# Status of Horticultural Crop Genetic Resources in India

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Horticultural crops consist of fruits, vegetables, ornamentals, root and tuber crops, spices and condiments, plantation crops and medicinal and aromatic plants. However, the present paper deals with genetic resources of fruits, vegetables and ornamentals. India is endowed with presence of rich diversity in large number of fruit crops and their wild relatives e.g. citrus, mango and banana etc. found predominantly in North eastern region, western peninsular tract and Western Ghats. In vegetables namely, brinjal, luffa, cucumber, pointed gourd, Indian spinach, dolichos bean etc., India is considered as a primary centre of origin. India is also native of important flowers like orchids, rhododendrons, muskrose, begonia, balsam, lily, lotus and a number of ornamental trees like kachnar, pink cassia, flame of the forest etc. A substantial number of valuable germplasm of fruits, vegetables and ornamentals including trait specific accessions have been introduced from different countries mainly from USA and Taiwan. The region wise diversity for fruits, vegetables and ornamental crops are given separately. Horticultural crops being vegetatively or seed propagated require complementary conservation strategies employing both *in situ* and *ex situ* methods. The vegetatively propagated perennial horticultural crops are conserved in field gene bank (FGB) whereas the seed propagated horticultural crops are conserved in seed bank at –20° C. Few horticultural crops, like banana and plantain (*Musa* spp.) either do not produce seeds or produce recalcitrant seeds such as coconut, cacao and many tree and shrub species, are conserved *in vitro*. The conservation of horticultural crop genetic resources is jointly managed by NBPGR along with National Active Germplasm Sites (NAGS).

**Key Words: Fruits, Germplasm, India, Medicinal and Aromatic Plants, Ornamentals, Vegetables**

India is endowed with a large number of native horticultultural crops. Rich diversity of about 50 different indigenous fruits and their wild relatives, totalling about 400 species exists in different agro-ecological regions of India (Rai and Gupta, 1996, Pareek *et al.*, 1998). The North-eastern region has maximum concentration of the wild relatives of fruits followed by the western peninsular tract and the western Himalayas. Rich diversity in North-eastern region is reported in citrus, mango and banana (Arora and Nayar, 1984; Ghosh, 1984). In citrus, *Citrus lemon, C. medica, C. jambhiri, C. ichangensis, C. latipes, C. macroptera, C. assamensis, C. indica* and *C. aurantium* are indigenous to this region. The Indian wild orange, *C. indica,* is found in the Naga hills, Garo hills of Meghalaya and Kaziranga forests of Assam. Similarly in mango, the wild forms of *Mangifera indica* and its allied species *M. sylvatica* occur in the forest of this region while *M. andamanica* is native to Andaman Islands. Rich diversity occurs in northwestern and eastern Himalayan region for *Pyrus, Rubus, Ribes* and *Prunus*. The Shillong plateau of Khasi hills in Meghalaya accounts for many *Prunus* species such as *P. nepaulensis, P. undulata* and *P. cerasoides.*

India is primary centre of diversity for aonla (*Emblica officinalis*), bael (*Aegle marmelos*), ber (*Ziziphus mauritiana*), citrus (*Citrus* spp.), jackfruit (*Artocarpus heterophyllus*), jamun (*Syzygium cuminii*), karonda (*Carissa carandas*), khejri (*Prosopis cineraria*), kokam (*Garcinia indica*), lasora (*Cordia mixa*), mango (*Mangifera indica*), phalsa (*Grewia subinequalis*), pilu (*Salvadora oleoides*), tamarind (*Tamarindus indica*) and woodapple (*Feronia limonia*) and secondary centre for banana, *Malus* spp., mulberry, pomegranate, *Prunus* spp., *Pyrus* spp. and *Rubus* spp.

The indigenous fruit species and their geographic distribution (Rai and Gupta, 1996) are presented in Table 1.

The Indian subcontinent has 80 species of major and minor vegetables apart from several wild species consumed as vegetables. India is primary centre of origin for brinjal (*Solanum melongena*), cucumber (*Cucumis sativus*), dolichos bean (*Lablab purpurens*), drumstick (*Moringa oleifera*), Indian lettuce (*Lactuca sativa*), Indian spinach (*Basella rubra*), ivygourd (*Coccinia cordifolia*), pointed gourd (*Trichosanthes dioica*), ridge gourd (*Luffa acutangula*), smooth gourd (*Luffa cylindrica*), sword bean (*Canavalia gladiata*) and winged bean (*Psophocarpus tetragonolobus*) and secondary centre for brassicas (*Brassica* spp.), chillies (*Capsicum* spp.), cowpea (*Vigna sinensis*), okra (*Abelmoschus* spp.) and pumpkin (*Cucurbita moschata*).

Overall, around 20-25 vegetable crops are commercially important and these comprise both indigenous and exotic species variability. Tropical

vegetable crops are grown throughout the country, as suitable agro-climates are available. The temperate vegetables have more specific requirements and are grown mainly in the Himalayan region and to some extent in higher ranges of the Western and Eastern Ghats. Also these are well adapted as cool season crops in northern/north-western plains and in the tarai foothills. The diversity, both in cultivated and wild species of vegetable crops that occurs throughout India (Arora, 1991) is presented in Table 2.

**Table 1. Region wise diversity for fruit crops and their wild relatives**

| Sl. No. | Agroecological Region(s) | Crops/ Species |
|---|---|---|
| 1. | Western Himalayan region | *Citrus, Carissa, Malus baccata, Myrica esculenta, Prunus armeniaca, P. cerasoides, P. cornuta, P. persica, Punica, Pyrus pashia, P. pyrifolia* and their wild relatives. |
| 2. | North-eastern Himalayan region | *Artocarpus, Citrus, Garcinia, Malus sikkimensis, Mangifera, Musa*, a few taxa of *Pyrus* viz. *P. sikkimensis* |
| 3. | Eastern Peninsular region | *Aegle, Annona, Artocarpus, Averrhoa, Emblica, Elaeocarpus, Limonia, Musa, Spondias, Syzygium, Tamarindus, Vitis* and *Zizyphus* |
| 4. | Western Arid/Semi arid region | *Capparis, Carissa, Cordia, Grewia, Phoenix, Prosopis* and *Ziziphus* spp. |
| 5. | Central region | *Artocarpus, Buchanania, Carissa, Cordia, Mangifera, Phoenix, Syzygium, Tamarindus, Terminalia* and *Ziziphus* spp. |
| 6. | Western Peninsular region | *Artocarpus, Citrus, Emblica, Garcinia, Mangifera, Musa, Spondias, Syzygium, Tamarindus, Vitis* |
| 7. | Island region (Andaman & Nicobar, Lakshadweep) | *Artocarpus, Garcinia, Mangifera, Syzygium, Vitis* |

**Table 2. Region wise diversity in vegetable crops and their wild relatives**

| Sl. No. | Agroecological Regions | Crops/ Species |
|---|---|---|
| 1. | Humid Western Himalayan Region | Amaranth, brinjal, carrot, chillies, cowpea, cucurbits, fenugreek, okra, peas, radish, spinach, turnip, *Basella rubra, Sechium edule, Solanum khasianum* and *S. hirsutum* |
| 2. | Humid Bengal / Assam Basin | Amaranth, brinjal, cowpea, chillies, cucurbits, okra, radish, spinach beet, *Abelmoschus manihot ssp. manihot, Basella rubra, Cucumis sativus var. sikkimensis, Edgeria dargelingensis, Melothria assamica, Momordica cochichinensis, Sechium edule, Solanum indicum, S. khasianum, S. surattense* and *Tuladiantha cordifolia* |
| 3. | Humid Eastern Himalayan Region and Bay Lands | Amaranth, brinjal, chillies, cucurbits, cowpea, okra, peas, radish, spinach, *Abelmoschus manihot ssp. tetraphyllus, Cucumis hystrix, Luffa echinata, Sechium edule, Solanum ferox, S. khasianum, S. torvum, S. sisymbrifolium* and *S. verbasifolium* |
| 4. | Sub humid Sutlej Ganga Alluvial Plains | Brinjal, cucurbits, fenugreek, garlic, peas, okra, onion, radish, spinach beet, *Abelmoschus manihot* sp. *tetraphyllus var. pungens, A. tuberculatus, Cucumis hardwickii, C. trigonus, Solanum indicum, S. khasianum, S. torvum, S. surattense* and *S. hispidum* |
| 5. | Humid Eastern and South -eastern Uplands | Amaranth, brinjal, cucurbits, carrot, chillies, cowpea, garlic, okra, radish, spinach, *Abelmoschus manihot* sp. *manihot, Solanum surattense* and *S. torvum* |
| 6. | Arid Western Plains | Amaranth, brinjal, cucurbits, carrot, chillies, cowpea, garlic, okra, radish, spinach beet, *Abelmoschus manihot ssp. manihot, Solanum surattense* and *S. torvum* |
| 7. | Semi arid Lava plateau and Central highlands | Amaranth, brinjal, carrot, cauliflower, chillies, cowpea, cucurbits, garlic, okra, onion, radish, spinach beet, *Cucumis setosus, Luffa acutangula var. acutangula, Solanum nigrum, S. khasianum, S. surattense, and S. torvum* |
| 8. | Humid to semi arid Western Ghats and Karnataka plateau | Brinjal, chillies, cucurbits, okra, *Abelmoschus crinitus, A. angulosus, A. ficulens, A. moschatus, A. manihot var. tetraphyllus, Basella rubra, Luffa acutangula var. acutangula, Melothria angulata, Solanum indicum, S. insanum, S. pubescens, S. surattense, S. torvum* and *S. trilobatum* |

