Nutraceuticals and their Biofortification in Vegetable Crops: A Review

Y. R. Parulekar[1*], P. M. Haldankar[2], N. V. Dalvi[1], B. R. Salvi[1] and T. Bhattacharyya[3]

[1]College of Horticulture, (DBSKKV), Dapoli, Maharashtra 415712 (India)
[2]Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra 415712 (India)
[3]former Vice Chancellor, Dr. B. S Konkan Krishi Vidyapeeth, Dapoli, Maharashtra 415712 (India)

Abstract

Increasing population, inadequate food coupled with malnutrition are bigger challenges in developing countries like India. As per WHO, the vegetable consumption should be 300 g day^{-1} capita^{-1} comprising of 125 g leafy vegetables, 100 g tubers and 75 g of other vegetables. There is deficit of 20 to 50 percent in vegetable consumption. About 43.5 per cent children in the country are facing problem of malnutrition. Vegetables are rich source of carbohydrates, proteins, fibres, vitamins and minerals like phosphorous, iodine and sodium. Nutraceuticals can help in overcoming malnutrition in human beings and are important to achieve nutritional security in the country by sustainable and cost effective means. Several nutraceuticals viz., glucosinolates, lycopene, folates, allyl propyl disulfide, quercetin and alliin helps in curing of various cancers, CVDs, diabetes, blood pressure and LDL cholesterol etc. Agronomic bio fortification, use of conventional breeding methods as well as transgenic approaches are most common methods of improving nutraceuticals properties in various vegetables. Increased level of iodine in tomato fruits was observed when crop was treated with potassium iodide. The foliar use of Zn was successful in increasing the Zn content in potato tubers. The application of Zn enriched organic manure elevated Zn levels in various solanaceous crops like tomato, pepper and brinjal. The vegetable varieties namely Bhu Sona, Bhu Krishna, Sree Kanaka are released as nutraceuticals varieties in tuber crops. Various vegetable varieties rich in nutraceuticals are also developed through transgenic approaches. Various aspects of Nutraceuticals and their biofortification in vegetable crops are reviewed in this paper.

***Corresponding author :** yogeshpar123@rediffmail.com
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Introduction

Presently two major concerns of developing countries are to overcome hunger and malnutrition. About 43.5 % children in India under the age of five years are chronically malnourished. Consumption of vegetables is generally considered to be associated with several positive effects on health. It has been shown that low consumption of fruits and vegetables is related to more cardiovascular disease and cancer (Lock *et al.* 2005, Martinez-Gonzalez *et al.* 2011, Mosby *et al.* 2011). India's estimated population in 2019 is 1.37 billion as per recent UN report. Indian population is increasing at the rate of 1.08 per cent annually (www.worldpopulationreview.com).

The National Food Security Act (NFSA) was passed in the year 2013 as an ordinance. It is a landmark legislation which marks out the rolling out of the largest food security program of the world. It provides for 5 kg person^{-1} month^{-1} of cereals to priority households and 35 kg month^{-1} of cereals to *Antyodaya* households at subsidized price with rice @ ₹ 3 kg^{-1}, wheat @ ₹ 2 kg^{-1} and coarse grains @ ₹ 1 kg^{-1} (Ranjan 2016). Implementation of food security in India and its success in controlling the malnutrition among the Indian population is the real issue. In the South Asian region, India is one of the fastest growing countries economically, educationally, and technologically. Despite economic progress, India has failed to combat malnutrition that adversely affects the country's socio-economic progress. India houses more than one-third of the world's malnourished children. Half of the world's malnourished children reside in 3 countries: Bangladesh, India, and Pakistan (Narayan *et al.* 2018). The UNICEF data 2018 indicated that the

