Research Review

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Management of genetic resources of perennial horticultural crops: a review

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ABSTRACT

India has a rich and varied heritage of biodiversity, encompassing a wide spectrum of habitats from tropical rain forests to alpine vegetation and from temperate forests to coastal wetlands. Out of 18 biodiversity hot spots identified in the world, four hotspots, i.e. The Western Ghats, Eastern Himalaya, Western Himalaya, and Nicobar islands are in India. Besides, India has 26 recognized endemic centres which are home to one-third of all the flowering plants identified and described so far. There are 8.7 million species of the world's biota. Of them, only 1.7 million have been described to date, and their distribution is highly uneven. About 7% of the world's total land area is home to half of the world's species, with the tropics alone, accounting for 5 million. India contributes significantly to the biodiversity of the world, accounting 7.31 % of the global plant diversity from 2.4% of the world's area.

KEY WORDS: Genetic resources, Perennial horticultural crops, Biodiversity, Habitats, Tropical rain forests, Alpine vegetation, Temperature forests, Coastal watlands

India has two major realms called the Palaearctic and the Indo-Malayan, and three biomass namely, tropical humid forests, tropical dry/deciduous forests, and the warm desert/semi-deserts. The endemism of Indian biodiversity is high. About 33% of the country's recorded flora are endemic to the country and are concentrated mainly in the North-East, Western Ghats, North-West Himalaya and the Andaman and Nicobar islands. Of the 49,219 plant species, 5,150 are endemic and distributed in 141 genera under 47 families, corresponding to about 30% of the world's recorded flora, which means 30% of the world's recorded flora is endemic to India. Of these endemic species, 3,500 are found in the Himalayas and adjoining regions and 1,600 in the Western Ghats alone. India is a centre of crop diversity — the homeland of 167 cultivated species and 320 wild relatives of crop plants. India's record in agro-biodiversity is equally impressive that it has 167 crop species and wild relatives. It is considered to be the centre of origin of 30,000-50,000 varieties, comprising rice, pigeonpea, mango, turmeric, ginger, sugarcane, gooseberries *etc.* and ranks seventh in terms of contribution to world agriculture. India is one of the 17 mega diverse countries of the world, holding approximately 8% of global biodiversity with about 45,000 plant species in 16 agroclimatic zones.

A large number of crops such as cucumber, brinjal, melon, mango, banana, coconut, black pepper, ginger, turmeric, cardamom *etc.* are important horticultural crops native to India (Table 1). Historically, the Kings and rulers used to conserve many of this diversity in then gardens around their palaces or in the vicinity of temples. Documented evidences indicate that the orchard in Lakhbagh in Darbangha established by Mughal Emperor Akbar consisted of one lakh mango trees, proving eloquently the interest the Mughal emperors had in making selections for quality. The Mughal gardens in Kashmir, Punjab, Delhi and Uttar Pradesh are testimony to their contributions to floriculture. The conservation of diversity and plants of different species in Botanic Gardens, on the pattern of Royal Botanic Garden at Kew, was replicated by Britishers. Other introductions are pineapple through Philippines, papaya, guava, cashew, chili and tomatoes were the introductions. Grapes were an introduction by Mughals in 1300. Grape was also introduced in southern part of the country into Salem and Madurai districts of Tamil Nadu by the Christian missionaries around 1832.

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Table 1. Diversity of world plant species

Approximate number of plant species	13-14,000,000
Number of described plant species	1,750,000
Number of higher plant species	300,000 to 500,000
Approximate number of edible plant species	75,000
Number of plant species used for food	7,000
Commercially important plant species	150
Plant species producing 90% of calories in human diet	30
Crop species producing 60% of global food requirement (rice, wheat, maize)	3

Sources: Wilson (1992); Dhillon and Saxena (2003); Engels and Visser (2006)

The father of modern conservation of Plant Genetic Resources in India is Prof. Harbhajan Singh who laid emphasis on introduction of germplasm which was later acclimatized and directly released for commercial cultivation as primary introductions or after selections or utilized as donor for specific traits in breeding varieties. His leadership during late-forties to mid-fifties resulted in selection of 60 varieties in 27 vegetable crops. Some of them, Golden Acre (cabbage), California Wonder (capsicum), Nantes (carrot), Arkel (garden pea), Japanese White (radish), Sugar Baby (watermelon) and Contender (French bean) are still popular in many parts of our country due to their farmer-and consumer-friendly characteristics. The Division then graduated to become a separate world famous institute called National Bureau of Plant Genetic Resources.

Table 2. India-centre of diversity of horticultural crops

Fruits	**Primary centre:** Mango, citrus, jackfruit, bael, aonla, ber, khejri, jamun, tamarind, phalsa, lasora, karonda, wood apple, pilu, bilimbi, Garcinia
	Secondary centre: Banana, pomegranate, mulberry, *Malus, Pyrus, Prunus, Rubus*
Vegetables	**Primary centre:** Brinjal, smooth guard, ridge guard, cucumber, parwal, *Amaranthus, Basella,* sword bean, winged bean, kundru, Dolichos bean, Indian lettuce, drumstick.
	Secondary centre: Cowpea, okra, chilli, pumpkin and Brassicas
Ornamentals	**Flowers:** orchids, rhododendrons, musk rose, begonia, balsam, globe amaranth, glory lily, foxtail lily, primula, blue poppy, lotus, water lily, clematis, tulip
	Trees: Kachnar, amaltas, pink cassia, *Butea,* India coral tree, Pride of India, Scarlet cordial, yellow silk cotton tree, karanj, tecomella, tulip tree, chalta, sita ashok, arjun, milchelia, kadamba, maulsari.
	Shrubs and climbers: *Jasmine, Ixora, Hamiltonia, Clerodendron, Crossandra,Plumbago, Tabernamontana, Trachlospermum, Passiflora, Clitoria, Porana, Gloriosa, Clematis*
Plantation crops, spices and condiments	Pepper, greater galangal, Bengal cardamom, Anethum, sowa, ajowain, cinnamon, cumin, curcuma spp., curry leaf, long pepper, betelvine, long pepper, ginger, Indian cinnamon, Indian tamarind, kokum and tamarind.
Tuber crops	Greater yam, lesser yam, potato yam, elephant-foot yam, yam bean, winged bean, alocasia, giant taro, colocasia.
Medicinal and aromatic plants	Muskdana, belladonna, jamalgota, Malabar grass, rosha grass, citronella, grass, lemon grass, datura, puskarmul, jasmine, saya, isabgol, patchouli, sarpagandha, sandal wood, costus, nuxvomica, Indian almond, vetiver, kutaki, bank-kakri, asparagus, atees, vatsnabh, Indian ginseng, ashoka, arjuna, bijayasal, kurchi, neem, guruchi, lodhara

