Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 05, Issue: 06 (NOV-DEC, 2025)
Available online at http://www.agriarticles.com

Biofortified Vegetable Crops: A Sustainable Way to Address the Global Malnutrition

*Pragti Negi and Nemi Chand Chopra
Dept. of Vegetable Science, College of Horticulture, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Gahrwal
*Corresponding Author's email: pragtinegi553@gmail.com

Biofortification consists of the Greek word "bios" meaning life, and the Latin word "fortificare" meaning to "make strong", which truly means to make life strong. It is a technique that makes use of biotechnology, traditional plant breeding and agronomic practices to enhance the nutritional composition of food crops, along with improving the plant traits like increased disease resistance and high yield. Amongst agronomic, conventional and transgenic approaches of biofortification, the genetic modification/ transgenic approach has been used extensively to improve many traits like nutritional status, delayed ripening, less bitterness and seedlessness. Hence, these tools are capable of enhancing the micronutrient density and vitamin content of many food crops, which eventually helps in combating the pressing issue of "Hidden hunger" and "Malnutrition" in developing nations.

Keywords: Hidden Hunger, Malnutrition, Micronutrients, Mineral Biofortification, Genetic Engineering

Introduction

Biofortification is the process of increasing the bioavailable amount of essential elements (Vitamins and Minerals) in the edible parts of crops to address micronutrient deficiencies, which can be done with the help of conventional breeding or modern biotechnology. It helps meet the daily micronutrient needs (such as iron, zinc) and Vitamin A of individuals, the deficiency of which causes several negative impacts like anaemia (more profound in women (44%) of developing countries), lessens the cognitive development, issues with the immune system, physical growth and visual impairment/blindness. Therefore, biofortification helps improve the nutritional status of numerous individuals in rural areas, which eventually prevents malnutrition and hidden hunger. This is a more environmentally friendly technique than conventional fortification or dietary supplements.

Strategies Involved

Biofortification in food crops can be done with the help of the following three techniques

1) Agronomical biofortification

The incorporation of fertilisers containing mineral nutrients (which are lacking in human diets) into the soil and their improvement concerning solubilization and mobilisation is known as "Agronomical Biofortification". The primary elements that are used in this technique involve Zinc, Iron, Copper, Iodine, Selenium, Magnesium and Calcium. In this context, the other important approach includes appropriate crop rotations, intercropping, and the involvement of beneficial soil microorganisms, which helps to boost the phytoavailability of mineral elements. However, the foliar application of fertilisers is considered a better option than the soil application because the latter makes the mineral elements (Fe or Zn) unavailable to roots.

