Tropical and Sub-tropical Vegetables: Plant Introduction, Achievements and Opportunities in South Asia

BS Dhankhar[1] and JP Mishra[2]
[1]*Department of Vegetable Science, CCS Haryana Agricultural University, Hisar-125004, Haryana, India*
[2]*Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi-110012, India*

Tropical and sub-tropical vegetables form a major part of the diet in South Asian countries and are also important as a valued source of nutrition. Enormous variability exists in these countries for one or more groups of such crops, but collection, introduction and exchange of stress resistant and high yielding germplasm is an ever-important consideration. Exchange of elite germplasm among South Asian countries under SAVERNET Phase has shown usefulness. India is the largest source of supply of indigenous as well as introduced/imported material for improving vegetable production in these countries. Till July 2006, 34,482 accessions of tropical and subtropical vegetables were introduced and 4,871 were exported from NBPGR, New Delhi (India) while 25,406 were maintained at its regional stations. Conservation status in seed gene banks in these countries as per SANPGR Report 2002 is 5,953 in Sri Lanka, 5,162 in Bangladesh and 1,216 in Nepal and low number in Bhutan and Maldives. Introductions have been utilized for improvement breeding in India, Sri Lanka and Bangladesh. In spite of newer and stricter guidelines imposed recently for movement of germplasm, the introductions are going to give a fillip in development of high yielding and/or stress (biotic and abiotic) resistant varieties. The article deals with the present status of introduction, conservation, utilization and classification of germplasm of important vegetables in South Asia and identifies trait-specific germplasm, the specific characters and sources for their introduction, particularly with reference to tropical and sub-tropical vegetables.

Key words: South Asia, Vegetable germplasm, Conservation, Introduction

It is well understood that while adaptability is a set of characters specific to a particular region or agro-climate, the attributes related with yield and sustainability (stress resistance) have to be pooled from diverse sources which highlights the need of plant introduction. Among South Asian countries, India has the advantage of having almost all types of agro-climates, a large area under undisturbed/partially disturbed forests as reservoir of variability, and a group of tropical and sub-tropical vegetables having maximum diversity and distribution (Seshadri, 1988). The existing variability is getting depleted irrespective of the national boundaries with the adoption of only few high yielding genotypes most suited to present day conditions of a particular region. The ill effects of this are due to narrowing of genetic base of varieties getting prone to biotic and abiotic stresses. Even a 'refuge' area is recommended in conjunction while using genetically modified (GM) pest resistant crops (varieties) in order to promote resistance management strategy which will help to prevent the break down of pest resistance in the GM crop. Such situations warrant for continued interchange and recombination of plant improvement material, particularly in South Asian countries where a good number of vegetables are grown and farmers are the most important part of the population.

South Asia comprises countries namely, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. Bhutan and Nepal have difficult sub-terrain and vegetables are of secondary importance, yet successive erosion of bio-diversity due to increasing population pressure, deforestation, land degradation and settlement requirements warrant conservation of native and introduced variability in vegetable crops and its systematic utilization in these countries. Sri Lanka and Bangladesh have established Plant Genetic Resources (PGR) Centre and sizable variability has been collected/ introduced. The status of genetic resources in tropical and sub-tropical vegetable crops in Sri Lanka, Bangladesh, Bhutan and Nepal is given below (SANPGR, 1998, 2000 and 2002).

Sri Lanka

Country's requirement of vegetables including root and tuber crops is fully met with local production. Though Sri Lankan farmers have maintained a rich bio-diversity in the country, however, with the increasing population pressure and need for economic development, there has been a progressive erosion of bio-diversity in the country. Also, there are areas unsuitable for high yielding varieties, sometimes due to un-favourable climatic conditions. Additionally, extensive deforestation, land degradation and opening of new lands for settlement have resulted in the erosion of the genetic diversity of crops and their wild relatives.