Source: Singh *et al.* 2009

Today India holds the world's largest germplasm in many crops, notable among them being coconut, areca nut, black pepper, mango, cardamom, cashew and many vegetable crops.

The National Active Germplasm Sites (NAGSs) is a unique feature in our system and a large number of germplasm are being maintained in these sites. Different field gene banks maintain a total of about 73,000 genetic resources having 9,240 accessions of fruits, 25,400 of vegetables and tuber crops, 25,800 of plantation crops and spices, 6,250 of medicinal and aromatic plants, 5,300 of ornamental plants, and 984 of mushrooms. There is International Gene Bank operating in crop like coconut which is hugely difficult to manage since they occupy a large area. There are about 129 horticultural crops on which NAGS works and the genetic resources are being maintained by various ICAR institutes and SAUs (Table 2).

Horticultural genetic resources (HGR) are a subset of agro-biodiversity that is related to horticultural plant species or their wild gene pool, having genetic material of actual or potential value. Horticultural plants comprise groups of important crop commodities which include fruits, vegetables, spices and condiments, ornamental plants, and aromatic and medicinal plants. These groups of crops, besides improving biological productivity and nutritional standards also have enormous export potential (Table 3).

Table 3. Genetic resources of horticultural crops

Crop	Total accessions
Fruits and nuts	7,084
Vegetables (including onion and garlic)	20,053
Ornamentals (including orchids)	3,499
Spices (including seed spices)	8,785
Plantation crops (including oil palm and cashew	2,709
Medicinal and aromatic plants+ RET species	2,570
Tuber crops and potato	10,094
Mushrooms	2,692
Total	57,486

Source : Ganeshan, 2015

GENETIC RESOURCES OF FRUIT CROPS

MANGO

Mango (*Mangifera indica* L.) is most important fruit crop in India having socio-economic significance. Mango originated as alloploid and its native home was recommended as Eastern India, Assam to Burma or possibly further in the Malay region. Introduction of superior types into Malay region from India is also an evidence of its origin in India. Based on detailed study of the history, phyto-geographical distribution of allied species, fossil records, and evidence of numerous wild and cultivated varieties in India, researchers considered origin of genus *Mangifera* probably in Burma, Siam, Indo-China and the Malay peninsula, but the birth of common mango is in Assam-Burma region and not in the Malay.

India is one of the world's richest germplasm centres where mango has been a predominant fruit crop for thousands of years. Genus *Mangifera* belongs to the family Anacardiaceae and almost all the commercial cultivars of mango are included in a single species *Mangifera indica*. However, a few commercial cultivars of South-East Asia belong to other edible species such as *M. altissima, M. caesia, M. cochinshinensis, M. foetid, M. griffithii, M. lagenifera, M. londipes, M. macrocarpa, M. odorata, M. pajang, M. pentandra, M. sylvatica* and *M. zeylanica*. There are 41 species in genus *Mangifera* with varied reports about number of species in this genus. Out of these, five species namely, *M. andamanica, M. indica, M. khasiana, M. sylvatica* and *M. comtosperma* have been reported from India.

A lot of genetic erosion in mango germplasm has taken place due to urbanization, industrialization and resultant felling of trees. On the other hand, most of the genepools have remained unexplored with regard to the study of the extent of variability in order to identity, collect and conserve the valuable germplasm *in-situ* or *ex-situ* for direct use as cultivars or in breeding programme to impart desirable traits to the commercial cultivars. The species of *Mangifera* occur mainly as complex biotic community in tropical humid forests, subtropical rain forests and tropical dry forests of Indo-Malayan biogeographic realm. For *in-situ* conservation, the region in hills of east Orissa, forests bordering Burma in Manipur valley which have rich genetic variability in wild forms of *M. indica* have been identified. There is urgent necessity to take measures for *in-situ* conservation of 15 species belonging to endangered, vulnerable and rare categories.

Substantial diversity of cultivated *M. indica* is being conserved in field gene banks at several centres in India, although very less variability of wild forms or other *Mangifera* species is represented in these collections like *M. Cambodiania, M. cochinchinensis, M. odorata* and *M zeylanica* also exist in few collections but the endemic India species like *M. sylvatica, M. andamanica, M. khasiana* need to be collected. Exploratory surveys were carried out at the Andaman and Nicobar islands to locate the genetic diversity and distribution of wild and indigenous mango species within the Islands. The indigenous mango species like *Mangifera andamanica, Mangifera griffithi* and *Mangifera camptosperma* were

found distributed in specific locations. The National Collection Centres have now been identified at Central Institute of Subtropical Horticulture, Lucknow, and Indian Institute of Horticultural Research, Bengaluru, to maintain the germplasm of mango. Besides this, many agricultural/horticultural universities are also maintaining the germplasm of mango.