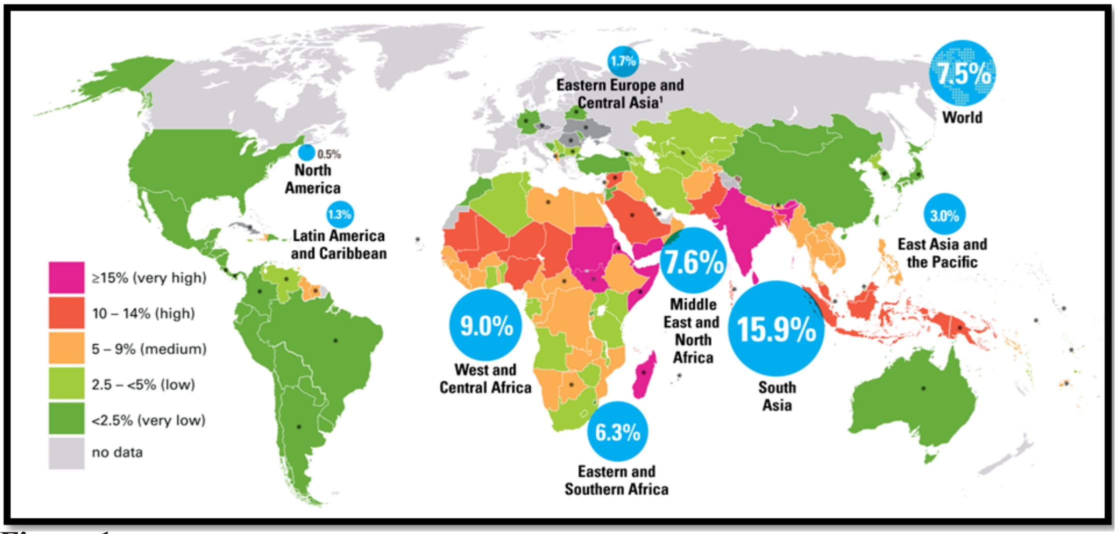


Figure 1. Malnutrition in Children. Source: UNICEF DATA (2018)

Table 1. Estimated average requirement of nutrients as per Dietary Reference Intake (DRI) .

Nutrients	Intake day^{-1}
CHO	260 g
Protein	50 g
Fat	70 g
Vitamin A	500-630 mg
Calcium	500-1000 mg
Iodine	73-95 mg
Iron	5-8.1 mg
Magnesium	200-350 mg
Selenium	35-45 mg
Zinc	6.8-9 mg

Source: Food and Nutrition Board, Institute of Medicine, National Academics, 2013.

highest malnutrition in children (15.9 %) is observed in South East Asia. This demands attention.

Malnutrition is associated with failure in taking healthy food containing various nutrients, minerals, vitamins as well as several phytochemicals which includes terpenes, chlorophylls, polyphenols and organo-sulphur compounds essential for healthy human body. The estimated average requirement as per Dietary Reference Intake (DRI) is given in Table 1.

Thus, hunger and malnutrition are two major concerns faced by the country. Vegetables are well known source of various nutrients, minerals as well as vitamins and are rightly known as protective food as they protect human body from several diseases. As per FAO, in balanced diet, 300 g of vegetables (125 g green leafy vegetables, 100 g of tubers and 75 g of other vegetables) should be consumed daily. However, though the per capita

Table 2. Important nutrients and vegetable sources.

Nutrients	Vegetables
Carbohydrate	Sweet potato, potato, and cassava
Protein	Pea, lima bean, French bean, and cowpea
Vitamin A	Carrot, spinach, and pumpkin
Vitamin B1	Tomato, chilli, garlic, leek, and pea
Vitamin C	Chilli, sweet pepper, cabbage, and drumstick
Calcium	Hyacinth bean, amaranthus, and palak
Iron	Amaranthus, palak, spinach, lettuce, and bitter gourd
Phosphorous	Pea, lima bean, taro, and drumstick leaves
Vitamin B5	Palak, amaranthus, bitter and pointed gourd
Iodine	Tomato, sweet pepper, carrot, garlic, and okra
Sodium	Celery, green onion, Chinese cabbage, and radish

Source: Gomathi *et al.* (2017)

consumption of vegetables has increased from 87.66 g in 1951 (Vanitha *et al.* 2013) to 357 g in 2017 still 20 to 50 per cent deficit is recorded in various groups of the society. Various vegetables which are recognised as sufficient source of different essential nutrients are given in Table 2.