Sri Lanka comes under Indo-Burma Mega Centre of Diversity where mostly tropical and sub-tropical vegetables are grown. Vegetable crop species that exhibit high genetic diversity are *Abelmoschus esculentus, Alternanthera sessilis, Amaranthus* spp., *Bassela alba, Canavalia gladiata, Centella asiatica, Cucumis melo, C.sativus, Ipomoea batatas, Lablab purpureus, Lagenaria siceraria, Luffa acutangula, Momordica charantia, Mucuna pruriens, Phaseolus lunatus, Solanum melongena, Trichosanthes anguina, Vigna umbellata, V. unguiculata* and also *Alocasia, Amorphophallus, Colocasia* and *Dioscorea.*

Among 288 crop wild relatives identified in Sri Lanka (up to 2003), 39 are in vegetables and 21 in root and tuber crops. These comprise vegetables *Abelmoschus* (4), *Amaranthus* (2), *Bassela* (2), *Lablab purpureus* (2), *Citrullus* and *Luffa* (1 each), *Momordica* (2), *Mucuna* (4), *Solanum* (8), *Trichosanthes* (4), *Vigna* (6), and tuber crops *Alocasia* (3), *Celosia, Coccinea, Colocasia, Cucumis, Aerva, Alternanthera, Ipomoea,* and *Amorphophallus* (1 each) and *Dioscorea* (9). Open canopy forest areas, secondary forests, disturbed grasslands and shrub jungles are rich in crop wild relatives.

Status of conservation of PGR in seed gene banks shows that vegetable legumes (1,042), solanaceous vegetables (1,057), cucurbits (648), leafy vegetables (134), other vegetables (298), root and tuber crops (301) and *Brassica* species (93) have been conserved till Nov. 2002. Additional collection/ introduction comprised vegetable legumes (311), solanaceous vegetables (440), cucurbitaceous vegetables (295), cruciferous vegetables (303), leafy vegetables (540), root and tuber crops (338) and other vegetables (153). The work on utilization of collections/ introductions is in progress. Regional variability in *Solanum* and *Lycopersicon* has been studied. Biochemical characterization of wild species and inter-specific crosses was made in *Abelmoschus* and *Solanum* (SANPGR, 2002).

Germplasm introduction from India (through exchange) has benefited significantly the vegetable improvement programme of Sri Lanka. Varieties in several tropical and sub-tropical vegetable crops have been developed and released utilizing indigenous and introduced germplasm. These include *Abelmoschus esculentus* (3), *Allium cepa* (5), *Capsicum annuum* (6), *Citrullus lanatus, Colocasia esculenta, Cucurbita maxima, Cucumis sativus* (1 each), *Ipomoea batatas* (9), *Luffa acutangula* (2), *Lycopersicon esculentum* (8), *Momordica charantia* (2), *Solanum melongena* (3), *Trichosanthes cucumerina* (3), and leafy vegetables (4). In tomato, marker development for resistance against bacterial wilt and heat tolerance is in progress. *Abelmoschus* and *Solanum* species are being utilized in improvement of these crops. Descriptor lists have been prepared and PGR catalogues with characterization and passport data have been published in tomato, okra, brinjal, winged bean and yard-long bean. A sizable number of germplasm has been supplied to international organizations as well.

Bangladesh

Bangladesh is a part of the Indian Gene Centre and significant diversity exists in agro-ecology. This helped in maintenance of rich diversity of vegetable crops, particularly in okra, eggplant, different cucurbitaceous crops, cowpea and a wide range of leafy vegetables. There is a wide distribution of wild relatives of eggplant and okra. Based on the survey of the variability, a Plant Genetic Resource Centre (PGRC) has been established in Bangladesh Agricultural Research Institute (BARI). Up to the year 2000, the PGRC had an *ex-situ* conservation of 4,310 germplasm of tropical and sub-tropical vegetables. A total of 4,389 accessions of vegetables, 773 of tuber crops and 344 of spices were collected till 2000 and all these have been conserved at PGRC, BARI. This covers almost all important vegetable crops. The characterization has been done for 1,470 accessions of vegetables, 289 of tuber crops and 126 of seed spices (SANPGR, 2000).

A good number of varieties have been developed primarily from indigenous germplasm or from those collected under Indo-Bangladesh collaborative programme some time back. Important among these are brinjal Uttara, Tarapari, Suktara; cabbage Provati; okra Bari Deros-1; bottle gourd Bari Lav-1; garden pea Bari Matorsuti-1, Bari Matorsuti-2, Tasa Kisan; radish Bari Mula-2; tomato Raton, Manik, Bari Tomato-3, Bari Tomato-4, Bari Tomato-5, hyacinth bean Bari Sim-1, Bari Sim-2; sweet potato Doulatpuri developed from indigenous material, and Tripti, Kamla, Sunduri sweet potato and 12 varieties of potato developed from exotic introductions (SANPGR, 1998).