In-vitro gene bank for mango is still not feasible since attempts to standardize tissue culture technique for mango are faced with problems of browning of both tissue and medium within few days of inoculation due to leaching of phenolic compounds from vegetative tissue into the culture media. Use of pollen storage and exchange of mango germplasm through pollen have a lot of advantages. This may be useful in hybridization programme designed to transfer genes for fruit colour to local varieties and the time lag can be shortened by the use of pollen rather than introduced bud wood.

BANANA

India is having vast diversity for banana and plantains, but only a few varieties/landraces are cultivated commercially and banana trade is dominated by only one or two cultivars especially Cavendish type. Genetic diversity of genus *Musa* comprising seeded wild species to seedless cultivars with various levels of ploidy, *viz.*, 2x, 3x, 4x *etc.* and different genomic compositions like AA, AB, AB, ABB, BB, ABB B, *etc.* In India, wild Musa species are largely distributed in the North-Eastern states, the Western and Eastern Ghats and Andaman and Nicobar Islands. The genus *Musa* has been classified into four major sections, namely *Eumusa, Rhodochlamys, Callimusa* and *Australiamusa*, but majority of the cultivated bananas originated from *Eumusa*. This is the biggest section in the genus and the most geographically widespread, with species being found throughout South East Asia from India to the Pacific Islands (Horry *et al.*, 1997). In India, more than 11 species have been reported including *M. acuminata* ssp. *Burmannicca, M. acuminata* ssp. *Burmannicoides, M. sikkimensis, M. balbisiana, M. nensium, M. thomsonii, M. itinerns, M. ochracea, M. flaviflora etc.*, which are widely distributed in the North-Eastern India.

Table 4. Distribution pattern of wild *Musa* species, Rhodochlamys and allied genus Ensete in India

Species	Distribution
M. ac.ssp.burmannicca	Western Ghats
M.ac.ssp.burmanicoides	Western Ghats and North-eastern India
M. balbisiana	Western Ghats, Andaman Nicobar Island and North-eastern India
M. itinerans	Arunachal Pradesh
M.cheesmanii	Arunachal Pradesh
M.ochracea	Tripura and Manipur
M.flaviflora	Arunachal Pradesh, Assam, Tripura, Mizoram, Meghalaya and Manipur
M.sikkimensis	Arunachal Pradesh, Nagaland, Manipur, Tripura and Meghalaya
M.nagensium	Nagaland and Mizoram
M. thomsonii	Nagaland and Mizoram
M. swarnaphalya	Arunachal Pradesh
M.saddlensis	Arunachal Pradesh
M.kuppiana	Arunachal Pradesh
M.velutinasubsp.markkuana	Arunachal Pradesh
M.velutinavar.variegata	Arunachal Pradesh
M. sabuana	Arunachal Pradesh
M.nagalandiana	Nagaland and Manipur
M.balbisianavar.andamanica	Andaman and Nicobar Island
Musa arunachalensis	Arunachal Pradesh
M. laterita	Western Ghats and Assam
M. aurantiaca	Arunachal Pradesh
M.velutina	Assam and Arunachal Pradesh
M. ornata	Tamil Nadu, Andhra Pradesh, Mizoram
M. rsaceae	Arunachal Pradesh
Ensete superubum	Western Ghats
Ensete glaucum	North-eastern India

Though there are many species in the section Eumusa, only *M. accuminata* and *M. balbisiana* are believed to have contributed to the evolution of resent day cultivated bananas which are sterile and parthenocarpic. The National Collection Centre for Banana is at National Research Centre for Banana, Trichy. Besides this, many agricultural/horticultural universities are also maintaining the germplasm of banana (Table 4).

GUAVA

Guava (*Psidium guajava* L.) is indigenous to tropical America, where it occurs in wild as well as in cultivated forms. It was common in many parts of the West Indies and that the improved forms were planted by the local people (Purseglove, 1981). It then spread throughout the tropics and has been naturalized in many countries. It has become a troublesome weed in Fiji. Burton, who visited in the early seventeenth century, mentioned the presence of guava trees in India in his memoirs. At present, it is grown throughout the length and breadth of the country from sea level to 1,300 m altitude and is so much acclimatized that it appears to be native of India.

The most important guava growing States are Uttar Pradesh, Bihar, Madhya Pradesh and Maharashtra. The genus Psidium of Myrtaceae family comprises about 150 species of small trees and shrubs (Hayes, 1970). About 20 species have edible fruits of which the most commonly cultivated is the common guava, *i.e. Psidium guajava* L. The value of the wild *Psidium* species mainly lies in their utilization as rootstocks for regulation of vigour, bearing, fruit quality and resistance to pests and diseases. *P. cujavillis, P. mole, P. cattlianum* and *P. guineense* can be used as rootstock (Mitra and Bose, 1990).

About Total 137 guava accessions are maintaining in field gene bank excluding Psidium species. Central Institute of Subtropical Horticulture, Lucknow and Indian Institute of Horticultural Research, Bangalore are NAGS for guava and maintaining guava germplasm. Apart from these, several universities also maintain germplasm of guava for conservation and utilization.

CITRUS

Citrus occupy an important position in India's fruit production. Citrus fruits, which include mandarin, sweet oranges, lemon, lime, pummelo *etc.*, are primarily consumed as fresh fruits and also processed, mainly to prepare squash, juice, marmalade and pickles. The indigenous Citrus species of India are *Citrus limon, Citrus karna, Citrus indica, Citrus nobilis, Citrus sinensis, Citrus assamennsis, Ciltrus limonica, Citrus megaloxycarpa, Citrus ichangensis, Citlrus latipes, Citrus macroptera, Citrus madurensis, Ciltrus limettiodes, Citrus rugulosa, Citrus pennivesiculata, Citrus medersapatana and Citrus nakoor.* During evolution, a remarkable diversity in citrus has developed due to natural hybridization and cultivation since ancient times.

