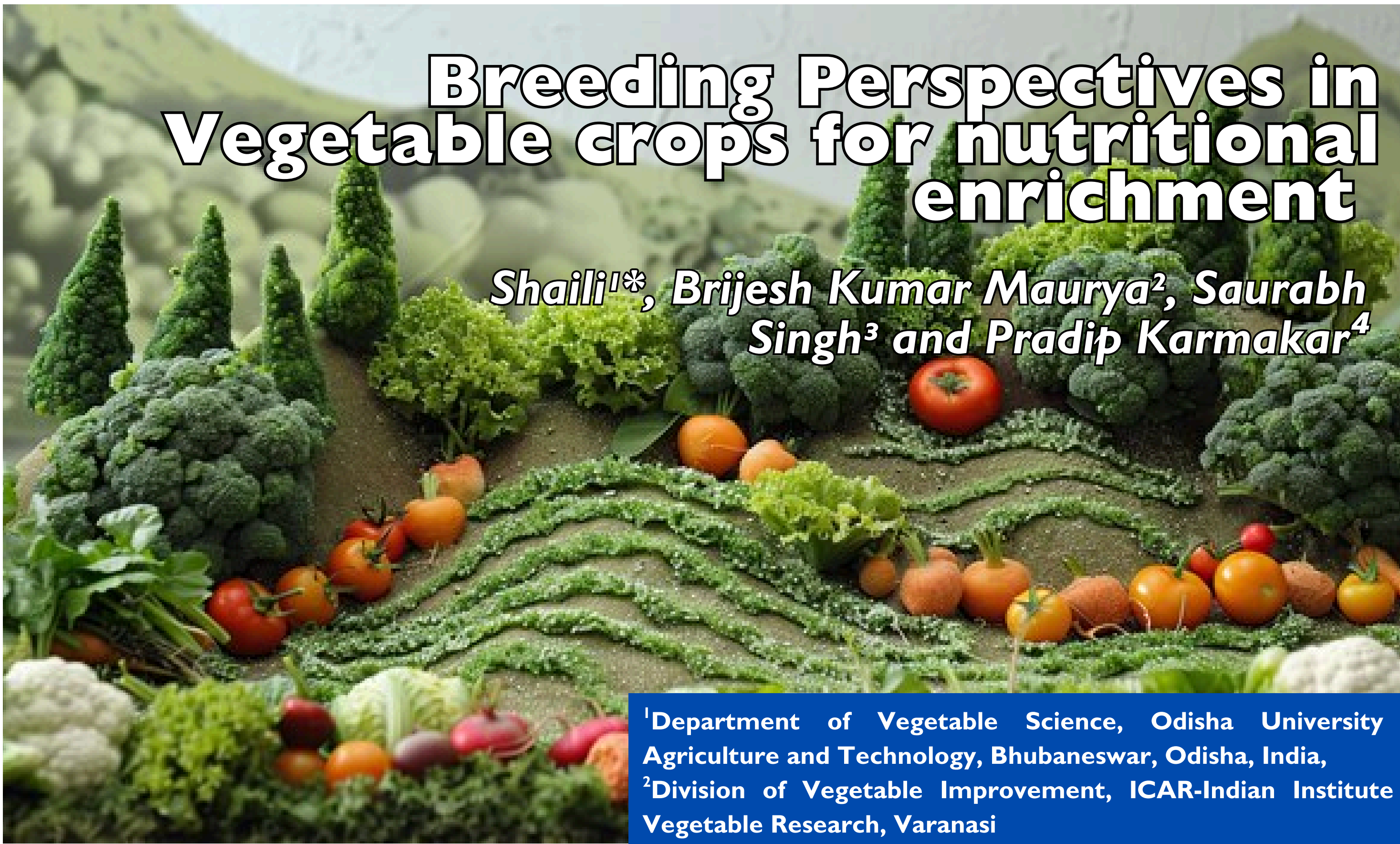
ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
Article No.: 09



