



Enhancing Nutritional Quality and Human Health through Biofortification and Sustainable Fruit and Vegetable Production in Salt-Affected Soils

Rajkumar* and Nirmal Singh

ICAR-Central Soil Salinity Research Institute, Karnal – 132 001, Haryana, India

*Corresponding author - rajhorticulture@gmail.com

India's horticulture sector stands as a cornerstone for achieving nutrition security amid rising concerns over hidden hunger. With approximately 369 million tonnes in 2024-25 of fruits and vegetables produced, horticultural crops deliver essential micronutrients like vitamins, minerals, antioxidants which combat malnutrition affecting nearly 35.5% of children and a significant adult population as per the National Family Health Survey (NFHS-5) report released by the Ministry of Health and Family Welfare. Innovations like biofortification, precision farming, and climate-resilient breeding not only amplify nutritional profiles but also improve health outcomes by reducing deficiencies in β -carotene, iron, zinc, vitamin A, and C. These practices foster sustainable food systems through resource-efficient methods, lower chemical inputs, and enhanced resilience to climate stresses, including salinity or sodicity. In salt-affected regions-covering over 6.73 million hectares, horticultural interventions may enable productive cultivation and turning these degraded lands into nutrient-rich food sources. This article explores innovations across fruit and vegetable crops, with a focus on salt-affected soil management, aligning with India's National

Mission for Sustainable Agriculture and Poshan Abhiyaan.

Biofortification and Innovations in Fruit Crops

Biofortification through conventional breeding, marker-assisted selection, and emerging tools like CRISPR-Cas9 has revolutionized fruit crops, delivering higher nutrient density without altering dietary habits. These varieties promote sustainable systems by requiring fewer inputs and supporting biodiversity.

Pomegranate (*Punica granatum*): tops the list with ICAR-National Research Centre on Pomegranate's Solapur Lal (released 2017). This biofortified variety boasts 5.6–6.1 mg/100g iron (double the popular Ganesh), 0.64–0.69 mg/100g zinc, and 19.4–19.8 mg/100g vitamin C in fresh arils, alongside high anthocyanins (395 mg/100g). Health benefits include improved haemoglobin levels and antioxidant protection against cardiovascular diseases. Sustainability comes from its medium salt tolerance (suitable for pH 8.5-9.0 soils when gypsum-amended) and suitability for drip irrigation, reducing water use by 30–40% compared to flood methods. Another

