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Bio-Fortification of Vegetable Crops

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Biofortification is derived from two words, i.e., bio is from a Greek word meaning life, and fortify care is derived from a Latin word meaning to 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 (Vandana *et al*., 2022).

Vitamin	Diseases and their symptoms	Available from
A (Retinol)	Poor vision, night blindness	Spinach, carrot, butter, mangoes
B1 (Thiamine)	Extreme weakness, beri beri	Eggs, meat, yeast
B2 (Riboflavin)	Retarded growth, bad skin	Green leafy vegetables, beans, peas, milk
B12 (Cyanocobalamin)	anaemia	Non-vegetarian food like meat
C (Ascorbic acid)	Scurvy,Swollen gums, loose teeth	Lime, lemon, oranges
D (Calciferol)	Rickets,brittle bones in children which break or bend easily	Milk, fish, liver oil
K (Phylloquinone)	Excessive bleeding due to injury	Green leafy vegetables
Name of Minerals	**Diseases and their symptoms**	**Available from**
Calcium	Brittle bones, excessive bleeding, bad muscular movement	Milk, green leafy vegetables
Phosphorus	Bad teeth and bones	Pulses, cereals, milk
Iron	Anaemia, lack of red blood cells	Green vegetables, pulses, meat
Iodine	Goitre, enlarged thyroid gland	Fish, salt, sea water
Copper	Low appetite, retarded growth	Pulses, leafy vegetables

What are the goals of bio-fortification?

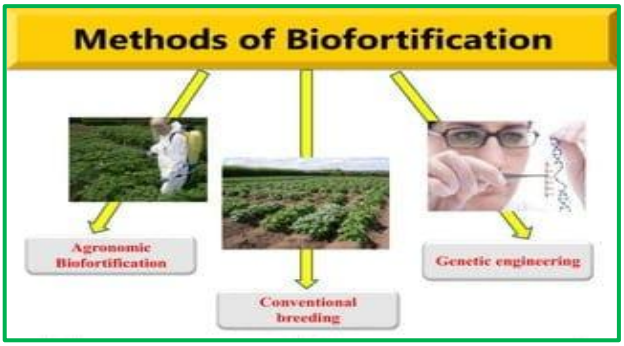
The basic goal of biofortification is to reduce mortality and morbidity rates related to micronutrient malnutrition and to increase food security, productivity, and the quality of life for poor populations in developing countries.

The importance of biofortification

- It is especially important for poor rural communities with finite access to a varied diet.
- Fortified foods or supplements. It can help people by improving their daily intake of micronutrients.
- Throughout their lifecycle, It is important for women and children since they face a greater risk of micronutrient malnutrition. For instance, according to the World Health Organization (WHO),

- According to estimates, two billion people with iron deficiency-induced anemia could be cured by
- Taking bio-fortified foods.
- To promote food security.
- To alleviate poverty.

