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Vegetable Genetic Resources to Mitigate Nutritional Insecurity in India

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Vegetable crops are key sources of essential micronutrients required for good health. They add fiber, flavor, taste, and nutritional quality to human diets. Increasing production and consumption of vegetables constitutes a direct and affordable way to deliver better health and overcome malnutrition. Vegetable production has the potential to generate more income and employment than any other segment of the agricultural economy. Vegetables can be grown on small areas of land, close to the consumers in urban and peri-urban settings, and they do not necessarily need advanced technologies to grow them. To realize those benefits, governments and donors need to give more weight and support to the ex situ, on-farm, and in situ conservation of genetic resources including farmers' varieties, landraces, and wild related species of global, as well as traditional, vegetables.

Key Words: **Alliums, Brassicas, Chillies, Cucurbits, Eggplant, Lettuce, Micronutrients, Spinach, Tomatoes, Vegetable legumes**

Introduction

Climate change and population growth in many developing countries impede progress toward achieving food and nutritional security. The historic success of the Green Revolution in terms of yield gains, together with lower food prices, ensured adequate quantities of staple cereal grain, thereby drastically reducing the problem of famine. However, after years of steady decline, the trend in world hunger is now slowly increasing in terms of under-nutrition and malnutrition. Hunger and under-nutrition among children, pregnant ladies, lactating mothers particularly in the economically weaker strata of the society is one of the pervasive health problem in developing country contributing to malnutrition and mortality at younger stage. Malnutrition is the single most important risk factor for disease. Diet-related diseases such as diabetes, cardiovascular disease, hypertension, stroke, cancer, and obesity are escalating at a global level. Despite of being the direct outcome of the food habit of any individual, nutrition has been perceived as a minor factor by policy planners in our country. Despite India being self-sufficient in food grain production, it was home to nearly one fourth of world population of the under-nourished people.

Of-late, diversified diets based on a range of crop species, are essential for nutritional security which could be achieved by shifting the policies of "calories fundamentalism" to "nutrition sensitive" ones. Importance of fruits and vegetables in the daily human diet promotes and recommends the consumption of 400 g of fruits and vegetables per day to provide necessary nutrient lacking in other food groups (WHO 2003). With the increasing epidemiological support on benefit of vegetable consumption on health, Indian Council of Medical Research (ICMR) recommended 300 g vegetable consumption (125 g leafy vegetable, 100 g root and tuber and 75g fruit vegetable) per capita per day. The diversity and quality of food produced and consumed is a decisive factor when addressing the triple burden of malnutrition, i.e., undernutrition, micronutrient deficiency, and over-nutrition. Although fruit and vegetables are usually mentioned jointly when addressing malnutrition, this article focuses mainly on the compilation and review the role of both global and traditional vegetables in addressing nutritional security and human health.

Economic Importance of Vegetables

Vegetables comprise a wide range of genera and species and are important component of a healthy diet. They ensure nutrition security through the provision of vitamins, antioxidants, minerals, fiber, amino acids, and other health-promoting compounds, while enhancing diversity, flavor, and taste of many otherwise bland staple dishes. Vegetables are rich sources of diverse group of

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nutraceuticals with specific health benefit. Being high value cash crops and an excellent source of vitamins and micronutrients, vegetables not only generate employment and income, but immensely contribute to gender equity, better livelihoods, and alleviate malnutrition from imbalanced diets in developing countries as well as in developed countries through increased vegetable consumption. Amongst various food groups, vegetables have been considered as important towards addressing the chronic issue of nutritional security. If integrated in the daily diet, several indigenous vegetables are rich source of micronutrients and have potential to contribute to nutritional security.

Diversity in Vegetable Species

A world vegetable survey showed that 402 vegetable crops representing 230 genera across 69 families ate cultivated worldwide. The most dominant vegetables are tomatoes, cucurbits (pumpkins, squashes, cucumbers, and gherkins), alliums (onion, garlic, shallot), and chillies (sweet and hot pepper; *Capsicum* spp.). Other major vegetable crops based on farm gate value of global production, are spinach, brassicas (cabbages, broccoli, rape), vegetable legumes, eggplants, lettuce and chicory, carrots and turnips, and asparagus. Production statistics usually do not list indigenous or traditional vegetables as these are often produced in home or family gardens or collected from the wild for family consumption, and they are, in general, only offered in local markets.