The important flowers native to India, are orchids, rhododendrons, musk rose (*Rosa moschata*), begonia (*Begonia* spp.), balsam (*Impatiens balsamina*), globe amaranth (*Gomphrena globosa*), gloriosa lily (*Gloriosa superba*), foxtail lily (*Eremurus himalaicus*), primula (*Primula denticulata, P. rosea*), Himalayan blue poppy (*Meconopsis aculeata*), lotus (*Nelumbo nucifera*), water lily (*Nymphaea* spp.), clematis (*Clematis montana*), and the wild tulip of Himalayas (*Tulipa stellata* and *T. aitchisonii*). The important native ornamental trees are kachnar (*Bauhinia variegata*), amaltas (*Cassia fistula*), pink cassia (*Cassia nodosa*), flame of the forest (*Butea frondosa*), Indian coral tree (*Erythrina indica, Erythina blakii*), pride of India (*Lagerstroemia flosreginae, L. thorelli*), scarlet cordia (*Cordia sebestena*), yellow silk cotton tree (*Cochlospermum gossypium*), karanj (*Pongamia glabra*), tecomella (*Tecomella undulata*), tulip tree or bhendi (*Thespesia populnea*), *Crataeva*

*roxburghii*, *Sterculia colorata*, chalta (*Dillenia indica*), Sita Ashok (*Saraca indica*), Arjun (*Terminalia arjuna*), *Mesua ferrea*, ficus (*Ficus benghalensis*, *F. religiosa*), *Michelia champaka*, kadamba (*Anthocephalus Kadamba*) and *Mimusops elengi*. Among the native shrubs and climbers, the most important ones are the jasmine (*Jasminum* spp.), madhavi (*Hiptage madablota*), *Mussaenda frondosa*, Ixora, (*I. coccinea*, *I. parviflora*, *I. barbata*. *I. undulata*), *Hamiltonia suaveolens*, *Holmskioldia sanguinea*, *Clerodendron inerme*, *Crossandra infundibuliformis*, *Plumbago rosea*, *Plumbago zeylanica*, *Tabernaemontana coronaria*, *Osmanthus fragrans*, *Passiflora leschenaultii*, *Clitoria ternatea*, *Porana paniculata* and *Gloriosa suberba* (Swaroop, 1995). The distribution of diversity of various ornamental plants has been given in Table 3.

### Germplasm Introduction

A substantial number of valuable germplasm accessions of horticultural crops has been introduced into India. During recent years, introduction of germplasm was directed towards breeding new cultivars and use of genetic variability for biotic and a biotic resistance. Some important introductions of fruit crops are listed in Table 4.

**Table 3: Region wise ornamental crops diversity in India**

| Sl. No. | Agroecological Regions | Crops/ Species |
|---|---|---|
| 1. | Humid Western Himalayan Region | *Aconitum, Acorus, Anemone, Arisaema, Arundinaria, Arundo donax, Barleria, Delphinium* spp., *Hedychium, Impatiens* spp., *Iris, Jasminum*, orchids, *Primula, Potentilla, Rhododendron, Ranunculus, Solidago, Rosa* spp. *Viola* spp. |
| 2. | Humid Bengal / Assam Basin | *Acacia, Aglaonema, Barleria, Bauhinia, Clerodendron, Cordylis, Crinum, Hiptage, Ixora, Jasminum* spp., *Magnolia, Muassaenda, Solidago*, Kadamba, neem, pride of India |
| 3. | Humid Eastern Himalayan Region and Bay Lands | *Aconitum, Acorus, Anemone, Arisaema, Barleria, Hiptage, Impatiens* spp., *Jasminum* spp., *Ligustrum, Lilium* spp., *Litsea, Magnolia, Meconopsis, Michelia, Murraya, Mussaenda, Rhododendrum, Solidago, Rosa* spp., orchids, primula |
| 4. | Sub humid Sutlej Ganga Alluvial Plains | *Acacia, Barleria, Impatiens* spp., *Ipomoea, Jasminum* spp., |
| 5. | Humid Eastern and South-eastern Uplands | *Acacia, Barleria, Impatiens* spp., *Ipomoea, Ixora, Jasminum* spp. Neem |
| 6. | Arid Western Plains | *Acaia, Delonix, Impatiens, Jasminum* spp., *Terminalia, neem* |
| 7. | Semi arid Lava plateau and Central Highlands | *Acacia, Bauhinia, Erythrina, Impatiens* spp., *Ixora, Terminalia, Jasminum* spp., neem, pride of India |
| 8. | Humid to semi arid Western Ghats and Karnataka plateau | *Acacia, Acalypha, Kadamba, Clerodendron, Crinum, Erythrina, Hiptage, Impatiens* spp., *Ixora, Michelia, Murraya, Pongamia, Jasminum* spp. bamboo, neem, orchids, pride of India |

**Table 4. Some important introductions of fruit crops**

| Species | EC Number(s) | Source country | Trait(s) |
|---|---|---|---|
| *Carica papaya* | 300205 | Pakistan | Ring spot virus tolerant |
| | 300205, 301870 | USA | Tolerant to ring spot virus |
| | 363845-46 | USA | Fruit with high TSS |
| *Carica* sp. | 100627 | West Indies | Fruit pear shaped, sweet |
| *Carica* sp. | 100613, 16 | West Indies | Pink fruit flesh, sweet |
| *Carica* sp. | 100614 | West Indies | Pentagonal fruit, yellow flesh |
| *Carica sp.* | 100615 | West Indies | Fruit large, cylindrical, sweet |
| *Carica sp.* | 100617 | West Indies | Fruit large, sweet |
| *Carica sp.* | 100620 | West Indies | Fruit medium size |
| *Carica sp.* | 100625 | West Indies | Fruit small, yellow flesh |
| *Carica sp.* | 100628, 30 | West Indies | Pink flesh |
| *Carica sp.* | 100631 | West Indies | Fruit flesh yellow, sweet |
| *Carica sp.* | 100621 | West Indies | Fruit pentagonal, red flesh |
| *Citrus paradisiaca* | 110577 | USA | Seedless |
| *Citrus sp.* | 175471 | USA | Troyer citrange hybrid |
| *Citrus sp.* | 313078 | Australia | Disease resistant root stock |
| *Citrus sp.* | 310461-480 | USA | Promising mandarin varieties |
| *Citrus sp.* | 309123 | USA | Promising citrus variety |

contd...

Table 4 contd...

| Species | EC Number(s) | Source country | Trait(s) |
|---|---|---|---|
| *Citrus sp.* | 38793-94 | USA | Mandarin hybrids |
| *Citrus sp.* | 310148-57 | Japan | Promising citrus variety |
| *Ficus carica* | 390352 | Iran | Large fruit |
| *Phoenix dactylifera* | 402391 | Iraq | Early maturity |
| *Prunus persica* | 335035 | USA | Medium size fruit |
| *Prunus persica* | 335036 | USA | Extra large fruit |
| *Psidium guajava* | 336561-64 | USA | Fruit large, white and red flesh. |
| *Psidium guajava* | 343059-60 | USA | Good fruit quality, resistant to fire blight |
| *Punica granatum* | 396385 | USA | Red fruit |
| *Punica granatum* | 396386 | USA | White fruit |
| *Pyrus communis* | 331116-17 | USA | Late maturity, fruit maroon red with faint stripes |
| *Pyrus communis* | 331112 | USA | Fruit large, yellow, blight susceptible |
| *Pyrus malus* | 112092-95 | UK | Root stock |
| *Pyrus malus* | 124252-53 | Canada | Root stock |
| *Pyrus malus* | 124310-13 | UK | Root stock |
| *Pyrus sp.* | 54900 | Taiwan | Fruit green skinned |
| *Pyrus sp.* | 54901 | Taiwan | Large fruit |
| *Vitis vinifera* | 159386-87, 90 | Australia | Seedless |
| *Vitis sp.* | 114712 | USA | Early maturity, fruit white |
| *Vitis sp.* | 114717 | USA | Black fruit |
| *Vitis sp.* | 114713 | USA | Early maturity, fruit black |
| *Vitis sp.* | 100233 | Hungary | Orange taste |
| *Vitis sp.* | 114716 | USA | Scented fruit |
| *Vitis vinifera* | 315471-74 | USA | Seedless, high yielding |
| *Vitis vinifera* | 61861-66 | USA | Wine type |
| *Vitis vinifera* | 117642 | Brazil | Wine type |
| *Vitis vinifera* | 94806, 11 | USA | Seedless |
| *Vitis vinifera* | 93528 | USSR | Fruit white, large |
| *Vitis vinifera* | 61874-75 | USA | Nematode resistant root stock |
| *Vitis vinifera* | 61861-74 | USA | Wine type |
| *Vitis vinifera* | 61874-75 | USA | Nematode Resstant root stock |
| *Vitis vinifera* | 28554-57 | West Germany | Fruit red |
| *Vitis vinifera* | 28551-53 | West Germany | Fruit white |
| *Vitis vinifera* | 251091-93, 209121 | USA | High yielding |
| *Vitis vinifera* | 339104-105 | Australia | Seedless, salt tolerant |

