrients Project," make use of plants to protect themselves with trace elements was not followed as a reasoned strategy to address vitamin and mineral shortages on a broader fore (Bouis et al. 2000). 1. The word "biofortification" was coined just a few years later to recount micronutrient fortification of plants by breeding applications (CGIAR 2002) and, the definition was introduced into the literature (e.g., Bouis et al. 2000; Welch and Graham 2000; Bouis 2002). Furthermore, provided that Golden rice which was one of the initial biofortified crops to make headlines, Since it was previously genetically engineered (Nash 2000), and considering the political and community issues surrounding this technology, a closer examination of biofortification and by what and where it intersects with genetically modified crops is essential. (book – chapter-6; handbook of food , politics and society).Plant breeding, transgenic methods, and agronomic practises can all be used to increase the bulkness of vitamins , minerals in a crop. When biofortified staple crops are eaten, will result in measurable changes in human fitness and wellbeing if done on a regular basis.

Principle for biofortification:

Modern agriculture has mostly succeeded in supplying the energy needs of the poor in emerging countries. In the previous 40 years, agricultural science has advanced significantly. In developed countries, the Malthus issue has been solved by prioritising increasing food output. Agriculture, on the other hand, must now rely on a new paradigm that will not only produce more food, but food of higher quality as well. Plant breeding will improve the nutritional quality of the main foods that poor people already eat, providing a low-cost, costeffective, long-term strategy of distributing additional micronutrients to the poor. This strategy will not only reduce the number of chronically malnourished people who need complementary treatments, but it will also assist them in maintaining their enhanced nutritional status. Biofortification also provides a feasible route into malnourished rural areas who may lack access to commercially marketed fortified foods and supplements. Unlike traditional supplementation and fortification programmes, which require continuing financial investments, a one-time investment in plant breeding will result in micronutrient-rich plants for farmers to grow all over the world for years to come.

Biofortification approaches:

Increased mineral nutrition through biofortification is a long-term strategy. Plant culture and genetic engineering can affect mineral bioavailability. The former could be helped by agronomic interference, plant breeding, and genetic alteration. Plant breeding and genetic engineering are frequently compared since, unlike agronomic treatments, they both require changing the genotype of a target crop. Both methods have the same purpose, but their scopes are vastly different. Plant breeding does this by crossing the best-producing plants over several generations and selecting those with desirable features, but genetic engineering takes genes from anywhere and combines them. Plant breeding is restricted to genes obtain from sexually suitable plants, although genetic engineering has no such restrictions and can also use artificial genes.

The main advantage of genetic modification and plant culture for mineral enrichment is that it only requires investment during the research and development stage, after which the nutritionally enriched crops become self-sustaining. Furthermore, as previously stated, mineral-rich plants are more resilient and tolerant of biotic stress, meaning that yields will improve as mineral content rises (Frossard et al. 2000; Nestel et al. 2006). In contrast to traditional intervention methods, genetic engineering and plant breeding are both economically and environmentally viable (Stein et al. 2008). While neither approach has yet produced commercially accessible nutritionally modified plants, this technique offers the best long-term cost-effectiveness and is expected to have a big impact in the future decades. Biofortification is more accessible than traditional measures in the long run since it removes restrictions such as infrastructure and enforcement. Plants also absorb metallurgic into organic forms that are naturally accessible and add to the natural flavour and texture of the diet. In economic studies, the health benefits of biofortification have been established in numerous ways, particularly when used in conjunction with conventional medicine.

Plant breeding:

Plant breeding systems use natural genetic variation to improve the degree and bioavailability of minerals in staple crops (Welch and Graham 2005). The discovery of genetic variation affecting heritable mineral traits, their stability under various state, and the viability of breeding for increased mineral fulfilment in consumable tissues without influence yields or other standard traits are all examples of breeding approaches. Breeding for higher mineral levels has many advantages over traditional interventions (e.g., sustainability); however, no high-mineral varieties developed using this process have yet been commercialised. This give back long evolution times, especially if a wild relative is needed to introgress the mineral trait. To speed up the recognization of high-mineral traits, breeders use molecular biology techniques including QTL maps and marker-assisted selection MAS, but they must account for variations in soil properties (e.g., pH, organic composition) which may hinder with mineral absorption and accumulation. for example, In dry, alkaline soils with low organic content, the mineral pool accessible to plant roots can be extremely limited (Cakmak 2008).

