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Approaches for improvement of quality traits in vegetable crops

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Abstract
Consumer interest in the quality of vegetable products has increased in recent years especially for the beneficial effects of vegetables on human health. Vegetable quality is a broad term and includes physical properties, flavor, and health–related compounds. Presently, improving the nutrient concentration in edible plant parts has become a goal because of the increasing public awareness towards human nutrition and health. Some land races, old varieties, pre-breeding lines and wild relatives are very good source of nutrients, generally governed by poly-genes and have ability to transfer the traits in elite background. Suitable poly-cross breeding approaches along with evaluation of large number of populations would be the best to enhance the nutrient concentration in vegetables. Complementarily, the use of biotechnological tool and molecular marker assisted selection as well as various agronomic factors such as grafting, soilless culture will certainly expedite the pace and prospects of success for nutrient enhancement of vegetable crops.

Keywords: Quality traits, vegetable crops, human nutrition

1. Introduction
Vegetables are recognized as an indispensable component of balanced diets because they provide different vitamins, minerals, dietary fiber and phytochemicals in food we consume. Vegetables constitute a main part of the human diet across the globe and occupy crucial role in human nutrition by acting as sources of phyto-nutraceuticals which includes different vitamins (*viz*., C, A, B1, B6, B9, E), minerals, dietary fiber and phytochemicals. Consumption of vegetables in the daily diet improves digestive system, vision, and decreased risk various heart related ailments, diabetes, and cancer. Vegetable breeders now lay emphasis on the quality of vegetable and value-added products as people are now more concern about health and nutrition. Therefore, there is a need to standardize growing technologies and development of new hybrids for production of quality vegetables.

2. Quality
The dictionary meaning of quality is the "Degree of excellence" for a specific use. Quality refers to many aspects like colour, size, nutrient content, shelf life and suitability for processing.

3. Quality trait
"A trait defines aspects of quality of produce". Each crop has specific and different set of quality traits. These differ from species to species depending upon plant part used as economic product (Shewfelt, 1999) [37]

3.1 Classification of quality traits
3.1.1 Morphological Traits
These are related to produce appearance mainly concerned with size & colour of the produce, e.g. fruit size, fruit colour etc. These traits are easily observable trait and usually plays the main role in determining consumer acceptance of the produce.

3.1.2 Organoleptic traits
Organoleptic traits are mainly concerned with palatability of the produce. E.g., taste, aroma, smell, juiciness, softness, etc. These traits are easily detected. These traits are very important in influencing consumer preferences.

3.1.3 Nutritional quality

Nutritional quality is to determine the value of the produce in human nutrition. It includes protein content & quality, oil content & quality, vitamin content, mineral content, etc., and also the presence of anti-nutritional factors. Most prevalent deficiencies in human beings are Fe, Zn, Vit. -A, Vit. - B9.

3.1.4 Biological quality traits

The biological traits included in this group define the actual usefulness of the produce for humans when consumed. Example-Protein efficiency ratio, biological value, body weight gained etc. These traits are not obvious to consumers & growers but are extremely valuable in determining the utility of produce for human consumption.

3.1.5 Other quality traits

These includes all other qualify traits that are not included in the previous categories.eg. Cooking quality and keeping quality of vegetables. Many of the traits in this group are of prime importance in determining the usefulness of the concerned produce.

4. Health benefits of different colored group in vegetable crops

4.1 Red coloured Vegetables

Red coloured vegetables contain lycopene, ellagic acid, quercetin, and hesperidin. These nutrients reduce the risk of prostate cancer, lower blood pressure, reduce tumor growth and LDL cholesterol levels, scavenge harmful free-radicals, and support joint tissue in arthritis cases.

4.2 Lycopene

A precursor in the biosynthesis of β-carotene. The best-known sources of lycopene are tomatoes (3 mg/100 g), watermelon (4.9 mg/100 g) and Asiatic carrot (0.65-0.78 mg /100 g).It induces the Phase II enzyme, which helps eliminate carcinogen and toxins from our body. Lycopene induces formation of protein connexin, one of the major building blocks of these channels. Lycopene is a specific inhibitor of cancer cell proliferation which is regulated by cellular process called cell cycle (Kim *et al*. 2002) [23]

4.3 Orange and Yellow Vegetables

They contain beta carotene, zeaxan thin, flavonoids, lycopene, potassium, and vitamin C. These nutrients reduce age-related macular degeneration and the risk of prostate cancer, lower LDL cholesterol and blood pressure, promote collagen formation and healthy joints, fight harmful free radicals, encourage alkaline balance, and work with magnesium and calcium to build healthy bones.

4.4 β-carotene

It is the precursor of Vitamin A. Carrot major source of β-carotene providing 17% of the total vitamin A consumption (Arscott and Tanumihardjo, 2010) [1]. β-carotene protect cells from lipid peroxidation & membrane damage (Martin *et al.* 1996) [31]. It can sharpen your ability to see in darkness a little.

4.5 Zeaxanthin

It helps to prevent macular degeneration- blocking blue light from reaching structure of retina, reduce risk of light induced oxidative damage which is the leading cause of visual impairment in people over the age of 50 years. (Krinsky *et al*., 2005) [24]

4.6 Purple vegetables

They contain nutrients which include, anthocyanin lutein, zeaxanthin, resveratrol, vitamin C, fibre, flavonoids, ellagic acid, and quercetin.Similar to the previous nutrients, these nutrients support retinal health, lower LDL cholesterol**.**

4.7 Anthocyanins

Antioxidants have been reported to prevent oxidative damage caused by free radicals. Protects from cardiovascular disease and cancer. Important sources are: Red radish (100-154 mg/100 g, brinjal (88 mg/100 g), Red Cabbage (322 mg/100 g) (Wu *et al*. 2006).

