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Biofortification: A Breeding Approaches in Agricultural Crops

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Abstract

Over half of the world's population suffers from micronutrient deficiency. Selenium, iron, zinc, iodine, and vitamin A deficiencies are common among the impoverished population. A sustainable and long-term strategy to address the negative effects of vitamin and nutrient deficiencies, biofortification is the practice of nutrient fortification in food plants using modern breeding, transgenic approaches, improved agronomy, and microbiological interventions to change genetic architecture, improve micronutrient uptake, and properly distribute nutrients in edible tissues to safe levels. It also involves reducing antinutrients in food staples to promote bioavailability of nutrients. With the combined efforts of national and international organizations, biofortification programs have been implemented in the potato, cassava, sweet potato, beans, cow pea, and banana industries in consideration of the nutritional impact of horticulture products.

Introduction

Acute malnutrition and micronutrient deficiencies affect two billion people globally; the majority of these persons are pregnant women and children under five (White and Broadley, 2009; WHO, 2012). Malnutrition is a contributing factor in over 45% of deaths in children under five (World Health Statistics, 2022). Malnutrition causes an 11% GDP reduction in Asia and Africa. Malnutrition is generally caused by consuming insufficient amounts of fruits, vegetables, animal products, and nutrient-rich meals; nevertheless, a significant proportion of the world's destitute cannot afford these foods and mostly rely on cereals and reasonably priced staples. Given that this improvement was attained with only a little increase in the consumption of zinc and vitamin A, it is probable that other micronutrients will also play a major role. Contrarily, biofortification is the process of increasing the concentrations of bioavailable micronutrients by means of traditional plant breeding, transgenics, and agronomic biofortification, which involves using fertilizers rich in micronutrients (FAO, 2017). The method of fortifying food involves making physical changes like adding salt to increase the nutritional density. This approach has caused global micronutrient deficiencies over time (Development efforts, 2017). The global poor's access to high-quality crop-based food has also been impacted by the negative impacts of climate change on crop output, unequal fertilization, and declining soil quality.

Biofortification types:

Despite the wide variety of biofortification methods available, they may be broadly categorized into two groups: those that employ agronomic methods (such applying micronutrient-rich fertilizers) and those that employ genetic breading methods. The following sections address the most popular methodologies that have been employed to date.

Biofortification through conventional breeding:

Over the past 10 years, the conventional breeding strategy has gained popularity and relevance. Recent research has demonstrated that this approach to micronutrient fortification is feasible, inexpensive, and generally acknowledged as compared to transgenics (Van Der Straeten et al., 2020). In order to apply this strategy, there must be enough genotypic diversity in the trait of interest. Utilizing these modern modifications can help crops become more vitamin and mineral dense. Superior-quality parent lines with high nutrient content are crossed with recipient lines with other desirable agronomical traits over multiple generations to develop plants with the right nutrient levels and agronomic features. The lack of genetic diversity in the gene pool may seriously restrict this approach; it may be addressed by mating with distant relatives, but doing so would impede the transfer of desired traits into the intended commercial cultivar. Alternatively, mutagens can be used to create commercial versions. Because breeding is so quick, many groups all over the globe have started breeding initiatives to increase the number of micronutrients in crops.

Biofortification through transgenic means:

Under certain conditions, the transgenic technology can serve as a backup plan for producing biofortified crops. Transgenic crops cannot be produced without understanding the functions of genes and applying them to alter plant metabolism (Newell-McGloughlin, 2008). By introducing processes from different species—most notably bacteria—new metabolic engineering paths can be found in crops (Newell-McGloughlin, 2008). Through gene integration, anti-nutrients that decrease nutrient bioavailability in the plant system can be reduced, and micronutrient concentrations and bioavailability can both rise at the same time. Furthermore, micronutrients can be transferred from one tissue to another through genetic modification, increasing the biochemical route's effectiveness and improving micronutrient availability in edible crop tissue (Yang et al., 2002; Agrawal et al., 2005). Many crops have undergone genetic manipulation to increase their micronutrient content. Many genes have been employed to target specific micronutrients, including as vitamins, minerals, essential fatty acids, and essential amino acids, in an effort to boost the nutritional content of crops.