Consumption of vegetables plays an important role in balanced diet as these commodities are rich in vitamins, antioxidants as well as phytochemicals. Especially vegetables play an important role in the maintenance of health and prevention of disease. A number of vitamins such as A, C, E, as well as carotene are excellent antioxidants, which also contribute to good health through other mechanisms, such as being co-factors for certain enzymes, and their involvement in oxidation-reduction reactions (Weisburger 1999, Podsedek 2007). Increase in vegetable consumption reduces the risk of cancer by 15%, cardiovascular disease by 30% and mortality by 20% (Rimm *et al.* 1996), by increasing the availability of antioxidants such as ascorbic acid, vitamin E, carotenoids, lycopenes, polyphenols, and other phytochemicals (Prior and Cao 2000). A diet rich in fresh vegetables protects individuals from the risk of most common epithelial cancers, including those of the digestive tract, and several non-digestive neoplasm. Selected antioxidants, β-carotene, vitamins C and E showed a significant inverse relation with the risk of oral, pharyngeal, oesophageal and breast cancers (Shetty *et al.* 2013).

The diversified and highly nutritive vegetables are of great importance in alleviating malnutrition. The presence of phytochemicals, in addition to vitamins and pro-vitamins, in vegetables which are referred to as nutraceuticals makes vegetables of crucial nutritional importance in the prevention of malnutrition and various diseases.

Considering the importance of nutraceuticals in prevention as well as curing of various chronic human diseases, the acceptance for consumption of vegetables biofortified with nutraceuticals is increasing. It has also attracted the attention of researchers towards development of vegetables having elevated levels of various phytonutrients through various means. Different methods have been adopted in developing nutraceuticals-rich vegetables.

1. Biofortification through agronomical methods
2. Developing biofortified varieties through conventional breeding methods
3. Use of transgenic techniques for vegetable bio fortification

Biofortification through agronomical methods
Several agronomical techniques *viz*., Seed treatment, foliar application, use of organic manures are used for increasing the nutraceuticals values in various vegetable crops. These various agronomical approaches are comparatively less expensive and quick as compared to any other methods of improvement. However, these techniques are useful for elevating mineral contents in various vegetables. The contents of various phytochemicals like terpenes, chlorophylls, polyphenols and organosulphur compounds cannot be fortified by using agronomical techniques. Ilupegu *et al*. (2015) conducted an experiment on impact of organic and inorganic fertilizers on nutritional and lycopene content of three tomato varieties under Nigerian conditions and reported that highest value of vitamin C content was recorded in variety *Roma* supplemented with 50 % NPK + 50 % tithonia compost (TC) i.e. Compost prepared from wild sunflower (*Tithonia divesifolia* and other weeds species containing 2.4 % N) (which was higher by 23 to 67 percent than the values obtained in other treatment combinations (Table 4).

The application of 100 % TC recorded the highest value of lycopene content (0.71 mg 100 g^{-1}) whereas it was least in non-fertilized plants (0.38 mg 100 g^{-1}) (Table 5).

Yudicheva (2014) conducted study on effect of

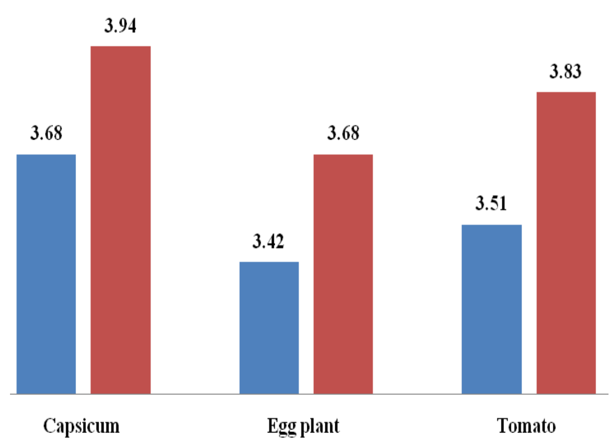


Figure 2. Effect of organic fertilizer "Riversm" on Zn content in solanaceous vegetables. Source: Yudicheva (2014)