Bhutan

Bhutan has a topography characterized by rugged mountains and fragile eco-systems and has largely sub-tropical/temperate climate. Only 7.8 per cent of the total land of the country is under cultivation, mainly vegetables. The agriculture in this country is in initial stage of modernization. There are around 27 traditionally grown vegetables. Potato is the major vegetable crop in Bhutan, followed by chili, radish, eggplant and turnip. The diversity is preserved in home gardens and back yards due to least disturbances and subsistence farming based on traditional practices. This way variability in the form of land races, primitive forms and some rare wild species are preserved *in situ*. Only traditional cultivars are in cultivation and little attention has been given to introduction of more promising germplasm from suitable destinations. National capacity building is in progress and thus *ex-situ* conservation is in the preliminary stage. In view of this there is a strong need for introduction of germplasm and its systematic utilization in Bhutan. A National Biodiversity Centre has been established under the Ministry of Agriculture and the *ex-situ* conservation of vegetable germplasm is in progress.

Nepal

Biodiversity has remained a neglected sector in Nepal and as such there is limited diversity in vegetable crops. About 600 edible plant species were identified up to the year 2000 and the *ex-situ* conservation of germplasm in vegetable crops numbered around 600. Important vegetable crops in Nepal are cucumber, eggplant, radish, beans, cauliflower and sponge gourd. The registration of indigenous variability in the form of vegetable germplasm has been initiated and registered genotypes in different crops are, amaranth (101), cucumber (154), beans (498), cowpea (220), peas (188) and pumpkins (55). The prospects of introductions in sub-tropical vegetable crops are bright.

Several crop varieties have been developed and released either by direct use of indigenous germplasm or through incorporation of useful genes from local germplasm through breeding programmes. The varieties Kathmandu Local cauliflower, Pyudiane Rato radish, Khumal Tane asparagus, Khumal Tane bean, Sarlahi Green eggplant, Kusle cucumber, Kantipure sponge gourd and Khumal Broad Leaf, Marpha Broad Leaf and Khumal Rato Pat broad leaf mustard- all have been developed through local selection for commercial cultivation (SANPGR, 2000).

Maldives

Maldives has exclusively a humid tropical- littoral environment. Most of the vegetables for consumption are transported from India. As such there is not enough indigenous variability. Very little attention has been given to introduce vegetable germplasm for conservation and utilization.

India

India has a rich reservoir of genetic diversity, particularly in tropical and sub-tropical vegetable crops. This is primarily due to ecological diversity and related subjects. Indian Gene Centre can be considered to be (a) Primary Centre of Diversity for *Luffa aegyptica, L. acutangula, Trichosanthes dioica*; (b) Secondary Centre of Diversity for *Vigna unguiculata* (cowpea), *Cyamopsis tetragonoloba* (cluster bean), *Abelmoschus esculentus* (okra) introduced from Africa and *Lycopersicon esculentus* (tomato), *Cucurbita* spp. (pumpkins), *Sechium edule* (Chocho, chayote), *Capsicum* spp. (chilies), *Amaranthus* spp. (amaranth) introduced from tropical America; or (c) Regional (Asiatic) Centre of Diversity for *Cucumis sativus* (cucumber), *Momordica charantia* (bitter gourd), *Lagenaria siceraria* (bottle gourd), *Trichosanthes anguina* (snake gourd) and certain *Brassica* spp. Some of these crops have originated here (Paroda and Arora, 1986).

A total of 34,482 accessions of tropical and sub-tropical vegetables were introduced upto July 2006 into India from over 50 countries (Dhankar and Mishra, 2005). The major contributors to these introductions into India are institutions like USDA, AVRDC and countries like USA, UK, Japan, Holland, USSR, Bulgaria, France, the Philippines, Australia and several others. During 2005, an additinal 244 germplasm of Indian origin were repatriated and 142 were received for national accessioning. Under cryo-preservation 432 vegetable seed samples have been preserved so far. A large amount of variability is maintained *in situ* as well as *ex-situ*. Sizable collections, both indigenous and exotic, are being maintained in National Gene Bank and Indian Institute of Vegetable Research (IIVR) (Table 1).