There was a long period of progressive evolution of the genus citrus. It has become difficult to ascertain the centres of origin of most of the citrus cultivars because of natural hybridization. Both inter-specific and inter-generic hybrids have made the identification of citrus species more difficult. The germplasm has not been collected thoroughly for want of proper survey and utilization goals.

The indigenous germplasm and potential varieties with respect to physiographic conditions of growing area on a global basis needs to be conserved in situ, and collected for the expansion of gene banks for utilization in the future. There is a huge diversity in citrus in the north-eastern region of India and is also considered as one of the major centers of citrus diversity. The region holds an important position with respect of citrus wealth. Favorable climatic conditions aiding in easy hybridization amongst different species and genera, has brought about numerous forms of citrus growing in wild and semi-wild condition.

Yet very little attention has been given for the characterization and evaluation of citrus germplasm of this region. The region has remained isolated for a long time. Even today, the accessibility is rather poor in many parts of this region. Central Institute of Citrus Research, Nagpur is NAGS centre for Citrus and maintaining larger collections of citrus species. Apart from these the regional stations in different regions such as Chettalli, Ludhiana, Jorhat Akola, Parbhani, Tirupati, Periyakulam and some universities are also maintains the regional diversity of their regions.

GRAPE

Grape (*Vitis vinifera* L.) belongs to order vitals and family Vitaceae. Most of the commercial cultivars belong to Vitis family. Species of *Vitis* family persist with diploid chromosome number 38 except *Vitis rotundifolia* (muscadine grape) which contains 2n=40 chromosomes. Some of *rotundifolia* species have classified under separate genus, *Muscadinia.* Commercially grown varieties belong to *Vitis vinifera* and *Vitis labrusca,* whereas species *V. riparia, V.berlandieri, V. rupestris, V. champinii* and their hybrids are used as rootstock.

Major grape-growing countries are China, Italy, United States of America, Spain, France, Turkey, Chile, Argentina, India and Iran. In India, consumption and production of table grapes are comparatively on higher side than the wine grapes. In India, National Research Centre for Grapes, Pune, is the National Active Germplasm Site for grapes. It comprised 437 grape

accessions which includes; 110 indigenous, 305 exotic, 22 rootstocks. The available genetic resources of grape have been utilized in investigating the existing genetic variability.

POMEGRANATE

Pomegranate (*Punica granatum* L.) is widely cultivated in arid and semi-arid regions of the world. It is known to be dry and hardy fruit crop. It belongs to Lythraceae family consisting of two species *viz., Punica granatum* L. and *Punica rotopunica* Balf. During the last decade, the area and production under pomegranate cultivation was rapidly increased because of concerted research efforts, value addition, outreach to farmers and marketing advisories. The National Research Centre on Pomegranate, Solapur, (Maharashtra), is national repository has 304 germplasm in the Field Gene Banks (FGBs). This includes 210 indigenous collections covering indigenous wild collections of North Eastern states and western Himalayas, cultivated and local types besides 94 exotic collections of USA, Turkey, Russia, Iran, Japan, Italy and Afghanistan. Recently, 120 USDA accessions have been collected from California, USA, by ICAR-IIHR, Bengaluru, through NBPGR, New Delhi.

Pomegranate cultivated types belongs to *Punica granatum* L. with two sub-species, *viz.* chlorocarpa and porphyrocrpa. Apart from edible types, ornamental types are also exists. The ornamental types are with double red flowers, largely sterile and no grown for edible fruit. Besides, there is a dwarf statured pomegranate which grows only up to 2-2.5 ft. with profuse, miniature flowers and small sized fruits called "nanna". Wild pomegranates are highly acidic types, popular as souring agent (anardana). "Bhagwa"is the most popular variety which occupies nearly 80% pomegranate area in India, due to its attractive red rind and red arils with low acidity (%). Super Bhagwa, Ganesh, Arakta, Mridula, Ruby, Dholka, Kandhari, Jyoti, G-137, Jallore Seedless, Jodhpur Red are the other important commercial varieties grown in different states of India. The available genetic resources of pomegranate have been utilized in investigating the existing genetic variability for different morphological, biochemical and molecular characters.

SAPOTA

Sapota was introduced in to India from Central and South America, specifically from the peninsula of Mexico. Its commercial cultivation was first taken up in Maharashtra during 1898. Since it is an introduced crop the natural seedling diversity is observed in pocket like, Gujarat, North Karnataka including Goa, Maharashtra. Important states of India where sapota is cultivated in commercial scale are Karnataka, Gujarat, Tamil Nadu, Maharashtra, Andhra Pradesh and West Bengal. The IIHR is National Active Germplasm Site (NAGS), and fifty accessions are maintained in field gene bank.

CUSTARD APPLE

Custard apple (*Annona squamosa* L.) was introduced in India from tropical America and found in wild form in many parts of the country. Custard apple growing regions in India includes Assam, Bihar, Madhya Pradesh, Maharshtra, Odisha, Rajasthan and Uttar Pradesh, Andhra Pradesh, Telangana and Tamil Nadu. Approximately 22,000 hectares area is under custard apple cultivation in India. Among the 166 species of Annona, six species such as *Annona squamosa, Annona reticulata, Annona atemoya, Annona cherimola, Annona glabra* and *Annona muricata* are commercially important and edible. At present, 10 varieties of custard apple and six species of Annona are conserved under in situ condition for its utilization in genetic improvement of custard apple at IIHR, Bangalore.