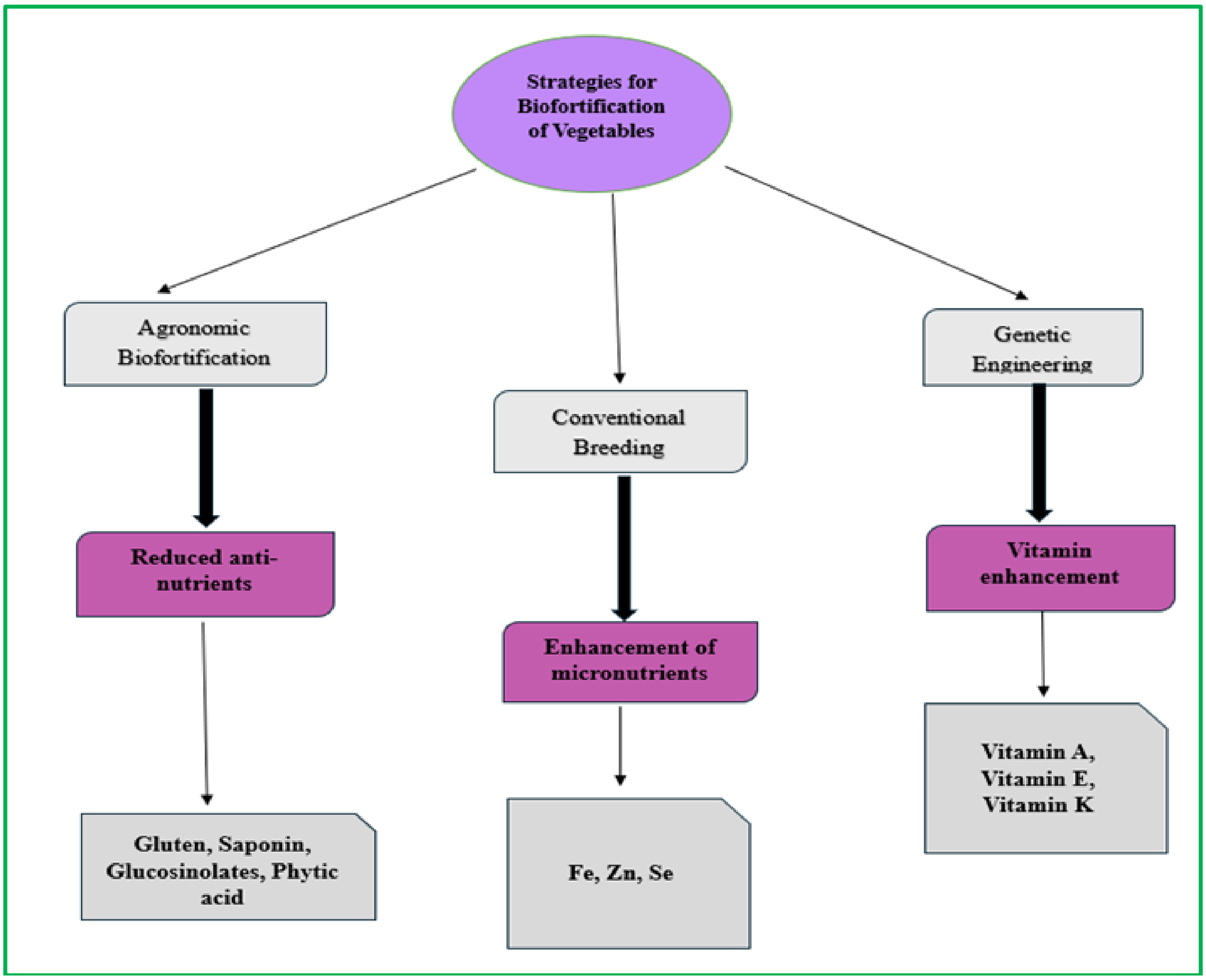

Fig: Strategies for Biofortification in Vegetables

Table 1: Biofortified Vegetable Crops Developed Through Agronomical Biofortification

Crop	Fertiliser used	Increased effect
Lettuce	Se + SA	Increased Se. Ascorbic acid, Flavonoids and anthocyanin content of leaves
Carrot and Broccoli	Se-enriched hyperaccumulator *Stanleya pinnata* (powder, dried plant).	Increased the Se concentration in carrot roots and Broccoli florets
Pea	KI, KIO3, Na2SeO3, Na2SeO.	No growth depression observed
Kohlrabi	KI, KIO3, Na2SeO3, Na2SeO4	The chlorophyll and carotene content gets increased by Se. I increased the anthocyanin content

2) Through Conventional Plant Breeding

Another long-term solution and a more environmentally friendly approach for carrying out biofortification is through the traditional plant breeding method. However, it is more time-consuming and may take many years to develop a superior variety having a good number of micronutrients.

Table 2a: Biofortified Vegetable Crops Developed Through Conventional Breeding Worldwide

Crop	Variety	Content- Rich in
Tomato	Sun Black	Anthocyanin
	Black Galaxy	
Potato	INIA321 Kawsay	Iron and Zinc content rich
Sweet potato	Ejumula, Kakamega, Vita kabode, Naspot 120 and Naspot 130	Vitamin -A
	Twatasha, Kokota and Chiwoko	Vitamin -A
Cassava	UMUCASS 36 (TMS 01/1368), UMUCASS 37 (TMS 01/1412), UMUCASS 38 (TMS 01/1371	Vitamin -A

Table 2b: Biofortified Vegetable Crops Developed Through Conventional Breeding in India

Plant Breeding Method	Crop	Variety	Content-Rich in
Pure line selection	Cauliflower	Pusa Beta Kesari	β-carotene (8.0-10.0 ppm
	Potato	Kufri Jamunia	Anthocyanin
	Sweet Potato	Bhu Sona	β-carotene (14.0 mg/100g)
		Bhu Krishna	Anthocyanin (90.0 mg/100g)
		Sree Kanaka	β-carotene
Mass selection	Carrot	Madhuvan Gajar	β-carotene content (277.75 mg/kg) and iron content (276.7 mg/kg
	Cowpea	Ooty-1	Carotene (38 mg/100 g)
		Pant Lobia-1	82 ppm Fe and 40 ppm Zn
		Pant Lobia-2	100 ppm Fe and 37 ppm Zn
	Potato	Kufri Neelkanth	Anthocyanin (100µg/100g)
	Radish	Pusa Gulabi	Anthocyanin
		Pusa Jamuni	Anthocyanin and Ascorbic Acid
	Pumpkin	Arka Chandan	Carotene (3333 IU)
Single Plant Selection	Brinjal	Pusa Safed Baigan 1	Rich in total phenol content (31.21 mg/100 g) and antioxidants (3.48 mg/100 g)
Hybridisation	Watermelon	Arka Jyoti, Durgapur Lal	Carotene
	Brinjal	Punjab Sadabahar	Anthocyanin
	Okra	Kashi Lalima	Anthocyanin (3mg/100g)
	Carrot	Kashi Krishna	Anthocyanin
	Potato	Kufri Neelkanth	Anthocyanin (100 µg/100g fresh weight)
	Tomato	Pusa Rohini	Vitamin C (3.12mg/100g)
	Bittergourd	Pusa Hybrid-4	Iron (18.28 mg/100g)

3) Genetic Engineering/Use of Transgenics

This method of biofortification is widely utilised across the globe to tackle the severe vitamin and mineral deficiencies. In contrast to conventional plant breeding methods, genetic engineering has the potential to incorporate desirable traits from one organism to another, hence, permits the development of elite cultivars. The following are examples of vegetable crops into which transgenics have been utilised to increase the specific nutrient.