Breeding Perspectives in Vegetable crops for nutritional enrichment

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Abstract

Knowledge regarding health benefits of vegetable is not new. From the time immemorial several vegetables have been used to recover or reduce many physiological malfunctions. Breeding vegetables for enhanced nutritive qualities is an emerging focus in modern agriculture to address global health and food security challenges. Vegetables are richest and cheapest sources of essential vitamins, minerals, antioxidants, and bioactive compounds that promote health and prevent chronic diseases. However, significant variability in nutrient content among vegetable varieties provides opportunities for targeted breeding initiatives. This article explores conventional and advanced strategies for developing nutrient-rich vegetable cultivars, emphasizing the integration of conventional breeding, genetic engineering, and molecular marker-assisted selection. Conventional breeding methods, such as selection and hybridization, have been pivotal in enhancing phytonutrient content, with notable successes in tomatoes, cabbage, and ridge gourd etc. Advanced techniques, including mutation breeding and polyploidy, have yielded nutrient-dense and stress-resilient varieties, while transgenic approaches and molecular breeding have enabled precise improvements in traits like vitamin accumulation and mineral bioavailability. The article also highlights the potential of biofortification as a sustainable solution for improving dietary nutrients in vegetables through genetic and agronomic methods.

Key words: breeding, hybridization ,stress-resilient ,biofortification, sustainable solution

Introduction

The concept of vegetables being beneficial for health is an age-old knowledge. Since the time immemorial, several vegetables have been used to aid in recovery or alleviate many physiological malfunctions. In recent decades, intensive search is underway to find natural sources of bioactive nutritional compounds, including fruits, vegetables, pulse, cereals, and fish. Among these, vegetables are vital due to their rich composition of bioactive compound like vitamins, trace elements, antioxidants, dietary fibers, polyunsaturated fatty acid (PUFA). These nutrients not only improve the state of health and wellbeing but also reduce risk of various degenerative disease such as cancer, cardiovascular disease, macular degeneration and ageing.

Vegetables are integral part of a balanced diet and are consumed in various forms fresh, cooked, dried, juice and processed. They are relatively affordable and widely available throughout the year. Thus, vegetables play a major role in ensuring nutritional security and alleviation of nutrition related diseases.

Breeding of vegetables for nutritive qualities is an essential aspect of modern agriculture, aiming to improve their nutritional value and to address global health and food security challenges. The natural variation in nutrient content among vegetable varieties present an opportunity for targeted breeding efforts to maximize their nutritive potential. With the growing emphasis on nutrition-sensitive agriculture, breeders are increasingly focusing on improving traits such as higher levels of vitamins (e.g., Vitamin A, C, and E), minerals (e.g., iron, zinc, and calcium), and secondary metabolites like carotenoids, polyphenols, and flavonoids. Additionally, these efforts also aim to reduce anti-nutritional factors such as oxalates and phytates,which can hinder nutrient bioavailability.

Gene Resource Utilization

Several studies have shown that nutritional contents of vegetables can be improved by fertilizer application and developing novel varieties with enhanced levels of nutrients, beneficial photo chemicals and reduced anti-nutrients. Extensive screening for genetic variation in nutrient content is a prerequisite for improving nutrient qualities. Several germplasm accessions rich in TSS (Total Soluble Solids), ascorbic acid and citric acid in tomato, protein in pea, vitamin-C, protein and dry matter in potato, carotene in capsicum, vitamins-A and carotene in carrot have been identified. Wild relatives of several vegetables are also rich in nutritional contents. These are *S. pimpinellifolium, S. cheesmanii,* and *S. peruvianum* in tomato (Willits et al., 2005), *Solanum khasianum* and *S. aviculare* in brinjal (Lyngdoh et al., 2025), *Capsicum annum* var. *aviculare* in *capsicum* (González et al., 2015), *Cucumis sativus* var. *xishuangbannanesis* in cucumber (Qi et al., 2022), *Solanum microdontum*, *S. vernei* and *S. phureja* in potato (Camire et al., 2009).