The temperate fruit and nut varieties grown in hilly regions of India are good examples of direct introductions (Table 5) as the farmers are using most of them as commercial varieties.

Since the inception of NBPGR in 1976, over 25,000 germplasm accessions of vegetable crops have been introduced. Some of the notable introductions are biotic resistant lines in tomato and melons, gynoecious lines in cucurbits and heat tolerant lines in chinese cabbage (Table 6). Some of the introductions have adapted well in Indian conditions and are popular amongst farmers (Table 7).

Introduced varieties and species have contributed significantly to the improvement of ornamental horticulture in India (Randhawa and Mukhopadhyaya, 1986; Chadha and Choudhury, 1986). Some of these introductions have been used directly for cultivations (primary introductions) while others (secondary

**Table 5. Temperate fruit and nut varieties introduced in hilly regions of India**

| Crop | Varieties |
|---|---|
| Almond | Nonpareil, Merced, Jordanalo, Waris, Walnut WS-325, WS-328, Budgam 1, Wasan-2 |
| Apple | Irish Peach, Benoni, Jonathan, Cox's Orange Pippin, Ambri, Red Delicious, Golden Delicious, American Apirouge, White Dotted Red, Queen's Apple, Yellow Newton |
| Apricot | Charmagz, Kaisha, Frogmore Early, Gilgeti Sweet, Amba, Quetta Sweet Cherry, Guigne Noir Gross, Black Heart, Biganreau Napolean, Bigarreau Noir Gross |
| Pear | China Pear, Beurre-de-Amanlis, Citron-des-Carmos, Clapp's Favorite, Fertility, William Bartlett, Beurre Hardy |
| Peach | World's Earliest, July Elberta, Peshawari, Elberta, Quetta |
| Plum | Sharp's Early, Formosa, Wickson, Satsuma, Burbank, Santa Rosa, Blue Imperative, Prune-d-Agen, Grand Duke |

**Table 6. Important vegetable germplasm introduced**

| Crop | EC number | Salient features | Country |
|---|---|---|---|
| **High yielding and desirable fruit types** | | | |
| Cauliflower | EC 348166 | High yielding early type | USA |
| Chillies | EC 391073 | Pungent type | Taiwan |
| | EC 391089-92 | Early maturity & Bunch type | Taiwan |
| | EC 347263 | High Pungent type | Taiwan |
| Cucumber | EC 398030 | Early & determinate type | China |
| Garlic | EC 367655-58 | High yielding and bold clove | Israel |
| Onion | EC 30802-11 | High bulb yielding | USA |
| | EC 378476-77 | High TSS & long shelf life | UK |
| Tomato | EC391024 | Long shelf life | Australia |
| | EC310299 | Slow ripening gene | USA |
| | EC321425-26 | Paste type | Taiwan |
| Watermelon | EC 380989-92 | Yellow flashed, early maturing | USA |
| | EC 393240-43 | Red flashed/round & small | USA |
| **Male sterile restorer lines and hybrids** | | | |
| Cabbage | EC 304718-25 | Cytoplasmic male sterile & restorer lines | USA |
| | EC 187228-30 | Male sterile lines | Canada |
| Cucumber | EC 382737-39 | Gynoecious lines | USA |
| | EC 329300 | Gynoecious (G4) | USA |
| Muskmelon | EC 348140-43 | Fl Hybrid (Early & Sweet) | USA |
| | EC 382726-36 | Male sterile gene (MS2 to MS5) | France |
| Tomato | EC 347359-68 | Hybrids (F1) | Taiwan |
| | EC 343391-95 | Fl Hybrids (Cherry Tomato) | Taiwan |
| | EC346011 | Stamenless line (F2) | USA |
| | EC346013 | Green Pistillate type | USA |
| | EC346014 | Green Pistillate type | USA |
| **Germplasm for abiotic resistance** | | | |
| Atriplex | EC319095-96 | Salt tolerance | Australia |
| Cabbage | EC 350918-28 | Heat tolerance | USA |
| | EC 168041-42 | Heat tolerance | USA |
| Capsicum | EC 334206 | Water submergence | Taiwan |
| Cauliflower | EC 164414-16 | Heat tolerance | USA |
| Chinese Cabbage | EC 345978 | Heat tolerance | Taiwan |
| Muskmelon | EC350603 | Sulphur tolerance | USA |
| | EC 342751-54 | Heat tolerance | Japan |
| Tomato | EC 399828-38 | Heat tolerance | USA |
| | EC 347359-68 | Heat tolerance | Taiwan |
| | EC 321425-26 | Heat tolerance | Taiwan |
| | EC 378682-83 | Low irrigation | Australia |
| **Germplasm for biotic resistance** | | | |
| Cabbage | EC 168041-42 | Club root & black root resistance | Taiwan |
| Cauliflower | EC 175800-06 | Multiple diseases resistance | USA |
| Chilli | EC 323333 | Multiple disease resistance | USA |
| Chinese cabbage | EC 345978 | Multiple disease resistance | Taiwan |
| Cucumber | EC 320526 | Multiple diseases resistance | USA |
| Garlic | EC 378476-77 | Pink rot Resistance | UK |
| Okra | EC 305616 | YVMV Resistance | Bangladesh |
| Muskmelon | EC 350602 | Aphid resistance | USA |
| | EC 350603 | WMB resistance | USA |
| | EC 330956 | Multiple disease resistance | USA |
| Tomato | EC 399828-38 | Multiple diseases resistance | USA |
| | EC 347369-90 | TMV & BW resistance | Taiwan |
| | EC 321890-928 | Viral diseases resistance | Taiwan |
| Watermelon | EC 383809 | Fusarium wilt resistance | USA |
| | EC 378523-24 | Fusarium wilt resistance | USA |
| | EC 333659-69 | Wilt resistance | USA |
| | EC 217073-74 | Fusarium & Gummy stem blight resistance | USA |

**Table 7. Important vegetable introductions directly adopted for commercial cultivation**

| Crop | Cultivar |
|---|---|
| Cabbage | Golden Acre |
| Capsicum | California wonder |
| Carrot | Nantes |
| Cauliflower | Improved Japanese |
| Cowpea | Pusa Barsati (selection ex- Philippines) |
| Frenchbean | Contender |
| Lettuce | Great Lakes |
| Pea | Arkel, Bonneville |
| Tomato | Sioux, La Bonita |
| Watermelon | Asahi Yamato, SugarBaby |

introductions) have been used in breeding for improving quality, productivity and imparting resistance against biotic and abiotic stresses in the available cultivars. To cite a few examples of primary introductions, *Mussaenda philippica*, the double-bracted mussaenda with white, pink and red colours from Thailand have acclimatized very well in the humid and mild climates of Kolkata, Bangalore and parts of Kerala. The introduction of many beautiful bougainvillea cultivars such as 'Lady Mary Baring', 'Golden Glow', 'Mahara' and 'Cherry Blossom' etc. has enriched Indian ornamental horticulture to a great extent. A variety called 'Hawaian Hibiscus' introduced earlier by Lalbagh, Bangalore has considerably changed the aesthetics of many gardens in and around Bangalore. Similarly, a large number of varieties introduced in rose and gladiolus are widely cultivated in the country. Singh *et al.*, 1990, have highlighted earlier notable introductions of ornamentals. Some important introductions pertaining to trees, shrubs, bulbous ornamentals, annuals and herbaceous perennials and orchids are listed in Table 8.