Biofortification using agronomic methods:

Agronomic biofortification, which makes use of fertilizers enhanced with micronutrients, is a rapid and simple method of raising the nutritional content of a crop. Human nutrition status is also improved by eating these crops (Cakmak and Kutman, 2017). Agronomic biofortification frequently employs techniques for fertilizer administration, mineral element solubilization, and mobility from source to sink (consumable portions of a plant). Potassium (K), phosphorus (P), and nitrogen (N) are macrominerals that aid in reaching higher output goals. The green revolution, which was brought about by a sharp increase in agricultural productivity as well as the creation and application of fertilizers rich in macronutrients, prevented starvation in the 1960s throughout the world, particularly in developing countries. As a result, it is suggested to administer micronutrients by alternate techniques including soluble form foliar sprays. If certain considerations are made, such as the type of fertilizer, application method, and timing, agronomic biofortification can be a low-cost and simple strategy.

Agronomic biofortification in cereals:

In addition to fertilizers, mycorrhizal fungi and biofertilizers are commonly employed for biofortification. When mixed with chemical and organic fertilizers, Bacillus aryabhattai has been shown to be advantageous for Zn biofortification of wheat grains Nutrient enrichment is the outcome of using plant-development-promoting rhizobacteria as an agronomic method for the biofortification of staple crops. Sorghum is grown all over the world for its grain and feed qualities. Crops are generally harmed by dirty and nutrient-deficient soil. Fertilizers, both organic and artificial, can improve yields and nutritional characteristics. It has been demonstrated that mycorrhizal fungi and bacteria that support plant growth significantly impact the metabolic profile and nutrient absorption (Dhawi et al., 2015; Dhawi et al., 2016). By increasing the soil's nitrogen and phosphorus content, phosphate-solubilizing bacterial inoculation of Azospirillum boosted grain output and protein content.

Agronomic biofortification in legumes:

It has been demonstrated that mycorrhizal fungi and bacteria that support plant growth significantly impact the metabolic profile and nutrient absorption (Dhawi et al., 2015; Dhawi et al., 2016). By increasing the soil's nitrogen and phosphorus content, phosphate-solubilizing bacterial inoculation of Azospirillum boosted grain output and protein content (Patidar and Mali, 2004). Cowpea yield outcomes, nodules plant-1, root length, absorption, and nutrient concentration were considerably increased by adding Mo to the soil in combination with foliar treatments of FeSO4-7H2O (0.5%) and ZnSO4-7H2O (0.5%) in order to solve the micronutrient deficit (Dhaliwal et al., 2022). The overall content of crude protein, carbohydrates, elements (Fe, Cu, Zn, and Mn), and several amino acids was increased when FeNPs were applied topically to broad-bean seeds. Selenium-rich soybeans have been grown by topically applying selenium complex fertilizers (Yang et al., 2003). Chickpeas that were enhanced with zinc and selenium were grown by spraying the leaves with the appropriate minerals (Poblaciones et al., 2014; Shivay et al., 2015).

Agronomic biofortification in oilseeds and vegetables:

Canola treated with fertilizers and plant growth-promoting rhizobacteria like Azospirillum brasilense and Azotobacter vinelandii exhibited higher levels of oleic acid, linoleic acid, and protein. Research has demonstrated that the presence of rhizobacteria significantly boosted the nutritional value of canola oil. Rhizospheric bacteria and their formulations to promote Se uptake in the plant have been the main means by which the primary goal of enhancing selenium (Se) in the mustard crop has been accomplished thus far. When selenite and seleniate were administered topically, the amount of selenium in potatoes increased (Poggi et al., 2000; Cuderman et al., 2008). Martin et al. conducted a study in 2020 on the foliar and soil application of zinc to biofortify broccoli. The results demonstrated that broccoli absorbed more zinc when zinc sulfate was applied topically and subsurfacely. An efficient agronomic method for producing Fe-biofortified quinoa grains is foliar Fe spraying. Because plants are sensitive to zinc, maintaining optimal yield and quality through agronomic biofortification necessitates managing zinc concentrations throughout each growing season. the agronomic biofortification of tomatoes through the application of sodium selenite (Na2SeO3) at different concentrations to raise the selenium content of tomato fruits and plants. After applying sodium selenite (5 mg L-1) to various plant parts and fruits, the majority of agronomic parameters, including the selenium content, improved. Carrots and broccoli were bio-fortified using a foliar spray of a Se solution increased with Se content (Banuelos et al., 2015).