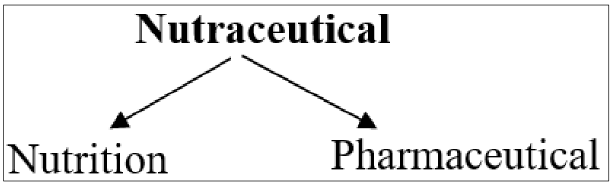
4.8 Lutein

It is a common carotenoid. Lutein provides nutritional support to our eyes; it protects the retina from sun damage by fighting free radicals that can harm the eyes. It is found in good amount in green leafy vegetables like broccoli (2.4 mg /100 g), spinach (12.9 mg/100 g), kale (15.8 mg/100 g) etc. (Sies and Stahl, 1995).

4.9 White vegetables

They contain nutrients such as beta-glucans, Polyphenol catechins epigallocatechin gallate (EGCG), SDG, and lignans that provide powerful immune boosting activity.These nutrients also activate natural killer B and T cells, reduce the risk of colon, breast, and prostate cancers, and balance hormone levels, reducing the risk of hormone-related cancers.

5. The term "Nutraceutical" was coined by Dr. Stephen De Felice in 1989



Nutraceutical is any substance that may be considered as food or part of a food and provides medical or health benefits, encompassing prevention and treatment of diseases. Nutrients are the food substances that ensure a normal deployment of the biological processes from the body of human and participate into the metabolic processes. The term nutraceutical describes particular chemical compounds found in foods that may prevent disease development. Phytochemical can underestimate the plant source of most of these protective compounds whereas phytonutrient describes quasi-nutrient status of such compounds. There are over 900 phytochemicals found in foods, one serving of a fruit or vegetable may have as many as 100 different phytochemicals.

Table 1: Common nutraceutical compounds in vegetable crops

Crop	Varieties	Nutraceuticals	Roles
Brinjal	Pusa Safed Baingan, 31.21 mg/100 g fw Pusa Hara Baingan 1, 33.5 mg/100 g fw Pusa Shyamla, 48.2 mg/100 g fw	Phenolics Phenolics Behera *et al.* 2009 [44]	Anti-oxidative, anti-mutagenic Obesity control, diabetes alleviation property Behera *et al.* 2009[44]
Bitter gourd	Pusa Aushadhi, 6.51 mg/100 g fw Pusa Rasdhar, 4.3 mg/100 g fw	Phenolics (Sawicki *et al.*, 2016) [36]	anti-carcinogenic, reduce cardiovascular diseases (Sawicki *et al.*, 2016) [36]
Onion	Pusa Madhvi, 101.2 mg/100 g fw Pusa Ridhi, 107.42 mg/100 g fw Pusa Soumya, 74.6 mg/100 g fw	Quercetin Behera *et al.* 2009[44]	Effective against various diseases such as lung cancer, osteoporosis and cardiovascular disease. (Sawicki *et al.*, 2016) [36]
Carrot	Pusa Yamdagini, 7.55 mg/100g fw Pusa Rudhira, 386 mg/100 g fw Pusa Asita, 339 mg/100 g fw	Beta-carotene Lycopene Anthocyanin Phenols (Sawicki *et al.*, 2016) [36]	Anti-inflammatory, anti-carcinogenic activities, Obesity control, diabetes alleviation property (Sawicki *et al.*, 2016) [36]
Beetroot	Crosby, 17.15 mg/g dw	Anthocyanin (Sawicki *et al.*, 2016) [36]	Anti-inflammatory, anti-carcinogenic activities, Obesity control, diabetes alleviation property (Sawicki *et al.*, 2016) [36]
Tomato	Pusa Rohini 4.5 mg/100 g fw	Lycopene Rao and Rao, 2007) [34]	specific inhibitor of cancer cell proliferation, induces formation of protein connexion Rao and Rao, 2007) [34]
Purple cauliflower	Graffiti, 375 mg/100g fw	Anthocyanin (Chiu *et al.*, 2010) [5]	Anti-inflammatory, anti-carcinogenic activities, Obesity control.
Broccoli	Green broccoli, 15.2-59.3 µ mol/100 g fw Purple broccoli,.26.3 µ mol/100 g fw	Glucosinolates (Verkerk *et al.* 2009)	Anti-cancer compound Verkerk *et al.* 2009)
Bathua	Pusa Green, 7.6 mg/100 g dw	Iron Behera *et al.* 2009 [44]	Essential for heath such as hemoglobin Behera *etal.* 2009 [44]

6. Quality Components of Fresh Vegetables

a) Appearance (visual)
The quality components in appearance include size, dimension, weight, volume, shape and form, smoothness, compactness, colour uniformity and intensity, gloss, nature of surface wax.

b) Texture
Texture includes firmness, hardness or softness, crispness, succulence, juiciness, mealiness, grittiness, fibrousness, toughness

c) Flavour (Taste and smell)
Includes: Sweetness, sourness (acidity), astringency, bitterness, aroma, off odour, off flavour.

d) Safety
Safety includes naturally occurring toxicants, contaminants (chemical residues, heavy metals), my cotoxins microbial contamination.

e) N-Quality Traits
N- quality traits include protein, Vitamin-A, Vitamin-C, Sugar and solids, Acidity, Lycopene, Carotene, Capsaicin, Cap santhin, Tomatine, Phenols, Glycoalkaloid, Colour, Post-harvest shelf life.

7. Quality Traits in Major Vegetable Crops

7.1 Tomato

7.1.1 Fresh market (Fruit quality)
- Appearance: fruit shape (oblong or square round), size or weight (80-90 g), smoothness (without ribs).
- Fruit colour: uniform, red and deep red.
- Fruit firmness
- Pericarp tissues have more sugars than the locular tissue.
- Acid content in locular tissue has predominant influence on fruit flavour.

7.1.2 Processing traits
- High TSS (5.5 °Brix or higher)
- Acidity: pH< below 4.35; low titrable acidity (0.4-0.5%).
- Solid/acid ratio of 15, sugar /acid ratio of 8.5.
- High vitamin C (but high vitamin C is pleiotropic on small fruits).