**Table 8. Important introductions in ornamentals (1982-2002)**

| Species | Accession No. | Source Country |
|---|---|---|
| **Trees** | | |
| *Areca minuta, A. cocinnea* | EC 336080, 81 | UK |
| *Bauhinia esculenta* | EC 153140 | USA |
| *Bixa orellana* | EC 339279 | Brazil |
| *Calamus acanthochlamys* | EC 336082 | UK |
| *Callistemon pallidus, C. viridifloris* | EC 154037, 45 | UK |
| *Calospatha scortechinii* | EC 336083 | UK |
| *Camellia sasanqua* | EC 322327-322329 | USA |
| *Chamaedorea* sp. | EC 336092, 93 | UK |
| *Chrysophila* sp. | EC 336091 | UK |
| *Colvillea racemosa* | EC 164651 | Hawaii |
| *Cryptomeria japonica* | EC 155219, 458266 | USA |
| *Cupressus arizonica* | EC 155224 | USA |
| *Labronecia kokicides* | EC 159934 | UK |
| **Shrubs** | | |
| *Bougainvillea* cvs. Allison Davy, Audery Delap, Barnabee, Glosebum, Crimson Glory, Improved, James Waker, Jamihuri, John Lattin, Lady Hudson, Lazat of Mysore, Magnifica Trailii, Mrs. Helen McClean, Orange Glory, Orange Glory, Princess Elizabeth, Raw Sawder, Rosenka, Ruby, San Diago, Snow White, Sun Rise, Variegatam, White | EC 174717-40 | Kenya |
| *Jasminum abyssinicum, J. dispermum, J. laurifolium f. nitidum, J. fluminense* sub sp. *Holstii, J. fluminense* sub sp. *fluminense* | EC 415780-83, 86 | UK |
| *Lagerstroemia* sp. cvs. Choctaw, Coddo, Tonto | EC 330228-30 | USA |
| *Rosa mayesii, R. gallica, R. foetida, R. spinosissima, R. canina, R. acicularis, R. ornissa sherardii, R. rubiginosa, R. pendulina, R. virginiana, R. rugosa* | EC 165797-07 | UK |
| Rose cvs. Paulamn Ingrid Bergaman, Poultal Sentimental, Poultex Texas, Poulvita inita, Teeny Weeny, Poulfillfin, Poulcat Caterpillar, Poulred Red Bells | EC 165966-73 | Denmark |
| Nobles, Mercedes, Golden Gate, First Red, | EC 448148-51 | Israel |
| *Rosa canina, R. inermis, R. heinsoln, R. hookeriana, R. schmide, R. superba, R. rubiginosa, R. laxa, R. multiflora, R. smitsstekelloze* | EC 168020-29 | Netherlands |
| **Bulbous plants** | | |
| *Aconitum napellus* | EC 154191 | Germany |
| *Cyclamen hederifolium* | EC 171976-77 | UK |

(Contd.)

Table 8 (Contd.)

| Species | Accession No. | Source Country |
|---|---|---|
| Gladiolus cvs. Mirage, Bright Promise, Sussex | EC 154209-11 | USA |
| Albutres, Angel Face, Balalaika, Kompanjero, Jurentus, Ares 301, Oklijalr 442, Edith Schoffield, Valja, Tereskhowa, Dawan Watch 470, Utrennij Tuman 480, Gold Medal 412, Olenka 392, Leningradskaja, Vesna 472, Academic Eich Feld | EC 155722-36 | USSR |
| Boy Scout, Melody, Inspiration, Honor Gourd, Apricot Queen, Rosette, Blue Isle, Chanticler, Oscar, Pink Parassol, Accolade, Pozobotte Bareebe, Friendship, Dawn Watch | EC 164724-37 | USSR |
| Whimsical, High Fashion, Regalaire, Chorus Girl, Ivory Tower, Star Dom, Snow Mars, Sweet leilani, Butter&Jelly, Pink Mist, Pearly White, Monchen, Rose Gem, April Angel, Azure Skoy, Bhishing Maid, Pink Gem, Prominence, Twenty Four Karet | EC 172789-2807 | USA |
| Green Isle, RFZ Special, Red Majesty, Romance, Isica Cleuf, Lavender Star, Froclich, Gaploin Sallant, Suneet Bou | EC 197953-61 | USA |
| Claret Royale, Mary Kittel, Soytime, Rou Dragon, Singh Joy, Snow Flower, Atom Dragon, Red Coccade, Lacy Lady, Wedding Sun, Star Sappire, Happy Birthday, Departing Sun, Kachnar, Flock, Red Sea, Red Boutain, Ever Glow, Inspiration, Red Bird | EC 197965-83 | USA |
| Slad Purple, Spring Fence,Lavender Spice, Spring Delagra, Life Line, Red Fort, Green Spire | EC 197985-88, 90, 92-94 | USA |
| Dunasty, Encore, Lorilee, Cecilt, Spaitan, Laurita, Accolade, That&Pink, Prominade, Clward, Golden Age, Ocapulco, Nacarat, Celebrity, Clafuarius, Dr. RO Magie, Queen, Highlight, Osage, Pink Lady | EC 206773-92 | Canada |
| Trader Horn, Novalux, White Projiate, Peter Pears, Rose Prince, | EC 217062-66 | Israel |
| Bid Time, Blue Spire, Day Dream, Little Gade Green, Olympus, Inspiration, Snow Sprite | EC 280567-73 | USSR |
| Amybeth, Bellsello, Astro, Angel Fire, Annabel, Arroros | EC 331458-63 | USA |
| *Gladiolus cardinalis* | EC 155737 | USSR |
| *Gladiolus byzantinus* | EC 165823 | UK |
| *Heliconia longiflora, H. lutea, H. necrobracteata, H. sarapiquensis, H. tatamancana, H. trichocarpa, H. umbrophil* | EC 425429-35 | USA |
| *Hippeastrum* | EC 175399-400 | USA |
| *Iris aphylla* | EC 165822 | UK |
| *Lilium* sp. | EC 445976 | Israel |
| **Annuals and herbaceous perennials** | | |
| *Antirrhinum* sp. (cvs. Trumpet Serenade, Large Flowered, Coronette) | EC 191657-191659 | UK |
| *Artemisia absinthium* | EC 154270, 155464 | UK, France |
| *Aster* sp. (cv.Ostrich Plume) | EC 191676 | UK |
| *Bellis* sp. | EC 332183 | Thailand |
| *Calendula officinalis* | EC 305851 | Egypt |
| *Celosia argentea, C. plumosa* | EC 151543, 178492 | Hungary, USA |
| *Chrysanthemum carinatum* | EC 207345 | France |
| *Chrysanthemum cinerarifolium* | EC 178452-89 | Australia |
| *Chrysanthemum fruitescens, C. flosculosum* | EC 207347,207348 | France |
| *Chrysanthemum morifolium* (cv. Snow Down) | EC 461856 | Israel |
| *Chrysanthemum nivellei, C. coronarium, C. praeoltum, C. segetum, C. serotinum* | EC 207349, 46, 50,51, 53 | France |
| *Chrysanthemum* sp. (cvs. Colli, Lamans, Pallet) | EC 445968, 73, 67 | Israel |
| *Chrysanthemum vulgare, C. viscosum* | EC 207352, 54 | France |
| *Cineraria maritima* (Silver Dust) | EC 172750 | USA |
| *Cineraria* sp. (cvs. Large Flowered, Gay Dwarf) | EC 191664, 65 | UK |
| *Cosmos* sp. | EC 332177, 84, 87 | Thailand |
| *Delphinium* sp. (cvs. Mixed, Pacific Giant, Dwarf Blue) | EC 191661-63 | UK |
| *Dianthus armeria, D. balbissii, D. barbatus, D. carthusianarum, D. carrevonianus, D. deltoids, D. pinifolius, D. plumarius* | EC 165809-16 | UK |
| *Dianthus* sp. (cvs.Crimson Knight, Crimson Picotes Knight) | EC 160241-42 | USA |
| *Dianthus* sp. (cvs. Mixed, Indian Carpet) | EC 191673, 74 | UK (Contd.) |

Table 8 (Contd.)

