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Biofortification in Vegetable Crops for Micro-Nutrients

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Introduction

According to Global Nutrition Report, 2018 anemia and stunting are the two forms of malnutrition burdens being experienced by our country.37.9 per cent of children under-5 are affected by stunting. 20.81 per cent of children under-5 is defined aswasted.51.4 per cent of women in reproductive age were affected by anemia. In India, 17.8 per cent of adult men and 21.6 per cent of adult women are overweight. Child wasting **is** the share of children under the age of five who are wasted (that is, who have low weight for their height, reflecting acute under nutrition) and child stunting is the share of children under the age of five who are stunted (that is, who have low height for their age, reflecting chronic under nutrition) (Anonymous, 2018).

World status of bio fortified crops

150 bio fortified varieties of 10 crops have been released in 30 countries. Testing ofanother 12 crops is being carried out in 25 countries. Harvest plus is the component of the CGIAR Research Program on Agriculture for Nutrition and Health. Launched in 2004, USA. Under joint venture of CIAT and IFPRI (Anonymous, 2017**).**

Biofortification And Zero Hunger Challenge:

- ✓ Second Global Conference on bio fortification recommend to the UN to celebrate 2018 - 2020 as the International Year of Bio fortified and Underutilized Crops
- ✓ To meet the Zero Hunger Challenge by 2030

Bio fortified staple foods cannot deliver high level of minerals and vitamins per day as fortified foods, but increase the daily adequacy of micronutrient intakes among individuals throughout the lifecycle. (Bouis*et al*., 2011)

What is Bio fortification ???

Greek word “bios” means “life” and Latin word “fortificare” means “make strong”. It refers to the nutrient enrichment of crops to address the negative economic and health consequences of vitamin and mineral deficiencies in humans (Prasad *et al.*, 2015).Bio-fortification differs from ordinary fortification because it focuses on making plant foods more nutritious as the plants are growing, rather than having nutrients added to the foods when they are being processed. Developing bio-fortified crops also improves their efficiency of growth in soils with depleted or unavailable mineral composition. Conventional breeding and genetic engineering techniques are the two approaches that is used to bio-fortify the crops with minerals like iron and zinc(Tiwari *et al.,* 2010). This approach not only will lower the number of severely malnourished people who require treatment by complementary interventions, but also will help them maintain improved nutritional status. Moreover,it provides a feasible means of reaching malnourished rural populations who may have limited access to commercially marketed fortified foods and supplements (Jena *et al.,* 2018).

Advantages of biofortification

Bio fortified crops are also a feasible means of reaching rural populations who may have limited access to diverse diets or other micronutrient interventions. Bio fortification puts a solution in the hands of farmers, combining the micronutrient trait with other agronomic and consumption traits that farmers prefer. Bio fortification, however, has two key comparative advantages: its long-term cost-effectiveness and its ability to reach underserved, rural populations. Unlike the continual financial outlays required for supplementation and commercial fortification programs, an upfront investment in plant breeding yields micronutrient-rich bio fortified planting material for farmers to grow at virtually zero marginal cost. Once developed, nutritionally improved crops can be evaluated and adapted to new environments and geographies, multiplying the benefits of the initial investment. Once the micronutrient trait has been mainstreamed into the core breeding objectives of national and international crop development programs, recurrent expenditures by agriculture research institutes for monitoring and maintenance are minimal.

Success of biofortification depends on combination of high nutrient density with high yields and high profitability, sufficient nutrients must be retained in processing and cooking and these nutrients must be sufficiently bioavailable and biofortified crops must be adopted

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by farmers and consumed by those suffering from micronutrient malnutrition in significant numbers (Jena *et al.*, 2018).

Methods of Biofortification

1. Agronomic biofortification
2. Gene biofortification
    a. Conventional breeding
    b. Genetic Engineering

1. Agronomic Biofortification

Agronomic bio fortification is the application of micronutrient-containing mineral fertilizer to the soil and/or plant leaves, to increase micronutrient contents of the edible part of food crops (White and Broadley, 2009). Success of agronomic biofortification depends on The presence and bioavailability of soil nutrients for plant uptake (soil to crop). Nutrient allocation within the plant and re-translocation into the edible part (crop to edible part). Bioavailability of nutrients to the human body (food to human). Bioavailability of micronutrients from soil to crop is influenced by many soil factors (i.e., pH, organic matter content, soil aeration and moisture and interactions with other elements). Addition of P also appears to induce Zn deficiency through dilution effects and interference with Zn translocation from the roots (Singh *et al.*1988). Degrees of success in agronomic biofortification are directly proportional to mobility of mineral element in soil and plant. (White and Broadley, 2003).

Bioavailability from crop to economic part is influenced by the crop (variety) – which defines whether micronutrients are (re-)localized into edible parts of the crop. Bioavailability of micronutrients in the food for the human body is influenced by many factors that can be either food or host related, micronutrient deficient people absorb micronutrient fastly(Gibson, 2007). Enhancers like ascorbic acid can increase iron bioavailability, while polyphenols and especially phytate or phytic acid are major inhibitors that form complexes with Fe and Zn and limit uptake in the human body. When calcium is present in the form of calcium oxalate the bioavailabilty will be 5 per cent but if calcium alone is present bioavailabilty will be 30 per cent (Clemens, 2014). Foliar pathways are generally more effective in ensuring uptake into the plant because immobilization in the soil is avoided (Garcia-Banuelos *et al.*, 2014). Foliar fertilization with micronutrients often stimulates more nutrient uptake and effcient allocation in the edible plant parts than soil fertilization for leafy vegetables (Lawson *et al.*, 2015).Agronomic biofortification has so far been most effective with Zn and Se then comes the iron which has low mobility in the plants (Cakmak 2014).