7.2 Potato
- Physical Appearance includes shape (round), size (medium), shallow eyes.
- Nutritional traits include dry matter content, reducing sugar, low glycoalkaloid content (20 mg/100g fw), high vitamin C and protein content.
- Potato chips: long-term storage, round or oval shape, 40-75 mm in size. Dry matter (21-25%), starch (16-20%), reducing sugar (<0.25%) uniformly distributed in cross-section.
- French fries: Oblong, or oval in shape, size >70 mm, Dry matter: 20-23%, 15-18% starch, reducing sugar (0.3%) distributed equally to avoid ‘sugar end’ effect in fries.
- High specific gravity (dry matter content) suitable for French fries, chips and dehydrated products.

7.3 Cole Crops

7.3.1 Cabbage
- Head shape include spherical or round, medium size head (1.0 kg or 0.8-0.9 kg), head compactness; Short core (< 25% of head diameter).
- Narrow and soft core is desirable for processing.
- Reduced content of goitrogenic Glucosinolates and higher content of desirable GLSs for good flavors and anti-carcinogenic effects.

7.3.2 Cauliflower
Curd colour, curd compactness, curd depth, curd shape, self-blanching.

7.3.3 Knol khol
Round, medium-sized knobs of desired colour-green or purple, low fibres and creamy white to greenish white flesh in tubers.

7.3.4 Broccoli
Fine buds, attractive green or purple heads, compact smooth heads.

7.4 Bulbous Crops
7.4.1 Onion
- Bulb size, shape, colour, narrow neck, dormancy, dry matter (>15% for white onion for dehydration; 9-13% in onion for fresh consumption).
- Dehydration: Snow white colour, globe shaped bulbs, thick neck, free from greening and moulds, high pungency and high TSS (>18%) and low reducing sugar.

7.4.2 Garlic
Bulb size index, bulb colour, clove colour, clove shape (sickle), number of cloves, clove diameter, TSS, dry matter.

7.5 Root crops
7.5.1 Carrot
Colour (red or orange), shape (cylindrical, uniformly tapering or stump rooted, broad or narrow shoulder), non-branching and non-forking, smooth surface without fibrous in roots, thick flesh, thin self-coloured core, high carotene and high sugar and dry matter in roots, good flavour and taste.

7.5.2 Beetroot
Uniform size, shape and colour, uniformly coloured roots without internal zoning or white rings.

7.5.3 Radish
Root length, shape and colour, pungency, taste and edible quality, late pithiness, non-forking roots.

7.6 Cucurbits
7.6.1 Cucumber
- Fruit colour includes light green, green or white depending upon consumer's preference.
- Shape comprises of uniformly cylindrical fruits without thin or crook neck or bulged blossom end.
- Size includes preferably medium-long for slicing and small for pickling.
- Spines comprises of few or none, preferably white.
- Seeds should be few and immature at edible stage of fruits.
- Bitter free fruits.
- Edible fruit without carpel separation.

7.6.2 Muskmelon
- Fruit quality includes shape, size, epicarp/skin colour and surface (smooth, sutures, netted).
- Flesh thick and attractive colour.
- Seed cavity, preferably small.
- Sweet taste, musky flavour, juiciness and high TSS (Not less than 10%; 11-13%).
- Good keeping quality, good transportability.

7.6.3 Watermelon
- Fruit shape comprises of (round/oblong), size/weight (large, medium or small).
- Skin/rind includes (tough, thickness, resistance to cracking, colour green, dark green or light green, striped or without stripes).
- Intermediate fruit shape
- Flesh: firm, colour – attractive red, pink or yellow.
- Seeds: smaller and fewer.
- TSS (more than 10%), Transportability and shelf-life.

7.6.4 Pumpkin
Thick fruit flesh and small seed cavity; Round /oblong/flat round fruit shape; Orange flesh colour, rich in β-carotene.

8. Breeding Approaches
8.1 Evaluation of Germplasm
For the development of phytonutrient rich variety, characterization of the vegetable germplasm is considered as primary step to achieve the goal. High nutrient content can be found in cultivated variety, obsolete variety, and landraces or in wild related species. All the available genetic resources, even the wild relatives will have to thoroughly analyze for phytonutrient like micro and macro nutrient, vitamins, pigment and antioxidants. The data related to nutrient and phytonutrient will be used for genetic diversity analysis. It will lead to identification of high nutrient content lines, which may be used for the development of nutritionally improved vegetable varieties. Tomato shows genetic variability for beta carotene content that had been utilized to breed varieties with high carotene content. The highest levels of lycopene, vitamin C, phenolics and solids contents were found in the small fruited wild relative *S. pimpinellifolium* the wild genotypes *S. cheesmaniae S. pimpinellifolium* and *S. habrochaites* were reported to have immense potential in improving mineral content of traditional tomato cultivars (Fernaindez-Ruiz *et al*. 2011) [9]. Guil Guerrero and Rebolloso-Fuentes (2009) [11] classified eight tomato varieties on the basis of moisture, crude protein, carbohydrates, total lipids, dietary fiber, ash, energy, vitamin C, fatty acids, carotenoid profiles, mineral elements, nitrate and oxalic acid. Fifty-three tomato genotypes were screened for their skin firmness, pericarp thickness, TSS, phosphorus, potassium, iron, zinc, copper, manganese, titra table acidity, â-carotene, lycopene and ascorbic acid.

Non-pungent *C. annuum* genotypes were reported to have significantly more α-cryptoxanthin, ascorbic acid, total phenolics and α-tocopherol content than pungent genotypes. Brown fruited genotypes reported to have ascorbic acid capsanthin, zeaxanthin, â-cryptoxanthin, â-carotene, á-tocopherol and lutein. Highest amount of ascorbic acid, carotenoids, and átocopherol were reported in red fruited 'Verdano Poblano' and 'Guajillo Ancho' (Hanson *et al*. 2004) [13]. *Capsicum baccatum* and *C. pubescens* known as Aji and rocoto, respectively and are originated in the Andean region.

Genetic variability for valuable fruit quality traits like sucrose content as well as high carotenoid and ascorbic acid contents in Cucumis melo. Genetic variability for valuable fruit quality traits like sucrose content as well as high carotenoid and ascorbic acid contents in Cucumis melo was reported by Burger *et al*. (2006) [3], and for minerals in ridge gourd (Karmakar *et al*. 2011) [21].