A large number of vegetable germplasm (25,406) is being maintained at 11 NBPGR Regional Stations and 40 National Active Germplasm Sites (NAGS) as per crop agro-ecology, and with breeders for specific crops.

The germplasm holding of tropical and sub-tropical vegetables at different regional stations of NBPGR and

Table 1. Conservation of germplasm of tropical and sub-tropical vegetables in India

Crop	PGR in National Seed Gene Bank, Delhi up to date	PGR at IIVR, Varanasi up to Dec. 2004
Ashgourd	172	84
Bittergourd	527	215
Bottlegourd	636	135
Brinjal (cultivated)	3,437	650
Brinjal (wild)	728	15
Cauliflower (Indian type)	147	81
Cucumber	226	50
Cucurbits	1,410	1,267
Ivygourd	18	15
Kakoda (*Momordica cochinchinensis*)	4	8
Kakrol (*M. dioica*)	38	26
Muskmelon	525	95
Okra (cultivated)	1,302	168
Okra (wild)	338	63
Peas and Beans	210	841
Pointed gourd	27	200
Pumpkins	65	150
Radish (tropical type)	251	75
Ridgegourd and Spongegourd	505	139
Snapmelon	190	150
Tomato (cultivated)	1659	1,174
Tomato (wild)	101	44
Watermelon	315	–
Total	**12,831**	**5,645**

Source: NBPGR, New Delhi

Table 2. Germplasm holdings of tropical and sub-tropical vegetables (at different NBPGR centres and NAGS)

(as in July 2006)

Crop	Holding
Bottlegourd	144
Brassicas	1,158
Brinjal (eggplant)	2,931
Carrot	7
Chili	1,589
Cowpea	2,698
Cucumber	245
Cucurbita	2,514
Fababean	548
Frenchbean	3,310
Lablab bean	1,100
Pea	1,859
Okra	3,469
Ridgegourd	28
Round melon	33
Snakegourd	8
Spongegourd	36
Tomato	3,478
Wingedbean	507
Total	**25,406**

Source: NBPGR, New Delhi

National Active Germplasm Sites is presented in Table 2.

Also a good number of vegetable germplasm has been exported for meeting outside demands. Till July 2006, 4,871 accessions were given to different countries on their request for research purposes.

Utilization of Introduced Germplasm in India

The germplasm in this group of vegetables has been acclimatized and directly released for commercial cultivation (Primary Introductions), or it has been used as donors for specific traits in breeding varieties (Brahmi, 1995). An account of primary and secondary introductions is given below.

A. Primary Introductions

Brinjal: Black Beauty (ex USA)

Cowpea: Pusa Barsati (sel. ex Phillippines), Pusa Phalguni (sel. ex Canada)

Garden Pea: Early Badger, Bonneville (ex USA), Arkel (ex France), Harbhajan (EC 33866 ex Portugal)

Okra: Perkin's Long Green, Clemson's Spineless (ex USA)

Onion: Early Grano, Red Grano, Pusa Ratnar (sel. from Red Grano), Bermuda Yellow (ex the Phillippines)

Radish: Pusa Chetki (sel. from Hawaiian germplasm)

Sweet Potato: Varieties mostly direct introductions or selections after hybridization

Tomato: Sioux, La Bonita, Marglobe, Kekruth (ex USA), Fire Ball, Scotia (ex Canada), Dwarf Money Maker (ex Israel), Molaki (ex Australia), Roma (ex Italy)

Watermelon: Sugar Baby (ex USA), Asahi Yamato (ex Japan)

B. Secondary introductions (Donors for desirable traits):

Cowpea: Aseem (tol. to root-knot nematodes, evolved from a cross between Pusa Phalguni and Pusa Barsati ex Philippines); Rituraj (developed from a cross between Pusa Do Fasli and EC 26410)

Cucumber: Tropical gynoecious lines with multiple resistance have been developed using Gy4 and Gy5 ex. USA)

Muskmelon: Pusa Sharbati, Punjab Sunehri (evolved utilizing cantaloupes ex USA)

Okra: Parbhani Kranti, Punjab Padmini, Pusa A-4, Sel.2, Sel.6-2, G-2 (tolerant to YVMV, evolved utilizing Ghana Collection ex. USA), Pusa Sawani (YVMV tolerant, evolved utilizing Best One ex. USA)

Sweet Potato: Rajendra Sakarkand (RS)-5, RS-35, Sree Nandini, Sree Vardhini, Varsha, Gouri are selections/ hybrid derivatives from introduced material.