Table 3. Nutraceuticals in various vegetables

Crop	Botanical name	Nutraceuticals	Disease control potential
Cole crops	*Brassica* spp.	Glucosinolates, Sulforaphane, Vitamin C, Luteolin, Apigenin	Breast cancer, stomach and lung cancer
Tomato and other Solanaceous crops	*Solanum lycopersicum, Capsicum* spp., *Solanum melongena*	Lycopene	Cancer, CVD, and arthritis
Artichoke	*Cynara cardunculus* var. scolymus	Silymarin	Liver diseases
GLV	*Amaranthus* spp. *Spinacea oleracea, Trigonella foenum-graecum*	Vitamin E, C and Folates	CVD, constipation
Onion and Garlic	*Allium cepa* *Allium sativum*	Allyl propyl disulfide, Quercetin, Alliin, Methiin	Stomach and colon cancer, cough and cold, diabetes, hypertension
Carrot, Pumpkin, Cantaloupe	Daucus carota, Cucurbita moschata, *Cucumis melo* var. *cantalupensis*	Vitamin A	Bladder cancer and lymphoma
Endive, Horse Radish	*Cichorium intybus* var. *foliosum* *Armoracia rusticana*	Kaempferol, Myricetin, Fisetin	Inhibit LDL, antioxidant, anti carcinogenic
Celery, Broccoli	*Apium graveolens* *Brassica oleracea* var. *italica*	Luteolin, Apigenin	Cancer of breast, skin
Legume vegetables	*Pisum sativum* *Vigna unguiculata* *Cyamopsis tetragonoloba*	Isoflavonoids	Osteoporosis and obesity and menopause
Okra	*Abelmoschus esculentus*	Quercetin and flavonol derivatives	Diabetes and Vitality
Potato	*Solanum tuberosum*	Lysine, Chlorgenic Acid	Cold sores and BP
Egg plant	*Solanum melongena*	Caffeic acid, Chlorgenic Acid, and Nasunin	CVD skin blemishes
Broccoli	*Brassica oleracea* var. *italica*	Glucobrassicin, Progoitrin, and Gluconasturtiin	Cancer
Soybean	*Glycine max*	Genistein Daidzein , and Nattokinase	Reduce LDL, coronary artery plaque
Turnip and Rutabaga	*Brassica rapa* *Brassica napus*	Glucoerucin and Glucoraphanin	Cancer and heart diseases
Beet root	*Beta vulgaris*	Ferulic Acid and Betanin	Skin disease, ant ageing
Sweet Potato	*Ipomoea batatas*	Anthocyanin, Chlorgenic Acid	Anti diabetic antiobesity
Red Chilli	*Capsicum annuum*	Capsaicin	Cancer, gastritis, headache
Red Onion	*Allium cepa*	Resveratrol	Anticancer, ant ageing
Asparagus Green Chilli	*Asparagus officinalis* *Capsicum annuum*	Rutin	Vericose Veins
Spinach	*Spinacea oleracea*	Patuletin and Spinacetin	Weight loss, good eye sight
Plantain	*Musa paradisiaca*	Benzoic and chlorogenic acid; citric and ferulic acid; oleanolic, Salicylic acid	Antimicrobial, anti-inflammatory, antitusive, cardiac stimulant

Table 4. Effect of fertilizer types on fruit vitamin C contents (mg 100 g^{-1}) of three varieties of Tomato

Fertilizer type	Tomato variety			Mean
	California wonder	Ogbomoso local	Roma VF	
Nil	12.4	12.4	16.8	13.9 c
100 % NPK	22.1	18.9	28.5	23.2 b
100 % TC	19.6	15.3	28.9	21.3 bc
75 % NPK +25 % TC	26.7	19.2	38.0	27.9 a
50 % NPK+50 % TC	26.1	21.6	38.2	28.6 a
25 % NPK+75 % TC	25.1	15.0	30.4	23.5 b
Mean	22 b	17.1 c	30.1 a	

llupegu *et al*. (2015)

Table 5. Effect of fertilizer types on lycopene contents (mg 100 g^{-1}) of three varieties of tomato