Table 2: - Wild relative of respective crops having quality traits

Crop	Wild relatives	Traits
Tomato	*S. hirsutum* *S. Pimpinellifolium*	β carotene Vit.C, TSS
	S. glabratum *S. cheesmanii*	Carotene TSS
Brinjal	*S. khasianum* *S. avuncular*	Low solasodine
Capsicum	*C. baccatum*	Capsaicin
Cucumber	*C. sativus var xishaungbannansis*	Carotene
Potato	*S. microdontum* *S. vernei* *S. phureja spp. phureja*	Calcium Starch Carotene
Amranthus	Arka Arunima (Pure line selection from IIHR 49)	Rich in Ca, Fe, low anti-nutritional factors

8.2 Hybridization

Selection and hybridization or in combination, have demonstrated as a high potential tool for enriching the nutritional quality. Genetic improvement of nutritional quality can be achieved through single plant selection targeting desirable traits or through intra specific or inter specific hybridization to produce new genotypes with enhanced nutritional quality. Genetic variability is essential for competent for successful selection of breeding strategy for enhancing nutraceuticals, and genetic variation for nutritional traits basically quantitative in nature. E.g. - The multiple crossing breeding techniques like double hybridization, three-way crossing, could be useful for increasing the mineral concentration in cabbage head.

The cabbage genotypes CMS-GA and Red Cabbage excelled as good general combiners for enzymatic antioxidants, responsible for stress tolerance, longer stay-green character and longer shelf-life.

Introgressions of segments of a chromosome from a wild relative, *Brassica villosa*, enhance glucosinolate levels in broccoli (Juge *et al*. 2007) [19]

Table 3: Notable Achievements

Crop	Varieties	Developed By	Attributes
Potato	K. Chipsona 1 K. Chipsona 2	CP2416 XMS78-79 F-6 X QBIB92-4	High dry matter, low sugar
Watermelon	Mateera AHW 19 Mateera AHW 25	Selection from local race	↑ TSS
Cowpea	Bidhan Barbati 1	Combination involving 3 sub species	↑Protein%
Spinach	Arka Anupama	IIHR10 X IIHR 8	High Vit. A, C, Carotene & Fe
Muskmelon	MH4-5	Durgapur Madhu x Hara Madhu	↑ TSS (13-16%)
Watermelon	RW-177-3 (Durgapur Lal)	Sugar Baby x K-3566	↑ TSS (10-11%)

8.2.1 Interspecific Hybridization

High quality lines derived from such crosses usually serve as parents in hybridisation program.

- *Lycopersicon esculentum x Lycopersicon hirsutum* – high beta carotene
- *Lycopersicon esculentum x Lycopersicon hirsutum* fsp. *glabratum* – high beta carotene

Interspecific hybridization improved the protein content of cowpea (Hazra *et al*. 2006) [14].

8.2.2 Mutation Breeding

Mutation breeding sometimes referred to as variation breeding, is the process of exposing seeds to chemical or radiation in order to generate mutants with desirable traits to be bred with other cultivars. Plants created using mutagenesis arte sometimes called as mutagenic plants or mutageic seeds. There are different kinds of mutagenic breeding such as using chemical mutagens like ethyl methanesulfonate and dimethyl sulphate, radiation transposons to generate mutants.

The major aim in mutation breeding is to develop and improve well adapted plant varieties by modifying one or two major traits to increase their productivity or quality. Mutation breeding is built on mutation induction and mutation detection. It has many comparative advantages i.e., it is cost effective, quick proven and robust.

- Mutation is an effective way to create variation rapidly in a genotype.
- Sweet potato- orange mutants are rich in beta-carotene (30-100 ppm) than white fleshed (2 ppm) (La Bonte and Don, 2012).
- Cauliflower- Spontaneous mutation results in 'orange curd'(Li *et al*., 2001) [26]

Five high pigment (hp) mutations were identified in tomato (*Solanum lycopersicum*), hp-1,hp-1w, hp-2, hp-2j and hp-2 dg.

- hp^{-1} and hp^{-1w} were mapped to the tomato Damaged DNA-binding protein locus (SlDDB1). Mutant plants carrying these mutations in *SlDDB1* are characterized by increased carotenoid content in fruits, higher anthocyanin (7.1 mg/100 g) content (Caspi *et al*.2008) [4]
- Point mutations to DEETIOLATED1 (DET1), which is responsible for the high pigment2 (hp2) tomato mutant, resulted in elevated levels of both carotenoid (0.82g/ 100g) and phenyl propanoid phytonutrients in ripe fruit (Jones *et al*. 2012) [18].
- Purple (Pr) gene mutation confers an abnormal pattern of anthocyanin accumulation (42.1mg/kg), giving the striking mutant phenotype of intense purple color in curds and a few other tissues.

Table 4: Mutants with Changed Quality Attributes

Solanum lycopersicum	Gamma rays Spontaneous	High dry matter & sugar Uniform ripening Increased β-carotene content
Capsicum annuum	fast neutron	Increased capsaicin & reduced pigmentation
	Gamma rays	Higher capsaicin content
	Sodium azide, EMS	(20-60% higher) High protein
Vicia faba	Irradiation, chemical mutagens	Increased protein content
Phaseolus vulgaris	X-rays	Yellow to green pods
	EI, DMS	Increased protein content
Trigonella foenum graecum	MMS	Increased crude oil content
B. oleracia var botrytis	Spontaneous	Orange curd mutant
B. pekinensis	EI, DMS	Increased ascorbic acid content
Solanum tuberosum	Gamma rays & radioisotopes	White skinned, fleet eyes from deep eyes
Ipomoea batatas	Gamma rays, EI	Variation in sugar content

G. Kalloo 1988 [20]

8.2.3 Polyploidy Breeding

Polyploidy refers to when an organism has more than two complete sets of chromosomes. Polyploidy was first discovered nearly one hundred years ago.