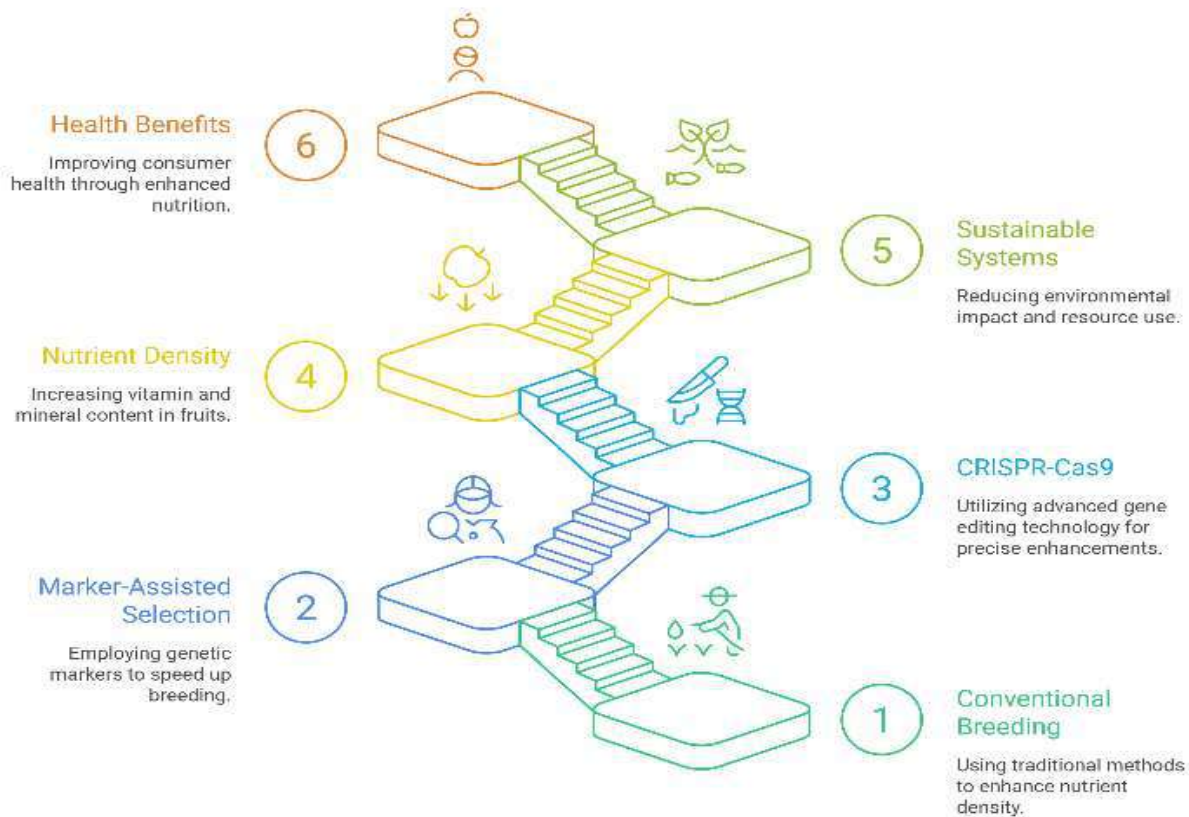


Figure 1. Achieving Sustainable Fruit Crop Bio fortification

pomegranate variety Solapur Anardana is processing-oriented due the availability of high acidity, good anardana recovery.

Mango (*Mangifera indica*), India's king of fruits, benefits from breeding programmes enhancing beta-carotene and vitamin A content. Varieties developed via molecular markers at ICAR institutes show 20–30% higher pro-vitamin A than traditional Amrapali, Mallika, Pusa Surya, Pusa Arunima, Pusa Lalima, and Pusa Shreshth. These carotenoid-rich mangoes combat vitamin A deficiency, linked to impaired immunity and vision issues. Innovations like high-density planting (HDP) with fertigation promote sustainability by optimising land use and cutting pesticide reliance through integrated

pest management (IPM). In health terms, regular consumption supports eye health and reduces oxidative stress. Mango hybrids like Arka Udaya, Ambika, Arunika showed the character like improved yield, colour, and shelf life

Banana (*Musa spp.*) features biofortified lines enriched with iron and pro-vitamin A through conventional and transgenic approaches. Research at ICAR-Central Institute for Subtropical Horticulture has yielded hybrids with 15–25% elevated micronutrients. These address anaemia prevalent in women and children. Sustainable practices include tissue culture propagation for disease-free planting material and intercropping with legumes for soil fertility, minimizing synthetic fertilizers. Health

outcomes encompass better gut health from resistant starch and muscle function from potassium.

Guava (*Psidium guajava*) hybrids like Pusa Pratiksha and Pusa Arushi (ICAR-IARI) deliver exceptionally high total soluble solids (12.50 to 13.6 °Bx), and ascorbic acid content (156.82–179.23 mg/100 g of pulp) via selective breeding. Other biofortified guava varieties are Arka Kiran, Arka Rashmi, Hisar Surkha, Lalit, Black guava and VNR Bihi etc. exceeds incidentally high in vitamin C and lycopene, with dual table/processing use and supports immunity, collagen synthesis, and iron absorption.

Foliar application of micronutrients, particularly combinations of Zinc (Zn), Boron (B), and Calcium (Ca), has been shown to increase the vitamin C (ascorbic acid) content in guava by significant margins, often reaching 20–30% or more over control treatments. Guava's low-input requirements and adaptability to marginal lands promote eco-friendly farming. IPM with biopesticides further enhances sustainability, while consumption aids in blood pressure regulation and anti-inflammatory effects.

Citrus (*Citrus spp.*, including oranges and lemons) varieties have been improved for vitamin C and flavonoid content through grafting and marker-assisted breeding. Enhanced lines show 10–20% higher ascorbic acid, bolstering antioxidant capacity against chronic diseases like diabetes. Sustainable innovations include canopy management and micro-irrigation, conserving water in arid zones. Health benefits extend to improved digestion and reduced inflammation, making citrus a staple for preventive nutrition.

Biofortification and Innovations in Vegetable Crops

Vegetable biofortification targets pro-vitamin A, anthocyanins, and minerals, delivering quick nutritional gains in everyday diets. Practices like protected cultivation and hydroponics amplify yields while conserving resources.

Cauliflower (*Brassica oleracea var. botrytis*) leads with ICAR-IARI's Pusa Beta Kesari 1 (2015), India's first pro-vitamin A-rich cauliflower at 8–10 ppm beta-carotene (negligible in conventional types). Curd yield hits 40–50 t/ha. This combats vitamin A deficiency, enhancing immunity and vision. Sustainable elements include heat-tolerant cultivation in NCR Delhi via raised beds, reducing water and pesticide needs. Health impacts include better child growth and reduced infection risks.

Potato (*Solanum tuberosum*) features ICAR-CPRI's Kufri Neelkanth and Kufri Manik, rich in anthocyanins (>100µg/100g FW and 68 mg/100g FW, respectively). These purple-fleshed varieties provide antioxidant benefits at yields of 36–38 t/ha. Anthocyanins fight oxidative stress, lowering risks of heart disease and cancer. Sustainability arises from short-duration maturity (90–100 days) and integration into rice-potato systems with minimal tillage. In Punjab contexts, they fit nutrient management for health-focused farming.