Table 3: Biofortification of Vegetables through the Transgenic Approach

Crop	Gene/Protein	Increased Nutrient Content
Cassava	Ferritin and *FEA1*	Iron
	Arabidopsis ZAT and ZIP	Zinc
	Phytoene synthase *crtB* and DXS	β-carotene
	ASP1 and Zeolin	Protein
Sweet Potato	*Crtl, CrtB, CrtY, LCYe*	β-carotene
	IBOR-INS Lutein	Lutein and Carotene
Potato	*nptII*	Amylopectin component of starch
	AmA1	Protein
	Strawberry d-galacturonic acid reductase (GaIUR) gene	Vitamin C
Tomato	HMT, S3H, and SAMT	Iodine
	GDP-l-galactose phosphorylase	Vitamin C
	Tomato pds-beta Lyc	β-carotene
Cauliflower	Or gene	β-carotene
Lettuce	Soya bean Ferritin gene	Iron
Carrot	CAXI	Calcium

Advantages of Biofortification

1) It is considered a more balanced approach to address malnutrition and hidden hunger.
2) The consumption of biofortified crops allows the intake of nutrients in their natural form.

3) The yield of biofortified crops is somewhat higher than contrast of traditional crops, along with some superior traits, being more advantageous for farmers' economic growth.
4) Biofortified crops involve a one-time investment for breeding technique and are self-sustainable too, hence cost-effective.

Future Thrust

The world population is rising at a rapid rate, so the demand for nutrient-rich foods is increasing too. Concerning this, biofortification of crops has become more important to develop nutrient-rich (rich in vitamins, minerals like iron, zinc and vitamin A) crop varieties, which will eventually aid in addressing global malnutrition. The future of biofortification is determined by the usage of advanced technologies along with multi-disciplinary collaboration, and the ultimate focus on sustainability to tackle micronutrient deficiencies. Further, more efforts are required to overcome the challenges that align with biofortification, like consumer acceptance, wider adoption by the farmers, collaboration and knowledge transfer, climate change adaptation, logistical hurdles, regulatory approval needed for GM crops and ethical considerations.

Conclusion

The full implementation of biofortification requires the assessment of the bioavailability of nutrients, evaluating the nutritional requirements of the targeted population and improving the absorption/retention levels of nutrients in the storage conditions. With the help of plant breeding, transgenics, and mineral fertiliser applications, there can be a substantial reduction in micronutrient malnutrition. Despite the development of numerous biofortified varieties, there is still a need to tackle the socio-political and economic challenges to boost their cultivation and consumption by the customers. The integrated efforts should be done by farmers, genetic engineers, and plant breeders, among others, to overcome the biggest hurdle of the acceptance of biofortified foods. Altogether, this bio-enrichment technique is a potential agricultural solution to upgrade the nutritional livelihoods of the malnourished population of developing nations.

References

1. Behera, S.R., Isha, Pandey, R., Dhathri, M., Negi, P., Jakhwal, R., Sahoo, S., Bhatt, H., Gairola, A. and Mohapatra, A. (2024). Agronomic Biofortification of Vegetable Crops–A Systematic Review. *Journal of Advances in Biology & Biotechnology*, 27(9): 942–956.
2. Kant, S., Patel, K.K. and Maurya, S.K. (2025). Biofortification: Challenges and Opportunities. *Eco-farming* (e-magazine). 5(1): 4-6.
3. Lal, M.K., Kumar, A., Kardile, H., Raigond, P., Changan, S.S., Thanku, N., Dutt, S., Tiwari, R.K., Chourasia, K.N., Kumar, D., Singh, B. (2020). Biofortification of Vegetables In Book Advances in Agri-Food Biotechnology. *Springer Nature*. 105-123.
4. Reddy, B.K., Vijayreddy, D., Chandra, B.K., Emmi, S.R., Hegde, S.S., Majumder, B., Kumar, D.P. (2024). A Comprehensive Review on Biofortification in Vegetable Crops. *Journal of Advances in Biology & Biotechnology*. 27 (8):1448-1458.
5. Rehan, Sharma, A. and Singh, P. (2020). Biofortification: Enriching Vegetable Crops with Nutrients to Reduce Global Hunger. *International Journal of Current Microbiology and Applied Sciences*. 11: 2499-2511.
6. Vignesh, M., Esakkiammal, S.D., Dhamini, A.A.M., Jeeva, S., Monish, V.K., Sabaressh, K., Sathya, M., Shivani, B., Sivaranjani, K. and Varshini, K. (2025). Biofortification of Vegetable Crops: A Mechanism to Optimise a Hidden Hunger. *Asian Journal of Soil Science and Plant Nutrition*. 11 (2): 329-342.