Tomato: Pusa Ruby (prolific bearer and virus tolerance, evolved from cross between Sioux and Improved Meeruti), Pusa Early Dwarf (from cross Red Cloud x Improved Meeruti), Pusa Red Plum (evolved by crossing cultivated variety with *L. pimpinellifolium*)

Tomato: Kekruth Ageti (sel. from Kekruth), H-24, H-36 (resistant to TLCV, developed utilizing *L. hirsutum f. glabratum*), MRT 3, MRT 8, MRT 12 resistant to root-knot nematodes, developed utilizing Nematex and Resistance Bangalore)

Watermelon: Arka Manik (resistant to PM, DM and Anthracnose, developed utilizing Crimson Sweet ex USA), Improved Shipper (sel. from Shipper ex USA), Pusa Bedana (seedless, developed utilizing tetraploid Tetra-2 ex USA).

Introductions as Source of Stress Resistance

The introductions are usually done with certain target traits like resistance against particular biotic or/and abiotic stresses (Mishra and Mishra, 2004). Some of such introduced germplasm have been identified as sources for resistance against one or more stresses under our conditions. A short account of some such examples is given in Table 3.

Such resistance sources have been utilized to develop varieties in India (Table 4) (Pandey *et al.*, 2005) which are available for introduction and utilization in other South Asian countries. Indian varieties of vegetables tolerant to abiotic stresses (Dhillon *et al.*, 2004) and those bred for improved nutrition are mentioned in Table 5 and 6.

Table 3. Identified sources of stress resistance in tropical and subtropical vegetable germplasm introduced in India

Crop	Stress	Sources of resistance
Brinjal	Bacterial wilt	EC104107, Florida Market
	Phomopsis fruit rot	EC305069, EC316274
	Root-knot nematode	*Solanum torvum, S. sisymbrifolium*
	Shoot and fruit borer	*S. khasianum*
	Frost	Black Torpedo, Long Tom 4
	Drought	Supreme, Violette Round
Chilli	CMV	EC312342, EC312349
	PBNV	EC121490
	Aphids	EC28, EC30, EC34
Cucumber	PM and DM	Poinsette
Muskmelon	Gummy Stem blight, PM and DM	AC70-54
	PM and DM	Campo, Edisto, PMR-45
Okra	YVMV	EC133408, EC169333, EC169334, Ghana Red
	Jassids	EC305656, EC305694, EC305695, *Abelmoschus moschatus*
Onion Short-Day	Purple blotch	EC328494, EC328492, EC328501, EC321463
Peas	Powdery mildew	EC342007
Tomato	Bacterial wilt	EC467725, EC438314-317, EC182761-182874, EC26511-13,
	Fusarium wilt	Florida, Pan American, PI 79532, Walter, Columbia, Roma, Floradade, *Lycopersicon pimpinellifolium* (for *Fusarium oxysporum* race 1, 2)
	Root- knot nematode	VFN-8, Nemared, Florida, Hawai Cross, Nematex, *L. peruvianum*
	High temperature	EC198416, EC501573-83, EC479027, -31, -34, 36,-139, -140, -141, -143, PS-1, 84 #42, Miniros
	Early blight	*L. pimpinellifolium, L. hirsutum*
	TLCV	*L. pimpinellifolium, L. hirsutum*
	Buck eye rot	*L. pimpinellifolium*
	Fruit borer, Fruit fly	*L. hirsutum, L. hirsutum f. glabratum*
	Low temperature	Cold Set, Ostenkinstkiz
	Drought	*L. pimpinellifolium*, 64#8
	Salinity	*L. cheesmanii*
Watermelon	DM, PM, Anthracnose	Crimson Sweet, Shipper, Charleston Gray