The term "indigenous vegetables" primarily refers to plants grown in their centers of origin or diversity, but also encompasses plant species introduced from other geographical areas that adapted well, naturalized, and evolved in the new environment. Indigenous vegetables are often more nutrient-dense than global vegetables, require low levels of external inputs, and cope well with abiotic and biotic stresses if grown on a small scale and in mixed cropping systems as is the case in their centers of origin. However, data on nutritional profiles of indigenous vegetables in raw and cooked forms are scarce.

With a few exceptions, private and public sector investments in vegetable research are mainly focusing on the development of hybrid cultivars of predominantly global vegetables, while indigenous or traditional vegetables are being neglected. High adaptability of these indigenous vegetable crops to biotic and abiotic stresses makes them a source of income and nutrition to the farmers during any such stress by combating malnutrition and poverty. Several organizations in NARS including the National Bureau of Plant Genetic Resources, New Delhi, ICAR-Indian Institute of Vegetable Research, Varanasi have a highly diverse collection of indigenous vegetables, and are engaged in multiplying selected lines of a wide range of crops while conserving their genetic resource base.

Since Independence, there has been marked increase in production, per capita availability and consumption of fruits and vegetables. A combination of agriculture research and efficient implementation of government policies have resulted in a shift in land use from staple crop farming to commercial farming particularly the cultivation of vegetables as cash crops and off-season cultivation under protected structures has ensured availability of adequate quantity and quality of safe vegetables of a particular season area throughout the year for consumption. This has in turn resulted in an increased supply of non-staple foods including vegetables, with a positive impact on the nutritional status of the country. Blessed with varied agro-climatic zones amenable to grow a wide range of vegetable crops, India is the second largest producer of vegetable crops in the world with 191.77 MT production next only to China with productivity of 18.52 t/ha (2nd advance estimate for 2019-20 of National Horticulture Board). Vegetables contribute 41.32% area and 59.32% production in total horticultural crops. Consumers are now offered more diversity and convenience but at the same time cheaper, less healthy, and highly processed food with high content of fats and sugars has been made more easily accessible and affordable and is, therefore, in high demand. However, increasing awareness of the importance of nutritious diet including fruits and vegetables is required to attain long-term outcome of such efforts and policies.

Nutritional Potential of Vegetables

Though the nutrient content in vegetables varies with the variety and hybrids, Toensmeier *et al.* (2020) have reviewed and classified the nutrient concentration cases in major vegetables based on the reference crop nutrient levels, thereby identifying multi-nutrient species to address traditional malnutrition. Each vegetable group contains a unique combination and amount of these phytochemicals, which distinguishes them from other groups for example the *Apiaceae* family (e.g. celery, parsley, carrot) is rich in flavonoids, carotenoids, vitamin

C, and vitamin E. Celery and parsley for example are among the best vegetables sources for the flavonoid apigenin and vitamin E, and carrots have an unique combination of three flavonoids: kaempferol, quercetin, and luteolin. The *Asteraceae* or *Compositae* family (e.g. lettuce, chicory) is rich in conjugated quercetin, flavonoids, and tocopherols. The *Cucurbitaceae* family (e.g. pumpkin, squash, melon, cucumber) is rich in vitamin C, carotenoids, and tocopherols. In a survey of 350 melon accessions of *Cucurbita melo* a 50-fold variation in ascorbic acid content, ranging from 0.7 mg to 35.3 mg/100g of fresh fruit weight was observed. Ascorbic acid and β-carotene content ranged from 7.0 to 32.0 mg/100g and 4.7 to 62.2 µg/l00g, respectively in sweet melons. Bitter gourd (*Momordica charantia*) has anti-diabetic properties and can be used to ameliorate the effects of type-2 diabetes. The *Chenopdiaceae* family (e.g. spinach, Swiss chard, beet greens) is an excellent source of folate and have been shown to inhibit DNA synthesis in proliferating human gastric adenocarcinoma cells.