Conventional plant breeding:

This enables crop scientists to develop the eating quality, nutritional ,and agronomic traits of major sustenance food crops significantly. Conventional breeding, contrastingly , is restricted because it can only use genetic diversity that is already present and visible in the crop being improved, or in rare cases, wild varieties that can cross with the crop. Furthermore, in order to attain higher levels of nutrition, traditional breeders must normally sacrifice yield and, in some cases, grain quality. for example, QPM, has taken decades of traditional plant breeding to mature into farmer-acceptable varieties. Multiple gains are often possible, such as along with Fe and Zn in rice and wheat, where the traits that lead to more zinc and iron in the plant besides lead to higher yield, according to some accounts. Other biofortified crops became successfully choose and grown for both nutritious (at least rainy season) and yield traits, such as the (OFSP) orange sweet potato assist by the HarvestPlus programme in Africa (Unnevehr et al. 2007).

Mutation breeding:

In both developed and developing countries, mutagenic breeding has been cast-off broadly to produce grain varieties with better grain quality and, in some cases, more yield and other attributes. This method takes advantage of the increased genetic diversity that can be acquired by causing mutations by chemical or irradiation treatments. More than 2500 varieties have been produced through mutation breeding, according to the FAO/IAEA website (Mutant varieties database). 1568 are from Asia, 695 from Europe, and 165 from the United States. The majority of European and American mutants are flowers, but the majority of Asian mutants are basic food crops like wheat, rice, corn, and soybeans. According to their website, one of the goals of the FAO/mutagenesis IAEA's programme is biofortification, but there don't appears to be any findings yet. In the US, mutagenic crops can be cultured and approved as organic crops, but transgenic crops generated by utilizing recombinant DNA (rDNA) applied science cannot. (Howarth E. Bouis et al., 2017).

Molecular breeding:

Since it depend on biological breeding action preferably than engineered gene edge in to alter the DNA of plants, marker-assisted breeding, also known as marker-assisted selection, is a strong tool of latest biotechnology which meets small cultural or controlling opposition and has been adopted prior to even by organic growers. With the advancement of genomics, the study of the position and function of genes, and the gradual decrease in the cost of screening plant tissue, this technique is rapidly expanding. Once scientists have pinpointed the position of a gene for a desirable trait, they create a probe that only tie up to a DNA fragment, known as a marker, that is specific to that gene. They can then use this marker to track and accelerate their attempts to introduce this trait into plant relative using traditional breeding methods reason being the marker could be identified in the tissue of fresh seedlings, the existence or missing of a preferred trait can be find out without waiting for a plant to grown, cutting the duration of a conventional crop growth period by years. If molecular breeding can cut the number of generations needed to produce a pure line variety by three generations, it can save three years of research time. In developed countries, both privatized seed corporation and government plant cultures have increased their use of molecular breeding, and it is increasingly out spread to developing nations. (Pray 2006). Plant breeders may use this technique to combine multiple genetic code that code for various traits into a single variety, such as QPM, disease defiance , and drought toleration in maize (Pray 2006). This method as also been utilized to locate recessive traits in plants that are difficult to find using traditional breeding or other methods.

Genetic engineering:

Genetic engineering, which uses modern biotechnology methods to inject genes directly into breeding varieties, is the newest tool in the arsenal against mineral deficiency. The genes might be come from any origin (along with animals and microbes) and are engineered to accomplish one or more of the following objectives (Zhu et al. 2007): (a) boost the efficiency with which minerals are mobilised in the soil, (b) reduce the level of antinutritional compounds, and (c) rise the level of nutrient enhancer composite such as inulin. Genetic engineering, also known as rDNA, is a technique that allows particular genes with desired traits to be moved directly into the living DNA of a target organism from a source organism (which does not have to be a related organism). The transgenic trait is introduced without the use of natural biological reproduction, but once in the plant, it can be passed down through the generations. This technique was initially begin in the lab in 1973, and it has been used to transform agricultural crop plants since the 1980s. If a useful gene has been established (which can take a long time and a lot of money), it is attached to both marker and promoter genes and then introduced into a plant, typically with the help of a nonviable virus called Agrobacterium. Plants produced by GE are known as transgenics, or more specifically, GMOs. Since it can add useful characteristics that aren't currently present in the seeds of individual plant species, GE has a wide scope. Golden rice, which contains the precursor to VA from a daffodil plant, required GE to be created. This was a quality that rice plants lacked, and it couldn't be implemented the traditional way since daffodils can't be crossed with rice plants. Furthermore, GE may take far less time than conventional or molecular breeding to integrate wanted traits into a plant. When it comes to biofortifying crops, breeders must figure out in what way to get the best results in the shortest amount of time considering their budget constraints. Plant breeding requires less laboratories and highly qualified human assets (molecular biologists) relative to marker assisted selection or biogenetics, and it is subject to fewer and less expensive regulatory hurdles. However, if a crop's genome lacks genes for VA precursors (for example), no amount of breeding can help. Plant breeding alone will not be enough to get them there, so scientists will have to turn to genetic engineering. Molecular breeding and genetic modifications also have advantages over conventional breeding in that they make it easier to cultivate crops with several desired nutritional traits, preserve the agronomic viability of biofortified crops, adapt agriculture improvements developed in the US to obscure crops in developing countries, and so on.

