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## Biofortification and Its Application in Vegetable Crops

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### Abstract

Approximately 800 million people be afflicted by starvation, however even more suffer from micronutrient malnutrition, also called “hidden hunger”, especially in the growing nations. Iodine, vitamin-A, iron, and zinc malnutrition are important worries. The malnutrition of minerals Fe, Zn and vitamin A are essential meals-related primary health problem amongst populations of the growing global inclusive of India in which there's a heavy dependence on cereal-primarily based diets and constrained get right of entry to fruits and vegetables. One such technique to combat the issue of micronutrient malnutrition is through Biofortification, a process of breeding vitamins into meals vegetation which gives a relatively value-effective, sustainable, and lengthy-term means of turning in greater micronutrients to rural populations in growing international locations. Presently, agronomic, conventional, and genetic engineering biofortification are 3 common strategies. Agronomic biofortification can offer temporary micronutrient will increase through fertilizers. In traditional plant breeding, determine lines with high nutrition or mineral tiers may be crossed over several generations to supply fruits and vegetables which have the desired nutrients. Genetic engineering processes are effective when the nutrient does not clearly exist in a crop (example, provitamin-A in sweet potato and cassava). Currently, there have been several reviews at the development of genetically modified crops to decorate tiers provitamin-A contents in plants like tomato, potato, cassava, sweet potato, beans and other vegetable plants.

**Keywords:** Biofortification, malnutrition, genetic engineering procedures, vitamins.

### Introduction

Growing population, insufficient meals and nutrients, hunger, malnourishment of vitamins and micronutrients and so on are the most important demanding situations to cope with maximum of the nations the world over. Vitamin-A deficiency major in growing international locations among youngsters and women's which results in >600,000 deaths each 12 months globally among youngsters <5 months of age. Some of the micronutrient malnourishment of populace approximately 60% of iron, 30% of zinc, 30% of Iodine and 15% of selenium are predominant. Inadequate availability of those critical vitamins and micronutrients resulted in lots of fitness and bodily issues in humans. Conventional agricultural practices can partially decorate the dietary content material in plant meals however biofortification is a practice of nutrient fortification into meals plants the usage of agronomic, traditional and genetic engineering breeding strategies to provide a sustainable and long term strategy to deal with bad impacts of diet & nutrient deficiencies. Biofortification works have been practiced in most of the horticultural crops like banana, cassava, beans, potato, orange sweet potato (OSP), cowpea, pumpkin and so on. Numerous conventional and genetically modified varieties had been released, even as additional types are inside the pipeline. The results of efficacy and effectiveness studies, in addition to latest successes in shipping, offer proof that

biofortification is a promising strategy for preventing hidden hunger. Biofortification is the technique of including nutritional value to the crop. It refers to nutrient enrichment of crops to cope with their poor monetary and fitness effects of nutrition and mineral deficiencies in humans.

Biofortification refers to growing genetically the bioavailable mineral content of meals vegetation. Developing biofortified vegetation additionally improves their efficiency of growth in soils with depleted or unavailable mineral composition. Breeding vegetation with multiplied phytonutrients is maximum effortlessly carried out with vegetation with quick juvenile intervals to reach fruiting stage along with veggies, berries and melons, however is a miles long run method for tree-fruit and nuts, which generally require a juvenile duration of many years earlier than fruit-set is possible. Alternative strategies encompass the identification of plant variants with superior phytonutrient stages within germplasm collections or inside existing industrial cultivars. This could perceive lines that may be already acceptable to purchasers, or instead perceive a potential donor discern with the proper phytonutrient historical past for transfer into a more applicable plant-type for intake.

### Importance of biofortification

Biofortification gives a relatively cost-effective, sustainable, and long-term approach of turning in greater micronutrients in particularly far off rural regions and it also supply clearly-fortified foods to populace corporations with confined get admission to commercially-advertised fortified foods. Biofortified staple ingredients can't supply as excessive level of minerals and vitamins consistent with day as supplements or industrially fortified ingredients, however they are able to help via growing the everyday adequacy of micronutrient intakes amongst people in the course of the lifecycle. Biofortification isn't predicted to deal with micronutrient deficiencies or get rid of them in all population corporations. No single intervention will remedy the problem of micronutrient malnutrition, but biofortification complements present interventions to sustainably offer micronutrients to the maximum inclined humans in a comparatively cheaper and cost-effective way. For instance, In line with World Health Organisation (WHO) estimation, biofortification should assist cure billion humans stricken by iron deficiency-prompted anemia.