Male sterile, tetraploid and self-incompatible lines introduced in several crops to ease hybrid development
CMV–*Cucumber mosaic virus;* PBNV – *Peanut bud necrosis virus*; PM–Powdery mildew; DM–Downy mildew; TLCV–*Tomato leaf curl virus;* YVMV–*Yellow vein mosaic virus.*

Table 4. Biotic stress-resistant Indian varieties/ elite lines of tropical and sub-tropical vegetables

Crop	Biotic stress	Resistant varieties
Brinjal (egg plant)	Bacterial wilt	BB-7, BB-44, BWR-12, SM-6-6, SM-6-7
	Phomopsis blight	Pusa Purple Cluster, Hisar Shyamal, Pusa Bhairav
	Little leaf (tol.)	H 7, H 8, H 9, H 10
Chili	CMV, TMV, LCV	Pusa Jwala, Pusa Sadabahar
	CMV, TMV, LCV, Fruit rot, Die-back	Punjab Lal
	LCV	Bhagya Lakshmi, Andhra Jyoti, Pant C-1, Pant C-2
Cowpea	Bacterial blight	Pusa Komal
Cucumber	PM, DM	Poinsette
	PM (tol.)	Swarna Poorna
	PM, DM, *Alternaria*	IIHR-177-1
Lablab bean	Viral diseases, Jassids, aphid and fruit borer	Pusa Sem-2, Pusa Sem-3
Muskmelon	PM, DM	IHR 352, Punjab Rasila
	PM	Arka Rajhans, Punjab Rasila, RM-43
	Fusarium wilt	Punjab Sunehri, Pusa Madhuras, Arka Jeet, Durgapura Madhu, Harela
	PM, DM, Anthracnose, *Alternaria, Fusarium* wilt	IIHR-190, IIHR-352
	CGMMV and DM	DMDR-2, DMDR-1, DVRM-1
Okra	YVMV	Pusa Sawani, Parbhani Kranti, Punjab-7, Punjab Padmini, Hisar Unnat, Varsha Uphar, Arka Abhay and Arka Anamika, Azad Kranti
	YVMV, Shoot and Fruit borer	Pusa A-4
Pumpkin	Fruit fly	Arka Suryamukhi
Tomato	Root-knot nematode	Pusa-120, Pusa Hybrid-2, NRT 3, NRT 8, NRT 12
	TLCV	H 24, H 36
Watermelon	Anthracnose, PM, DM	Arka Manik

CGMMV: *Cucumber green mottle mosaic virus* , TLCV: Tomato leaf-curl virus, CMV: *Cucumber mosaic virus*, TMV: *Tobacco mosaic virus;* PM–Powdery mildew; DM–Downy mildew; LCV–Leaf curl virus; YVMV–*Yellow vein mosaic virus.*

Table 5. Indian varieties of tropical and sub-tropical vegetables resistant to abiotic stresses

Abiotic stress	Resistant varieties
High Temperature	**Cluster Bean:** Pusa Nav Bahar
	Tinda: Arka Tinda, Tinda Ludhiana, Tinda Tonk
	Long melon: Arka Sheetal, Punjab Long
	Bittergourd: Pusa Do Mausami, Kalyan Sona
	Bottlegourd: PSPR, PSPL, Pusa Naveen, Pusa Sandesh, Arka Bahar
	Radish: Pusa Chetaki
	Turnip: Pusa Sweti
Low Temperature	**Bottlegourd:** Pusa Santushti
	Tomato: Pusa Sheetal, Pusa Sadabahar
Warm humid climate	**Bittergourd**: Arka Harit, Priya, MC-84, MDU-1, Konkan Tara, Co-1, Co-Long
Soil Salinity	**Okra:** Pusa Sawani

Table 6. Indian varieties of tropical and sub-tropical vegetables bred for improved nutrition