Polyploidy breeding can act as an important tool for the evolution of new crop species

Polyploids can be induced due to aberration in cell division. This can be used to enhance nutraceuticals and colors. Tetraploids in radish, pumpkin, muskmelon and watermelon- highly productive and have improved quality. Tetraploid muskmelon- rich in soluble solid, soluble sugar and vitamin C contents (Zhang *et al*., 2010) [42]. Triploid and tetraploid watermelon- increased range of lycopene than diploid cultivars (Liu *et al*., 2010) [5].Auto-tetraploid cultivar of fenugreek- larger leaf area and larger productivity concerning seed number, pod number than diploids and rich in K, Na, Ca and P. Choudhary and Rajendra (1980) [6] recorded ascorbic acid content of 50 mg/100 g in tetraploid var. Pusa Jyoti of palak which was higher as compared to diploid var. All Green. Sreekumari *et al*. (2004) [40] studied the tuber yield of triploids and diploids of cassava. It was observed that the tuber yields of triploids were superior than the diploid cultivars. Similarly, the starch content and dry matter were higher in triploids as compared to diploids. Kaveh *et al*. (2014) [22] conducted an experiment to study the effect of different ploidy levels on glycoalkaloid content of four Solanum melongena cultivars. It was observed that the tetraploid accessions had lower glycoalkaloid contents than diploid during fruit set.

8.3.4 Molecular breeding of healthy vegetables

Investigation on the metabolic profile of Or gene mutants reported that â-carotene is the principal carotenoid compound in edible portion.10 AFLP markers, tightly linked with Or locus and developed functional SCAR markers to simplify positional cloning of Or gene which is very benificial for improving the quality.QTL analysis of fruit antioxidants in tomato using *S. pennellii* introgression lines detected a total of 15 QTL including, six for ascorbic acid, and nine for total phenolics (Rousseaux *et al*. 2005) [35].

In broad bean zt 2 gene specific SCAR marker identified that increase protein content and reduced fiber content in the seeds, in future it should help to identify tannin free broad bean varieties (Gutierrez *et al*. 2008) [12]. The gene regulating β-carotene content was incorporated into cultivated background of cucumber from *Cucumis sativus* var. *xishuang bannanesis*. Inheritance pattern of b-carotene in endocarp shown that the trait is controlled a single recessive gene. Seven SSR makers specific to endocarp carotene content were identified on linkage group three and mapped in cucumber chromosome along with the putative candidate gene. Sinclair *et al*. (2004) [38] identified two QTL affecting Vitamin C in melon and they were responsible for 14 and 12 percent phenotypic variation, respectively. Four out of the nine molecular markers reported steadily linked with sweetness of fruits.

Seven SSR makers were identified which can be utilized in marker assisted breeding for developing cucumber germplasm with high beta carotene content in the fruits.

Song *et al*. (2010) [39] reported that the common cucumbers have low level of carotenoid i.e., only 22 to 48 ìg/100 g, but Xishuangbanna gourd has high level of carotenoid quantified as 700 ìg/100 g on flesh weight basis. Thus Xishuangbanna gourd has unique advantage as a germplasm to be used for enhancing nutritive value of the cucumber.

9. Genetic engineering for nutritional enrichment of vegetable crops

Genetic engineering facilitates vegetable breeders to integrate preferred transgene(s) into desirable back ground which may be well established varieties for enhancing their nutritive value significantly. Nevertheless it offers distinctive prospects to improve nutritive quality and bringing various health benefits. Different vegetables were genetically transformed to enhance their nutritional quality by increasing nutritive composition or improve flavour, and by reducing anitinutritional factor including bitterness. It can also increase the carotenoid content of crop plant by manipulating the metabolic sink through transgenic approach in vegetables. Genetic engineering integrate preferred transgene(s) into desirable back ground which may be well established varieties for enhancing their nutritive value.

- Transgenic carrots with increased Ca content have possibility to improve the uptake of Ca.
- Zinc fortified lettuce developed through genetic engineering can overcome Zn deficiency.
- Deficiency of folic acid considered as an international health issue, could be solved with genetically engineered tomato having folic acid content.
- Transformation of carrot with bacterial *crtB* gene reported ninety three time rise in carotenoid content.
- Agrobacterium mediated genetic transformation of lettuce reported to increase zinc content up to 400 mg/g on dry weight basis (Zuo *et al*., 2002) [43].
- Substantial increase in the flavonoid content was reported in tomato genetically transformed with petunia CHI-A gene, that encrypting chalcone isomerase (Muir *et al*. 2001) [32]. In tomato ten time enhanced flavonoid content reported through ectopic expression of the transcription

factors LC and C1 from corn (Le Gall *et al*. 2003) [25]. Transformation of carrot with bacterial *crt*B gene reported ninety three time rise in carotenoid content (Maass *et al*. 2009) [30]. Agrobacterium mediated genetic transformation of lettuce with a mouse metallothionein mutant â-cDNA reported to increase zinc content up to 400 ìg/g on dry weight basis (Zuo *et al*. 2002) [43].

10. Agronomical approaches

10.1 Bio- Fortification

About 800 million people suffer from hunger, but even more suffer from micronutrient malnutrition, also called "hidden hunger". Bio-fortification increases the bio-available concentrations of micronutrients in edible portions of plants through crop management. Agronomic bio-fortification is the application of micronutrient- containing mineral fertilizer to the soil and/ or plant leaves (foliar), to increase micronutrient contents of the edible part of food crops. Increasing iron levels of Amaranthus plants by using *S. platensis* as microbial inoculant when compared with control reported that *Spirulina platensis* has been used as bio fortifying agent to enhance the iron status in *Amaranthus gangeticus* plant. The use of fertilizer "Riverm" during cultivation of sweet pepper, eggplant and tomatoes helps to be enriched by zinc. Bio fortified vegetables contain 6.60-8.59% of Zn more than control. Se-enriched *S. pinnata* is valuable as a soil amendment for enriching broccoli and carrots with healthful forms of organic-Se. Onions and carrots were bio-fortified by foliar application of a solution of Se that was enriched to 99.7% Se (Gomathi *et al*., 2017) [45].