All the legumes (*Fabaceae* or *Leguminosae* family; e.g. bean, pea and soy-bean), seeds are good sources of dietary fiber and iso-flavonoids. Some legumes are also rich in iron. Cruciferous vegetables (*Brassicacea* or *Cruciferae family*) which include, cabbage, brocolli, cauliflower, Brussels sprouts, kales, Chinese cabbage, turnip, rutabaga, radish, horseradish, watercress, mustards, among other vegetables, provide the richest sources of glucosinolates in the human diet. Based on one of the largest and most detailed reviews of diet and cancer, the World Cancer Research Fund in USA concluded that a diet rich in crucifers is likely to protect humans against colon, rectum, and thyroid cancers, and when consumed with vegetables rich in other phytonutriceuticals. Crucifers rich in glucosinolates including broccoli, cabbage, Brussels sprouts, and kale have been shown to protect against lung, prostate cancer, breast cancer, and chemically induced cancers.

Alliums vegetables (*Alliaceae family*) include, garlic, onion, leek, chive, Welsh onion, among other vegetables. They are rich in a wide variety of thiosulfides, which have been linked to reducing various chronic diseases. Owing to the presence of prebiotic polysaccharides, which are poorly degraded by the gut enzymes, and the presence of flavonoids, onions have been shown to possess antidiabetic potential. Consumption of *Allium* vegetables has been found to retard growth of several types of cancers. For instance, there appears to be a strong link between the consumption of onions and the reduced incidence of stomach and intestine cancers.

A study of the factors determining micronutrient bioaccessibility in leafy vegetables revealed that the pectin content of the leaves impaired carotenoid bioaccessibility. Leafy vegetables are rich in condensed tannins, such as drumstick tree (*Moringa oleifera*), had exceptionally low content of pectin and were characterized by high micronutrient bioaccessibility. Therefore, selection and development of cultivars with high micronutrient and low pectin content is a good approach to improve absorption of micronutrients by the human gut.

In the present scenario it is important for diversification towards traditional crops because the current dependence on a few major crops may result in food scarcity. Traditional, underutilized crops, especially those which are locally available and culturally acceptable, are ideally placed to play a much greater role in contributing to improved nutrition and health. These underutilized crops are also referred by other terms such as orphan, under-exploited, underdeveloped, new, novel, promising, neglected, alternative, pseudocrops or local crops. Some of these crops include *Chenopodium,* amaranth, *oca*, *kalazeera*, buckwheat, basella, fenugreek, moringa etc. which are resistant to adverse climatic conditions and can be used to improve food supply as well as income to the growers.

Fresh leaves and tender shoots are consumed as vegetable throughout the world. Several leafy vegetables are produced and consumed in India *viz.,* Amaranth, Spinach beet, Basella, fenugreek, bathua, mustard and other minor crops grown regionally across the country. Green leafy vegetables are rich source of nutrients such as minerals (Fe, Zn, Ca, K, P and Mg), vitamins (vitamins A, K, C, E, and B complex), essential amino acids, antioxidants, phytochemicals and dietary fibre which are beneficial for the maintenance of good health, and prevention of diseases and malnutrition. These foods are ideal for weight management as they are typically low in calories. They are useful in reducing the risk of cancer and heart disease since they are low in fat, high in dietary fiber, and rich in folic acid, vitamin C, potassium and magnesium, as well as containing a host of phytochemicals, such as lutein, β-cryptoxanthin, zeaxanthin, and β-carotene. Because of their high magnesium content and low glycemic index, green leafy

vegetables are also valuable for persons with type 2 diabetes. The high level of vitamin K in greens makes them important for the production of osteocalcin, a protein essential for bone health. Green vegetables are also a major source of iron and calcium for any diet. Green leafy vegetables are rich in beta-carotene, which can also be converted into vitamin A and also improve immune function.