Sweet Potato (*Ipomoea batatas*) includes ICAR-CTCRI's Bhu Sona (14 mg/100g pro-vitamin A) and Bhu Krishna (90 mg/100g anthocyanin, salinity stress tolerant). Yields reach 18–20 t/ha with high dry matter. Beta-carotene addresses vitamin A gaps, while anthocyanins offer anti-diabetic properties. Its

drought and salt tolerance promote sustainable cultivation in marginal soils via vine cuttings and organic mulching. Health outcomes support eye health and blood sugar control.

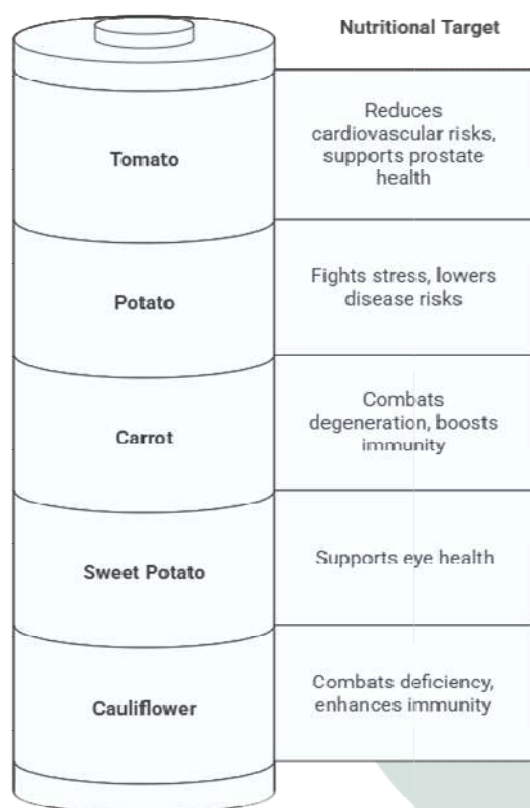


Figure 2. Vegetable bio fortification targets diverse nutritional benefits

Tomato (*Solanum lycopersicum*) benefits from CRISPR-edited lines and conventional high-lycopene varieties (e.g., Pusa Ruby derivatives). Pusa Ruby contain a high lycopene content, measured at approximately 5.49 mg/100 g in fresh, red-ripe fruit. These reduce cardiovascular risks and support prostate health. Innovations like hydroponics and vertical farming in polyhouses enhance nutrient density while saving 70% water and enabling year-round

production. IPM minimises chemical residues for safer consumption.

Carrot (*Daucus carota*) varieties such as Pusa Kulfi (high lutein) and Pusa Ashita (anthocyanin-rich black carrot) deliver elevated pro-vitamin A and antioxidants via targeted breeding. Root yields exceed 250 q/ha. These combat macular degeneration and boost immunity. Sustainable practices include precision sowing and drip systems, conserving soil health. Regular intake improves skin health and reduces chronic disease incidence.

Sustainable Practices in Salt-Affected Soils

Salt-affected soils (saline/sodic) pose major challenges in India, especially Punjab's canal-command areas where sodicity (high ESP) and salinity ($EC > 4$ dS/m) reduce productivity. Horticulture thrives here through tolerant varieties and integrated practices that enhance nutrition while restoring soil health for sustainable systems.

Key crops include pomegranate (Solapur Lal - medium tolerance up to 9–12 dS/m ECe), guava (low tolerance but viable with management), and sweet potato (Bhu Krishna - explicitly salinity-tolerant). Vegetables like tomato and brinjal respond well to grafting onto wild salt-tolerant rootstocks (e.g., *Solanum torvum* for brinjal/tomato), boosting yields by 20–30% under stress. Carrot and cauliflower require careful management but benefit from raised beds.

Core practices

- **Gypsum application** (2–5 t/ha for sodic soils) displaces sodium, improving structure and infiltration-proven by ICAR-CSSRI

trials to reclaim 20–30% more land for horticulture.

- **Drip irrigation and mulching** minimize salt accumulation by precise water delivery (leaching requirement 10–20%) and organic mulches (e.g., crop residue) that conserve moisture and suppress weeds.
- **Organic amendments** (FYM + green manuring with dhaincha) enhance microbial activity, chelate salts, and build organic carbon for long-term sustainability.
- **Precision nutrient management** via soil testing avoids excess fertilisers that exacerbate salinity, incorporating zinc and iron foliar sprays to maintain biofortified crop quality.
- **Grafting and raised-bed planting** for tomato/brinjal enable cultivation in EC 4–6 dS/m zones, while agroforestry with ber or pomegranate adds carbon sequestration.

Conclusion

Innovations in biofortified fruits (pomegranate, mango, banana, guava, citrus) and vegetables (cauliflower, potato, sweet potato, tomato, carrot), coupled with salt-soil practices, offer a holistic pathway to nutrition security, better health outcomes, and sustainable food systems. By scaling ICAR technologies through farmer cooperatives, extension services, and policy support, India can combat malnutrition, restore degraded lands, and build resilient horticulture. Stakeholders must prioritise seed availability, awareness campaigns, and market linkages for these nutrient powerhouses. Embracing such practices not only feeds the nation but nourishes it for generations-paving the way for a healthier, greener India.