**Table1: Source of nutrients from vegetables**

Nutrients	Vegetables
<b>Carbohydrate</b>	Sweet potato, potato, cassava
<b>Protein</b>	Pea, lima bean, French bean, cowpea
<b>Vitamin A</b>	Carrot, spinach, pumpkin
<b>Vitamin B<sub>1</sub></b>	Tomato, chilli, garlic, leek, pea
<b>Vitamin B<sub>5</sub></b>	Palak, amaranthus, bitter gourd, pointed gourd
<b>Vitamin C</b>	Chilli, sweet pepper, cabbage, drumstick
<b>Calcium</b>	Hyacinth bean, amaranthus, palak
<b>Iron</b>	Amaranthus, palak, spinach, lettuce, bitter gourd
<b>Phosphorus</b>	Pea, lima bean, taro, drumstick leaves
<b>Iodine</b>	Tomato, sweet pepper, carrot, garlic, okra
<b>Sodium</b>	Celery, green onion, Chinese cabbage, radish

### Methods of biofortification

Biofortification may be done through 3 strategies

- Agronomic Biofortification
- Conventional plant breeding
- Genetic engineering

**Agronomic Biofortification:** Application of fertilizers to increase the micronutrients in fit to be eaten elements. Maximum suitable micronutrients for agronomic biofortification are Zinc (foliar spray of  $ZnSO_4$ ), Iodine (Soil application of iodide or iodate), and Selenium (as selenate). Foliar utility is the short and smooth method of nutrient utility to fortification of micronutrients (Fe, Zn, Cu and many others) in vegetation. Numerous studies have found that the mycorrhizal associations increase Fe, Se, Zn and Cu concentrations in crop flora. AM-fungi growth the uptake and performance of micronutrients like Zn, Cu, and Fe and so on. Sulphur oxidising bacteria will increase the sulphur content material in onion.

**Application of agronomic biofortification of vegetable crops with Iron:** Tomato plants can tolerate high stages of iodine, stored each inside the vegetative tissues and fruits at concentrations that are more than enough for the human weight loss program and conclude that tomato is a fantastic crop for iodine-biofortification applications. The fruit awareness of iodine detected in 5 mm iodide-handled plants changed into greater than sufficient to cover every day human consumption of 150  $\mu g$ . Increasing iron stages of *Amaranthus* flowers through the usage of *S. Platensis* as microbial inoculant when in comparison with manipulates and also suggested that *Spirulina platensis* has been used as biofortifying agent to beautify the iron status in *Amaranthus gangeticus* plant.

**Application of agronomic biofortification of vegetable crops with Zinc:** The relationship between tuber Zn awareness and foliar Zn application followed a saturation curve, accomplishing a maximum at approx. 30 mg Zn  $kg^{-1}$  DM at a foliar Zn application price of 1.08 g  $plant^{-1}$ . No matters a 40-fold increase in shoot Zn awareness as compared to the unfertilised controls following foliar Zn fertilisation with 2.16g Zn  $plant^{-1}$ . The usage of fertilizer "Riverm" all through cultivation of sweet pepper, eggplant and tomatoes helps to be enriched via zinc. Biofortified greens incorporate 6.60-8.59 % of Zn more than manage.

**Application of agronomic biofortification of vegetable crops with Selenium:** Se-enriched *S. Pinnata* is treasured as a soil modification for enriching broccoli and carrots with healthy forms of natural-Se. Onions and carrots were bio-fortified via foliar utility of an answer of  $^{77}Se$  that become enriched 99.7% as  $^{77}Se$ . In brassica veggies selenium application did now not have an effect on the yield or oil content. High accumulation of Se inside the seeds and meal of (1.92–1.96  $\mu g$  Se  $g^{-1}$ ) turned into detected.

**Conventional plant breeding:** Conventional breeding particularly targeted on yield attributes and resistance breeding from ultimate 4 decades and shortage of priority on nutritional components ends in reduced amount of nutrient fame in the existed types. Examples of minerals that their mean concentration within the dry matter has declined in several plant-based foods are Fe, Zn, Cu and Mg. Latest progress in conventional plant breeding has given emphasis on fortification of essential vitamins, antioxidants and micronutrients. The ability to growth the micronutrient density of staple foods via conventional breeding requires good enough genetic version in concentrations of  $\beta$ -carotene, other practical carotenoids, iron, zinc, and other minerals exists among cultivars, making selection of nutritionally suitable breeding materials possible.