Techniques of biofortification



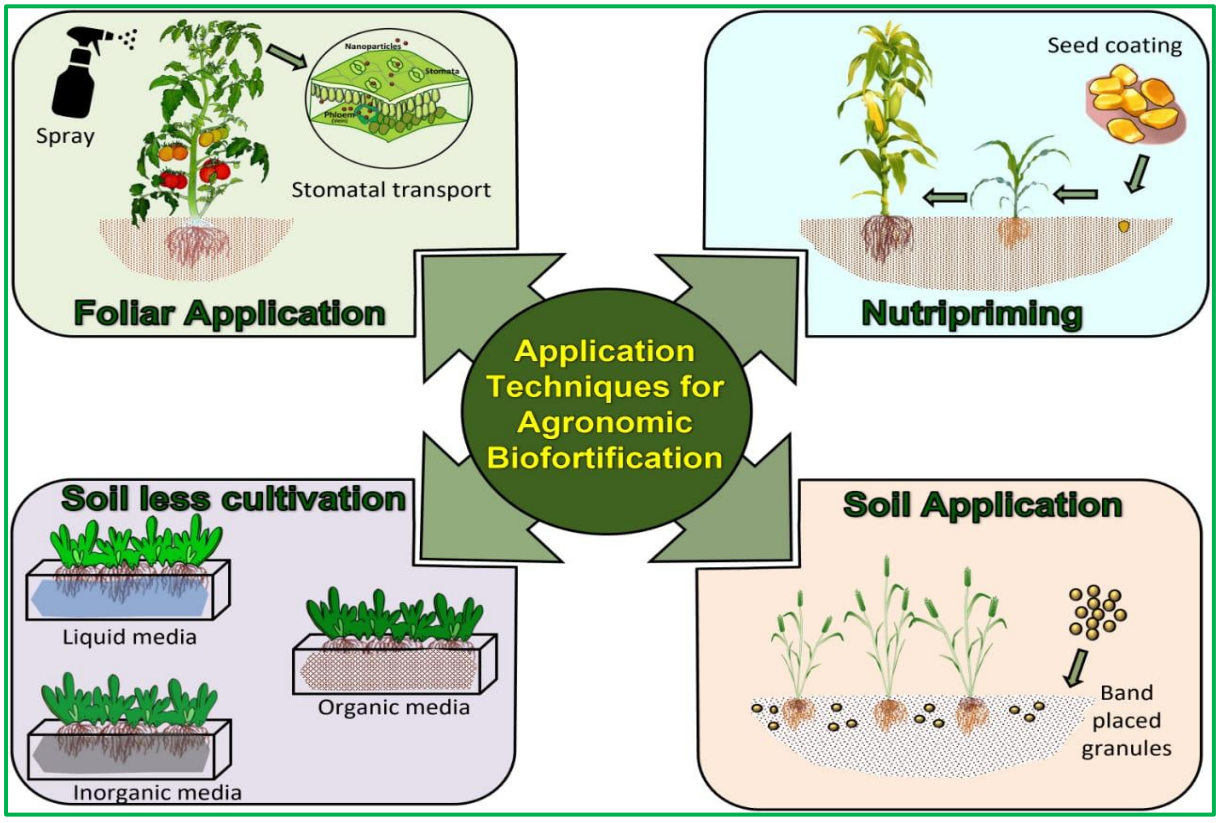
Three techniques can be used to achieve biofortification.

1. Agronomic Biofortification
2. Conventional plant breeding
3. Genetic engineering

- **Agronomic Biofortification:** Agronomical biofortification refers to the technique of using fertilizer or fortification by using seed treatment, foliar application, and organic manure to increase the nutraceutical values since these are very cheap and rapid methods for evaluating the mineral content of various vegetables.

Examples:

- **Amaranths:** A microbial inoculant, “Spirulina platensis," is used as a biofortifying agent to enhance the iron level of crops. Seed treatment in various forms was given to the seeds of Amaranths genetics, viz., The sample after two hours of soaking recorded a high content (18.35± 0.03 mg g^{-1}) of iron (Kalpana et al., 2014).
- **Lettuce:** Iodine application as iodate in biofortification programs has been confirmed to improve the foliar biomass, antioxidant response, and accumulation of phenol compounds in lettuce plants but also supplement the human diet with phenolic compounds and the trace element iodine (Blasco et al., 2013).

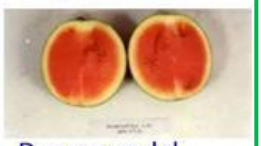


- **Conventional Plant Breeding Method:** Conventional breeding practices help in increase the concentration of minerals like β-carotene, carotenoids, amino acids, amylase, carbohydrates etc, through making proper selection of breeding material to increase nutritional efficiency.