Fertilizer type	Tomato variety			Mean
	California wonder	Ogbomoso local	Roma VF	
Nil	0.41	0.32	0.42	0.38 d
100 % NPK	0.40	0.31	0.57	0.43 c
100 % TC	0.78	0.57	0.79	0.71 a
75 % NPK +25 % TC	0.54	0.42	0.61	0.52 b
50 % NPK+50 % TC	0.50	0.38	0.63	0.50 b
25 % NPK+75 % TC	0.49	0.48	0.51	0.48 c
Mean	0.52 a	0.41 b	0.59 a	

llupegu *et al.* (2015)

environmentally safe new generation organic manure “Riversm” on zinc content in biofortified tomato. Tomatoes which were grown with the use of “Riversm” accumulated in their structure 3.94 mg kg^{-1} of zinc, that is 0.26 mg kg^{-1} (or 6.60%) more than in vegetables grown under standard conditions (without fertilizer). The reference sample of eggplant contained 3.42 mg kg-^{1} of zinc and the studied sample contained 3.68 mg kg^{-1}, i.e., showing an increase in zinc content to 7.10 %. The content of biofortified tomatoes included 3.84 mg kg $^{-1}$ of zinc, and the tomatoes grown without the use of fertilizer – 3.51 mg kg^{-1}, i.e. increasing the amount of recorded investigational micronutrients to 0.33 mg kg^{-1} (or 8.59 %).

Biofortification of *Amaranthus gangeticus* using *Spirulina platensis* as microbial inoculant to enhance the iron levels was investigated by Kalpana *et al.* (2014). *Amaranthus gangeticus* leaves are good source of dietary minerals including calcium, iron, magnesium, phosphorous, zinc, copper and manganese (Tucker 1986). Seed treatment in various forms was given to the seeds of *Amaranthus viz.*, seed soaking for different times, seed soaking in different timings of spirulina and seed treatment with different ratios of vermicompost and organic manure. The sample with two hours of soaking recorded a high content (18.35±0.03 mg g^{-1}) of iron. The increased iron content in the *Amaranthus* with supplementation of *Spirulina* may be attributed due to the seeping of *Spirulina* in to the seed through the seed coat and finally into the cotyledons where the action of growth hormones gets triggered. The sample with 30 g concentration of *Spirulina* showed an increase in the iron content (20.88±0.48 mg g^{-1}) followed by the 20 g concentration of *Spirulina* (17.70 ± 0.58 mg g^{-1}). The *Amaranthus* seeds were also treated with different ratios of *Spirulina* and vermicompost. The ratio 25:75 recorded a high iron content (43.99±0.77 mg g^{-1}) when compared to the control and reference standard.

Biofortification of Potato: Increase in Zn content in potato was reported by White *et al.* (2012) through foliar application of Zn at various concentrations. Maximum increase in Zn content was recorded by three foliar applications of double dose of Zn (3.6 g Zn $plant^{-1}$) (Figure 3).

Developing biofortified varieties through conventional breeding methods

Popular conventional breeding methods like selection, introduction, and hybridization have been exploited for developing nutraceuticals in vegetables as well as tuber crops. Several resistant sources of nutraceuticals have been identified and transferred in popular cultivars through traditional breeding methods. This method uses intrinsic properties of crop however it may take comparatively very long time for developing new variety as well as the success of the breeding programme depends upon the available variability (Yadav *et al.* 2017). In India following varieties are developed in various vegetables and tuber crops (Table 6). Indian Agriculture Research Institute (IARI) has strengthened the work on development of nutraceuticals vegetable specifically on temperate vegetables. Several donor parents have been identified in different vegetables having nutraceutical values.

In cauliflower, Pusa Beta Kesari 1 have been released in 2015 as first biofortified variety through pure line selection containing high beta carotene (8.0 to 10.0 ppm) as compared to negligible beta carotene content in most of the popular varieties of cauliflower (Figure 4).

Table 6. Donar parents having nutraceutical values in different vegetable crops

Crop	Trait	Donor(s)
Tomato	High ascorbic acid	*S. pimpinellifolium*, Double Rich
	Pro-vitamin A (beta carotene)	Crimson and Caro Red
Potato	High protein content	*S. phureja, S. vernei*
Pea	Protein	GC 195, Kinnauri, Laxton
Pumpkin	Carotene	Golden Delicious
Carrot	Vit- A	Pusa Meghali
Pepper	Carotene	Douxed Alger

Yadav *et al*. (2017)