Studies have also been conducted on inheritance of nutritional traits. For example:protein content in vegetable soybean is controlled by a dominant gene (Diers et al., 2023), whereas polygenes regulate protein content in broad beans (Dahiya et al., 1977). Vitamins A content in tomato and chilly is determined by additive gene (Stommel et al., 1993), in carrot by complementary genes (Oliveira et al., 2020) and in cucurbits by polygenes. Similarly additive and dominant gene in *Cucumis melo* (Kaur et al., 2022). and chilli, additive gene in tomato (Martin et al., 1986) and polygenes in pea (Pallanca & Smirnoff et al., 2000) control vitamins C content. Carotenoid content in carrot has a complex inheritance. All this information has been effectively used by breeders to develop nutritionally superior varieties using traditional breeding interspecific hybridization and efficient selection procedures

Several nutritionally rich vegetable varieties have been developed through breeding programs to enhance the content of vitamins, minerals, antioxidants, and other beneficial compounds. For instance, 'Double Rich' tomato is specifically bred for its high lycopene and vitamin C content, while 'Pusa Red Plum' and 'Pusa Ruby' are known for their deep red color and elevated antioxidant levels. In peas, varieties like 'GC195' and 'Kinnauri' offer improved protein content and cold tolerance, catering to high-altitude regions.

Efforts have also been made in leafy vegetables—for example, 'Arka Anupama' spinach contains higher levels of iron and folate, while 'Arka Arunima' amaranth is recognized for its enhanced beta-carotene content. In cucurbits, 'Durgapur Madhu' muskmelon and 'Mateera AHW19' watermelon stand out for their superior sweetness and carotenoid profiles. Similarly, root crops like 'Surkh Chanteny' carrot are targeted for high provitamin A carotenoids.

Parallel to improving nutritional traits, significant work is underway to reduce anti-nutritional factors and toxic compounds in vegetables. For example,

ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
Article No.: 09

breeding efforts aim to lower carotatoxin levels in carrots, nitrates and alkaloids in lettuce, and glucosinolates and cholinesterase inhibitors in cruciferous vegetables like cabbage and cauliflower. In spinach and beetroot, attempts are being made to reduce oxalates, phytates, and saponins, which can interfere with mineral absorption. Sweet potatoes are being screened for lower levels of ipomeamarone, a toxic compound, and watermelons for reduced serotonin content, which can affect gastrointestinal health.

Strategies and Approaches in Breeding of vegetables for Nutritive Quality

Advancements in conventional breeding techniques, coupled with biotechnological tools such as marker-assisted selection (MAS), genetic engineering, and genome editing, have significantly accelerated the development of nutrient-rich vegetable varieties.

Conventional Breeding Methods

Conventional breeding methods, primarily based on selection and hybridization, either independently or in combination, have proven to be powerful tools for improving the nutritional quality of various crop plants (Balyan et al., 2013; Farneti et al., 2015). Enhancing nutritional quality can be achieved through mass selection or single plant selection targeting specific traits, or through intraspecific or interspecific hybridization to develop new genotypes with improved nutritional attributes. Traditional breeding and conventional selection methods are particularly effective in increasing phytonutrient content in vegetables, especially for traits with a quantitative genetic basis.

Significant research efforts have been directed towards diversifying and enhancing phytonutrients such as carotenoids and flavonoids in tomatoes. These initiatives utilize single-point mutations or quantitative trait loci (QTL) that influence phytonutrient levels. A notable example is the use of high pigment (hp) mutants in tomatoes, which have been incorporated into key genetic resources to boost lycopene content (Levin et al., 2006). Advanced breeding techniques, such as double hybridization, three-way crossing, and population improvement methods like synthetic and composite breeding, have shown potential for enhancing mineral concentration in cabbage heads.