TEMPERATE FRUITS AND NUT CROPS

Temperate fruits comprising of pome (apple, pear and quince) and stone (cherry, apricot, peach, plum, nectarine) along with nuts (walnut and almond) contribute significantly to national economy. These crops adapted to the Himalayan ecosystem have high degree of biodiversity. Their cultivation is restricted to temperate region of India like Jammu and Kashmir, Himachal Pradesh, Uttarkhand, Arunachal Pradesh *etc.* Biodiversity in temperate fruit crops lies with the availability of alternate crops like Cape Gooseberry, Rose Hops, Minor nuts (Hazel Nut, Pecan Nut, Pistachio Nut) *etc* having chilling requirements which are met under temperate conditions. Thus adoptability of these crops will help in combating the challenges of climate change and thus act as alternate crops. Different biodiversity conservation sites in the form national repository is being planned by NBPGR and CITH for maintaining and conserving the biodiversity of temperate fruits and nuts at different places to ensure the security of germplasm.

ARID ZONE FRUITS

To harness genetic variability for varietal improvement of arid fruit crops such as ber, pomegranate, bael, aonla, custard apple, date palm, phalsa, lasoda, wood apple, tamarind, cactus pear, karonda, jamun, salvadora and fig, it is imperative to build a rich germlasms bank. The ICAR-Central Institute for Arid Horlticulture, Bikaner, Rajasthan ever since its inception is striding forward in this direction and has one of the richest germplasm pool of underutilized arid fruits. Besides, it has also been recognized as National Active Germplasm Site (NAGS) for arid fruits (Table 5).

Table 5. Status of germplasm of arid fruits at NAGS at CIAH.

Name	Scientific name	No. of Accessions
Ber	*Ziziphus mauritiana*	373
Bordi	*Z. roltundifolia*	22
Pomegranate	*Punica granatum*	195
Custard apple	*Annona squamosa*	09
Aonla	*Emblica officinalis*	24
Date palm	*Phoenix dactylifera*	64
Bael	*Aegle marmelos*	57
Jamun	*Syzigium cumini*	52
Tamarind	*Tamarindicus indica*	25
Cactus pear	*Opuntia ficusndica*	20
Phalsa	*Grewia subinaequalis*	8
Fig	*Ficus carica*	8
Mulberry	*Morus spp.*	15
Marula nut	*Sclerocarya birrea*	01
Mahua	*Madhuca latifolia*	50
Chironji	*Buchanania lanzen*	30
Khirni	*Manilkara hexandra*	30
Karonda	*Carissa carandus*	48
Lasora	*Cordia myxa*	65
Pilu	*Salvadora spp.*	02
Ker	*Capparis decidua*	06
Manila tamarind	*Pithocelobium dulce*	03
Wood apple	*Feronia limonia*	12

Source : CIAH, Bikaner

TROPICAL UNDERUTILIZED FRUITS

There are several fruits originated and naturized in the tropical humid region of India. These are either wild or cultivated in very limited area but these have potential to be a major fruit due to their nutritional value or other attributes. Among these mangosteen, durian, rambutan, avocado, kokum, Malabar tamarind, yellow mangosteen, kronda, Maayan apple, rose apple, langsat, egg fruit, carambola, dragon fruit, velvet apple, longan, macadamia nut, pummello, sour sop, pulasan, bilimbi, hog plum are important ones. A large number of accessions of these fruits have been collected and maintained in the field gene bank at IIHR and its regional stations for conservation and utilization.

CASHEW NUT

Cashew (*Anacardium occidentale* L.) belongs to the family Anacardiaceae and is a native of Brazil. The family comprises of bout 60 genera and 400 species of trees and shrubs with resinous bark and grows most abundantly in the tropics in both eastern and western hemisphere (Ohler, 1979). The Anacardium genus comprises of 20 species and the cultivated species *A. occidentale* L. is andromonoecious, with male and hermaphrodite flowers in the same inflorescence. Within the species *A. occidentale*, there is a wide variation in colour, size and shape of the apple, as well as in size and shape o the nuts. The time of flushing, flowering varies among different types. There are also differences in leaf size and leaf shape and numerous other characters. Cashew was introduced to India by Portuguese during 16th century. Molecular studies have

Table 6. Status of cashew germplasm in India

State	At NCFGB	At AICRP centres	Total
Andaman and Nicobar Islands	10	--	10
Andhra Pradesh	103	48	151
Arunachala Pradesh	2	--	2
Assam	3	--	3
Chhattisgarh	5	61	66
Goa	45	--	45
Karnataka	135	128	263
Kerala	72	181	253
Maharashta	45	297	342
Manipur	1	--	1
Meghalaya	11	--	11
Mizoram	1	--	1
Orissa	21	97	118
Tamil Nadu	46	200	246
Tripura	3	--	3
West Bengal	14	92	106
Exotic	22	--	22
Total	539	1104	1,643

Source: DCR, Puttur

shown the possibility of its introduction repeatedly over a period of time but at a single location, *i.e.* West coast (Archak *et al.*, 2009).

Presently, the cashew plants in wild state as well as in well managed orchards are seen in Maharashtra, Goa, Karnataka and Kerala along the west coast, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal on the east coast. To a limited extent, the crop is also seen growing in Chhattisgarh, Gujarat, Assam, Arunachal Pradesh, Meghalaya, Tripura, Manipur, Nagaland and Andaman and Nicobar Islands. Seedling origin plants are in plenty in forests and plantations managed by state cashew development corporations throughout the country. This diversity is considerably captured in germplasm surveys and so far 539 accessions have been collected and conserved by the National Cashew Field Gene Bank (NCFGB) in the Directorate of Cashew Research, Puttur.