Intervarietal hybridization

Crop	Variety	Colour	Amount
Brinjal	Punjab Sadabahar - Jap Long x R-34	Blackish purple	Anthocyanin
Watermelon	Arka Jyoti - IIHR -20 ×Crimson Sweet	Crimson red	Carotene
	Durgapura lal – Sugar baby × K3566	Dark red	Carotene
Tapioca	Sree Visakam	Yellow	Beta carotene
Sweet Potato	Sree Rethna	Purple skin & Yellow flesh	Carotene

Punjab Sadabahar



Durgapura lal

Sree Visakam

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H.P. Singh, Vegetable Varieties of India, 2011

Local selection

Crop	Variety	Colour	pigments
Watermelon	Durgapura kesar	Yellow	Carotene
Palak	Punjab Green	Purple (stem)	Anthocyanin Beta carotene
	Pusa Bharathi	Green	Beta carotene
Amaranthus	Pusa Lal Chaulai	Red(Magenta)	Anthocyanins
	Arka Arunima	Purple	Anthocyanins
Basella	Local Red	Red	Carotenoids
	Local Green	green	Leutin
Pumpkin	Arka chandan	Bright orange	Carotene
carrot	Ooty 1- half sib progeny selection of DC-3	Deep orange	Carotene
	Shalimar -1	Orange	Carotene -56.1 mg/100g

Durgapura Kesar

Arka Chandan

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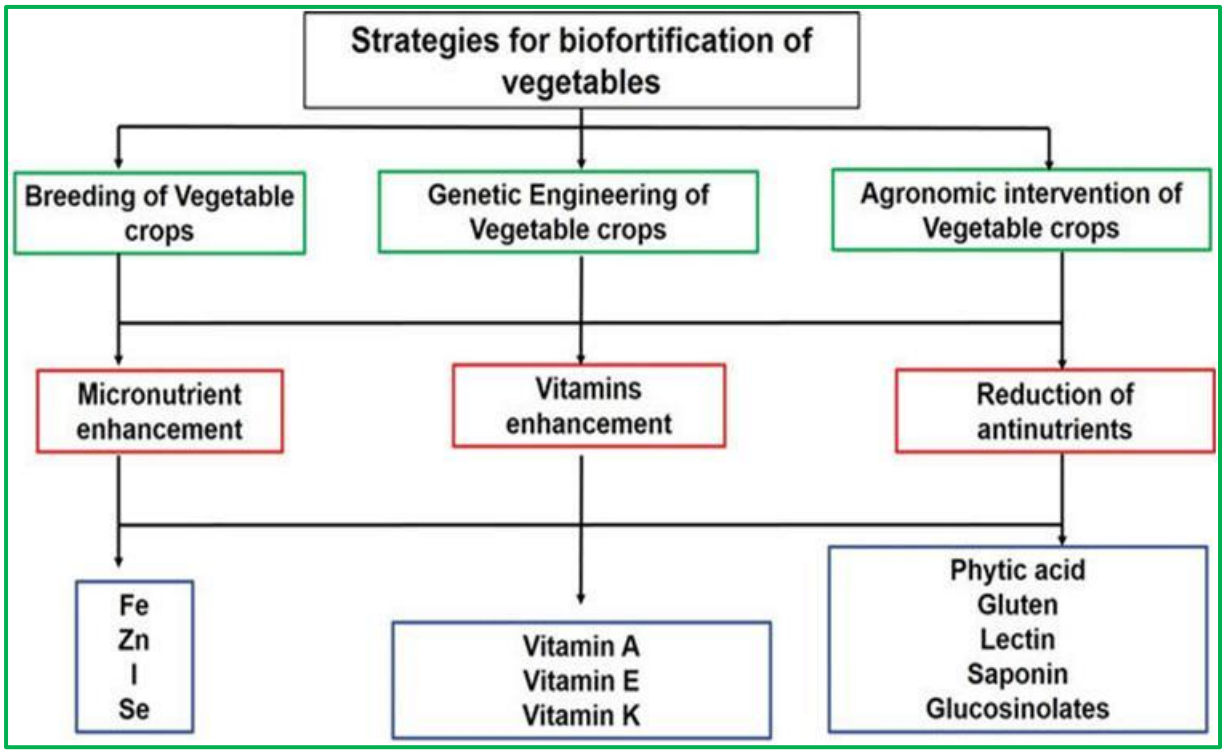
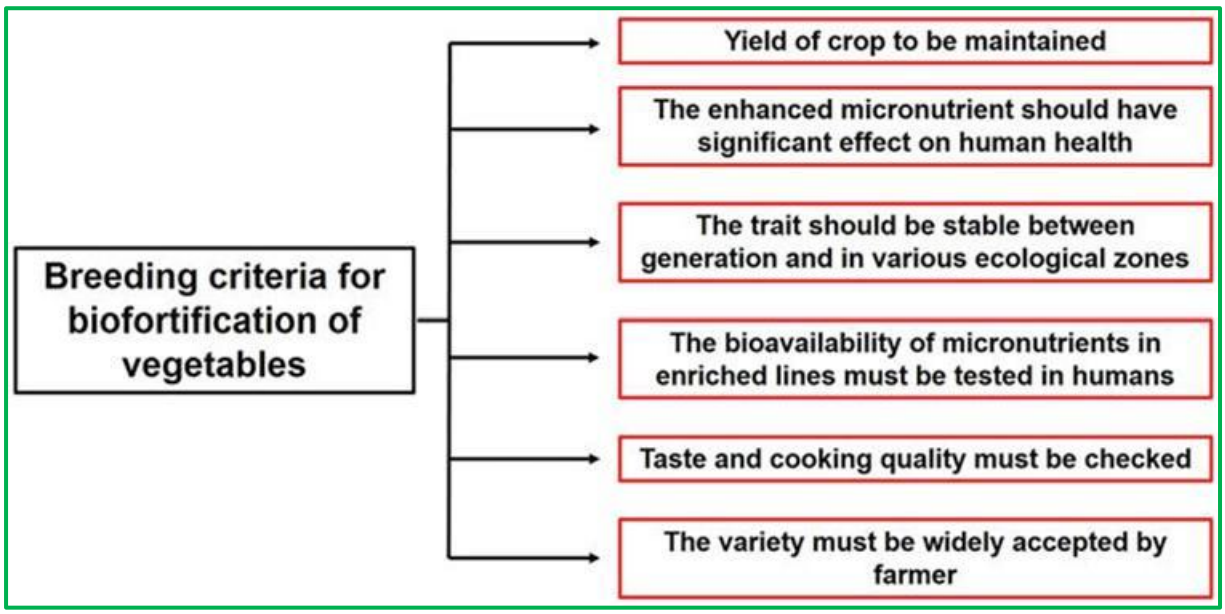
H.P. Singh, Vegetable Varieties of India, 2011