**Table2: Examples of biofortification in vegetable crops**

Crop	Biofortified mineral nutrients
Tomato	Chlorogenic acid, stilbene, flavonoids, anthocyanin, Folate, phytoen, lycopene $\beta$ -carotene, provitamin A, Zinc, Iodine
Potato	Amin acid, protein, anthocyanin, starch, carbohydrate (fructan)
Onion, Broccoli	Selenium
Lettuce, Beans	Iron

Carrot	Calcium
Radish	Selenium
Brassica spp.	Selenium, carotene
Cassava	Protein, carotene and mineral contents Zn, Se, Cu, I
Sweet Potato	Protein, Carotene
Broccoli	Selenium
Cucumber	Potassium
Spinach	Iodine
Pumpkin	Carotenoids

### Application of biofortification in vegetable crops through plant breeding

**Cassava:** An essential crop in many developing countries carries Fe and Zn only in low concentrations. Therefore, the focal point of bio-fortification tasks is solely on increasing beta-carotene awareness. Studying 632 accessions from the CIAT germplasm collection of 5500 accessions and detected germplasm with beta-carotene concentrations above 20  $\mu\text{g/g}$ , suggesting an excessive genetic variability that might make it viable to successfully biofortify cassava and meet the daily retinol requirements of adults. It was viable to increase genuine protein in cassava roots measured by way of amino acid contents through inter-specific hybridization and the interspecific hybrid has 10-fold lysine and 3-fold methionine than commonplace cassava cultivar.

**Sweet Potato:** The main purpose of the bio-fortification applications is the substitute of white fleshed low pro-vitamin A sweet potato varieties with orange fleshed high pro-vitamin A flowers. Harvest Plus has set the target stage for sweet potatoes at  $32\mu\text{g g}^{-1}$ , however, varieties with concentrations as much as  $100\mu\text{g g}^{-1}$  exists already. Workers supplied the kids with either orange fleshed potato with a beta-carotene concentration of approximately a  $100\mu\text{g g}^{-1}$  in the cooked root or white fleshed potato without any beta-carotene over a length of 11weeks. Vitamin-A liver store had been elevated within the remedy organization as compared to the manage group. Furthermore it has been shown that retention of beta-carotene from orange fleshed sweet potatoes whilst boiled could be very excessive with approximately 80% of the preliminary attention.

**Beans:** In dietary terms, beans are frequently called the “negative guy’s meat” for his or her less expensive rate as a protein source and their wealthy content of minerals (particularly Fe and Zn) and vitamins. The benefits and wishes of mineral biofortification in not unusual bean, beginning with the steps of breeding for the trait which includes germplasm screening, inheritance, physiological, or bioavailability studies and completing with product development within the shape of new biofortified sorts.

**Cow Pea:** A pioneer study on biofortification of cow pea has initiated G.B. Pant university of Agriculture and generation, Pantnagar, India. Early maturing high Fe and Zn fortified varieties namely Pant Lobia-1(82ppm Fe and 40ppm Zn), Pant Lobia-2 (100ppm Fe and 37 ppm Zn) were evolved by conventional plant breeding and launched in 2008 and 2010. Latest years, biofortification in vegetables is mainly centered via transgenic techniques. Subsequently this evaluation article is in reality discussed with gene manipulation.

**Genetic Engineering:** Genetic engineering is frequently defined as an era this is crucial for destiny food, feed and electricity wishes. Biotech crop hectares improved by means of greater than a 100-fold from 1.7 million hectares in 1996 to 179.7 million hectares in 2015. For the reason that first huge-scale advent of Flavr-Saver tomato in 1996, a file 175.2 million hectares of biotech Plants were grown globally in 2013, at an annual boom price of 3%. This unprecedented high increase price beginning from 1.7 million hectares in 1996 to a 175.2

million hectares in 2013 makes biotech vegetation the quickest adopted Crop generation in recent records, growing about 100-folds among 1996 and 2013. Transgenic vegetation, Generally known as genetically modified (GM) crops enable plant breeders to bring favourable genes, often Previously inaccessible, into elite cultivars, enhancing their value substantially and provide precise opportunities for Controlling bugs, viruses and different pathogens, in addition to dietary quality and fitness blessings.

Loss of enough version some of the genotypes for the favoured character/trait inside the species, or while the crop itself isn't always suitable for traditional plant breeding (due to loss of sexuality) then genetic engineering gives a valid alternative for increasing the attention and bioavailability of micronutrients in the edible crop tissues.