Perennial vegetables are neglected and underutilized class of crops with potential to address current nutrtitional challenges. They represent 33–56% of cultivated vegetable species, and occupy 6% of world vegetable cropland. Despite their distinct relevance to climate change mitigation and nutritional security, perennial vegetables receive little attention in the scientific literature. Compared to widely grown and marketed vegetable crops, many perennial vegetables show higher levels of key nutrients needed to address deficiencies. Trees with edible leaves are the group of vegetables with the highest levels of these key nutrients. Individual "multi-nutrient" species are identified with very high levels of multiple nutrients for addressing deficiencies. Under exploited vegetables are increasingly been recognized as essential for food and nutritional security. Global diversity in vegetable crops is estimated at about 400 species, with about 80 species of major and minor vegetables are reported to have originated in India. It provides a promising economic opportunity for reducing rural poverty and unemployment and providing farm diversification strategies. The nutritional composition studies could be used to develop strategies to promote the consumption, acculturation and commercialization of these vegetables.

Minor vegetable have immense potential for contribution to a particular pocket's of food production because they are well adapted to existing as well as adverse environmental conditions and are generally resistant to pests and pathogens. Minor legumes may be a cheap, alternate source of protein and can alleviate protein malnutrition among preschool children in rural areas. Nutritious pods of *Parkia roxburghii* are consumed as staple legume vegetable in the NEH region of the country. Similarly, *Mucuna pruriens* is considered one of the most preferred legume vegetables in tribal people of Uttar Pradesh, Bihar and Jharkhand. A vast reservoir of leafy vegetables belongs to group of underutilized vegetables, which are rich source of vitamins, minerals, fiber and diversity in the diet. Furthermore, they have been a traditional part of cropping systems, especially in home gardens. Their cultivation, utilization and acceptability should not be a problem. Minor vegetables as a whole can, therefore, make an impact on the nutritional status of population, yet among food crops, they are neglected. They are generally low in energy and dry matter content, but immensely important as source of protective nutrients, especially vitamins, mineral and phyto-chemicals. Vegetables are the most important source of vitamin A, which is deficient in most part of the world where rice based diets predominate, blinding thousands of children, annually.

Phytochemicals in Vegetables

Phytochemicals/ phytonutrients / phytonutriceuticals are organic compounds derived from plants that have health promoting properties. Besides the common nutrients such as carbohydrates, amino acids and protein, there are certain non- nutrient phytochemicals in vegetables that have biological activity against chronic diseases. They are low in fat and, like all plant products, contain no cholesterol. Most phytochemicals are found in relatively small quantities in vegetable crops. However, when consumed in sufficient quantities, phytochemicals contribute significantly towards protecting living cells against chronic diseases. Major phytochemicals have been classified in to ten different classes based on their biological activities including carotenoids (α- and β-carotene, β-cryptoxanthin, lutein, lycopene, and zeaxanthin), glucosinolates (sulforaphane, indole-3 carbinol), inositol phosphates (phytate, inositol tetra and penta phosphates), cyclic phenolics (chlorogenic acid, ellagic acid, and coumarins), phyto-estrogens (isoflavones, daidzenin, genistein, and lignans), phytosterols (campestrol, β- sitsterol, and stigmasterol), phenols (flavanoids), protease inhibitors, saponins, and sulfides and thiols.