Similarly, Regional Cashew Gene Banks (RCGBs) have been established at All India Coordinated Research Project (AICRP) centres which are maintaining a total of 1104 accessions (Table 5). Three wild species namely, *Anacardium pumilum, A. othonianum* and *A. microcarpum* are also conserved. The collection also has seedling accessions of 23 exotic collections of which nine were collected from Brazil, Nairobi, Mtwara, Lindi, Nacala, Mozambique, Ex Tanganyka, Singapore and Australia and 14 from Republic of Panama (Table 6).

MANAGEMENT OF GENETIC RESOURCES

Exploration and Collection

India has rich biodiversity with respect to mango, Citrus spp, jackfruit and related species, Bael, *Garcinia, Prunus* spp, *Musa* spp. *Syzygium, Zizyphus, Terminalia, Punica* sp. *etc.* The culture effected are being made to collect the available diversity in fruit, vegetables, flowers, medicinal and aromatic crops, spices, plantation crops and mushroom. National Bureau of Plant Genetic Resources, conducted targeted exploration in the biodiversity hot spots in collaboration with other Horticultural Research Institutes, State Agricultural Universities and other concerned department. Apart from these, the crop specific institutes also conducted surveys and collect germplasm of their mandated crops. The IC numbers of all these collected accessions is collected from NBPGR after receiving the passport data and samples.

Germplasm Introduction

A large number of valuable germplasm of horticulture crops have been introduced in India. In recent years, the focus is on introduction of germplasm with resistance to abiotic and biotic stresses. Large collection of Papaya *(Carica papaya)* and its wild relatives, Cactus spp., Date palm, pomegranate, pear apple, peach, almond, plum, grape, oil palm and its wild relatives has been introduced from different countries.

Germplasm Characterization

Characterization is the description of plant germplasm which determines the expression of highly heritable characters ranging from morphological or agronomical features to seed proteins or molecular markers.

Morphological characterization : Characterization of germplasm is essential to provide information on the traits of accessions assuring maximum utilization of germplasm collection to final users. The recording and compilation of data on important characteristics which distinguish accessions within a species, enables an easy and quick discrimination among phenotypes. It facilitates a check on true-to-type of homogeneous samples, allowing detection of misidentifications or duplicates and indicating possible errors made during other gene bank operations. It can be carried out at any stage of the conservation process, as long as there are sufficient numbers of seeds or plant materials to sample. It should be done as soon as possible to add value to any collection. It is, however, very time consuming and expensive and therefore, often delayed or done during regeneration in many gene banks to reduce costs.

Most genetic resources collections are made up of population or landraces which are genetically variable. It may therefore, be necessary to collect data at the plant level, rather than at the plot level, because knowledge of the average value of a descriptor for an accession as a whole is not always sufficient. In order to facilitate standardization of information obtained during characterization, Bioversity International has been coordinating the development, publication and updates of various plant descriptor lists in close cooperation with crop experts and gene bank curators. The crop descriptors are available for major horticultural crops. Characterization is also increasingly done using complementary characterization of methods to capture the full information. Characterization may include morphological descriptors, herbarium samples, digital pictures, nutritional traits etc. A set of morphological descriptors can be used to describe the phenotype. The descriptive traits used will vary with the species.

Molecular characterization : New methods have made molecular analysis and genotyping useful techniques for studying diversity. A variety of molecular techniques are used, including cytological markers, biochemical markers and molecular genetic markers such as SSR, EST-SSR, AFLP, RAPD. Their choice depends on the research into molecular methodologies for the crop,

facilities and expertise available in each gene bank. Characterization of various fruit plants can be carried out with the help of different markers. Markers are those particular plant features which can be documented with confidence, comparative affluence and ease. However, two basic types of markers have been reported i.e., non-morphological makers (molecular markers) and naked eye polymorphism or morphological makers. DNA fingerprinting, genetic diversity analysis and marker assisted selection using the frontline DNA technologies are used for molecular characterization of germplasm.

Germplasm Evaluation

Preliminary evaluation of germplasm consists of recording a limited number of additional agronomic traits thought desirable by users of the particular crop. Characterization of physiological characters by curators can be of considerable help to the breeders through providing baseline data, such as vernalisation requirement, times of flowering and maturity, which would help to narrow the selection of potential breeding stock. Further, characterization consists of recording potential agronomic characters which will determine the usefulness of an accession for a specific purpose in specific circumstances. Typically, these include stress tolerance, disease and pest resistance and quality characters. Evaluation for many of these traits is outside the ability of most curators.

In the widest sense, the detailed evaluation of large collections requires multidisciplinary approach, specific testing conditions involving disciplines of cytogenetics and evolution, physiology, pathology, entomology, biochemistry and agronomy. They all contribute information that bears on the choice and utilization of genetic resources by the breeders. Cytogenetic information is essential for the use of many of crops. The genetics of host-parasite interaction is equally essential for the choice of resistant genotypes of any status. In horticultural crops, the evaluation of the germplasm is done by the respective crops institute.

Germplasm Conservation

The aim of conservation is to support sustainable development by protecting the using biological resources in such a way that do not diminish the diversity available in genus and species or destroy important habitats and ecosystems. Biodiversity can be conserved either *in-situ* or *ex-situ.*

In-situ conservation : *In-situ* conservation is on-site conservation or the conservation of genetic resources in natural populations or in the area where it grows naturally. It includes establishment of national park, biosphere reserve or gene sanctuary. In India, government has established 18 biosphere reserves for conservation of flora and fauna under Ministry of Environment, Forest and Climate change based on the UNESCO Man and the Biosphere (MAB) programme. In *in situ* conservation, plant species are promoted to grow in their natural habitats where evolutionary processes continue to operate, making it a dynamic system. Genetic variability is generated through mutation, pollen and seed dispersal, and recombination within and among populations.