Crop	Varieties	Superior nutrition factor
Muskmelon	Arka Jeet, Durgapura Madhu	Vitamin C
Bitter gourd	Arka Harit, Priya, Pusa Hybrid1, Pusa Hybrid 2	Vitamin C and iron
Pumpkin	Arka Chandan, Pusa Hybrid1, Pusa Vikas	Vitamin A
Amaranth	Pusa Kiran, Pusa Kirti, Pusa Lal Chaulai	Vitamin A, C, Calcium and Iron
French bean	Pusa Parvati	Protein
Garden pea	Arkel, Pusa Pragati	Protein
Cowpea	Pusa Phalguni, Pusa Barsati, Pusa Do Fasli	Protein
Lablab bean	Pusa Sem 2, Pusa Sem 3	Protein
Cluster bean	Pusa Mausami, Pusa Sadabahar, Pusa Nav Bahar	Protein
Indian spinach (Palak)	Pusa Jyoti, Pusa Bharati, Pusa Harit	Vitamin A, C, Iron and Calcium
Bathua (Chenopod)	Pusa Bathua-1	Vitamin A, C, Iron and Calcium
Tomato	Pusa Uphaar, Pusa Hybrid-2, Pusa Rohini	Vitamin C
Carrot	Pusa Meghali, Pusa Yamadagni	Vitamin A

Future Considerations for Introduction of Tropical and Sub-Tropical Vegetable Germplasm in South Asia

A. Search for sources of resistance

Crop	Considerations
Bittergourd:	Resistance against viruses and fruit fly, higher sex (female: male) ratio, less temperature sensitivity for fruiting
Bottlegourd:	Suitability for fruit setting under high and low temperatures, variable vine length, small, slow developing seed, resistance against virus, mildews and pests
Brinjal:	Resistance against little leaf, bacterial wilt, *Phomopsis* blight, fruit borer and root-knot nematodes, heat tolerance (for fruit-set)
Chili:	Multiple virus (TMV, CMV, LCV), anthracnose and bacterial spot resistance, perennial types, suitability for tropical conditions with export potential
Cucumber:	Suitability for hot and hot-humid weather cultivation, multiple disease and virus complex resistance, stable gynoecious forms
Lablab bean:	Low sensitivity to photoperiod and temperature, resistance against viruses and anthracnose, bushy habit and drought tolerance
Muskmelon:	Resistance to viral diseases, downy mildew, wilt, fruit fly, and also non-dessert forms.
Okra:	Resistance against YVMV, powdery mildew, Cercospora, *Fusarium* wilt and damping off. Also resistance against major pests, viz., shoot and fruit borer, jassids, white fly, mites and root-knot nematodes; suitability for export.
Onion:	Photo-insensitivity, resistance against thrips, purple blotch, blight and storage diseases, allied *Allium* spp. and primitive forms
Pumpkin:	Suitability for fruit setting under LD and SD conditions, particularly in *C. moschata*, resistance against viruses and powdery mildew
Tomato:	Tolerance to high/low temperature (for fruit-set) and cracking; resistance against TLCV, TMV, bacterial wilt, *Fusarium* wilt and root-knot nematodes, suitability to wet tropic and drought conditions
Watermelon:	Suitability for transport (tough skin) and storage, resistance against anthracnose, WMV, collection of allied species
Amaranth:	Low oxalate, high protein and vit. A in leaves, fast regeneration potential
Gardenpea:	Suitability for high temperature and humidity conditions, resistance against wilt, mildew and leaf miner
Sweet potato:	Earliness, high protein and Beta-carotene content; resistance against weevil

B. Search for improved nutrition and quality

Crop	Improved quality	Improved nutrition
Bittergourd	Fruit shape, colour, surface	Phosphorus and potassium in fruits
Bottlegourd	Slow seed development, flesh thickness	Anti-oxidants, minerals, vitamins
Brinjal	Desirable shape, colour, lustre and low seed content in fruits	High folic acid in fruits
Chili	Oleoresin, fruit colour, shape	High capsaicin, oleoresin and vit. C in fruits
Cucumber	Fruit shape, colour, size and flesh thickness	Carotene content and aroma
Gardenpea	Fruit shape, colour and seeding	Protein content of pods
Leafy vegetables	Leaf colour, size and regeneration rate	Anti-oxidants, minerals and vitamins
Muskmelon	Colour, thickness, firmness, aroma/flavour in flesh	TSS, vit. C, flavonoids and phenols
Okra	Fruit shape, size, colour	High protein in fruits
Pumpkins	Fruit size, shape, flesh colour and thickness	Ascorbic acid, β-carotene and anthocyanin content in fruits
Tomato	Firmness, shelf life, acidity	High TSS, vit. A, C, and lycopene
Watermelon	Flesh colour, texture and seed arrangement	TSS, carotenoids, phytochemicals, phenols