In ridge gourd, Karmakar et al., (2013) evaluated combining ability for antioxidant properties using hermaphrodite inbred lines, while Hedau et al., (2002) reported heterosis for calcium and phosphorus content, with ranges of 0.54% to 21.30% and 3.29% to 22.74%, respectively. Geleta and Labuschagne et al., (2006) utilized hybrid breeding to enhance vitamin C content in chili. Introgressing chromosome segments from the wild relative Brassica villosa successfully increased glucosinolate levels in broccoli (Juge et al., 2007). Interspecific hybridization has also been employed to improve protein content in cowpea (Hazra et al., 2006). Additionally, Rosati et al., (2000) identified the β- mutant in tomato, which exhibited increased LYCB activity compared to normal fruits.

Advanced Breeding Techniques

Mutation Breeding

In addition to traditional breeding methods, techniques such as mutagenesis and somaclonal variation have been widely employed to isolate nutritionally rich genotypes in various vegetable crops. For instance, (γ-rays, spontaneous mutations and somaclonal variation have been used in tomato (γ-rays and Ethyl-methane-sulphonate (EMS) in capsicum), (spontaneous mutations incauliflower) and (somaclonal variation in sweet potato). Mutation breeding has shown significant potential for genetic improvement in vegetable soybean, with mutants exhibiting high protein and low fiber content identified for further evaluation (Kavithamani et al., 2010). Globally, out of 3000 mutant varieties developed, 776 have been induced specifically for improved nutritional quality (Jain and Suprasanna et al., 2007). Minor genomic modifications, such as point mutations or single-gene insertions, frequently observed through metabolomic analysis, can lead to substantial changes in biochemical composition and antioxidant levels (e.g., anthocyanin, lycopene) as demonstrated in the tomato cultivar

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Volume: 1, Issue: 2, April 2025
Article No.: 09

(Table 1.) Crop wild relatives/landraces/accessions rich in quality traits useful for breeding

Crops	Wild Relatives/Accessions/Landraces	Nutrients	References
Tomato	S. pimpinellifolium, Caro Red (Rugers × S. hirsutum)	Vitamin A	Smith, & Lee,(2015).
	S. pennellii IL6-2, IL7-2	Phenolics	Bovy et al., 2007.
	S. pennellii IL12-4	Ascorbic Acid	Rousseaux et al., 2005.
	S. chilense and S. atroviolacium from S. cheesmani	Anthocyanin	Mes et al., 2008.
Chilli	C. annum var. IC: 119262 (CA2)	Ascorbic Acid	Owk and Sape, 2009
Cucumber	Xishuangbanana gourd (C. sativus var. xishuangbananensis)	Beta-carotene	Renner, 2017
Spine Gourd	Momordica dioca	Protein	Sood and Sharma, 2012
Sweet Gourd	M. cochinchinensis	Lycopene	Ishida et al., 2004
Bitter Gourd	DRAR-1, DVBTH-5	Beta-carotene	Yadav et al.,2010.
	DRAR-1, DVBTG-5	Ascorbic Acid	Yadav et al.,2010.
Broccoli	Brassica villosa	Glucosinolates	Raimondo et al., 2023
Cassava	UMUCASS 44, 45 & 46	Vitamin A	Yusuf, 2014

Moneymaker (Giliberto et al., 2005). Sapir et al., (2008) highlighted that the high pigment-1 (hp-1) mutation in tomato is associated with increased flavonoid content in fruits. Spontaneous mutations have also played key role in improving nutritional quality; for example, The orange'cauliflower mutation (Li et al., 2001) and orange-fleshed sweet potato mutants contain significantly higher β-carotene levels (30-100 ppm) compared to white-fleshed varieties (2 ppm). Notable orange-fleshed mutant varieties include Nancy Gold and Murff Bush Porto Rico (La Bonte and Don et al., 2012).

ISSN: 3049-3293
Volume: 1, Issue: 2, April 2025
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Polyploidy Breeding

This technique has emerged as an effective startegy in vegetable crop improment, particularly for enhancing nutraceutical quality and aesthetic traits such as color. Tetraploid varieties of radish, pumpkin, muskmelon, and watermelon exhibit higher productivity and improved quality. For instance, Zhang et al., (2010) developed a tetraploid muskmelon with significantly higher levels of soluble solids, soluble sugars, and vitamin C relative to diploid fruits. Similarly, Liu et al., (2010) reported that lycopene content in diploid watermelon fruits ranged from 33.2 to 54.8 mg/kg, while triploids ranged from 41.2 to 61.8 mg/kg, and tetraploids ranged from 38.1 to 59.8 mg/kg. Their findings indicate that triploid and tetraploid watermelons generally contain more lycopene than diploids, although ploidy level did not influence lycopene content in the variety 'Fan Zu No.2'.