10.2 Green house

Greenhouse production of vegetable presents some advantages compared to open-field production with regard to quality assurance. The big advantage is that the controlled conditions offer a way to optimize environmental parameters (light, temperature, humidity, and atmospheric CO_2) and the product is not exposed directly to sudden changes of climate conditions. Besides, the cultivation factors, such as water supply, can be better regulated under protection. This can be combined with the addition of a precise amount of fertilizer in the irrigation water. Despite advantages in comparison to open-field production, the greenhouses are never completely free from the influences of stress situations, especially with respect to heat and light energy. For example, in low tech greenhouses the lack of artificial light to supplement the natural radiation during winter season could cause an increase of nitrate content in leafy vegetables like lettuce. Moreover, the covering material can modify the light spectrum inside the greenhouse affecting the quality of the product. For instance, glass covering absorbs almost all UV-B (280-320 nm) in the natural solar radiation reducing polyphenol synthesis. In fact, Stewart *et al*. (2000) [41] reported that field-grown tomatoes in Spain and South Africa contain four- to five-fold more flavonols than those in the United Kingdom, where glasshouses are used for plant cultivation. Flavonoid content in New Asia salad (Gynura bicolor) cultivated in Germany was much higher in field-grown than in glasshouse-grown plants. In agreement with well-known results for other vegetable crops, He (1999) shows that the glucosinolate content of different Chinese brassicas is lower if cultivated in the greenhouse than in the field. This is reflected in a different taste and flavor compared to field vegetables. Greenhouse grown vegetables are often more sensitive to some plant disorders (e.g. tip burn for lettuce) than in outdoor cultivation. Plants in a greenhouse are given high level of water, heat, and fertility, and forced to grow much faster than they would outdoors. This optimized environment results in higher growth rate that almost always is associated with susceptibility to physiological conditions such as tip burn.

Soilless culture systems, the most intensive production method in today's horticulture industry enables application of specific quality management. Gruda (2009) [10] indicated that the nutrient solution management is the major factor which can effectively modify product quality, for instance, electrical conductivity (EC) of the nutrient solution, chemical forms of the elements, nutrient management, temperature of the nutrient solution, pH, etc. Proper management of the ion concentration of the nutrient solution can provide an effective tool to improve the vegetable quality. Many investigations have shown that using solutions with moderate EC, achieved by adding NaCl or nutrients, improved proper management of the ion concentration of the nutrient solution can provide an effective tool to improve the vegetable quality. Many investigations have shown that using solutions with moderate EC, achieved by adding NaCl or nutrients. Inoue *et al*., 1997 reported that increasing the Fe concentration in the nutrient solution 6 hours before harvest enhanced Fe content in lettuce from 0.8 to 3.0 mg per 100 g of fresh weight without phytotoxic city symptoms.

10.3 Irrigation management and salinity

Major horticultural productions are located in hot and dry climates (e.g. Mediterranean basin) where water quality and availability is often not adequate to meet the grower demand. Deficit irrigation strategies have been proposed to save water and optimize or stabilize yield and improve fruit quality of vegetables. One of these strategies is regulated deficit irrigation (RDI), which has been explored as a way of controlling vegetative growth and improving fruit quality. It consists of removing or reducing the irrigation input for specific periods during the growing cycle. Tomato greenhouse trials using the cultivar 'Virosa' showed that fruit quality was improved under the RDI regime mostly due to higher concentrations of soluble sugars and higher colour intensity. However, the increment in quality was not enough to compensate the pronounced yield loss. Glasshouse trials with hot pepper demonstrated that lower fruit load in RDI plants might have favored carbon partitioning to fruits and increased the content in soluble solids by about 20%. Field studies with two cultivars of watermelon showed that deficit irrigation practices reduced total marketable yield by 15 to 36%, respectively, but had no effect on fruit quality (lycopene content).

Another irrigation technique called partial root-zone drying (PRD) has been studied. This irrigation technique results in a better fruit quality, expressed by higher concentrations of anthocyanins, phenols and glycosylglucose in the fruit. Experiments with the tomato cultivar 'Petopride' showed that the fruits from plants subjected to PRD since fruit set until harvest, had significantly higher total soluble solids than the other treatments and saved more water (up to 25%). The use of saline water in many cases it improves the fruit quality. In melon, watermelon, and zucchini squash, increasing rhizosphere salinity improved fruit quality by increasing fruit dry matter and total soluble solids contents.

10.4 Grafting

Grafting has become an imperative vegetable production since chlorofluorocarbon based soil fumigants were banned from use on grounds of environmental protection. Grafting vegetable plants onto resistant rootstocks is an effective tool that may enable the susceptible scion to control soil- borne diseases, environment stress and increase yield. The characteristics of three areas might be affected by grafting as a result of translocation of metabolites associated with fruit quality to the scion through xylem and/ or modification of physiological processes of the scion. Characteristics showing these effects could be fruit appearance (size, shape, colour, and absence of defects and decay), firmness, and texture, flavour (sugar, acids and aroma volatiles) and health related compounds (desired compounds such as minerals, vitamins). Selection of appropriate rootstock cultivars for specific scions is also crucial for an optimal yield and fruit quality. Grafting which is the union of two or more pieces of living plant tissue that they grow as a single plant, has become a common practice in many parts of the world for Solanaceous and Cucurbitaceous plants in the management of soil borne disease and to improve abiotic stress tolerance. Firmness is one of the typical attributes used to describe the fruit texture. Grafting can influenced the firmness in a highly significant way. Watermelon fruits obtained from plants grafted onto Lagenaria rootstocks and *Cucurbita maxima* × *Cucurbita moschata* rootstocks were firmer by 24% and 27%, respectively, than the fruits from the ungrafted plants independent of cultivar, rootstock and growing conditions (greenhouse vs. open field).

A substantial increase in melon firmness from 'Proteo' plants grafted onto 'P360' (Cucurbita *maxima* Duchesne × Cucurbita *moschata* Duchesne) by 19-32%.