Tissue cultures:

Using sophisticated tissue culture techniques, scientists can now grow plants from a single cell or tissue. These procedures have made disease-free planting material for clonally reproduced crops like bananas widely available. When tissue culture is combined with embryo rescue techniques, plant breeders may use genetic code from a crop's wild and weedy family, which may not normally cross among cultivated crops. This allows breeders to increase cultivated crop genetic diversity while also adding valuable features from wild and weedy relatives. Scientists have used these approaches to cross Asian and African rice varieties, resulting in the Nerica rice variety, which has witnessed increasing success in Africa due to agronomic features such as increased yield and water stress resilience. Tissue culture is a useful technique for reproducing tubers and roots, such as potatoes and cassava, which are also being researched for biofortification. 2017 (Howarth E. Bouis et al.).

LIST OF FEW BIOFORTIFIED CROPS:

Maize:

In southern Africa, the CIMMYT and the IITA are leading provitamin A in maize breeding efforts in collaboration with NARES. In temperate maize, genetic variations for the goal (15ppm) of provitamin A carotenoid was discovered through germplasm screening, that was later bred into tropical diversity of plants. Recent advancements in marker-assisted selection applied science have sped up and improved the perfection of point out genes regulating important maize traits. In 2012, Zambia (3 varieties) and Nigeria (two varieties) published variants that can supply 25% of the EAR for grown-up women and preschool children. Brazil's Embrapa (www.bio-fort.com.br) has recorded a maize variety for issue in South

America that produces identical amounts of provitamin A. heterogeneity capable of providing 50% of EAR are currently being created. Provitamin A losses are less than 25% in Africa due to food proceeding and cooking process (Li etal.,2007). The storage stability tests with the varieties published in 2012 are not yet finished; a earlier analysis of different varieties revealed 25–60 percent provitamin A decay after dry and four months of dark storehouse at 25ºC. (Burt etal.,2010). Bio availability was initially thought to be 12-1 but more effective biochanging rates of 3 to1 and 6.5 to1 were found in nutrition studies (Muzhingi etal.,2011; Liang etal.,2010).

Zambia is conducting nutritional effectiveness trials, with findings due in 2013.

Rice:

Rice supplies up to 80% of the energy consumed in many Asian countries. The IRRI and the BRRI grow high-zinc rice varieties for Bangladesh and India (BRRI). The initial breeding goal in polished rice was 24 ppm zinc, an increase of 8 ppm above the marketable base-line zinc concentration. Official registration studies in Bangladesh and India are high yielding varieties with over 75 % of the target; releases are expected in 2013. In Brazil a rice high-zinc variety was discovered and released by Embrapa in 2012, and in China in 2011 it released a rice high-iron variety; company research is continuing on the high-zinc quality in this Chinese line.

Retention examine have convey that parboiling is not a substantial decrease in zinc contented of rice and not so much as Zn, as Fe is more homogeneous via the brown rice seed (Resurreccionetal.,1979; Liangetal.,2008). The loss of rice zinc during grinding and washing prior to cooking were quantified through the controlled studies of the BRRI. In the mixed grain, approximately 10% of the zinc was lost prior to cooking when washed (Juliano, 1985). When rice is poured into excessive water volumes, so another 10-14 percent of zinc can be lost before serving (Dipti,2012). Bioavailability or effectiveness of zinc-biofortified rice has not been demonstrated so far. Demonstrating the effectiveness of a food-based zinc intake intervention in response to relatively low levels of additional zinc intake is difficult because the levels of serum Zinc are not highly sensitive. More responsive zinc status biochemical indicators are needed and further research is needed in order to determine the effect on human health of zinc interventions.