Genetic engineering allows vegetable breeders to comprise preferred transgenes into elite cultivars, thereby enhancing their fee considerably. It in addition offers particular possibilities for enhancing dietary high-quality and bringing different health advantages. Many vegetable crops were genetically changed to improve tendencies along with better nutritional repute or higher flavour, and to reduce bitterness, slow ripening, higher nutritional repute, seedless fruit, and improved sweetness and to reduce anti-nutritional factors.

### **Transgenic approaches for biofortification**

#### **Tomato**

**Antioxidants:** Fruits and greens include a wide variety of antioxidants together with anthocyanins and carotenoids which include lycopene and  $\beta$ -carotene and vitamin C and E. In transgenic fruit which acquire trans-resveratrol, there may be a boom inside the tiers of ascorbate and glutathione, the soluble antioxidants of number one metabolism, as well as in the total antioxidant activity.

**Carotenoid- rich tomato:** Lycopene is an amazing antioxidant with the potential to save you epithelial cancers and enhance human health. Consequently, there is significant hobby in elevating the ranges of carotenoids in tomato fruit by using genetic manipulation and thereby enhancing the dietary nice of the crop. The *Psy-1* enzyme catalyzes the primary dedicated step of the carotenoid biosynthesis pathway via producing phytoene from GGPP (geranylgeranyl diphosphate). A good way to boom the carotenoid content of fruit, the *Psy-1* gene was constitutively expressed in tomato.

**Anthocyanin- rich tomato:** To enrich the anthocyanin content of the fruits of a commercially cultivated tomato cultivar, Arka Vikas by fruit specific expression of two transcription factors *Ros1* and *Del* by Agrobacterium-mediated transformation. The average anthocyanin content of the transgenic fruit was  $0.1 \text{ mg g}^{-1}$  fresh weight, which were 70-100 folds higher than that of the control fruits.

**Flavonol- rich tomato:** Transformation of tomato with the *Petunia chi-a* gene encoding chalcone isomerase. Resulting transgenic tomato strains produced a growth of as much as 78-fold in fruit peel flavonols, specifically due to an accumulation of rutin. Through growing 78-fold of overall fruit flavonols turned into executed thru ectopic expression of an unmarried biosynthetic enzyme, chalcone isomerase.

**Folate- rich tomato:** Engineering a moderate increase in pteridine production can appreciably decorate the folate content material in food plant life and that boosting the PABA supply can produce further gains. While transgenic PABA- and Pteridine- over production trends were blended by crossing, vine-ripened tomato fruit amassed up to 25-fold extra folate than manipulate. Expressing a yeast S-adenosylmethionine decarboxylase gene (*ySAMdc; Spe2*) fused with a ripening-inducible E8 promoter to mainly increase tiers of the polyamines spermidine and spermine in tomato fruit at some point of ripening. This led to an increase in lycopene, prolonged vine existence, and more advantageous fruit juice high-quality.

**Table 3: Engineering for quality improvement in tomato**

Fruit trait	Inserted target
<b>Carotenoid content</b>	Dxs, CrtB, CrtI, CrtY, PSY-1, CRY-2, CYC-B, LCY-B, LCY-B, CHY-B, DET1, COP1LIKE, CUL4, FIBRILLIN, Spermidine synthase, PG
<b>Flavonoid content</b>	CHI, CHS, CHI, F3H, FLS, MYB12, STS, CHR, FNS-II, Del, Ros1
<b>Ascorbic acid content</b>	GaLDH, GME, GCHA and/or ADCS
<b>Nutritional content</b>	Crt1, Same

**Potato**

The single gene overexpression of genes encoding chalcone synthase (CHS), chalcone isomerase (CHI) and Dihydroflavonol reductase (DFR) ended in a full-size growth of measured phenolic acids and anthocyanins in potato.

**Starch- rich potato:** Starch is the primary storage issue of carbohydrate in potato tubers accounting as much as 70% of tuber dry matter. Bacterium *Escherichia coli gene glg C16* encoding bacterial ADPGP Pase whilst transferred into potato, the transgenic plant confirmed excessive starch content material within the tubers.

**Protein-rich potato:** Expanded nutritive price can be finished in potato via expressing a non-allergenic seed albumin gene from *Amaranthus hypochondriacus* by protein-wealthy potato expressing the seed protein gene *AmA1* (*Amaranth Albumin 1*). On the biochemical degree, expression of *AmA1* in each classes of transgenic results in a high boom in all vital amino acids, particularly lysine, tyrosine, and the sulfur amino acids with corresponding boom in general protein content material.