Selection operates on this variability leading to the development of new plant types with improved adaptability. *In situ* conservation, in addition to natural habitats in protected areas and national reserves also needs to be carried on-farm in the areas where landraces and locally adapted farmers varieties are cultivated. This requires active farmers participation to conserve landraces and traditional farmers varieties. The novel genetic resources may be conserved even in home gardens. On-farm conservation is of particular importance in countries like India, to conserve local genetic diversity and to provide diverse food and other products for household needs and local markets, where livelihood depends on traditional subsistence farming systems. Some on-farm conservation models have been developed to define priorities for what and where to conserve based on biological and socio-economic criteria.

Ex-situ conservation : Conservation of plant genetic resources outside their natural habitat is known as ex-situ conservation. It facilitates conservation in controlled conditions and makes possible reintroduction of species into wild. It can be achieved in the following ways (1) Seed gene banks, (2) Botanical garden (3) Field gene banks (4) in-vitro banks (5) Cryopreservation banks and (6) DNA banks.

Seed conservation : Seed conservation is aimed at maintenance of high seed quality in terms of viability and vigour for various periods. Two types of collections are maintained in gene bank (i) active collections under medium term condition (4°C) from which samples are drawn for evaluation and distribution and ii) base collections are maintained at (-20°c) for long term storage. Most of fruits crops are vegetatively multiplied and their seeds are not used for multiplication. But most of the rootstocks are multiplied through seeds. These seeds can be stored for short term storage for next season. The seeds of some rootstocks alike Rangpur lime etc. loose their viability quickly these can be stored at low temperature. The seed propagated fruits like papaya seeds can be stored at low temperature for short term and midterm conservation.

Botanical garden : Botanical gardens are used to conserve those species which are loses their viability

during seed gene bank storage. There are many field gene banks/botanical gardens maintained by government and non-governmental organizations in India. National Biodiversity Authority (NBA), an autonomous and statutory body of the Ministry of Environment and Forests, Government of India listed existence of 109 botanical gardens across 18 states in India. The role of most botanical gardens in conserving intra species diversity is limited because these conserves only few accessions per species or taxon. However, this plays a greater role in public awareness and education. Botanical gardens are mainly used to display a great number of different exotic species. There is a possibility that a few well managed gardens lay emphasis on conservation of certain group of species as living collections.

Field gene banks : Field gene banks are important for conservation of germplasm of perennial crops. All the horticultural research institutes and research stations are maintaining field genes of the important crops of their respective regions. National Bureau of Plant Genetic Resources has designated National Active Germplasm Sites for different horticultural crops (Table 7). These designated sites have the responsibility of overall germplasm management including conservation of the allotted crop(s) and work in association with the NBPGR.

Pollen cryobank conserves nuclear genetic diversity (NGD) of important horticultural crops. Long term conserved pollen in the form of nuclear genetic diversity of citrus, papaya, grape, mango, tomato, eggplant, onion, capsicum, rose, gladiolus, gerbera, carnation and RET species of medicinal plants are continued to be cryopreserved in liquid nitrogen. The pollen cryobank was maintained and managed by periodic replenishment of the cryogen, for maintaining a constant cryogenic temperature throughout the storage duration. Cryopreservation involves storage of ant material at low temperature in liquid nitrogen or nitrogen vapour (-154°C to -196°C). At this temperature the cell division and metabolic processes stop and hence the plant material can be stored for larger period without alteration.

Cryopreservation of those species tht can easily be regenerated into whole plant from the stored propagules is a promising option for safe, long-term storage of germplasm. Status of cryopreserved germplasm of horticultural crops at the cryobank NBPGR, New Delhi include 1071 accessions of fruits and nuts (*Aegle marmelos, Citrus* sp., *Capparis decidua, Juglans regia, Prunus* sp., *Zizyphus* sp.) covering 111 species. Cryopreservation requires limited space, involves very little maintenance and is considered to be a cost effective option. Engelmann (1997) has reviewed cryopreservation protocols developed using different techniques. Once these techniques are further refined, large-scale adoption should be possible.

Pollen storage : Pollen storage was mainly developed as a tool for controlled pollination of asynchronous flowering genotypes especially fruit tree species. The potential advantage of this method in conserving germplasm can be readily appreciated; the relatively small quantity of the specimen required for a single accession and exchange of germplasm through pollen

Table 7. Designated National Active Germplasm Sites (NAGS) for horticultural crops

Crop	Designated NAGS
Arid fruits	Central Institute of Arid Horticulture, Bikaner
Banana	NRC Banana, Tiruchirapalli
Cashew	Directorate of Cashew Research, Puttur
Citrus species	Central Institute of Citrus Research, Nagpur
Grapes	NRC for Grapes, Pune
Aonla, Bael& Litchi	NRC Litchi , Muzaffarpur
Jackfruit	Indian Institute of Horticultural Research, Bangalore
Mango	Central Institute for Sub-Tropical Horticulture, Lucknow
Subtropical fruits	Indian Institute of Horticultural Research, Bangalore Central Institute for Sub-Tropical Horticulture, Lucknow Indian Institute of Horticultural Research, Bangalore
Mulberry	Central Silk and Mulberry Genetic Resources Centre, Hosur
Oil Palm	Indian Institute of Oil Palm Research, Pedavegi
Plantation Crops	Central Plantation Crops Research Institute, Kasargod
Temperate horticulture Crops	Central Institute of Temperate Horticulture, Srinagar NBPGRRS, Shimla
Tropical fruits	Indian Institute of Horticultural Research, Bangalore

poses fewer quarantine problems compared with seed of other propagules. In recent years, cryopreservation techniques have been developed for pollen of an increasing number of species and cryobanks of pollen have been established for fruit tree species in several countries (Alexander and Ganeshan, 1993). Pollen collections of mango cvs. 'Totapuri', 'Alphonso', Langra and a dwarf variety were cryopreserved. *In vitro* germination of pollen cultured in sucrose medium using the cellophane procedure was found to be ideal. Pollen collections from different species, cultivars and hybrid lines were made from Vitis, Poincirus, Citrus and Musa species and preserved at -20°C and -196°C.