- **Genetic Engineering:** Genetic engineering techniques use an illimitable gene pool to produce new cultivars through transfer of desirable characters from one organism to another organism to develop elite cultivars and improve its value. Examples: Cassava, Cabbage, Potato, Tomato

Crop	Gene	Content rich in	References
Tomato	pGAntho	Anthocyanin	(Manmohan *et al.*, 2013)
Potato	AmA1	Protein	(Chakraborty *et al.*, 2010)
Lettuce	Ferritin	Iron	(Sharma *et al.*, 2017)
Cauliflower	Or gene	Beta-carotene	(Kalia *et al.*, 2016)
Sweet potato	IBOR-INS	Lutein and Carotene	(Park *et al.*, 2015)
Cassava	PSY	Vitamin –A	(Sharma *et al.*, 2017)
Carrot	CAX1	Calcium	(Yadava *et al.*, 2020)





Advantages of Biofortification

- Targets mainly low-income households.
- Low recurrent costs.
- A bio-fortified crop system is highly sustainable.
- Increase in nutritional quality in daily diets.
- improvement of plant or crop quality and increment
- variability in germplasm.

Disadvantages of Biofortification

- It takes time to implement.
- Public awareness is needed.

Future challenges

- Consumer preference
- Production of crops for human nutrition with increased iron concentration.
- Promoting large-scale prospective studies on assessing the effects of nutrient enhancement in major crops on 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 transport within the plant body.

Conclusion

- Biofortification helps overcome nutrient deficiency economically, especially in rural areas.
- Application of bio-fortified crops would benefit farmers by increasing their income in the long run.
- Functional crops can play an important role in fighting against different types of nutrition deficiency and malnutrition.

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