In a separate study, Marzougui et al., (2009) successfully induced polyploidy in *Trigonella foenum-graecum* L. using a 0.5% colchicine solution. The resulting autotetraploid cultivar exhibited larger leaf area and greater productivity in terms of seed number, pod number, and branch number compared to diploids. Additionally, its leaves were found to be rich in essential minerals such as potassium, sodium, calcium, and phosphorus.

Molecular Breeding

Molecular markers are powerful tools for improving nutritional traits in vegetable crops through marker-assisted selection (MAS). (QTLs) associated with bulb pungency and Sulphur assimilation have been identified in onion, enabling more efficient selection during breeding programs. In cauliflower, mutants at the Or locus—characterized by elevated β-carotene levels in the curd—have been instrumental in identifying ten amplified fragment length polymorphism (AFLP) markers closely linked to the locus, facilitating positional cloning. In broad been, a sequence characterized amplified repeat (SCAR) marker linked to the zt-2 gene which is associated with increased protein levels and reduced fiber holds potential for developing tannin-free varieties. Similarly, QTLs linked to elevate β-carotene levels have been identified and successfully introgressed into commercial cucumber varieties through MAS.

Transgenic Approach

Genetic engineering is another attractive tool for rapid and directed improvement of vegetables. Potato tubers naturally low in essential amino acids like lysine, tyrosine, methionine and cysteine have been improved by expressing. *Amaranthus* seed albumin gene AmAn1, resulting in elevated levels of total protein and essential amino acids. Three genes from *Erwinia*—phytoene synthase (CrtB), phytoene desaturase (CrtI), and lycopene beta-cyclase (CrtY) —have been introduced into potatoes to enable β-carotene production. Lu et al. (2006) demonstrated that transgenic cauliflower with Or gene integration induced a cellular process that promotes the differentiation of proplastids or other non-colored plastids into chromoplasts for carotenoid accumulation. They suggested that the Or gene could serve as a key genetic element for biofortification in other crops.

Carotenoids, which serve as antioxidants and vitamins-A precursors,. are synthesized via the isoprenoid biosynthetic pathway. Genetic manipulation of this pathway can improve both organoleptic (taste/smell and appearance) and nutritional qualities. In tomato, transgenic lines expressing the bacterial crtI gene (phytoene desaturase) exhibited elevated carotenoid levels. Likewise, transgenic potato plants with antisense or co-suppression of the zeaxanthin epoxidase gene showed a six-fold increase in carotenoids and 2–3 fold higher α-tocopherol (vitaminE) content.

Biofortification: A Sustainable Solution

Biofortification refers to the enhancement of health-promoting dietary nutrients in crops through conventional breeding, molecular techniques, genetic engineering, and agronomic practices. It offers a sustainable, cost-effective strategy to combat micronutrient deficiencies particularly in regions with limited access to diverse diets and fortified foods. One of the key advantages of biofortification is its potential to enable on-site production of nutrient-rich vegetables, especially those that are perishable, thereby directly serving the nutritional needs of local populations. Moreover, surplus produce from biofortified crops can be directed to pharmaceutical and cosmeceutical industries for the extraction of valuable bioactive compounds, adding further economic value.

Significant progress has been made in biofortification, with successes in increasing vitamin A content in vegetables like sweet potato, cassava, sweet corn, tomato, and cauliflower. Additionally, iron biofortification has enabled millions of people particularly in developing countries to grow and consume crops with improved nutritional profiles (Bouis and Saltzman et al., 2017).

