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Biofortification: An Effective Strategy to Alleviate Malnutrition

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Food security is defined as uninterrupted access to sufficient food at an affordable price for a healthy existence at all times. Food security, according to FAO (2000), is when it is secured that all people at all times have physical, social, and economic access to sufficient, safe, and nutrient-dense food that satisfies their nutritional requirements and culinary preferences for a healthy and active lifestyle. The term 'nutrition' refers to components of food security such as caring practices, health services, and healthy environments. Nutritional security is described as ensuring that all household members have adequate protein, energy, vitamins, and essential nutrients at all times. Essential nutrients are those that are required for plants to complete their life cycle, are not substituted by other elements, and are directly engaged in plant metabolism. Nutrients are separated into macro- and micronutrients based on the quantity necessary. Plants require macronutrients in greater proportions than micronutrients. Carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulphur (S), magnesium (Mg), calcium (Ca), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl), and nickel (Ni) are the seventeen elements required by higher plants. Out of these Fe, Mn, Zn, Cu, B, Mo, Cl, and Ni have been classed as micronutrients, which are nutritionally significant elements required in relatively tiny quantities to complete the life cycle of organisms (plants or people). Iron (Fe), Zinc (Zn), Calcium (Ca), Molybdenum (Mo), Boron, Nickel (Ni) Selenium (Se), Iodine (I), Fluorine (F), Chromium (Cr), Vanadium (V), Silicon (Si) are among the micronutrients used in Human diet. Among these Seven Zn , Fe, Cu, Mo, B, Ni are common in humans as well as in plants. Green revolution has aided in increasing the food production that has resulted in a significant reduction in hunger, calorie, protein, and other macronutrient malnutritions and thus ensuring food as well as nutritional security. However, this resulted in great depletion of micronutrients from soil reserves, exacerbating wide spread deficits of micronutrient levels. The common micronutrient deficits in living beings, according to WHO, are iron (Fe), zinc (Zn), vitamin A (beta-carotene), selenium (Se), and iodine (I). Low productivity, diminished cognition, learning disabilities in youngsters, lower worker productivity, increased morbidity and death rates, immune system impact, and high health-care expenditures were all observed in the population affected by these deficits. Iron insufficiency affects more than 2 billion individuals, while zinc deficiency is estimated to affect a similar number of people. Iron deficiency leads to anemia and impairs mental development and learning capacity, besides aggravating weakness and fatigue, and may lead to the risk of women death during child birth. Likewise, zinc deficiency causes stunting, lowers immunity, and increases risk of diarrhoeal disease and respiratory infections. The implications of malnutrition have also been evident in national economies. A sedentary adult should ingest 0.8g of protein per kg of body weight, or 0.36 g each pound, according to the Dietary Reference Intake report for macronutrients. That means the average inactive guy should consume 56 g of protein per day, while the average sedentary woman consumes 46 g (WHO) The recommended daily allowance (RDA) for iron is 9-13 mg per day for children, 17-21 mg per day for adults, and for Zinc RDA is 5-8 mg per day for children, and 10-12 mg per day for adults.

The most effective intervention to alleviate mineral malnutrition is the implementation of a varied diet including fresh fruit, vegetables, fish and meat. This is impractical in many countries because such food is not widely available, but even where fresh food is abundant, there can be compliance issues that result in persistent low level malnutrition. Where infrastructure allows, mineral nutrition can be improved using supplements (usually in tablet/sachet form) or conventional fortification (where minerals are added to processed foods, such as packaged cereals).Unfortunately, such strategies have been largely unsuccessful in developing countries because of insufficient funding, poor governance, and a poor distribution network . A more recent development is biofortification.

Biofortification is the development of nutrient dense food crops using the best agronomic practices, breeding approaches and modern biotechnology, without sacrificing agronomic performance and important consumer preferred traits. Conventional interventions have a limited impact, so biofortification has been proposed as an alternative long-term approach for improving mineral nutrition. Biofortification focuses on enhancing the mineral nutritional qualities of crops at source, which encompasses processes that increase both mineral levels and their bioavailability in the edible part of crops. Biofortification is also likely to be more accessible than conventional interventions in the long term because, it removes hurdles such as the reliance on infrastructure and compliance. Moreover, plants assimilate minerals into organic forms that are naturally bio-available and contribute to the natural taste and texture of the food. Economic studies have shown the many potential health benefits of biofortification as well.