| Species | Accession No. | Source Country |
|---|---|---|
| *Dianthus* sp. (cvs. Scarlet Knight, Orange Knight) | EC 160238, 43 | USA |
| *Dianthus* sp. (cvs. White Knight, Yellow Knight) | EC 160239, 40 | USA |
| *Dianthus superbus, D. tukestanicus* | EC 165817, 18 | UK |
| *Digitalis grandiflora* | EC 391046-48 | Kew |
| *Digitalis purpurea* | EC 391050-66 | Kew |
| *Eschscholzia caespitosa* | EC 198306 | USA |
| *Eschscholzia californica, E. mexicana* | EC 198307,8 | USA |
| *Geranium* sp. (cvs. Mustang, Picasso, Ringo Deep Scarlet, Pinto Salmon, Pinto Red, Ringo Scarlet, Ringo Salmon, Pinto Rose, Ringo Rose, Ringo White) | EC 174209-18 | Netherlands |
| *Gomphrena globosa* | EC 165024 | USA |
| *Gypsophylla paniculata* | EC 462002 | Israel |
| *Iberis amara* (cvs. Dwarf Fairy, Fairy) | EC 191666-67 | UK |
| *Impatiens* sp. | EC 332178 | Thailand |
| *Lathyrus odoratus* (cvs. Flag Ship, Knee Hi, Geam Elegance) | EC 191646-48 | UK |
| *Limonium sinuatum* | EC 445970-72 | Israel |
| *Lisianthus* sp. | EC 416708-13 | USA |
| *Lunaria annua* | EC 165825 | UK |
| *Matricaria chamomile* | EC 154026 | UK |
| *Mesembryanthemum nodiflorum* | EC 154046 | UK |
| *Molucella laevis* | EC 280585 | USSR |
| *Ornithogalum saundersiae* | EC 152937 | UK |
| *Ornithogalum virens* | EC 152936 | UK |
| *Pelargonium hortorum, P. capitatum, P. odoratissimum* | EC 152502-4 | USA |
| *Pelargonium roseum* | EC 153415, 151525 | USA |
| *Petunia hybrida* | EC 387074 | Taiwan |
| *Phlox drummondii* | EC 191660 | UK |
| *Portulaca* sp. | EC 332175 | Thailand |
| *Salvia officinalis* | EC 167545 | USA |
| *Salvia officinalis* | EC 165838 | USSR |
| *Salvia sclarea* | EC 154279 | UK |
| *Mathiola incana* (cvs. Ten Weak, Brompton, Virginia, Night Scented) | EC 191668-71 | UK |
| Sweet alyssum | EC 332181 | Thailand |
| *Tagetes* sp. (cv. Queen Sophiya) | EC 173416 | USA |
| *Tagetes erecta* | EC 179949-179990 | Netherlands |
| *Tropaeolum majus* | EC 165826 | UK |
| *Verbeena* sp. | EC 332182 | Thailand |
| *Verbena* sp. | EC 191675 | UK |
| *Vinca* sp. | EC 332179 | Thailand |
| *Viola* sp. (cvs. Imperial Silver, Imperial Orange, Imperial Golo, Imperial White) | EC 341919-22 | USA |
| *Viola* sp. (Magestic Giants) | EC 341918 | USA |
| *Viola* sp. (cvs. Melody, Padparakja, Pansy 1099) | EC 341931-33 | USA |
| *Viola* sp. (cvs.Tezier Bred, Spring Maoic Ultra, Vernale, Mid Flue, Universal, Yellow) | EC 341923-28 | USA |
| *Viola wittrockiana* (Rock White) | EC 341935 | USA |
| *Zinnia* sp. | EC 332173,86 | Thailand |
| **Orchids** | | |
| *Cattleya aclandia* | EC 341691 | UK |
| *Cattleya mooreana* (Heid 3712), *Dendrobium formosum* (BEGR 16 3817), *Dendrobium melaloucaphilum* (FAIK 3827), *Dendrobium tangerinum* (FLID 3788),*Dendrobium scopa* (FLID 3785), *Dendrobium lasianthera* (FLID 3791),*Dendrobium munificum* (SPRU), *Dendrobium unicum* (BEGR 17), *Dendrobium lineale (Slag), Dendrobium speciosum var. curvicaule, Coelogyne susanae* (CRMO 1922), | EC 385462-72 | UK |
| *Laelia jongheana* | EC 341701 | UK |
| *Laelia perrinii, Laelia jongheana, Laelia pjisteri* (WLTR) | EC 341700,701, 345478 | UK |
| *Paphiopedilum adductum* (ANLA 3769),*Paphiopedilum bullenianum* var. *celebesense* | EC 385475-76 | UK |
| *Paphiopedilum* sp., *Paphiopedilum druryii* | EC 341702, 703 | UK |

## Germplasm Collection

Besides introductions from abroad, a large amount of germplasm of horticultural crops have been collected by NBPGR from diversity rich areas of India and presented in Table 9. A sizable number of accessions of brinjal (5207) and okra (2240) in vegetables and banana (645), citrus (873), mango (298) and ber (353) in fruits were collected. There is a need for greater emphasis for the collection of horticultural crops from diversity rich areas of the country. The gaps in collections be identified and unexplored areas or the under explored areas may be covered extensively for germplasm collection.

**Table 9. Horticultural germplasm collected by NBPGR**

| Crop group/ crop | Accessions (no.) | Crop group/ crop | Accessions (no.) |
|---|---|---|---|
| **Vegetables** | | **Fruits** | |
| Ash gourd | 515 | Tomato | 502 |
| *Alocasia* sp. | 6 | Water melon | 128 |
| Bitter gourd | 1018 | Other vegetables | 300 |
| Bottle gourd | 1267 | Almond | 55 |
| Brinjal | 5207 | Aonla | 128 |
| Broad bean | 183 | Apple | 21 |
| Cabbage | 38 | Apricot | 16 |
| Carrot | 56 | Bael | 129 |
| Cauliflower | 150 | Banana | 645 |
| Chillies | 3062 | Ber | 353 |
| Chinese cabbage | 9 | Cashew | 55 |
| *Citrullus* sp. | 39 | Chironjii | 97 |
| Colocasia | 929 | *Citrus* | 873 |
| Cucumber | 801 | Custard apple | 277 |
| *Cucumis* spp. | 553 | Grapes | 8 |
| *Cucumis hardwikii* | 59 | Guava | 53 |
| Fababean | 39 | Hazelnut | 38 |
| Fenugreek | 58 | Jackfruit | 235 |
| French bean | 1741 | Jamun | 107 |
| Ivy gourd | 175 | Khirni | 14 |
| Kale | 3 | Lakoocha | 37 |
| Knol khol | 2 | Lasora | 41 |
| Leafy brassica | 27 | Malabar tamarind | 139 |
| Lima bean | 7 | Mango | 298 |
| Long melon | 8 | Mangostein | 6 |
| *Momordica dioica* | 11 | Mulberry | 16 |
| Musk melon | 442 | Papaya | 72 |
| Okra | 2507 | Passion fruit | 14 |
| Onion | 718 | Peach | 13 |
| Pea | 896 | Pear | 42 |
| Pointed gourd | 328 | Phalsa | 187 |
| Pumpkin | 1503 | Pomegranate | 295 |
| Radish | 234 | *Rubus* sp. | 18 |
| Ridge gourd | 725 | Sapota | 17 |
| Round gourd | 76 | Strawberry | 3 |
| Satputia | 62 | Tamarind | 110 |
| Sembean | 1056 | Walnut | 297 |
| Snake gourd | 79 | Wood apple | 1 |
| Snap melon | 718 | Other Fruits | 123 |
| *Solanum gilo* | 20 | **Ornamentals** | |
| Spinach | 215 | Canna | 4 |
| Sponge gourd | 973 | Marigold | 18 |
| Summer Squash | 11 | Orchid | 150 |
| Sword bean | 25 | Other ornamentals | 36 |

## Conservation Approaches and Methods

In horticultural crops the conservation aspect has largely remained unorganised. Complementary conservation strategies employing both *in situ* and *ex situ* conservation are essential in this group of crops.

### (I) *Ex situ conservation*

When germplasm conservation is attempted outside its natural habitat, it is known as *ex situ* conservation. Germplasm is conserved in the form of clonal material, seedlings, seed, pollen and DNA. *Ex situ* collections may

also be established to ensure the ready availability of reproductive material, either through a genebank or through a production source in the area where the material is to be used.

*(a) Field gene bank*

Many horticultural species are either difficult or impossible to conserve as seeds because of seeds being recalcitrant or reproduce vegetatively. Hence they are conserved in field genebanks (FGBs). In species with long juvenile phase as in tree fruits species, FGBs provide easy and ready access to conserved material for research and utilisation. Further for a number of plant species, the alternative conservation methods are not fully developed yet so that they can be effectively used. However, FGBs may run a risk of being damaged by natural calamities, infection, neglect or abuse. *Ex situ* conservation of tree species using FGBs require a substantial number of individual genotypes to be an effective conservation measure hence FGBs require more space, especially for large tree species, and they may be relatively expensive to maintain. The alternative/supplementary method of FGBs in vegetatively propagated crops could be maintenance of plants in Clonal Repository. The advantages of this method over FGBs are less space requirement, easy management and cost effectiveness. In addition, clonal collections being dwarf in size can be maintained in protected controlled green houses and the danger of natural calamities is minimal.