Grafting can affect the soluble solid content in different way depending on the rootstock-scion combinations. The total soluble solids concentration of melons grafted onto the pumpkin interspecific hybrid 'P360' (*Cucurbita maxima* Duchesne × Cucurbita moschata Duchesne) was reported to be lower than those from engrafted cv. 'Cyrano' (*Cucumis melo* L. var can *taloupensis* Naud).

Proietti *et al*. (2008) [33] demonstrated that mini-watermelon grafted onto the commercial rootstock of squash hybrid rootstock ('PS 1313' - Cucurbita maxima Duchesne × Cucurbita moschata Duchesne) increased the lycopene concentration by 40% in comparison to those recorded on ungrafted plants.

Huang *et al*. (2009) [16] showed that cucumber fruit quality of three grafting combinations (self-grafted cucumber, or grafted onto two commercial rootstocks: *Cucurbita ficifolia* Bouche and *Lagenaria siceraria* Standl.) was affected in a different way with increasing the NaCl in the nutrient solution from 0 to 60 mm. Under unstressed conditions, contents of soluble sugar in plants grafted onto fig leaf gourd (Cucurbita ficifolia Bouche) were lower than those in self- grafted plants. However, a higher content of soluble sugar in the plants grafted onto fig leaf gourd was observed under salt stress.

Fernández-García *et al*. (2004) [8] observed in tomato that grafting had a strong effect on lycopene than β-carotene, fruits from grafted 'Fanny' had doubled the lycopene concentration of ungrafted 'Fanny' under the same conditions.

11. Conclusion

Nutritional qualities and associated health benefits of vegetable crops is becoming important criteria for their increase in consumers diet.

- Although vegetables are rich in health beneficial compounds but in certain crops the content of public health significance nutrients are low.
- Therefore, Breeding programmes for improving the content of nutrients and shelf life in vegetables are becoming more important for breeders.
- Thus conventional breeding techniques in combination with biotechnological tools will make it possible to get enriched vegetables in a much faster and efficient way.
- Also various agronomic techniques like bio-fortification could make an impact, because it is sustainable and scalable approach to counter micronutrient malnutrition.

12. References

1. Arscott, Tanumihardjo SA. Carrots of many colors provide basic nutrition and bioavailable phytochemical acting as a functional food. Journal of Agriculture Food Chemical. 2010;9:324-326.
2. Behera TK, Singh S. Advances in vegetable breeding for nutraceuticals and quality traits. Indian Journal of Genetics. 2019;79:216-226.
3. Burger Y, Saar U, Paris H, Schaffer A. Genetic variability for valuable fruit quality traits in Cucumis melo. Israel Journal of Plant Sciences. 2006;54:233-242.
4. Caspi N, Levin I, Reuveni M. A mutation in the tomato DDB1 gene affects cell and chloroplast compartment size and CDT1 transcript. Plant signaling and behaviour. 2008;3:9:641-649.
5. Chiu LW, Zhou X, Burke S, Wu X, Prior RL, Liu L. The purple cauliflower arises from activation of a MYB transcription factor. Plant physiology. 2010 Nov;154(3):1470-80.
6. Choudhury Ba, Rajendran R. Pusa Jyoti, a highly nutritive palak. Indian Horticulture. 1980;25:5-6.
7. Colla G, Rouphael Y, Cardarelli M, Massa D, Salerno A, Rea E. Yield, fruit quality and mineral composition of grafted melon plants grown under saline conditions. Journal of Horticultural Science Biotechnology. 2006;81:146-152.
8. Fernández-García N, Martínez V, Cerda A, Carvajal M. Fruit quality of grafted tomato plants grown under saline conditions. Journal of Horticulture Science and Biotechnology. 2004;79:995-1001.
9. Fernandez-Ruiz V, Olives AI, Camara M, Sanchez-Mata MC, Torija ME. Mineral and trace elements content in 30 accessions of tomato fruits (*Solanum lycopersicum* L.,) and wild relatives (*S. pimpinellifolium* L., *S. cheesmaniae* L. Riley, and *S. habrochaites S.* Knapp and D.M. Spooner). Biological Trace Element Research. 2011;141:329-339.
10. Gruda N. Do soilless culture have an influence on product quality of vegetables? Journal of Applied Botany and Food Quality. 2009;82:141-147.
11. Guil-Guerrero JL, Rebolloso-Fuentes MM. Nutrient composition and antioxidant activity of eight tomato (*Lycopersicon esculentum*) varieties. Journal Food Composition and Analysis. 2009;22:123-129.
12. Gutierrez N, Avila CM, Moreno MT, Torres AM. Development of Scar markers linked to zt 2, one of the genes controlling absence of tannins in faba bean. Australian Journal of Agricultural Research. 2008;59:62-68.
13. Hanson PM, Yang R, Lin S, Ledesma D. Variation for