**Protein on Bio Cassava Plus** to growth the minerals zinc and iron, vitamins A and E, protein contents and lower cyanogen content, delay postharvest deterioration and development of virus-resistant types through hybridization and selective breeding techniques.

**Amino acid-rich potato:** High important amino acid encoding *heaae* gene was transferred to potato clones K-2 and K-7 and it showed boom in critical amino acids. This synthetic gene fragment (HEAAE-DNA), 292 base pairs in length, codes for a protein composed of about 80% critical amino acids.

**Table 4: Recent updates of transgenic research in potato for quality improvement**

Quality trait	Gene	Source
<b>Amino acid-rich storage protein</b>	<i>AmA1</i>	<i>Amaranthus hypochondriacus</i>
	<i>tar1</i> (tarin)	<i>Colocasia esculenta</i>
	<i>Boxla, BoxIIa, BoxlaIIa2</i>	<i>Bertholletia excels</i> (Brazil nut)
<b>High amylose starch</b>	<i>SBE I antisense</i>	Potato
<b>Carbohydrate engineering</b>	<i>SUSI</i> (sucrose synthase)	Potato
<b>High tuber galactose</b>	<i>stUGE451 stUGE51</i>	Potato
<b>High tuber fructose</b>	<i>xyIA</i> (glucose isomerase)	<i>Thermus thermophilus</i>

**$\beta$ -carotene-rich potato:** The single gene overexpression or simultaneous expression of genes encoding chalcone synthase (CHS), chalcone isomerase (CHI), and dihydroflavonol reductase (DFR) resulted in a sizeable increase of measured phenolic acids and anthocyanin. The *crtB* gene turned into additionally converted into S. Phureja, resulting in a boom. In total carotenoid content material to 78 $\mu$ g carotenoid g<sup>-1</sup> DW in the most affected transgenic line.

As a way to decorate the carotenoid content material of potato tubers, transgenic potato flowers had been produced expressing an *Erwinia uredovora crtB* gene encoding phytoene synthase, mainly within the tuber of *Solanum tuberosum* L. In growing tubers of transgenic

*crtB* Desiree lines, carotenoid ranges reached 35 $\mu\text{g}$  carotenoid  $\text{g}^{-1}$  DW and the stability of carotenoids modified substantially as compared with controls. The *crtB* gene turned into also transformed into S. Phureja, once more ensuing in an increase in overall carotenoid content to 78  $\mu\text{g}$  carotenoid  $\text{g}^{-1}$  DW within the most affected transgenic line. In those tubers, the most important carotenoids had been violaxanthin, lutein, antheraxanthin, and  $\beta$ -carotene.

Enhancing carotenoid accumulation by expression of *or* in transgenic potato: Cauliflower *Or* gene represents a singular gene mutation. It reasons many low pigmented tissues of the plant, maximum rather the edible curd and the shoot meristem to build up excessive tiers of  $\beta$ -carotene and turn these tissues orange. The *Or* gene has been remoted by a map-based cloning strategy. This gene appears to represent a regulatory gene in controlling carotenoid accumulation. It features in increasing the sink capacity instead of changing the expression of genes involved in carotenoids biosynthesis.

To take a look at whether or not *Or* may be used as a brand new genetic tool to beautify carotenoid content in a main staple crop, *Or* turned into converted into potato plant life beneath the manager of a granule-sure starch synthase gene to reap tuber specific expression. Remarkably, expression of *Or* inside the transgenic potato tubers results in the manufacturing of orange yellow tubers. HPLC evaluation confirmed that this colour alternate is certainly related to more advantageous degrees of carotenoids, such as the accumulation of  $\beta$ -carotene that is gift at negligible amounts in the controls. The overall carotenoid contents in the tubers expressing the *Or* transgene had been six fold better than those in the controls. This successful transformation result demonstrates that *Or* functions across plant species and may be used as a novel molecular tool to enrich carotenoid contents for improving the dietary price of crops.

Low sugar potato: Genetically changed potato flowers have also been produced in the Czech Republic. These are potatoes with an inserted gene for phosphofructokinase from bacterium *Lactobacillus bulgaricus*. Moreover, potatoes containing higher quantities of easy sugars turn brown all through frying and are therefore less appealing for clients. Transgenic potato flora not only has decrease sugar content, but moreover, chips organized from such potatoes are lighter in coloration than those organized from non-changed ones.