Vegetables have been shown to protect against specific types of cancer for example, the crucifers (*Brassicaceae*) including Broccoli, Brussels sprouts, Kale and Cabbage have been shown to protect against lung and chemically induced cancers. The alliums (*Liliaceae*), including garlic, chive, and onion have been shown to protect against stomach cancer, the solanaceous vegetables (*Solanaceae*) including tomatoes and pepper have been shown to protect against esophageal, gastric, and prostrate cancers. The chenopods (*Chenopodiaceae*) including spinach and chard have been shown to

inhibit DNA synthesis in proliferating human gastric adenocarcinoma cells. There is increasing evidence for a link between antioxidant nutrients (e.g. vitamin C, vitamin E, β-carotene and selenium) in fruits and vegetables and lower risk of cardiovascular disease. Studies have found that 34 per cent reduction in mortality is due to cardiovascular disease among those who consumed vegetables rich in vitamin E and C. A 30-40 per cent reduction in risk of colon cancer in populations with higher vegetable consumption, especially garlic and dietary fiber has also been reported. In addition to reducing cancer and cardiovascular diseases, a diet high in vegetables has also been linked to reducing rheumatoid arthritis, anemia, diabetes, macular degeneration and gastric ulcer. The carotenoids, Vitamin E, and Vitamin C are now firmly established as protective dietary antioxidants with additional beneficial functions. Polyphenols and flavonoids are also gaining prominence and the protective role of folate is above dispute. All of these components are uniquely found in fresh and cooked vegetables, which underline the importance of vegetables in healthy diets. Major antioxidants and polyphenolic compounds present in different vegetable crops has been provided in Table 1.

Source for Minerals and Micronutrients Supplements

Wide ranges of minerals and trace element are present in vegetables. Leafy vegetables and crucifers are rich source of minerals and trace element. Calcium, phosphorus and iron are important minerals have major role in bone health and prevention of anaemia. The important trace element found in vegetables are Zn, Cu, Mn, Se played an important role in immune function, body defence against oxidative stress. Interest in selenium as a nutraceuticals has increased dramatically in the last three decades as a results of several studies that demonstrated that increased risk of cancer with low selenium intake. Broccoli and garlic are rich source of selenium when grown on high selenium rich soil. Chromium is another trace element which may be effective in optimizing insulin metabolism and lowering plasma cholesterol levels. On an average a man excretes daily about 20 to 30 g of mineral salts, consisting mostly of chlorides, sulphate and phosphates of sodium, potassium, magnesium and calcium and this output must be recuperated by the intake of food stuffs. In case of the growing body, provision must be made for additional amounts of many of the elements to ensure adequate growth of the tissues. Underutilized vegetables are considered to be a reservoir of various mineral nutrients. Looking into the prevalence of high level of micronutrient malnutrition among the vulnerable sections in the developing countries and the increasing prevalence of chronic degenerative diseases globally, the need for exploration of underutilized foods is significant to overcome the nutritional disorders. The diet and food based approach in combating micronutrient malnutrition is essential for its role in increasing the availability and consumption of micronutrient rich foods. Increasing the utilization of green leafy vegetables (GLV) in our diet, known to be rich sources of micronutrients as well as dietary fiber can be a food-based approach for ensuring the intake of these nutrients. It is essential that the locally available GLV, which are inexpensive and easy to cook, be used in the diets to eradicate micronutrient malnutrition and also to prevent the degenerative diseases.

Table 1. Major antioxidants and polyphenolic compound in vegetable crops

Major antioxidants	Sources
β-Carotene	Carrot, fennel, kale, mustard greens, pumpkin, red pepper, lettuce, spinach, sweet potatoes, swiss chard, winter squash.
Vitamin C	Broccoli, brussels sprouts, watermelon, cauliflower, green pepper, red cabbage, red pepper, potatoes
Lutein/ zeaxanthin	Kale, broccoli, spinach, winter squash, brussels sprouts, celery, leeks, mustard greens, peas, green onions, summer squash
Lycopene	Tomato, watermelon
Vitamin E	Dark green leafy vegetables, sweet potatoes
Lipoic acid	Dark leafy green vegetables, especially spinach and broccoli
Flavonoids	Onions, soybeans Onion, lettuce, endive, horse radish, tomato and beans.
Polyphenols	Grapes, nuts, oranges, strawberries, green tea, black tea, red wine
Anthocyanin	Red cabbage, purple broccoli, brinjal, rhubarb, radish, black carrot, onion
Flavones	Celery, tomato, brinjal, garlic, onion
Isoflavone	Soybean, pea, broccoli, asparagus, alfalfa, okra

Medicinal Importance of Vegetables

Naturally occurring nutraceuticals have potentiality to overcome growing problem of non-communicating diseases like cancer, cardiovascular disease, alzheimer, diabetes and so on through there multiple health promoting function. Vegetables are rich sources of diverse group of nutraceuticals with specific health benefit.