antioxidant activity and antioxidants in a subset of AVRDC The World Vegetable Center Capsicum Core Collection. Plant Genetic Research. 2004;2:153-166.
14. Hazra P, Chattopadhaya A, Dasgupta T, Kar N, Das PK, Som MG. Breeding strategy for improving plant type, pod yield and protein content in vegetable cowpea (*Vigna unguiculata*) Proc. Ist IC on Indig. Veg. and Legumes Eds. M.L. Chadha *et al*. Acta Hort, c2007, p.752.
15. He H. Studies Growth Adaptation and Identification of Glucosinolates on Chinese Brassicas. Thesis, Herbert Utz Verlag, Munich, Germany, c1999, p.170.
16. Huang Y, Tang R, Cao Q, Bie Z. Improving the fruit yield and quality of cucumber by grafting onto the salt tolerant rootstock under NaCl stress. Scientia Horticulturae. 2009;122:26-31.
17. Inoue K, Kondo S, Adachi A, Yokota H. Production of iron enriched vegetables: Effect of feeding time on the rate of increase in foliar iron content and foliar injury. Journal of Horticulture Science and Biotechnology. 2000;75:209-213.
18. Jones M, Prunier FP, Marcel F, Piednoir E. Characterization of alleles of tomato light signalling genes generated by tilling. Phytochemistry. 2012;79:78-86.
19. Juge N, Mithen RF, Traka M. Molecular basis for chemoprevention by sulforaphane: A comprehensive review. Cellular
and Molecular Life Sciences. 2007;64:1105-1127.
20. Kalloo G. Vegetable Breeding. CRC-Press Publisher. c1988, p.211.
21. Karmakar P. of Vegetable Science, IARI, New Delhi, India; c2011.
22. Kaveh H, Nemati H, Ahmadi FS, Davarynejad G. Effects of different ploidy levels on glycoalkaloid content of four Solanum melongena cultivars. Advances in Environmental Biology. 2014;8:48-52.
23. Kim L, Rao V, Rao LG. Effect of lycopene on prostrate LNCAP cancer cells in culture. Journal of Medicinal Food. 2002;5:181-87.
24. Krinsky N, Landrum J, Bone RA. Biologic mechanisms of the protective role of lutein and zeaxanthin in the eye. Annual Review of Nutrition. 2003;23:171-201.
25. Le-Gall G, DuPont MS, Mellon FA, Davis AL, Collins GJ, Verhoeyen ME, Colquhoun IJ. Characterization and content of flavonoids glycosides in genetically modified tomato (*Lycopersicon esculentum*) fruits. Journal Agriculture and Food Chemistry. 2003;51:2438-2446.
26. Li L, Paolillo DJ, Parthasarathy MV, Dimuzio EM, Garvin DF. A novel gene mutation that confers abnormal patterns of betacarotene accumulation in cauliflower (*Brassica oleracea* var. botrytis). Plant Journal. 2001;26:59-67.
27. Li X, Wang Y, Cha S, Tian H, Fu D, Zhu B, Luo Y, Zhu H. Lycopene is enriched in tomato fruit by CRISPR/ Cas9- mediated multiplex genome editing. Frontiers in Plant Science. 2018;9:1-12.
28. Liu Z, Liang J, Zhang S, Wu J, Cheng F, Yang W, Wang X. Enriching Glucoraphanin in Brassica rapa through replacement of BrAOP2.2/ BrAOP2.3 with nonfunctional genes. Frontiers in Plant Science. 2017;8:1-8.
29. Liu Ze-fa, Min Zi-yang, Sun Xiao-wu, Cheng Juan, Hu Yi-hong. Study on induction and characterization of tetraploid plants in pumpkin. Journal of North China Agricultural University. 2015;30:125-129.
30. Maass D, Arango J, Wust F, Beyer P, Welsch R. Carotenoid crystal formation in Arabidopsis and carrot roots caused by increased phytoene synthase protein Levels. PLoS One. 2009;4:e6373.
31. Martin KR, Failla ML, Smith JC. Beta carotene and lutein protect hepG2 human liver cells against oxidant-induced damage. The Journal of Nutrition. 1996;126:2098-2106.
32. Muir SR, Collins GJ, Robinson S, Hughes S, Bovy A, Ric De *et al*. Overexpression of petunia chalcone isomerase in tomato results in fruit containing increased levels of flavonols. Nature Biotechnology. 2001;19:470-474.
33. Proietti S, Rouphael Y, Colla G, Cardarelli M, De Agazio M, Zacchini M, *et al*. Fruit quality of mini-watermelon as affected by grafting and irrigation regimes. Journal of Science Food and Agriculture. 2008;88:1107-1114.
34. Rao V, Rao S. Role of anti-oxidant lycopene in cancer and heart disease. Journal of the American College of Nutrition. 2007;19:563-569.
35. Rousseaux MC, Jones CM, Chetelat DAR, Bennett A. Powell A. QTL analysis of fruit antioxidants in tomato using *Lycopersicon pennellii* introgression lines. The Applied Genetics. 2005;111:1396-1408.
36. Sawicki T, Baczek N, Wiczkowski W. Betalain profile, content and anti-oxidant capacity of red beet root dependent on the gene and root part. Journal of Functional Foods. 2016;27:249-261.
37. Shewfelt RL. What is quality? Postharvest Biology and Technology. 1999;15:197-200.
38. Sinclair JW, Park OS, Crosby KM. Identification of QTL affecting Vitamin C in Melon. Subtropical Plant Science. 2004;56:10-15.
39. Song H, Chen J, Staub JE, Simon PW. QTL analysis of orange color and carotenoid content and mapping of carotenoid biosynthesis gene in cucumber. Acta Horticulturae. 2010;871:607-614.
40. Sreekumari MT, Abraham K, Edison S, Unnikrishnan M. Taro Breeding in India. In: Guarino, L., Taylor, M. and Osborn, T. (eds) Pro. 3rd Taro Symposium, Nadi, Fiji. Secretariat of the Pacific Community. c2004, p. 202-207.
41. Stewart A, Bozonnet S, Mullen W, Jenkins GI. Occurrence of flavonols in tomatoes and tomato based products. Journal of Agriculture and Food Chemistry. 2000;8:2663-2669.
42. Zhang W, Hao H, Ma L, Zhao C, Yu X. Tetraploid muskmelon alters morphological characteristics and improves fruit quality. Scientia Horticulturae. 2010;125:396-400.
43. Zuo X, Zhang Y, Wu B, Chang X, Ru B. Expression of the mouse metallothionein mutant ââ-cDNA in the lettuces (*Lactuca sativa* L.). Chinese Science Bulletin. 2002;47:558-562.
44. Behera, Aharonian F, Akhperjanian AG, Anton G, De Almeida UB, Bazer-Bachi AR, Becherini Y, *et al*. Probing the ATIC peak in the cosmic-ray electron spectrum with HESS. Astronomy & Astrophysics. 2009 Dec 1;508(2):561-564.
45. Gomathi M, Rajkumar PV, Prakasam A, Ravichandran K. Green synthesis of silver nanoparticles using Datura stramonium leaf extract and assessment of their antibacterial activity. Resource-Efficient Technologies. 2017 Sep 1;3(3):280-284.