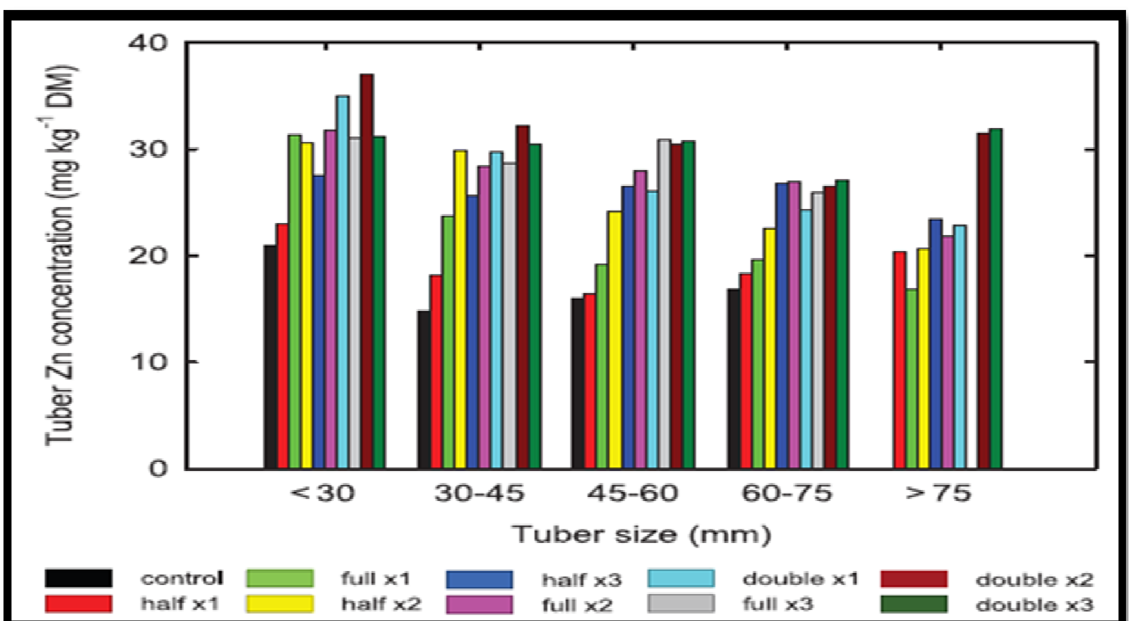


Figure 3. Biofortification of Potato by foliar application of Zinc. Source: White *et al.* (2012)

Figure 4. Pusa Beta Kesari 1First biofortified cauliflower

Nutraceutical enrichment in tuber crops

The major aim of the bio-fortification programs is the replacement of white fleshed low pro-vitamin A sweet potato varieties with orange fleshed high pro-vitamin A plants (Gomathi *et al.* 2017). Furthermore, it has been shown that retention of beta carotene from orange fleshed sweet potatoes when boiled is very high with about 80% of the initial concentration (van Jaarsveld *et al.* 2006). Central Tuber Crop Research Institute (CTCRI) have released number of biofortified varieties rich in various nutraceuticals have been released for commercial cultivation in potential areas. In sweet potato, Bhu Sona, Sree Kanaka and Bhu Krishna whereas in tapioca Sree Visakham have been released as biofortified varieties (Table 7).

Table7. Biofortified Varieties released in Tuber crops

Crop	Variety	Character	Developing Institute	Source
Sweet Potato	BhuSona	• Developed through pureline selection • High β-carotene (14.0 mg $100g^{-1}$) as compared to 2.0-3.0 mg $100g^{-1}$ • 27 – 29% dry matter • Total sugars 2-2.4% • Recommended for cultivation in Odisha • Released in year 2017	CTCRI, Thiruvanantpuram	Yadav *et al.* 2017
	Sree Kanaka	Tubers with dark orange flesh colour and very high beta carotene	CTCRI, Thiruvanantpuram	www.ctcri.org
	Bhu Krishna	• Developed through pureline selection • High anthocyanin (90.0 mg $100g^{-1}$) • Tolerant to high salinity • Dry matter: 24.0-25.5% • Starch: 19.5% • Total sugar: 1.9-2.2% • Recommended for cultivation in Odisha • Released in year 2017	CTCRI, Thiruvanantpuram	Yadav *et al.* 2017
Potato	MS/8-1565 (Kufri Neelkanth)	produces attractive purple coloured ovoid uniform tubers with shallow eyes and yellow flesh. It possesses higher anti-oxidants as compared to other red-skin indigenous varieties. It is main season table potato variety having medium maturity with high tuber yield, field resistance to late blight, good keeping/ culinary quality and suitable for growing in North-Indian plains	CPRI, Shimla	http://cpri.icar.gov.in
Tapioca	Sree Visakham	Carotene content in tubers is 466 IU $100gm^{-1}$	CTCRI, Thiruvanantpuram	