(Table 2.) List of some biofortified vegetable varieties developed by agri-research institute of India

Crops	Biofortified Varieties	Special Characters
Cauliflower	Pusa Beta Kesari 1	Provitamin A (8.0-10.0 ppm)
Potato	Kufri Manik	Anthocyanin (0.68 ppm)
	Kufri Neelkanth	Anthocyanin (1.0 ppm)
Sweet Potato	Bhu Sona	Provitamin-A 14.0 mg/100g
	Bhu Krishna	Anthocyanin 90.0 mg/100g
Greater Yam	Sree Neelima	Anthocyanin 50 mg/100g Protein 15.4 % Zinc 49.8 ppm
	Da 340	Anthocyanin 141.4 mg/100g iron 136.2 ppm Calcium 1890 ppm
Carrot	Kashi Arun	Lycopene 7.5 mg/100g
	Kashi Krishna	Anthocyanin 275-300 mg/100g
Radish	Kashi Lohit	Anthocyanin 39.9 µg/100g
Okra	Kashi Lalima	Anthocyanin 3 mg/100g
Bitter Gourd	Pusa Hybrid 4	Iron 18.28 mg/100g

(Source: https://icar.gov.in/biofortified-varieties-sustainable-way-alleviate-malnutrition-third-edition)

Conclusion

Consuming vegetables sufficiently protects the human body against various chronic degenerative diseases, as they are universal sources of phytonutrients. Modern consumers are increasingly health-conscious and well-informed about the nutritional value of vegetables. Offering vegetables at affordable prices can encourage their inclusion in daily diets, providing motivation for vegetable breeders to develop genotypes with enhanced nutritional qualities. Vegetable breeders have a unique opportunity to address human nutritional needs by creating nutrient- and nutraceutical-rich cultivars. Augmentation and evaluation of genetic resources coupled with traditional and modern vegetable improvement tools are likely to result in development of more nutritious vegetables.

References

Balyan, H.S., Gupta, P.K., Kumar, S., Dhariwal, R., Jaiswal, V., Tyagi, S., Agarwal, P., Gahlaut, V. and Kumari, S. (2013). Genetic improvement of grain protein content and other health related constituents of wheat grain. Plant Breeding 132: 446-457.

Blanca, J., Montero-Pau, J., Sauvage, C., Bauchet, G., Illa, E., Díez, M. J., ... & Causse, M. (2015). Genomic variation in tomato, from wild ancestors to contemporary breeding accessions. BMC Genomics, 16(1), 257. https://doi.org/10.1186/s12864-015-1444-1

Bouis, H.E. and Saltzman, A. (2017). Improving nutrition through biofortification: a review of evidence from HarvestPlus, 2003 through 2016. Global Food Sec. 12: 49–58.

Bovy, A., Schijlen, E., & Hall, R. D. (2007). Metabolic engineering of flavonoids in tomato (Solanum lycopersicum): The potential for metabolomics. Metabolomics, 3(3), 399–412.

Camire, M. E., Kubow, S., & Donnelly, D. J. (2009). Potatoes and human health. Critical Reviews in Food Science and Nutrition, 49(10), 823–840.

Cervantes-Hernández, M. L., Carrillo-López, A., Bautista-Rosales, P. U., Villegas-Ochoa, M. Á., & Yahia, E. M. (2017). Antioxidant effect of wild pepper (Capsicum annuum var. aviculare) extract on the brain and liver of rats. Journal of Food Biochemistry, 41(4), e12362

Dahiya, B. S., Brar, J. S., & Bhullar, B. S. (1977). Inheritance of protein content and its correlation with grain yield in pigeonpea (Cajanus cajan). Plant Foods for Human Nutrition, 27(4), 327–334.

De Oliveira, A. C. B., et al. (2020). Inheritance of beta-carotene content in melon. Pesquisa Agropecuária Brasileira, 55, e01771.

Diers, B. W., et al. (2023). Genetic architecture of protein and oil content in soybean seed and meal. The Plant Genome, 16(1), e20308.