#### **Cauliflower**

A success cloning of a cauliflower *Or* gene reveals that manipulation of chromoplast formation to offer a powerful metabolic sink for carotenoid sequestration and deposition exerts a profound effect on carotenoid accumulation. The demonstration of use of the *Or* gene to growth carotenoid content material in transgenic potato illustrates an opportunity new approach to supplement consequences relying on expression of carotenogenic genes for reinforcing carotenoid degrees in meals plants.

#### **Cabbage**

Red cabbage offering large amount of anthocyanin and providing high antioxidant residences which may decrease the danger of cardiovascular diseases, brain issues and most cancers.

#### **Carrot**

Genetically engineered carrot containing increased Ca levels may boost Ca uptake, thereby reducing the incidence of Ca deficiencies such as osteoporosis. Transgenically modified carrots expressed increased levels of the plant Ca transporter SCAX1.

#### **Pumpkin**

The total carotenoid and  $\beta$ -carotene isomers contents elevated consistent with the cooking strategies carried out and excessive contents of general carotenoids in pumpkin.

#### **Cassava**

Cyanogen-free cassava: Cassava, however, carries doubtlessly poisonous levels of the cyanogenic glucoside, linamarin. The cyanogens ranges in leaves (200-1, three hundred mg CN equivalents/kg dry weight) and roots (10-500 mg CN equivalents/kg dry weight) of many

cassava cultivars are higher than the maximum advocated cyanide tiers (10 mg CN equivalents/kg dry weight) in foods set up by the FAO. The cyanogen content material of cassava foods can be decreased to safe degrees by using maceration, soaking, rinsing and baking; however, short-reduce processing techniques can yield poisonous food merchandise.

To generate cyanogenic cassava flowers targeted the genes (CYP79D1 and CYP79D2) encoding the cytochrome P450s that catalyze the primary dedicated-step in linamarin synthesis for decreased stages of expression. As an end result each leaf and root levels of linamarin are decreased up to 94% and 99%, respectively, in CYP79D1/CYP79D2 antisense vegetation.

Enhancing protein content in cassava: So that you can growth the dietary first-rate of cassava garage roots, which incorporate as much as 85% starch in their dry weight, however are deficient in protein, an artificial *ASPI* gene encoding a storage protein rich in important amino acids(80%) changed into added into embryonic suspensions of cassava through *Agrobacterium*-mediated gene switch.

**Table 5: Released vegetable varieties**

Crop	Varieties	Attributes
Tomato	Pusa Uphar Pusa Rohini Pusa Hybrid 2 Pusa Red Plum	Vitamin C & Lycopene
Carrot	Pusa Asita Pusa Rudhira Pusa Vrishti Pusa Yamdagni Pusa Meghali Pusa Nayanjyoti	Anthocyanin Lycopene beta carotene
Paprika	KTPL-19	Capsathin
Radish	Pusa Jamuni Pusa Gulabi	Anthocyanin Lycopene
Red cabbage	Red Acre Kinner Red	Anthocyanin
Palak	Pusa Bharati Pusa Jyoti	Ascorbic acid Vitamin A, C, Fe, Ca
Bittergourd	Pusa Aushadi Pusa Vishesh Pusa Hybrid 1 Pusa Hybrid 2 Pusa Hybrid 3 Pusa Hybrid 4 Pusa Hybrid 5	Beta carotene Ca & Fe Ca & Fe
Pumpkin	Arka Chandan	Beta carotene
Tapioca	Sree Visakam	Beta carotene

Sweet potato	Sree Kanaka BHU Krishna BHU Sona BHU Kanti	Beta carotene
Amaranthus	Amaranthus 105 Pusa Kiran	Carotene and protein Fe
Garden pea	Pusa Pragati and Arkel	Protein
Bathua	Pusa Bathua 1	Beta carotene

## Conclusion

Biofortification gives a feasible method of achieving malnourished populations in exceedingly far off rural regions, turning in obviously fortified meals to people with confined get entry to commercially-marketed fortified ingredients, which might be more comfortably to be had in city regions. Biofortification and commercial fortification, therefore, are especially complementary. In the words of M.S. Swaminathan, “GM foods have the capacity to remedy among the international’s hunger and malnutrition problems, and to assist shield and hold the surroundings by means of increasing yield, pleasant and lowering reliance upon chemical insecticides. Yet there are numerous demanding situations ahead for governments, especially in the areas of protection checking out, law, industrial policy and meals labelling.

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