Source Countries for Introductions*

Bittergourd	:	South East Asia
Bottlegourd	:	African countries, Indo-gangetic plains
Chilies (hot)	:	Principally from South America
Cucumber	:	Multiple locations
Ivygourd and Chow-Chow	:	India (north-eastern part and middle Himalayas)
Lablab bean	:	Eastern peninsular tract, Orissa (India), etc.
Muskmelon	:	Feral forms from North-Eastern India, resistance sources from Central Asia, Middle East, Africa and global gene banks and cultivated types from India, Afghanistan, Pakistan, Japan, etc.
Okra	:	African countries, South East Asia and India
Pointedgourd	:	India (Bihar, Bengal, Assam)
Pumpkin	:	Central and South America
Snakegourd	:	Southern India and peninsular parts
Sweet Potato	:	USA, Japan, China, Fiji, New Zealand, Taiwan, Australia, Tanzania, Nigeria, India
Tomato	:	Various destinations
Watermelon	:	Allied species from African countries; cultivated forms from USA, Japan and India

*Also from institutions like AVRDC, Taiwan, USDA Gene Banks and PGR Centres of South and South-East Asia

Germplasm Exchange among South Asian Nations

The experience under the South Asia Vegetable Research Network (SAVERNET) programme Phase I and II emphasizes the continuance of such programmes with better zeal. Some of the results of SAVERNET are given below.

Six countries exchanged 96 varieties of 13 vegetable crops for evaluation. Indian tomato varieties Pusa Sheetal, Pusa Ruby, Arka Vikas, Pant Bahar, Punjab Chhuhara performed well in Bhutan, Nepal and Pakistan. Sri Lankan Tomato T245, T89 did well in India, Nepal and Pakistan. Bangladeshi tomatoes Ratan and Manik did well in India, Nepal and Sri Lanka. Indian brinjal varieties Pusa Purple long, Pusa Kranti and Pant Rituraj did well in Bangladesh. Sri Lankan chili MI 2 and KA 2 performed well in India and Bangladesh. Indian okra varieties Parbhani Kranti, Pusa A-4, Arka Anamika and Arka Abhay performed superior for yield and YVMV resistance in India, Pakistan and Sri Lanka. Pusa A-4 gave highest pod number (45/plant). Cucumber varieties Shabi Ghenchu from Bhutan and Ly 58 from Sri Lanka, along with Pusa Samyog from India were found superior at various locations. Muskmelon hybrid Pusa Rasraj from India, and Ravi and T96 from Pakistan were superior in yield and quality.

Conclusion

Cultivated types with wider adaptability and higher productivity, processing quality and stress resistance will still form the major thrust in introductions. Besides wild related forms having resistance against one or more biotic/abiotic stresses need to be introduced for developing pre-breeding material where crossability is difficult or else for direct utilization in developing commercial varieties. An integrated gene management strategy has to be developed in each mandate vegetable crop. In addition to varieties, new vegetable crops also need to be introduced, particularly for improved nutrition, value addition and export. Even exchange of elite germplasm among South Asian countries can help a lot in boosting vegetable production as experienced in one of the SAVERNET programmes on varietal evaluation.

In agricultural terms, the richest country is one that has maximum bio-diversity. During earlier days bio-diversity was considered a common heritage of mankind and introduction used to be a free and frequent activity. Global conventions during recent years have altered the concept. Now bio-diversity is the sovereign property of the nation in whose political frontiers it occurs, and as such, the introduction of germplasm now involves certain procedures, commitments and cautions on part of the ordering agency or person. Further, as suggested by Dr. M. S. Swaminathan, concerned public institutions should create novel genetic combinations under well-designed pre-breeding program and through participatory breeding involving grass-root farmer breeders, get the novel genetic traits for resistance to biotic and abiotic stresses incorporated in to locally adapted varieties (Swaminathan, 1999). This will ensure ecological, economic and social sustainability as well.

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