Wheat:

CIMMYT is responsible for the production of high-zinc wheat for India and Pakistan. At 33 ppm of zinc was the initial breeding target for whole wheat, an increase of 8 ppm over the base line of zinc concentration. High-zinc wheat is expected to be motivated by its better agronomical characteristics as opposed to current common specimens. Zinc content and tolerance to new strains of yellow and stem rust are at the heart of breeding. Multi-location studies both in India and in Pakistan are ongoing and India anticipates the first release of 75% of the zinc target level for 2013. In China in year 2011 a variety of wheat with a concentration of zinc of 44 ppm was published overhead the target amount (www. pluschina.org harvest).

In general, the loss of the wheat mineral is proportional to the length and strength of the brewing process, while bioavailability increases as the phytate reduces simultaneously. In the context of conventional milling and cooking, the PAU assesses the losses in iron and zinc. In a women's absorption analysis in Mexico, the overall zinc absorbed was substantially greater than non-biofortified wheat in the biologically fortified variations (Rosado etal.,2009). This finding will be validated for genotype specific variations in the concentration of the phytate by added zinc intake and effect studies in 2013, as phytates possess inhibitory impact on the absorption of iron.

Pearl millet:

In the states of India Maharashtra, Gujarat, Rajasthan and Uttar Pradesh, Pearl millet is a local staple, the target region to produce biologically secure pearl millet. The breeding target was set at 77 ppm of iron and the base line was increased by 30 ppm. In collaboration with NARES and the private sector, the ICRISAT conducts pearl millet breeding research. The famous ICTP-8203 open pollinated variant (OPV) was enhanced to create ICTP-8203 Fe, the first biofortified variety containing a hundred percent of its target. In 2012, the ICTP 8203-Fe was made public. Hybrid varieties of up to 100% on-target performance are in the works.

Pearl millet iron has a poor bioavailability in humans (Guiro etal.,1991). In a recent study in India, researchers found a substantial differentiation in total iron intake within a biofortified and a control variety of pearl millet in children aged 2–3 years. Furthermore, when eaten as porridge, their on concumption from ICTP 8203-Fe pearl millet occur higher (7%) apart from initially presume for breeding target levels (5 percent). These bioavailability findings were later confirmed in Benin women of child bearing age in a follow-up analysis.
In 2013, both studies are scheduled to be released.

Lentil, cowpea and sorghum:

As detailed below, supplementary crops are being tradationally bred for excessive micronutrient levels. In general, goals levels as a % of EAR have not yet been established, and further research is needed to supply nutrition proof for biofortification's effectiveness in these crops.

The ICARDA is leading a study to biofortify lentils with more iron and zinc. Since 2009, varieties have been evaluated in Bangladesh, Ethiopia, India, Nepal, and Syria, among other countries. Early-screening-identified mineral-dense varieties are already being promoted for large-scale cultivation in Bangladesh. In Nepal, the publication of a candidate variety (ILL7723) is expected in 2012.

G.B. PantUniversity of Agriculture and Technology, Pantnagar, India, is leading Cowpea study. The Uttarakhand government launched two early-maturing cowpea varieties with high iron and zinc varietie, Pant Lobia-1 and Pant Lobia-2, in 2008 and 2010, respectively. These varieties have now been added to the national seed multiplication scheme, and farmers can now obtain seed. In 2008 and 2009, Brazil also published three high-iron cowpea varieties grown by Embrapa.

Multilocation and on-farm adaptation studies has been carried out in India in 2013 with zinc-and iron-dense sorghum hybrids formed at ICRISAT. Marketing can be planned for 2015 if competitive mineral-density hybrids arise. (Amy Saltzman et al.,2013).

Compatible advantages :

Deficiencies in micronutrients affect two billion or one in three individuals worldwide (FAO et al., 2015). These defects occur when vitamins and minerals are too poor to support good health and growth and are absorbed and absorbed. Agricultural research has raised production and accessibility of calorically solid staple crops for developing countries beyond the last 50 years, but the manufacturing of micronutrient-wealthy non-staple products such as fruits, pulses and animal produce have not increased equally. Food prices that are not stable have gradually risen, making it harder and harder for poor people to afford food quality (Bouis et al., 2011a). Micronutrient shortages can be significantly reduced in the long run by increasing the development of micronutrient-rich foods and enhancing dietary diversity. Biofortified crops will help in the near future to resolve micronutrient deficiencies by rising the daily adequacy of the intakes of micronutrients between the people during the life cycle (Bouis et al., 2011b).