SWOT analysis of agronomic biofortification (Susana *et al.*, 2013)

Strengths:	Comparatively simple method than other methods and suitable for immediate results.
Weakness:	Success limited to minerals and dependent on several factors, needs regular application of nutrients, expensive and difficult to distribution.
Opportunities:	Often used as a compliment to other strategies
Threats:	Negative environmental impact, reverse exhaustion (Eg:Se)

2. Gene biofortification

Traditional breeding mainly focused on yield attributes and resistance breeding from last four decades and lack of priority on nutritional aspects leads to decreased amount of nutrient status in the existed varieties. Examples of minerals that their mean concentration in the dry matter has declined in several plant-based foods are Fe, Zn, Cu and Mg (Susana *et al.*, 2013). Recent progress in conventional plant breeding has given emphasis on fortification of important vitamins, antioxidants and micronutrients.

a. Conventional plant breeding

The potential to increase the micronutrient density of staple foods by conventional breeding requires adequate genetic variation in concentrations of β-carotene, other functional carotenoids, iron, zinc, and other minerals exists among cultivars, making selection of nutritionally appropriate breeding materials possible. Fe and Zn levels and up to a 6.6-fold variation has been reported in beans and peas (Gregorio *et al.*, 2000).Steps in biofortification by conventional plant breeding are as given below (Anonymous, 2017)

Precedent plant breeding was based on yield attributes and resistance breeding and prominence was not given on nutritional aspects but present plant breeding is concentrated on fortification of vitamins, antioxidants and micronutrients in edible parts (Prasad *et al.*, 2015).

Diets rich in broccoli (*Brassica oleracea* var *italica*) have been associated with maintenance of cardiovascular health and reduction in risk of cancer. These health benefits have been attributed to glucoraphanin that specifically accumulates in broccoli. The

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development of broccoli with enhanced concentrations of glucoraphanin may deliver greater health benefits. Three high-glucoraphanin F_1 broccoli hybrids were developed in independent programmes through genome introgression from the wild species *Brassica villosa*. Glucoraphanin and other metabolites were quantified in experimental field trials. Global SNP analyses quantified the differential extent of *Brassica villosa* introgression. The high-glucoraphanin broccoli hybrids contained 2.5-3 times the glucoraphanin content of standard hybrids due to enhanced sulphate assimilation and modifications in sulphur partitioning between sulphur-containing metabolites. All of the high-glucoraphanin hybrids possessed an introgressed*Brassicavillosa* segment which contained a *Brassicavillosa* Myb28 allele. Myb28 expression was increased in all of the high-glucoraphanin hybrids. Two high-glucoraphanin hybrids have been commercialised as Beneforté broccoli (Traka *et al.*, 2013)

SWOT analysis (Susana *et al.*, 2013)

Strengths:	Successful for minerals and vitamins, one-off cost, easier distribution, longterm strategy
Weakness:	Long development time, success limited to minerals available in the soil.
Opportunities:	Wide public acceptance, simple legal frame work
Threats:	Requires genetic variation

b. Genetic engineering

Lack of sufficient variation among the genotypes for the desired character/trait within the species, or when the crop itself is not suitable for conventional plant breeding (due to lack of sexuality) then genetic engineering offers a valid alternative for increasing the concentration and bioavailability of micro nutrients in the edible crop tissues. One of the main concerns is these-called ‘gene flow’ environmental problem, i.e. the concern of transfer of foreign genes to non-target species (Winkler, 2011).Micronutrient powders, popularly known under their original name of Sprinkles, are a form of ‘home fortification’ that also provide several nutrients at once. In sachets for a single serving, they are sprinkled on top of normal foods. Beginning with just, encapsulated iron, they have now developed numerous varieties, with as many as 15 vitamins and minerals, appropriate for the nutritional problems of specific areas. Cauliflower is grown and consumed extensively all year round in India, but is deficient in vitamin A, it was identified as a preferred crop for biofortification in order to address a malnutrition problem in the country. Report on the introgression of the β-carotene (pro-vitamin A)-enhancing Or gene from donor line EC625883 into Indian cauliflower 'Pusa Sharad' (DC 309) and the parents of 'Pusa Hybrid-2' (CC-35 and DC 18-19). The β-carotene content of BC_1F_1 plants of the dark-orange category was 2.0314.64 μg g^{-1} (DC 309 × EC625883), 7.03-15.99 μg g^{-1} (CC-35 × EC625883) and 4.5218.60 μg g^{-1} (DC 18-19 × EC625883).

The combination of high RPG and β-carotene content was recorded in two plants, 18-19-1-7-7 (18.60 μg g^{-1}) and 18-19-1-3-6 (17.94 μg g^{-1}). Promising lines showing more than 10 μg g^{-1} β-carotene in BC_1F_1 were advanced to BC_1F_2 and BC_2F_1 (Kalia *et al.*, 2018).

Conclusion

Biofortification helps in overcoming nutrient deficiency economically, especially in rural areas. Promoting large-scale prospective studies on nutritional ascepts, productivity along with consumer preference. Need for collaboration between plant breeders, molecular biologists and nutrition scientists. Enhancing the mineral uptake efficiency of the important crops and efficiency with which minerals are mobilized in the soil. Address the challenges ahead for governments, especially in the areas of safety testing, regulation, industrial policy and food labelling.

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