Approaches of biofortification

Biofortification can be achieved by different approaches viz. Agronomic interventions , Genetic engenering and breeding methods.

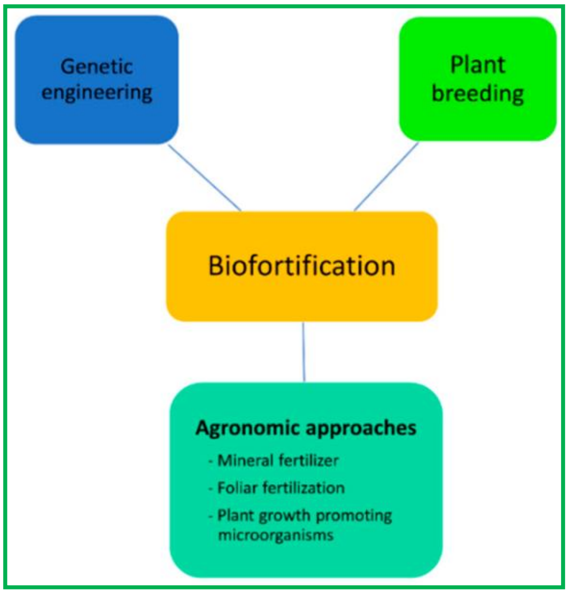
Agronomic biofortification: Agronomic biofortification provides an immediate and effective route to enhancing micronutrient concentrations in edible crop products. The application of mineral micronutrient fertilizers to soils or plant leaves to increase micronutrient contents in edible parts of crops – and it's potential to fight hidden hunger is called as Agronomic fortification. Micronutrient fertilization is most effective in combination with NPK, organic fertilizers and improved crop varieties, highlighting the importance of integrated soil fertility management. In developed countries such as Finland and New Zealand, this strategy has been applied successfully to increase the amount of Selinium (Se) in the population's diet. Agronomic biofortification works for twin objective of increasing the concentration of the micronutrients in the grains and simultaneously improving the bioavailability of micronutrients in the grains to alleviate the micronutrient deficiency in human beings and also animals. Hence agronomic biofortification of various micro nutrients especially zinc and iron , can be done through soil and foliar applications. The use of micronutrient in important food crops is one of the ways to boost up the productivity and to improve the seed quality parameters. Various experiment revealed that foliar application of zinc enhanced the growth parameters, yield parameters and quality as well as productivity.

One drawback of agronomic intervention is the cost and impact of the fertilizers. Fertilizer use is likely to increase the cost of food, thus reducing its availability to the most impoverished people. The expensive fertilizers must be applied regularly, with no direct yield incentive for farmers in developing countries, so the intervention would likely be omitted to save costs even though seeds produced under rich mineral conditions germinate more vigorously than those in poor soils. There is also concern about the impact of increased fertilizer use on the environment.

Breeding approach: Plant breeding programs focus on improving the level and bioavailability of minerals in staple crops using their natural genetic variation (Welch and Graham 2005). The HarvestPlus program was established by the Consultative Group on International Agricultural Research (CGIAR) to improve human nutrition by breeding new varieties of staple food crops consumed by the poor. It is a global alliance of institutions such as the International Rice Research Institute (IRRI),the International Maize and Wheat Improvement Center (CIMMYT), the International Center for Tropical Agriculture (CIAT) and the International Institute of Tropical Agriculture (IITA). Its aims include the discovery of genetic variation affecting heritable mineral traits, checking their stability under different conditions and the feasibility of breeding for increasing mineral content in edible tissues without affecting yields or other quality traits. Feasibility data, mainly for enhancing Fe and Zn, has been collected in the different centers and a summary of their results has been published.

Although breeding for increased mineral levels has several advantages over conventional interventions (e.g. sustainability), no high-mineral varieties produced by this method have been introduced onto the market thus far. This reflects the long development times, particularly if the mineral trait needs to be introgressed from a wild relative. Breeders utilize molecular biology *techniques such as quantitative trait locus (QTL) maps and marker-assisted selection (MAS) to accelerate the identification of high-mineral varieties, but they have to take into account differences in soil properties (e.g. pH, organic composition) that may interfere with mineral uptake and accumulation. For example, the mineral pool available to plant roots may be extremely low in dry, alkaline soils with a low organic content.