Biofortification is a supplement to current treatments such as supplementation and industrial food fortification, as no single intervention can eliminate micronutrient deficiencies. Biofortification, conversely, has two distinct advantages: long-run costeffectiveness and the potential to access rural communities that are underserved. Unlike supplementation and commercial fortification schemes, which entail ongoing financial outlays, an upfront investment in plant breeding yields micronutrient-rich biofortified planting material for farmers to expand at virtually no marginal cost. Nutritionally on the mend crops can be tested and adjusted to new environments and geographies once they've been established, multiplying the returns on the initial investment. Recurrent expenses at agriculture research institutes as a means to oversee and maintenance are limited but once micronutrient quality has been incorporated into the core breeding goals of national and worldwide crop development programmes.

Furthermore, biofortified plants provide a viable means to rural communities with insufficient access to a variety of diets or other micronutrient procedures. Based on current consumption trends, target micronutrient quantity for biofortified crops are ready to meet the nutritional needs of women and children. Farmers have a solution thanks to biofortification, which combines the micronutrient feature with other agronomic and consumable traits that they prefer. Surplus biofortified crops discover their way into countryside and urban retail outlets after they have met the needs of the household Affordable cost:

Biofortification costs US$15–$20 each Disability Adjusted Life Year (DALY) saved, according to ex-post cost-effectiveness statistics for sweet potato orange in Uganda, which the World Bank considers extremely economical (World Bank, 1993; HarvestPlus, 2010). Biofortification is cost-effective, according to the results of ex-ante cost-effective studies, based on the cost per DALY saved for each country-crop-micronutrient combination utilising World Bank standards (Meenakshi et al., 2010). Furthermore, the Copenhagen Consensus identified biofortification as one of the most cost-effective investments in economic growth for reducing micronutrient shortages. For every dollar invested in biofortification, up to $17 in benefits could be received (Hoddinott et al., 2012). The cost-effectiveness of every given intervention is dependent by the seed, micronutrient, and transportation country. (Saltzman et al., 2013; Lividini and Fiedler, 2015; Asare-Marfo et al., 2013; de Brauw et al., 2015) go over the methodologies for determining cost effectiveness in more depth. (Howarth E. Bouis and colleagues, 2017) Limitations:

Micronutrients like Fe, Zn, and vitamin A (the three Harvest Plus target nutrients) can be stored in biofortified staple foods throughout one's life, including in infants, teenagers, adult women, men, and the elderly. However, the potential benefits of biofortification depend on the amount of staple food consumed, the prevalence of current micronutrient deficiencies, and the micronutrient requirement as influenced by daily micronutrient losses from the body and special needs for processes such as development, pregnancy, and lactation.

A decade will pass before a first wave of biofortified crops becomes widely accepted in many developing countries. Biofortification will take its place alongside supplementation, food securing, and nutrition education as an effective strategy for reducing micronutrient deficiency only when this occurs and attributable impact is verified, as measured by substantial reductions in the abundance of Fe, Zn, and vitamin A deficiencies.

Conclusion:

Biofortification allows malnourished communities in rural locations to receive naturally secure foods that would otherwise be unavailable or have limited access to commercially supplied fortified foods that are easier to come by in urban areas. As a result, biofortification and industrial fortification are mutually beneficial and complementary. Finally, for optimal nutrition and consumption of a variety of nutrients and other substances in diverse combinations, enough nutrition is required. As a result, increasing consumption of a variety of nutrient-dense foods in affluent countries is the most effective and final answer to ending undernutrition as a public health issue. It holds a lot of promise for plant scientists to collaborate across disciplines to explore remedies for a range of nutritional deficits. Human nutritionists must be well-versed in food and nutrition sciences. For example, kids should be informed about the vitamin and mineral content of the relevant foods, as well as compounds (such as prebiotics) that aid in the growth and development of bacteria. Their bioavailability is inhibited, but this can be changed. Plant breeders must be mindful of both the historical and current significant influences on nutrient use that agricultural research might have had (e.g., trace mineral bioavailability in modern varieties compared to conventional varieties' bioavailability) and the plant breeding's ability for future developments in health and diet.

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