Pollen of *Citrus limon Burm*, cvs. 'Sevelle' 'Eureka' and 'Italian' retained the viability under storage conditions of -18oC and germinated moderately after 100 days of storage without appreciable loss of viability. It was observed that the percentage germination decreased to 25-30 per cent in 'Seville' after 150 days and 25 per cent in 'Eureka' and 'Italian' of fresh pollen after 100 days. Long-term pollen preservation of Citrus aurantifolia and 4 cultivars of Citrus limon Burn 'Seville', 'Hill Lemon', 'Italian' and 'Nepali Obong' was initiated at Cryo-genic temperature with pre-treatment like freeze-drying and pre-freezing in liquid nitrogen fumes.

All cultivars and flower types retained their capacity to germinate *in-vitro* after 3.5 years of cryogenic storage. Papaya cvs. Washington and Coorg Honey Dew and *Carica cauliflora* L. pollen were preserved at -3°C, -18°C and -196°C. Pollen preserved in liquid nitrogen (cv. Washington and *Carica cauliflora*) continued to maintain high viability, profiled *in-vitro*, after a period of one year and 8 months. Pollen samples have been retained in liquid nitrogen for prolonged storage durations, since gemination capacity was not affected even after 7 year of storage.

The investigations on pollen preservation in grape varieties viz, Ánab-e-Shahi, Bangalore Blue, Bangalore Purple, Black Champa and Queen of Vineyards revealed that pollen collected from these varieties were assessed for their capacity to germinate *in vitro* and stored at -196°C in liquid nitrogen. It was successfully cryopreserved for 5 years without any loss of viability. However, pollen storage alone cannot conserve the cytoplasmic genetic diversity of a species. There is a need to assess the potential drawbacks of excluding maternal genes and their feasibility of ovule storage and in vitro fertilization techniques. In addition, effective sample techniques to cover a population or gene pool are needed.

DNA storage : Storage of DNA is another approach to conservation. Genetic engineering has broken down the crossability barriers and transgenic plants incorporating genes from virus, bacteria, fungi and even mice have become reality. Such efforts have lead to realization of storage of total genomic information in the form of DNA libraries. However, strategies and procedures have to be developed on how to use the material stored in the form of DNA Therefore, the role and value of this method for PGR conservation is not completely clear as yet.

In vitro conservation : Tissue culture techniques are of great interest for collecting, multiplication and storage of plant germplasm. Tissue culture systems allow propagation of plant material with high multiplication rates in an aseptic condition. Virus free plants can be obtained through meristem culture in combination with thermotherapy, thus ensuring disease free plants and simplifying quarantine procedures. Some crop species such as banana and plantain (*Musa* spp.) do not produce seeds or produce recalcitrant seeds such as coconut, cacao, and many tree and shrub species. Crops such as potato, yam, cassava and sweet potato have either sterile genotypes or produce orthodox seeds which are highly heterozygous, therefore, making seed storage of limited interest for the conservation of particular gene combinations.

These species are mainly propagated vegetative to maintain clonal genotypes. The miniaturizations of explants allow reduction in space requirements and reduce labour costs. Protocols have been optimized for 23 horticultural crops, which are being conserved under normal and reduced culture conditions. *In-vitro* plants of Jackfruit accessions have been successfully conserved for 4 years under standard culture conditions prior to first subculture. While more jackfruit accessions are accessed *in vitro*, 4 citrus accessions are maintained *in vitro* and conservation attempts has resulted in maintaining *in vitro* plants under reduced culture conditions for 6 months.

Registration of germplasm : Unlike the developers of released cultivars, scientists associated with the development of improved germplasm and genetic stocks (new sources of resistance, male sterility, varied types of mutants, cytogenetic stocks etc.) have no mechanism for recognition. Lack of formal recognition of such useful materials and role of scientist in development of these materials, discourages them from sharing valuable materials with other workers. Consequently, most of such valuable material remains underutilized or get lost. With the recent developments concerning IPR and other related issues, due recognition of these materials has become all the more important. Keeping these considerations in view, the Indian Council of Agricultural Research has identified National Bureau of Plant Genetic Resources (NBPGR) as the nodal agency for implementation of plant germplasm registration.

These are maintained at National Gene Bank, NBPGR, New Delhi or different National Active Germplasm Sites (NAGS). Further to promote on farm conservation of elite lines and germplasm and encourage farmers, Protection of Plant Varieties and Farmers' Right Authority (PPV & FRA) is registering farmers varieties and awarding custodian farmers.

FUTURE THRUSTS

- Use of GIS for geo-referencing/gap analysis and prediction and distribution of species using environment variables to plan future explorations.
- Use of GIS for mapping of trait-specific germplasm with respect to bioactive compounds.
- Use of biotechnological tools like *in-vitro* storage/ cryopreservation including pollen preservation to strengthen the conservation of germplasm.
- Use of molecular marker tools like SSR/SNP/ GWAS) improve the understanding of extent, nature and distribution of diversity and develop the varieties with high yield and quality for sustainable production.
- Priority for collection of wild relatives and under exploited genetic resources.
- Introduction of targeted germplasm for crop improvement
- Evaluation of germplasm for yield, quality, shelf-life, and resistance to biotic and abiotic stresses.
- Registration of germplasm, breeding lines and parental lines
- Awareness generation related to patenting, farmers right and benefit sharing.

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