Nutraceutical enrichment in root crops

Pioneer research work on developing nutraceutical varieties have been initiated by Indian Council of Agricultural Research (ICAR), New Delhi. In carrot, Pusa Rudhira has been released which is nutritionally rich as compared to other carrot varieties. The variety was tested to have higher levels of carotenoid (7.41 mg) and phenols (45.15 mg 100g^{-1}). The primary benefit of these substances lies in their antioxidant property that guards against certain types of cancer, apparently by limiting the abnormal growth of cells. Pusa Rudhira is a boon to farmers and consumers as well. Similarly, Pusa Asita an improved carrot variety was released having long black roots with self coloured core (www.iari.res.in).

In radish, the pink and purple fleshed radish varieties were released by Indian Agriculture Research Institute (IARI). Pusa Gulabi is first pink fleshed radish variety released in 2013 which is high in total carotenoids, anthocyanin and optimum in ascorbic acid content which grows exceptionally well in the heat of summer where as Pusa Jamuni is first purple fleshed nutritionally rich variety high in anthocyanin and ascorbic acid content (ztmbpd. iari.res.in).

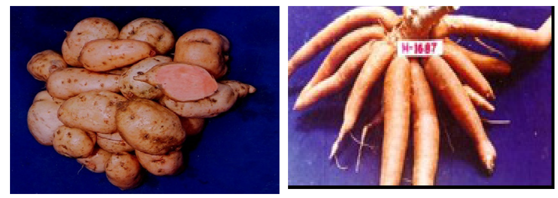
An improved nutritionally rich brinjal variety 'Pusa Safed Baigan 1' has been released by IARI in 2018. It is white coloured oval round fruited variety suitable for cultivation in kharif season in north plains. It has high total phenol content (31.21 mg GAE 100g^{-1}) and high antioxidant activity (3.48 CUPR AC µ moltrolox g^{-1}, 2.58 FRAP µ moltrolox g^{-1}) (www.agriicarjrf.com).

The nutritional value of cucumber (*Cucumis sativus* L.) can be improved by the introgression of β-carotene (i.e, provitamin A and/or orange flesh) genes from "Xishuangbanna gourd" (XIS; *Cucumis sativus* var. Xishuangbannanesis Qi et Yuan) into US pickling cucumber. However, the genetics of β-carotene content has not been clearly defined in this US market type (Cuevas *et al.* 2010).

Use of transgenic techniques for nutraceutical biofortification

The various transgenic approaches are becoming popular for developing nutraceuticals in vegetable crops. This method is quite rapid and applicable directly for elite varieties. This technique enables the plant breeder to transfer favourable gene responsible for particular

BhuSona Bhu Krishna



Sree Kanaka SreeVisakham

Figure 5. Biofortified varieties in sweet potato

Pusa Asita

Pusa Rudhira

Figure 6. Nutraceutical varieties developed in carrot

Pusa Gulabi – Nutritionally rich radish variety

Pusa Jamuni – Nutritionally rich radish variety

Figure 7. Nutraceutical varieties developed in raddish

Figure 8. Pusa Safed Baigan 1.

Table 8. Achievements in bio-fortified nutraceuticals in some vegetables

Crop	Biofortified element /mineral/ Vitamin	References
Tomato	Chlorogenic acid, flavonoids, anthocyanin, stilbene	Rosati *et al*. 2000, Muir *et al*. 2001, Giovinazzo *et al*. 2005
	Folate, phytoene & β- carotene lycopene, provitamin A	DellaPenna 2007
Onion & Broccoli	Selenium	Adhikari 2012
Lettuce	Iron	Goto *et al.* 2000
Carrot	Calcium	Morris *et al.* 2008, Park and Lee 2003
Radish	Selenium	Fernandes *et al.* 2014
Brassica spp.	Selenium	Seppanen *et al*. 2010

nutraceutical value to the cultivated variety having wider adaptability. It further offers unique opportunities for improving nutritional quality and bringing other health benefits. Many vegetable crops have been genetically modified to improve traits such as higher nutritional status or better flavour, and to reduce bitterness, slow ripening, higher nutritional status, seedless fruit, increased