Genetic Engineering: Genetic engineering is the latest weapon in the armory against mineral deficiency, and uses advanced biotechnology techniques to introduce genes directly into breeding varieties. The genes can come from any source (including animals and microbes) and are designed to achieve one or more of the following goals. It increases the mobilization of minerals in soil , enhances mineral uptake efficiency of plant, improves the transport of minerals from the roots to storage tissues, such as grain. This approach also Increase the capacity of storage tissues to accumulate minerals in a form that does not impair plant vegetative growth and development, but remains bio-available for humans. The major advantages of genetic engineering over conventional breeding are the diversity of the source of genetic information, the speed with which modified elite varieties can be generated and, perhaps most important for the future, the fact that nutritional traits for different vitamins and minerals can be stacked in the same plant without highly complex breeding programs. Genetic engineering currently offers the only opportunity to produce nutritious staple food.



Challenges in Bio-fortification

Anti Nutrients: The absorption of Fe, Zn and Ca by the gut is hindered by some limiting factors like phytate and tannins. Phytate concentration is more pronounced in seed or grain part of the plant. Phytate concentration in edible portions of the plant is varied intra-specifically independent of differences in Fe and Zn concentrations. Non-transgenic techniques helped in developing low phytic acid (LPA) mutants. Unexpectedly, plants with LPA mutations often show higher levels of grain Fe, Zn and Mg (or similar levels to those in found in wild type), although they do have reduced concentrations of seed Ca. Tannin concentration in edible tissues also varies greatly between varieties. Hence, breeding for reduced concentrations of these antinutrients appears feasible.

Other future challenges

- Consumer preference-due to colour changes (e.g.Golden Rice) biofortified crops may not be preferred by the consumers.
- Detailed knowledge on mechanisms regulating iron compartmentalisation in various plant organs will offer a major contribution for reaching such goal.
- Promoting large-scale prospective studies on assessing the effects of nutrient enhancement in major crops in relieving malnutrition and other associated health problems
- Improving the efficiency with which minerals are mobilized¬ in the soil Enhancing the mineral uptake efficiency of the important crops.
- Expanding the understanding of mineral accumulation¬ and the transport within the plant body

Conclusion

Conventional interventions such as fortification and the provision of supplements have been successful in limited cases, such as the iodization of salt and the addition of Fe to wheat flour. The main problem with such strategies is they are not sustainable without long-term support and monitoring. In contrast, biofortification tackles the problem of mineral deficiency at source, by helping plants to accumulate more minerals. Although investment is required at the development stage, high-mineral plant varieties should be self-perpetuating and hence sustainable without further funding, making this a much more cost-effective process over the long term (Nestel et al. 2006). Although Agronomic biofortification is the easy and fastest way of fortification by fortification through breeding and genetic engineering is particularly advantageous because it removes the economic burden and potential environmental problems caused by the need for mineral fertilizers, it can be applied anywhere crops are grown, and requires minimal compliance, making it highly suited to developing countries with dispersed, impoverished, rural populations relying on subsistence agriculture.

References

1. Rattan, R.K., Kumar, M., Narwal, R.P. and Singh, A.P., 2009. Soil health and nutritional security–micronutrients. In *Proceedings of the platinum jubilee symposium. Indian Society of Soil Science, New Delhi* (pp. 249-265).
2. Fageria, N.K., Baligar, V.C. and Clark, R.B., 2002. Micronutrients in crop production. *Advances in agronomy*, *77*, pp.185-268.
3. Gómez, M.I., Barrett, C.B., Raney, T., Pinstrup-Andersen, P., Meerman, J., Croppenstedt, A., Carisma, B. and Thompson, B., 2013. Post-green revolution food systems and the triple burden of malnutrition. *Food Policy*, *42*, pp.129-138.
4. . Welch, R.M. and Graham, R.D., 2004. Breeding for micronutrients in staple food crops from a human nutrition perspective *Journal of experimental botany*, *55*(396), pp.353-364.
5. Gómez-Galera, S., Rojas, E., Sudhakar, D., Zhu, C., Pelacho, A.M., Capell, T. and Christou, P., 2010. Critical evaluation of strategies for mineral fortification of staple food crops. *Transgenic research*, *19*(2), pp.165-180.