Thus it is clear that establishment of FGBs plays a major role in conservation strategy for horticultural genetic resources. Field collections of horticultural germplasm are located in the NBPGR network of regional stations besides horticultural crop based National Active Germplasm Sites (NAGS). Status of fruit and ornamental germplasm in field genebank at various locations has been presented in Table 10 and 11 respectively.

**Table 10. Status of fruit germplasm in field genebank at various locations**

| Crop | Location |
|---|---|
| Almond | CITH (15), HPKVV (4), NBPGR Bhowali (5), NBPGR Shimla (15), YSPUHF (62) |
| Aonla | CIAH (34), FRS Aurangabad (10), GBPUAT (10), HAFRP (10), NBPGR Bhowali (4), NBPGR Issapur (4), NBPGR Ranchi (10), NBPGR Shillong (9), NBPGR Thrissur (53), NRCAF (6), PDKV Katol (4), TNAU (2) |
| Apple | CITH (143), NBPGR Bhowali (22), NBPGR Shimla (144), YSPUHF (79) |
| Apricot | HPKVV (2), CITH (2), NBPGR Bhowali (5), NBPGR Shimla (42), YSPUHF (5) |
| Bael | CIAH (16), GBPUAT (34), HAFRP (10), NBPGR Bhowali (7), NBPGR Issapur (10), NBPGR Jodhpur (2), NBPGR Ranchi (28), NRCAF (3) |
| Banana | CISH, (112), NBPGR Shillong (103), NBPGR Thrissur (303), NRC Banana (1141) |
| Ber | CARI (12), CIAH (323), FRS Aurangabad (45), GAU Anand (42), GBPUAT (23), MPKV Rahuri (9), NBPGR Amravati (14), NBPGR Issapur (11), NBPGR Jodhpur (42), NBPGR Ranchi (3), NBPGR Bhowali (3), NBPGR Shimla (11), NRCAF (6), PDKV Sindhewahi (6), UAS RS Raichur (13) |
| Cactus pear | CIAH (103), NRCAF (5) |
| Cashew | ARS Chintamani (104), CRS Bapatla (129), CRS BBSR (9), CRS Madakkathara (113), FRS Aurangabad (7), GAU Ahmedabad (5), NRC Cashew (451), RARS Pilicode (64), RFRS Vengurla (161), RRS Jhargram (83), RRS Vridhachalam (263) |
| Cherry | CITH (7) |
| Chestnut | NBPGR Shimla (2) |
| Citron | NBPGR Bhowali (11), NRCC (13) |
| Citrus hybrids | NBPGR Bhowali (4), NRCC (25) |
| *Citrus indica* | NBPGR Thrissur (2), NRCC (4) |
| *Citrus jambhiri* | NBPGR Bhowali (12), NRCC (54) |
| *Citrus* spp. | ICARRCNEH (65), NBPGR Bhowali (34), NBPGR Shillong (74), NBPGR Thrissur (2), NRCC (85) |
| Custard apple | HAFRP (25), IIHR(11), MPKV Rahuri (17), NBPGR Jodhpur (1), NBPGR Ranchi (24), UAS RS Raichur (5) |
| Datepalm | CIAH (93), NBPGR Jodhpur (3), GAU RS Mundra, Kachchh (27), RAU Bikaner (34) |
| European plum | YSPUHF (9) |
| Fig | CARI (2), FRS Aurangabad (3), IIHR (8), MPKV Rahuri (9), NBPGR Bhowali (7), NBPGR Shimla (4), UAS RS Raichur (2) |
| Filbert | NBPGR Shimla (2) |
| Fortunella | NRCC (2) |
| Grape | CARI, A&N island (12), CISH, (14), GBPUAT (4), IIHR (101), MPKV Rahuri (60), NBPGR Bhowali (5), NBPGR Shimla (11), NRCG (323), UAS Bangalore (6), UAS Dharwad (23), UAS RS Raichur (9) |
| Guava | BAC Sabour (14), CARI (2), CISH, (95), GAU Ahmedabad (5), GBPUAT (16), GKVK Bangalore (6), HAFRP (48), HPKVV (3), ICARRCNEH (25), IIHR (38), KAU (4), NBPGR Shillong (15), NRCAF (2), PDKV RS Sindhewahi (3), TNAU (2), UAS Bangalore (6), UAS Dharwad (3), UAS RS Raichur (2) |

(Contd.)

Table 10 (Contd.)

| Crop | Location |
|---|---|
| Hazelnut | NBPGR Bhowali (2), NBPGR Shimla (2) |
| Jackfruit | GBPUAT (9), HAFRP (111), NBPGR Bhowali (2), NBPGR Ranchi (55), NBPGR Thrissur (72), UAS Bangalore (20) |
| Jamun | HAFRP (7), KAU (3), NBPGR Ranchi (26), PDKV Sindhewahi (2) |
| Karonda | CIAH (5), GBPUAT (9), KAU (2), NBPGR Bhowali (6), NBPGR Issapur (3), NBPGR Jodhpur (12) |
| Ker | CIAH (65), NBPGR Jodhpur (141) |
| Khejri | CIAH (30) |
| Kiwifruit | CITH (6), HPKVV (5), ICARRCNER Meghalaya (7), NBPGR Shimla (8), YSPUHF (7) |
| Lasora | CIAH (64), NBPGR Bhowali (4), NBPGR Jodhpur (110), NBPGR Ranchi (5), NRC Af (2) |
| Lemon | HAFRP (1), NBPGR Bhowali (7), NBPGR Issapur (2), NBPGR Jodhpur (2), NBPGR Thrissur (3), NRCC (17) |
| Lime | HAFRP (2), HPKVV (5), NBPGR Bhowali (33), NBPGR Issapur (4), NBPGR Thrissur (3), NRCC (55), PDKV RS Katol (4) |
| Litchi | BAC Sabour (20), CISH, (33), GBPUAT (17), HAFRP (51), HPKVV (5) |
| Macadamia | YSPUHF (6) |
| Mandarin | NBPGR Bhowali (21), NBPGR Issapur (1), NRCC (29), PDKV RS Katol (35) |
| Mango | BAC Sabour (157), CARI (24), CISH, (686), FRS Aurangabad (51), GAU Ahmedabad (188), GBPUAT (93), GKVK Bangalore (20), HAFRP (248), IIHR(256), MPUAT Udaipur (35), NBPGR Issapur (3), NBPGR Ranchi (22), NBPGR Thrissur (128), NRCAF (4), PDKV RS Katol (19), PDKV RS Sindhewahi (16), TNAU (29), UAS Bangalore (20), UAS Dharwad (47), UAS RS Raichur (24) |
| Moringa | CIAH (3), NBPGR Bhowali (2) |
| Mulberry | NBPGR Bhowali (2), NBPGR Issapur (4), NBPGR Jodhpur (16), |
| Oilpalm | GAU Mundra (12), NRC Oilpalm (96) |
| Olive | YSPUHF (19) |
| Papaya | CARI (6), GBPUAT (24), IIHR (20), NBPGR Amravati (24), UAS RS Raichur (6) |
| Passion Fruit | NBPGR Shillong (4) |
| Peach | CITH (2), GBPUAT (18), HAFRP (5), HPKVV (5), ICARRCNER Meghalaya (13), NBPGR Bhowali (6), NBPGR Shimla (41), YSPUHF (53) |
| Pear | CITH (9), GBPUAT (17), HPKVV (4), NBPGR Bhowali (10), NBPGR Shimla (60), YSPUHF (39) |
| Pecan nut | CITH (2), HPKVV (6), NBPGR Shimla (11), YSPUHF (6) |
| Persimmon | HPKVV (3), NBPGR Bhowali (3), NBPGR Shimla (8) |
| Phalsa | CIAH (5), NBPGR Jodhpur (5) |
| Pilu | CIAH (2) |
| Pineapple guava | NBPGR Shimla (4) |
| Pistachio nut | NBPGR Shimla (2) |
| Plum | CITH (6), GBPUAT (22), HPKVV (7), NBPGR Bhowali (5), NBPGR Shimla (32), YSPUHF (38) |
| Pomegranate | CARI (3), CIAH (185), CITH (7), GKVK Bangalore (4), HAFRP (8), IIHR (13), MPKV Rahuri (52), NBPGR Amravati (20), NBPGR Bhowali (2), NBPGR Issapur (49), NBPGR Jodhpur (25), NBPGR Shimla (155), UAS Bangalore (4), UAS Raichur (4), YSPUHF (36) |
| Poncirus | NRCC (18) |
| Pummelo | NBPGR Thrissur (2), NRCC (52), |
| Quince | NBPGR Shimla (3) |
| Rangpur Lime | NRCC (29) |
| Ribes | NBPGR Bhowali (26) |
| Rubus | NBPGR Bhowali (21), NBPGR Shimla (24) |
| Sapota | CARI (3), FRS Aurangabad (2), GBPUAT (5), GKVK, Bangalore (9), HAFRP (12), KAU (7), PDKV Katol (2), PDKV RS Sindhewahi (2), TNAU (10), UAS Bangalore (9), UAS Dharwad (9), UAS RS Raichur (3) |
| Sour Orange | NBPGR Bhowali (3) |
| Strawberry | CITH (36), HPKVV (10), NBPGR Bhowali (72), NBPGR Shimla (24), YSPUHF (20) |
| Sweet Lime | NBPGR Bhowali (42), NBPGR Issapur (3), NRCC (5) |
| Sweet Orange | NRCC (43), PDKV RS Katol (4), UAS RS Raichur (1) |
| Tamarind | FRS Aurangabad (3), GAU Ahmedabad (2), HAFRP (30), NBPGR Jodhpur (1), NBPGR Ranchi (51), TNAU (3), UAS Bangalore (21) |
| Tree tomato | NBPGR Shimla (2) |
| Vaccinium | NBPGR Bhowali (5) |
| Viburnum | NBPGR Shimla (2) |
| Walnut | CITH (38), NBPGR Bhowali (27), NBPGR Shimla (83), YSPUHF (18) |