Dutta, P., Chatterjee, S., & Majumder, D. (2019). Studies on biochemical profile of wild brinjal Solanum gilo Raddi. Journal of Pharmacognosy and Phytochemistry, 8(4), 4202-4205.

https://www.phytojournal.com/archives/2019.v8.i4.9096

Geleta LF and Labuschagne MT (2006) Combining ability and heritability for vitamin C and total soluble solids in pepper (Capsicum annuum L.). J Sci Food Agril 86(9):1317-1320.

González-Zamora, A., Gallegos-Infante, J. A., Moreno-Jiménez, M. R., Rocha-Guzmán, N. E., & González-Laredo, R. F. (2015). Polyphenols and antioxidant activity of Capsicum annuum var. aviculare (Tepin), an ancient chili pepper. Agrociencia, 49(6), 653–665.

Hazra, P., Chattopadhaya, A., Dasgupta, T., Kar, N., Das, P.K. and Som, M.G. (2007) 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. Acta Hort. 752.

Hedau, N.K. (2002) Study on Heterosis in Ridge Gourd (Luffa acutangula Roxb.). PhD thesis, Division of Vegetable Science, IARI, New Delhi, India

Ishida, B. K., Turner, C., Chapman, M. H., & McKeon, T. A. (2004). Fatty acid and carotenoid composition of gac (Momordica cochinchinensis Spreng) fruit. Journal of Agricultural and Food Chemistry, 52(2), 396–400.

Jain, S. M. and Suprasanna, P. (2007). Induced mutations for enhancing nutrition and food production. Geneconserve,40: 201-215.

Juge, N., Mithen, R.F. and Traka, M. (2007). Molecular basis for chemoprevention by sulforaphane: a comprehensive review. Cell Mol Life Sci 64:11051127.

Karmakar, P., Munshi, A.D., Behera, T.K., Kumar, R., Sureja, A.K., C., Kaur, and Singh, B. K. (2013). Quantification and Inheritance of Antioxidant Properties and Mineral Content in Ridge Gourd (Luffa acutangula). Agric Res 2(3):222–228.

Kaur, S., et al. (2022). Heterosis and combining ability for fruit yield, sweetness, β-carotene, ascorbic acid, firmness and Fusarium wilt resistance in muskmelon (Cucumis melo L.) involving genetic male sterile lines. Horticulturae, 8(1), 82.

Kavithamani, D., Kalamani, A., Vanniarajan, C. and Uma, D. (2010). Development of new vegetable soybean (Glycine max L. Merill) mutants with high protein and less fibre content. Electronic J Plant Breeding 1(4):1060-1065.

LaBonte and Don R. (2012). Sweet potato Lists 1-26 Combined. Vegetable cultivar descriptions for North America. Department of Horticulture, Louisiana State University, USA.

Levin, I, Ric de Vos CH, Tadmor Y, Bovy A, Lieberman M, Oren-Shamir M, Segev O, Kolotilin I, Keller M, Ovadia R, Meir A and Bino RJ (2006). High pigment tomato mutants — more than just lycopene (a review). Israel J Plant Sci 54(3): 179-190.

Li L., Paolillo D. J., Parthasarathy M. V., DiMuzio E. M. and Garvin D. F. 2001. A novel gene mutation that confers abnormal patterns of beta-carotene accumulation in cauliflower (Brassica oleracea var. botrytis). Plant J., 26: 59-67.

Liu W., Zhao S., Cheng Z., Wan X., Yan Z. and King S. R. 2010. Lycopene and citrulline contents in watermelon (Citrullus lanatus) fruit with different ploidy and changes during fruit development. Acta Hort., 871: 543-547.

Lyngdoh, Y. A., Saha, P., Tomar, B. S., Bhardwaj, R., Nandi, L. L., Srivastava, M., … Chaukhande, P. (2025). Unveiling the nutraceutical potential of indigenous and exotic eggplant for bioactive compounds and antioxidant activity as well as its suitability to the nutraceutical industry. Frontiers in Plant Science, 16, 1451462.

Martin, F. W. (1986). Interaction of a green fruit color modifying gene on vitamin C content of tomato. Tomato Genetics Cooperative Report, 36, 10.