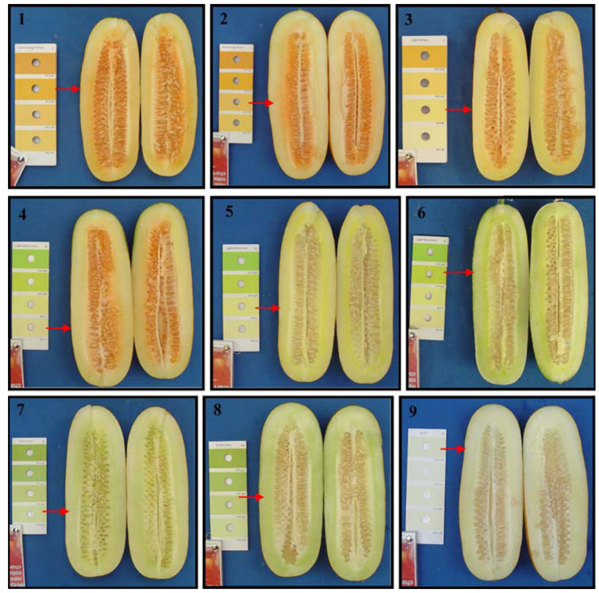


Figure 9. Crosses made between XIS (PI509549) and *Cucumis sativus*

sweetness and to reduce anti-nutritional factors. Many vegetable crops have been genetically modified through various transgenic techniques for several nutritional traits which are enlisted below (Gomathi *et al.* 2014).

- Better flavour
- To reduce bitterness
- Delay in ripening
- More shelf life
- Higher nutritional status,
- Seedless fruit,
- Increased TSS, acidity, and sugar: acid blend
- Reduce anti-nutritional factors.

Potato

Transgenic potato plants containing a gene for non-allergenic protein AmA1 from *A. Hypochondriacus* were produced. Tubers of such modified potato plants are in contrast to control plants characterized by increased production of all amino acids (Chakraborty *et.al*. 2000). These are potatoes with an inserted gene for phosphofructokinase from bacterium *Lactobacillus bulgaricus*. Potatoes containing higher amounts of simple sugars turn brown during frying and are consequently less attractive for consumers. Transgenic potato plants not only have lower sugar content, but moreover, chips prepared from such potatoes are lighter in colour than those prepared from non-modified ones (Navratil *et al.* 1998).

Sweet Potato

To increase the levels of carotenoids in the storage roots of sweet potato, transgenic sweet potato plants over expressing IbOr-Insunder the control of the cauliflower mosaic virus (CaMV) 35 Spromoter in an anthocyanin-rich purple-fleshed cultivar (referred to as IbOrplants) was developed. IbOrplants exhibited increased carotenoid levels (upto 7-fold) in their storage roots compared to wild type (WT) plants, as revealed by HPLC analysis. Thus over-expression of IbOr-Inscan increase the carotenoid contents of sweet potato storage roots.

Tomato

The strategy adopted involved pathway extension beyond β-carotene through the expression of the β-carotene hydroxylase (CrtZ) and oxyxgenase (CrtW) from *Brevundimonas* sp. in tomato fruit, followed by β-carotene enhancement through the introgression of a lycopene β-cyclase (β-Cyc) allele from a *Solanum galapagense* background.

Conclusion

Hunger and malnutrition are major issues which need attention on priority. Nutraceuticals biofortified vegetables are having potential to handle these issues. It is one of the ecofriendly and cost effective possible solution. Development, production and consumption of such vegetables needs to be popularized for preventing and controlling various health issues. Agronomic biofortification, use of conventional breeding methods as well as transgenic approaches are most common methods of improving nutraceuticals properties in various vegetables. Restrenthening the augmentation, collection and evaluation of germplasm, development of hybrids, varieties, to induce mutants with higher nutritional values, exploitation of molecular biology and cellular genetics, close interaction between nutritionists and breeders to increase awareness, strengthening research on indigenous vegetables are the necessary steps to enhance biofortification of Nutraceuticals in vegetable crops.

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