**Table 11. Status of important ornamental crops at different locations**

| Crop | Location |
|---|---|
| Anthurium | BCKVV (8), IIHR (11), KAU (27), TNAU HRS, Yercaud (55), UBKVV (11) |
| Carnation | BCKVV (6), PAU (7), SKUAS&T (8), YSPUHF (32) |
| Chrysanthemum | AAU (23), ANGRAU (22), RAU (45), IIHR (76), MPKV Pune (28), MPUAT (39), NBRI (129), RPRC (104), SKUAS&T (40), TNAU (75), UAS (23), YSPUHF (55) |
| Gerbera | RAU (11), BCKVV (16), GBPUA&T (20), ICARRC, Meghalaya (62), IIHR (25), MPKV Pune (22), PAU (8), SKUAS&T (13), TNAU HRS, Yercaud (46) |
| Gladiolus | ANGRAU (27), BAU (15), GBPUA&T (42), IARI (47), IIHR (74), MPKV Pune (50), MPUAT (63), PAU (36), SKUAS&T (60), IARI Katrain (29) |
| Orchids | BCKVV (24), ICAR RC, Meghalaya (15), KAU (67), TNAUHRS, Yercaud (13), UBKVV (125) |
| Rose | IIHR (517), MPKV (24), NBRI (7), PAU (169), RAU (118), RPRC (111) |
| Tuberose | AAU (6), BCKVV (6), GBPUA&T (4), KAU (4), MPKV (7), NBRI(2) |

(Source: Bhattacharjee *et al.* 2002)

The designated NAGS for different horticultural crops are as presented in Table 12. These designated sites have the responsibility of overall germplasm management including conservation of the allotted crop(s) and work in association with the NBPGR. There is need to designate more sites as field repositories for the horticultural crops like the temperate vegetables (IARI, Katrain, HP), tropical vegetables and ornamentals (IIHR Bangalore) and apple (FRS Mashobra, HP).

**Table 12. Designated National Active Germplasm Sites (NAGS) for horticultural crops**

| Crop (s) | Designated NAGS |
|---|---|
| Arid fruits | NRC on Arid Horticulture, Bikaner |
| Banana | NRC on Banana, Tiruchirapalli |
| Cashew | NRC for Cashew, Puttur |
| Citrus species | NRC on Citrus, Nagpur |
| Grapes | NRC for Grapes, Pune |
| Aonla, Bael & Litchi | Central Horticultural Experiment Station, Ranchi |
| Jackfruit | Indian Institute of Horticultural Research, Bangalore |
| M & AP | NRC on M & AP, Anand |
| Mango | Central Institute for Sub-Tropical Horticulture, Lucknow |
| Mulberry | Central Silk and Mulberry Genetic Resources Centre, Hosur |
| Oil Palm | NRC on Oil Palm, Eluru |
| Onion & Garlic | NRC for Onion & Garlic, Nasik |
| Orchids | NRC for Orchids, Gangtok |
| Ornamentals crops | National Botanical Research Institute, Lucknow |
| Plantation crops | Central Plantation Crops Research Institute, Kasargod |
| Potato | Central Potato Research Institute, Shimla |
| Spices | Indian Institute of Spices Research, Bangalore |
| Temperate horticulture crops | Central Institute of Temperate Horticulture, Srinagar |
| Tropical fruits | Indian Institute of Horticultural Research, Bangalore |
| Tuber crops | Central Tuber Crops Research Institute, Thiruvanathapurum |
| Vegetables | Indian Institute of Vegetables Research, Varanasi |

### *(b) Seed Gene Bank*

This method is almost universally applied to the orthodox seed species like vegetables. Due to the extended life span of seeds stored under optimum conditions, it will not be necessary to regenerate the seeds at frequent intervals. Reducing frequency of regeneration results in cost-effective maintenance of germplasm. More importantly it minimises the genetic erosion resulting from genetic drift in small populations that may be grown for regeneration; genetic shifts resulting from natural selection when material is grown out in the field. 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. Work is also in progress on alternative methods of storage of seeds such as the maintenance of seed imbibed storage (recalcitrant seed storage at higher moisture content), cryopreservation of seeds (for extended life span than in long term storage), and storage of ultra dry seeds (drying to moisture content of 2.5%) in hermetically sealed containers under ambient conditions. Status of vegetable germplasm stored in National Gene Bank, NBPGR, New Delhi has been presented in Table 13.

**Table 13. Status of horticulture germplasm stored in National Gene Bank, NBPGR, New Delhi**

| Crop (s) | Accession stored (no.) | Crop (s) | Accession stored (no.) |
|---|---|---|---|
| Ash gourd | 15 | Musk melon | 104 |
| Atriplex | 12 | Okra | 1350 |
| Bitter gourd | 196 | Okra (wild) | 366 |
| Bottle gourd | 157 | Onion | 897 |
| Brinjal and *Solanum* spp. | 2079 | Papaya | 23 |
| Cabbage | 46 | Pea | 2645 |
| Carrot | 35 | Pumpkin | 75 |
| Chilli | 1914 | Radish | 149 |
| Chinese cabbage | 108 | Ridgegourd | 49 |
| Cluster bean | 2594 | Round gourd | 13 |
| Coriander | 287 | Round melon | 15 |
| Cowpea | 2479 | Snake cucumber | 8 |
| Cucumber | 121 | Sowa | 59 |
| Custard apple | 57 | Spinach | 52 |
| Fenugreek | 412 | Sponge gourd | 33 |
| French bean | 1065 | Sponge gourd (wild) | 18 |
| Lablab bean | 384 | Tomato | 997 |
| Long melon | 14 | Water melon | 45 |

### (c) In vitro *Conservation*

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 vegetatively to maintain clonal genotypes. At present the most common method to conserve the genetic resources of these difficult crops is as whole plants in the field. There are, however, several serious problems with field genebanks as described earlier. In addition, distribution and exchange from field gene bank is difficult because of the vegetative nature of the material and the greater risk of disease transfer. The conservation of rare and endangered plant species has also become an issue of concern. Plant tissue culture repository and cryopreservation techniques are employed to conserve the above described genetic resources.

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. The miniaturizations of explants allow reduction in space requirements and reduce labour costs. Among horticultural crops germplasm conserved at *in vitro* repository, NBPGR, New Delhi include *Allium sativum* (117 accessions), *Allium* spp. (14), *Musa* spp. (341), *Actinidia chinensis* (3), *Aegle marmelos* (1), *Fragaria* spp. (48), *Prunus* sp. (2), *Rubus* spp. (5), Malus spp. *(4), Morus* sp. (42) and *Vitis vinifera* (1). However there are two technical problems associated with this method and need improvement. Firstly, the genetic instability of the material conserved as tissue culture due to somaclonal variation at the time of regeneration of the tissue into seedlings, and secondly, the length of storage the tissue is limited.

### *(d) Cryopreservation*

Cryopreservation involves storage of plant 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 that 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 389 accessions of vegetables (*Abelmoschus* spp., *Capsicum annuum, Lycopersicon* spp., *Solanum* spp.) covering 55 species and 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.

*(f) 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 poses fewer quarantine problems compared with seed or 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). 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 the feasibility of ovule storage and *in vitro* fertilization techniques. In addition, effective sample techniques to cover a population or gene pool are needed.

*(g) 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 realisation 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.

*(h) Botanical/Herbal Gardens*

The role of most botanical gardens in conserving intra-species diversity is limited because these conserve only a 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. Herbal gardens resemble botanical gardens except that these maintain medicinal and aromatic plants. Herbal gardens are getting more importance these days because the medicinal and aromatic plant groups is the most threatened among horticultural plants.