Number of minor vegetables possesses several desired medicinal properties. Drumstick is known for its medicinal properties since time immemorial and its

leaves are used by physicians of traditional medicine for the treatment of hypertension. Hypotensive action of alcoholic extract obtained from the dried drumstick leaves in patients with moderate to severe hypertension. The anti-perkinsonian and prolactin reducing effects of minor legume vegetable, *Mucuna pruriens* have been reported. Eating leaves of *Polygonum plebeium* as vegetable improves lactation. Macro and micro-scopic studies on the underutilized leafy vegetable *Alternanthera sessilis* and *Portulaca quandrifida* and the inflorescence analysis of its powder, quantitative microscopy and micro chemical tests have been reported. Antifibrionolytic activity of the roots of minor leafy vegetable *Boerhaavia diffusa* has been found to be due to a phenol glucoside, punarnvoside. It was found effective in controlling IUD induced bleeding in monkeys. List of minor vegetables reported to have significant pharmacological activity is given in Table 2.

Table 2. Underexploited vegetables possessing medicinal properties

Vegetables	Family	Activity
Boerhaavia diffusa L.	Nyctaginaceae	IUCD
Carica papaya L.	Caricaceae	Anti- androgenic
Cissus quandragularis L.	Vitaceae	Analgesic
Coleus forskohlii (Willd.) Briq.	Labiatae	CNS depressant, Hypotensive Spasmolytic
Costus speciosus (Koen. ex Retz.) Sm	Costaceae	Hypotensive
Cyamopsis tetragonoloba (L.) Taub	Papilionaceae	Hypoglycaemic, Hypolipidaemic
Gymnema sylvestre (Retz.) Schult	Asclepiadaceae	Hypoglycaemic
Mollugo cerviana (L.) Ser.	Molluginaceae	Cordiostimulant
Momordica charantia L.	Cucurbitacea	Hypoglycaemic, Hypolipidaemic
Trianthema portulacastrum L	Aizoaceae	Analgesic, Antipyretic, CNS depressant

The benefits of cultivating indigenous crops and conserving their germplasm over the introduced HYVs include cultivation of indigenous crops can make agriculture more genetically diverse and sustainable, consumption of domestically cultivated indigenous crops can reduce the carbon footprints and imports, the indigenous crops are highly adapted to the climatic conditions of the land, and consumption of indigenous foods contribute to food diversity and enrichment of diet with micronutrients provides health benefits due to the interactions between the inherited genes and food nutrients. However, there may be few challenges in reviving indigenous species, which may include farmers' willingness in the propagation of indigenous varieties, identifying the farmers with traditional knowledge of crop cultivation, encouraging the farmers with large landholdings to cultivate indigenous crops, awareness among the consumers and stakeholders about the ecological and health benefits of indigenous varieties, support of the government to the farmers for the propagation of these crops in small and large scale, and development of mechanization suitable for processing indigenous crops, as the existing machines are designed for the HYVs, and employing the same techniques for the processing of indigenous crops may lead to the loss of micronutrients and phytochemicals.

Conclusions

The effective utilization of vegetable genetic resources in breeding programs and testing and deployment of newly developed varieties with tolerance to abiotic stresses and resistance against multiple diseases and insect pests in farmers' fields will ultimately benefit the farming community and consumers. By doing so, a significant reduction or, even better, a complete elimination of the obvious and persistent gap between WHO-recommended and actual intake levels of fruits and vegetables would make a significant contribution to the achievement of Sustainable Development Goals related to food and nutrition security and good health, in particular aiming at doubling agricultural productivity and incomes of small-scale food producers, ensuring sustainable food systems, and maintaining genetic diversity.

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