Conclusion:

Diversity in food products can help combat micronutrient deficiencies, but not everyone can afford it, particularly in underdeveloped and emerging nations. Increasing the concentration of vital nutrients in cereals, fruits, vegetables, and other local foods would generally help mitigate the harmful effects of climate change or any other global calamity by making less but richer food available. Increasing the biofortification of crops with agronomic traits can be a beneficial strategy. Progress in fertilizer composition and application techniques has led to notable improvements in the efficiency of agronomic biofortification. The development of these technologies has highlighted the importance of agronomic biofortification in terms of micronutrient enrichment. Investments in the development of agronomic biofortification techniques are crucial to the success of genetic and transgenic biofortification, as they ensure the availability of micronutrients in forms that genetically-biofortified crops that are micronutrient-hungry can access.

References:

Banuelos, G. S., Irvin, A., Ingrid, J. P., Yang, S. I., John, L. F. (2015). Selenium biofortification of broccoli and carrots grown in soil amended with se-enriched hyper accumulator stanleyapinnata. Elsevier 16 (6), 603–608.

Barrameda-Medina, Y., Begona, B., Marco, L., Sergio, E., Nieves, B., Diego, A., et al. (2017). Zinc biofortification improves phytochemicals and amino-acidic profile in brassica oleracea cv. bronco. Plant Science 258, 45–51.

Bilski, J., Jacob, D., Soumaila, F., Kraft, C., Farnsworth, A. (2012). Agronomic biofortification of cereal crop plants with fe, zn, and Se, by the utilization of coal fly ash as plant growth media. Adv. Biores. 3 (4), 130.

Bouis, H. E., Welch, R. M. (2010). Biofortification-a sustainable agricultural strategy for reducing micronutrient malnutrition in the global south. Crop Sci. 50, S20–S32. doi: 10.2135/cropsci2009.09.0531.

Buturi, C. V., Coelho, S. R. M., Cannata, C., Basile, F., Giuffrida, F., Leonardi, C., et al. (2022). Iron biofortification of greenhouse cherry tomatoes grown in a soilless system. Horticulturae 8 (10), 858.

Chattha, M. U., Hassan, M. U., Khan, I., Chattha, M. B., Mahmood, A., Chattha, M. U., et al. (2017). Biofortification of wheat cultivars to combat zinc deficiency. Front. Plant Sci. 8. doi: 10.3389/fpls.2017.00281.

ciksoz, S. B., Yazici, A., Ozturk, L., Cakmak, I. (2011). Biofortification of wheat with iron through soil and foliar application of nitrogen and iron fertilizers. Plant Soil 349 (1), 215–225. doi: 10.1007/s11104-011-0863-2

Hidoto, L., Worku, W., Mohammed, H., Taran, B. (2016). Agronomic approach to increase seed zinc content and productivity of chickpea (Cicer arietinum l.) varieties on zinKabir, A. H., Paltridge, N., Stangoulis, J. (2016). Chlorosis correction and agronomic biofortification in field peas through foliar application of iron fertilizers under fe deficiency. J. Plant Interact. 11 (1), 1–4.c deficient soils of southern Ethiopia. Adv. Life Sci. Technol. 42, 1–10.

Martin, A. R., Broadley, M. R., Poblaciones, M. J. (2020). Soil and foliar zinc biofortification of broccoli: Effects on plant growth and mineral accumulation. Crop Pasture Sci. 71 (5), 484–490.

Poblaciones, M. J., Rengel, Z. (2016). Soil and foliar zinc biofortification in field pea (Pisum sativum l.). grain accumulation and bioavailability in raw and cooked grains. Food Chem. 212, 427–433. doi: 10.1016/j.foodchem.2016.05.189.

Yasin, M., El-Mehdawi, A. F., Anwar, A., Pilon-Smits, E. A. H., Faisal, M. (2015a). Microbial-enhanced selenium and iron biofortification of wheat (Triticum aestivum l.) - applications in phytoremediation and biofortification. Int. J. Phytoremediation 17, 341–347. doi: 10.1080/15226514.2014.922920