(i) *In Situ Conservation*

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.

**Registration of Plant 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 the role of scientist in development of these materials, discourages them from sharing the 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. The elite material/ genetic stocks registered at NBPGR pertaining to horticultural crops are aonla (1 line), ber (3), cashew (9), mango (1) among fruits; round melon (1) and snap melon (2), bitter gourd (1), bottle gourd (2), brinjal (2), chilli/sweet pepper (3), cucumber (2), fenugreek (2), garlic (2), kachri (2), pea (5) pointed gourd (1), potato (1) and tomato (3) among vegetables and balsam (1), gladiolus (4) and orchid (2 lines) among ornamentals. These are maintained at National genebank, NBPGR, New Delhi.

**Future Thrusts**

- Priority for collection of wild relatives and under exploited genetic resources.
- Introduction of targeted germplasm for crop improvement.
- Establishment of core collection.
- Evaluation of germplasm for yield, quality, shelf life, and resistance to biotic and abiotic stresses.
- Genetic enhancement / prebreeding involving collections from primary, secondary and tertiary genepools.
- The morphological, biochemical and molecular characterization of valuable genetic resources.
- Registration of germplasm, breeding lines and parental lines.
- Conservation of germplasm.
- Awareness generation related to Patenting, Farmer's right and Benefit sharing.

**References**

Alexander MP and S Ganeshan (1993) Pollen storage. In: KL Chadha and OP Pareek (eds) *Advances in Horticulture*, Vol. I, Malhotra Publishing House, New Delhi, pp 481-496.

Arora RK (1991) Plant diversity in the Indian gene centre. In: Paroda RS and RK, Arora (eds) *Plant Genetic Resources-Conservation and Management, Concept and Approaches.* IBPGR, Regional Office for South & SE Asia, New Delhi, pp 25-54.

Arora RK and ER Nayar (1984) *Wild Relatives of Crop Plants in India.* NBPGR Sci. Monograph No. 7, 90p.

Bhattacharjee SK, Suchitra Pushkar and P Naveen Kumar (2002) *Passport Data of Flower Crops Germplasm.* AICRP on Floriculture (ICAR), Div. of Floriculture and Landscaping, IARI, New Delhi, 210p.

Chadha KL and Choudhury B (1986) *Ornamental Horticulture in India.* ICAR, New Delhi, 217p.

Engelmann F (1997) Present development and use of *in vitro* culture techniques for the conservation of Plant Genetic Resources. *Acta Hort.*, **447:** 471-75.

Ghosh SP (1984) *Horticulture in North-eastern India.* Assoc. Publi, New Delhi.

Pareek OP, Sharma S and Arora RK (1998) *Underutilised Edible Fruits and Nuts.* An Inventory of Genetic Resources of their Regions of Diversity. IBPGR, Regional Office For South & SE Asia, New Delhi, 235p.

Rai M and PN Gupta (1996) Distribution and diversity of indigenous tropical fruits. In: *Genetic Resources of Tropical Fruits.* NBPGR, New Delhi, pp 19-43.

Randhawa GS and Mukhopadhyay A (1986) *Floriculture in India.* Allied Publishers, New Delhi, 654p.

Swaroop V (1995) *Garden Flowers.* National Book Trust, N. Delhi, 276p.

Singh, BP, Gupta PN and Rana RS (1993) New Introductions in ornamentals. *J. Ornamental Hort.* **1(1):** 68-72.

## ABBREVIATIONS

| | | |
|---|---|---|
| AAU | – | Assam Agricultural University, Jorhat, Assam |
| ANGRAU | – | Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad |
| ARS, Chintamani | – | Agricultural Research Station, Chintamani |
| BAC, Sabour | – | Bihar Agricultural College, Sabour |
| BAU, Ranchi | – | Birsa Agricultural University, Ranchi |
| BCKVV | – | Bidhan Chandra Krishi Vishwavidyala, Mohanpur |
| CARI | – | Central Agricultural Research Institute, Andaman & Nicobar Islands |
| CIAH | – | Central Institute of Arid Horticulture, Bikaner |
| CISH | – | Central Institute of Sub-Tropical Horticulture, Lucknow |
| CITH | – | Central Institute of Temperate Horticulture, Srinagar |
| CRS, Bapatla | – | Cashew Research Station, Bapatla |

| | | |
|---|---|---|
| CRS, BBSR | – | Cashew Research Station, Bhuwaneshwar |
| CRS, Madakkathara | – | Cashew Research Station, Madakkathara |
| FRS, Aurangabad | – | Fruit Research Station, Aurangabad |
| GAU, Ahmedabad | – | Gujarat Agricultural University, Ahmedabad |
| GAU, Anand | – | Gujarat Agricultural University, Anand |
| GAU, RS Mundra | – | Gujarat Agricultural University, Regional Station Mundra |
| GBPUAT | – | G.B.Pant University of Agriculture & Technology, Pantnagar |
| GKVK, Bangalore | – | University of Agriculture Sciences, GKVK campus, Bangalore |
| HAFRP | – | Horticulture and Agroforestry Research Programme, Ranchi |
| HPKVV | – | Himachal Pradesh Krishi Vishwavidyalaya, Palampur |
| IARI | – | Indian Agricultural Research Institute, New Delhi |
| IARI | – | Indian Agricultural Research Institute, Regional Station Katrain |
| ICARRCNEH | – | ICAR Research Complex for North Eastern Region, Barapani |
| IIHR | – | Indian Institute of Horticultural Reseatrch, Bangalore |
| KAU | – | Kerala Agricultural University, Veilanikara |
| MPKV, Pune | – | Mahatma Phule Krishi Vidyapeeth, Pune Campus |
| MPKV, Rahuri | – | Mahatma Phule Krishi Vidyapeeth, Rahuri |
| MPUAT | – | Maharana Pratap Univ. of Agric. & Tech., Udaipur |
| NBPGR, Amravati | – | National Bureau of Plant Genetic Resources, Regional Station Amrawati |
| NBPGR, Bhowali | – | National Bureau of Plant Genetic Resources, Regional Station Bhowali |
| NBPGR, Issapur | – | National Bureau of Plant Genetic Resources, Experimental Station Issapur |
| NBPGR, Jodhpur | – | National Bureau of Plant Genetic Resources, Regional Station Jodhpur |
| NBPGR, Ranchi | – | National Bureau of Plant Genetic Resources, Regional Station Ranchi |
| NBPGR, Shillong | – | National Bureau of Plant Genetic Resources, Regional Station Shillong |
| NBPGR, Shimla | – | National Bureau of Plant Genetic Resources, Regional Station Shimla |
| NBPGR, Thrissur | – | National Bureau of Plant Genetic Resources, Regional Station Thrissur |
| NBRI | – | National Botanical Research Institute, Lucknow |
| NRC Banana | – | National Research Centre for Banana, Trichi |
| NRC Cashew | – | National Research Centre for Cashew, Puttur |
| NRCAF | – | National Research Centre for Agroforestry, Jhansi |
| NRCC | – | National Research Centre for Citrus, Nagpur |
| NRCG | – | National Research Centre for Grape, Pune |
| PAU | – | Punjab Agricultural University, Ludhiana |
| PDKV, Katol | – | Dr. Punjab Rao Deshmukh Krishi Vishwavidyalay, Regional Station, Katol |
| PDKV, Sindewahi | – | Dr. Punjab Rao Deshmukh Krishi Vishwavidyalay, Regional Station Sindhewahi |
| RARS, Pilicode | – | Regional Fruit Research Station, Pilicode |
| RAU | – | Rajendra Agricultural University, Pusa |
| RAU, Bikaner | – | Rajasthan Agriculture University, Bikaner |
| RFRS, Vengurla | – | Regional Fruit Research Station, Vengurla |
| RPRC | – | Regional Plant Resources Centre, Bhuwaneswar |
| RRS, Jhargram | – | Regional Research Station, Jhargram |
| SKUAS&T | – | Sher-e-Kashmir University of Agriculture Science and Technology, Srinagar |
| TNAU | – | Tamilnadu Agriculture University, Coimbatore |
| TNAUHRS | – | Tamil Nadu Agriculture University, Horticulture Research Station Yercaud |
| UAS, Bangalore | – | University of Agricultural Sciences, Bangalore |
| UAS, Dharwad | – | University of Agricultural Sciences, Dharwad |
| UAS, RS Raichur | – | University of Agricultural Sciences, Regional Station Raichur |
| UBKVV | – | Uttar Banga Krishi Vishwavidyalay, Coochbihar |
| YSPUHF | – | Dr YS Parmar University of Horticulture & Forestry, Solan |