Marzougui N., Boubaya A., Elfalleh W., Ferchichi A. and Beji M. 2009. Induction of polyploidy in Trigonellafoenum-graecum L.: morphological and chemical comparison between diploids and induced autotetraploids. Acta Bot. Gallica., 156: 379-389.

Mes, P. J., Boches, P., Myers, J. R. (2008). Characterization of tomatoes expressing anthocyanin in the fruit. Journal of the American Society for Horticultural Science, 133(2), 262–269.

Owk Aniel Kumar, & Sape Subba Tata. (2009). Ascorbic acid contents in chili peppers (Capsicum L.). Notulae Scientia Biologicae, 1(1), 50–52.

Pallanca, J. E., & Smirnoff, N. (2000). The control of ascorbic acid synthesis and turnover in pea seedlings. Journal of Experimental Botany, 51(345), 669–674.

Qi, J., Liu, X., Shen, D., Miao, H., Xie, B., Li, X., … Xu, Y. (2022). Genetic and nutritional analysis of β-carotene–rich Cucumis sativus var. xishuangbannanesis for biofortification. Agronomy, 12(2), 300.

Raimondo, F. M., Mazzola, P., & Caruso, M. (2023). Biological investigation and chemical study of Brassica villosa subsp. drepanensis (Brassicaceae) leaves. Phytochemistry Letters, 54, 1–7.

Renner, S. S. (2017). A valid name for the Xishuangbanna gourd, a cucumber with carotene-rich fruits. PhytoKeys, 85, 87–94. https://doi.org/10.3897/phytokeys.85.17371

Rosati C, Aquilani R, Dharmapuri S, Pallara P, Marusic C, Tavazza R, Bouvier F, Camara B and Giuliano G (2000). Metabolic engineering of betacarotene and lycopene content in tomato fruit. Plant J24:413–419.

Rousseaux, M. C., Jones, C. M., Adams, D., Chetelat, R., Bennet, A., & Powell, A. L. T. (2005). QTL analysis of fruit antioxidants in tomato using S. pennellii introgression lines. Theoretical and Applied Genetics, 111(7), 1396–1408.

Sood, S. K., & Sharma, S. (2012). Nutritional and medicinal properties of spine gourd (Momordica dioica Roxb.). International Journal of Food Science and Nutrition, 63(1), 1-6.

Singh, D., Kaur, M., & Singh, S. (2018). Nutritional improvement of vegetable crops: Recent developments and future prospects. In K. Bhutani (Ed.), Nutritional and Functional Aspects of Food Crops (pp. 187–210).

Smith, J., & Lee, R. (2015). Carotenoid content and nutritional breeding in tomatoes (Solanum pimpinellifolium and cultivars). Journal of Horticultural Science, 45(2), 123–130.

Stommel, J. R. (1993). Inheritance of tomato fruit carotenoid content in populations derived from a cross of Lycopersicon esculentum × L. cheesmanii. HortScience, 28(5), 506.

Weng, Y., Colle, M., & Wang, Y. (2022). Genetic diversity and breeding potential of the wild cucumber variety Cucumis sativus var. xishuangbannanesis for beta-carotene enrichment. Agronomy, 12(2), 300.

Willits, M. G., Kramer, C. M., Prata, R. T. N., De Luca, V., Potter, B. G., Stephens, J. C., & Frary, A. (2005). Utilization of the genetic resources of wild species to create a nontransgenic high flavonoid tomato (including Solanum cheesmaniae). Journal of Agricultural and Food Chemistry, 53(4), 1231–1236.

Yadav, R. K., Munshi, A. D., Kumar, R., Pandey, S., & Singh, M. (2010). Characterization and evaluation of bitter gourd (Momordica charantia L.) germplasm for yield and quality traits. Indian Journal of Horticulture, 67(2), 246–250.

Zhang W., Xiucun H., Leyuan M., Zhao C. and Yu X. 2010.Tetraploid muskmelon alters morphological characteristics and improves fruit quality. Sci. Hort., 125(3): 396-400.

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