6. Anonymous. 2010. Nutrient requirements and Recommended dietary allowances for Indians. Indian council of medical Research ,NewDehli
7. Nestel P, Bouis HE, Meenakshi JV, Pfeiffer W. Biofortification of staple food crops. The Journal of nutrition. 2006; 136(4):1064-1067.
8. Combs, G.F., 2001. Selenium in global food systems. *British journal of nutrition*, *85*(5), pp.517-547.
9. Saakshi, R. Almad, Pandit S. Rathod, V. Rachappa, B. M. Dodamani and Ananda. N. 2020. Growth, Yield and Economics of Pigeonpea as Influenced by Biofortification of Zinc and Iron. *Int.J.Curr.Microbiol.App.Sci.* 9(02): 3088-3097
10. Rayman, M.P., 2002. The argument for increasing selenium intake. *Proceedings of the nutrition Society*, *61*(2), pp.203-215.
11. Yashona, D.S., Mishra, U.S. and Aher, S.B., 2018. Response of pulse crops to sole and combined mode of zinc application: A review. *Journal of Soils and Crops*, *28*(2), pp.249-58.
12. Aciksoz, S.B., Yazici, A., Ozturk, L. and Cakmak, I., 2011. Biofortification of wheat with iron through soil and foliar application of nitrogen and iron fertilizers. *Plant and Soil*, *349*(1), pp.215-225.
13. Sunder, S., Pareek, B.L. and Sharma, S.K., 2003. Effect of phosphorus and zinc on dry matter, uptake of nutrients and quality of clusterbean. *Annals of Agricultural Research*, *24*(1), pp.195-196.
14. Basole, V.D., Deotale, R.D., Ilmulwar, S.R., Raut, S.S. and Kadwe, S.B., 2003. Effect of hormone and nutrients on morpho-physiological characters and yield of soybean. *J Soils Crops*, *13*, pp.135-139.
15. Ali, E.A. and Mahmoud, A.M., 2013. Effect of foliar spray by different salicylic acid and zinc concentrations on seed yield and yield components of mungbean in sandy soil. *Asian J. Crop Sci*, *5*(1), pp.33-40.
16. Saini, A.K., 2017. Effect of iron and sulphur fertilization on growth and yield of greengram [Vigna radiata L.]. *Journal of Pharmacognosy and Phytochemistry*, *6*(4), pp.1358-1361.
17. Rathod, P.S., Dodamani, B.M. and Patil, D., 2016. Effect of micronutrients on growth and productivity of pigeon pea under rainfed conditions. *Res. Environ. Life Sci*, *9*(6), pp.748-750.
18. Hanumanthappa, D., Vasudevan, S.N., Shakuntala, J.B., Muniswamy, N.M. and Macha, S.I., 2018. Enrichment of iron and zinc content in pigeonpea genotypes through agronomic biofortification to mitigate malnutrition. *Int. J. Curr. Microbiol. App. Sci*, *7*, pp.4334-4342.
19. Welch RM, Graham RD (2005) Agriculture: the real nexus for enhancing bioavailable micronutrients in food crops. J Trace Elements Med Biol 18:299–307.
20. Gregorio GB (2002) Progress in breeding for trace minerals in staple crops. J Nutr 132:500S–502.
21. White PJ, Broadley MR (2005) Biofortifying crops with essential mineral elements. Trends Plant Sci 10:586–593.
22. Ghandilyan A, Vreugdenhil D, Aarts MGM (2006) Progress in the genetic understanding of plant iron and zinc nutrition. Physiol Plant 126:407–417.
23. Zhu C, Naqvi S, Gomez-Galera S et al (2007) Transgenic strategies for the nutritional enhancement of plants. Trends Plant Sci 12:548–555.
24. Nestel, P., Bouis, H.E., Meenakshi, J.V. and Pfeiffer, W., 2006. Biofortification of staple food crops. *The Journal of nutrition*, *136*(4), pp.1064-1067..