Wild Relatives of Crop Plants in India
Collection and Conservation

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Agro-biodiversity (PGR)-41

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January 2005

Citation: Pandey, Anjula, D. C. Bhandari, K. C. Bhatt, S. K. Pareek, A. K. Tomer and B. S. Dhillon. 2005. Wild Relatives of Crop Plants in India: Collection and Conservation. National Bureau of Plant Genetic Resources, New Delhi, India. 73 p.

Copies available from:
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E-mail: director@nbpgr.delhi.nic.in; Website: http://nbpgr.delhi.nic.in

Cover photos: *Cucumis prophetarum* and *Sesamum alatum*

Published by: The Director, National Bureau of Plant Genetic Resources, New Delhi 110 012, India and printed by Yugantar Prakashan Pvt. Ltd., WH-23, Mayapuri, Phase-I, New Delhi 110 064.

Preface

Wild species especially the wild relatives of crop plants (WRCPs) are invaluable source of resistance to several biotic and abiotic stresses, yield, nutritional quality, adaptation and genetic diversity. However, their utilization in the crop improvement programmes depends largely on their availability as well as their crossability relationship with the cultivated types. Destruction of habitats and changing land use pattern have led to their genetic erosion. Hence, their collection and conservation require immediate attention for sustainable utilization.

The National Bureau of Plant Genetic Resources (NBPGR), New Delhi is the nodal organization in India for the management of plant genetic resources (PGR). Since, its inception in 1976, efforts have been made for the collection and conservation of plant genetic resources including wild relatives. However, these activities gained impetus during the last five years with the implementation of a mission mode sub-project on "Sustainable Management of Plant Biodiversity" under National Agricultural Technology Project (NATP).

Realizing the importance of wild relatives and related taxa in crop improvement programmes, it became imperative to compile the available information on their collection and conservation for effective utilization. This compilation deals with the general introduction to the WRCPs with specific emphasis on collection and conservation activities by NBPGR and its partners. It contains five chapters: chapter 1 deals with the general introduction and diversity in wild relatives. Importance of wild relatives for desirable traits and strategies for their collection and conservation have been highlighted in chapters 2 and 3. National efforts made for collection and conservation during 1976-2004 have been discussed in chapter 4. Chapter 5 deals with concerns and future thrusts on the management of wild relatives.

It is hoped that this information will serve as a reference material for the researchers, educationists, students and policy makers dealing with agriculture, genetics, plant breeding, biology, PGR management, etc. In addition it could be of immense value in identification, collection, conservation and utilization of wild relatives as well as setting priorities for future collection missions.

Authors express their sincere gratitude to Dr. Mangala Rai, Secretary, Department of Agricultural Research and Education (DARE) and Director General, Indian Council of Agricultural Research (ICAR) for encouragement and support. Sincere thanks are due to Dr. G. Kalloo, Deputy Director General (Horticulture and Crop Science), ICAR; Dr. J. C. Katyal, Deputy Director General (Education) and National Director, National Agricultural Technology Project (NATP) and Dr. S. L. Mehta, Former National Director, NATP for the motivation and help provided in various ways. Our sincere thanks to Dr. K. P. Agrawal, National Coordinator (Mission Mode) and staff of Project Implementation Unit (PIU), NATP for providing all need-based support to the NATP sub-project on Sustainable

Management of Plant Biodiversity. We sincerely acknowledge the help rendered by our colleagues at NBPGR Headquarters and its Regional Stations and all the partners for providing their willing support and cooperation from time to time in the successful implementation of various activities.

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Introduction

Early agriculturists selected crop plants from wild species on the basis of reproductive potential, adaptation to climatic vagaries and the traits associated with production. During domestication, a small number of gene combinations accumulated in crop species resulting in narrow genetic diversity. The search for genetic diversity in economic plants is a constant goal for the breeders. This diversity can be broadened by the utilization of wild relatives of crop plants (WRCPs). Adaptation to biotic and abiotic stresses has made the local landraces and wild relatives extremely useful in various breeding programmes.

Plant genetic resources (PGR), one of the crucial components of agro-biodiversity, are extremely valuable for present and future generations of human kind. The spectrum of PGR comprises diversity from the genepool and centres of cultivation and material developed through breeding programmes. Functional classification of PGR broadly includes landraces, improved cultivars, wild/ weedy relatives and related taxa of crop plants alongwith their wild progenitors and potential domesticates (Box: 1.1). Among these the diversity in wild/ weedy relatives and related taxa of crop plants is crucial for the improvement of crops. The genes for various traits stored in the wild genepool have been extensively used in improvement of many crops. Interestingly, in some crops they are the only available genetic resources (Arora and Pandey, 1996). The augmented facts necessitate urgent measures for collection and conservation of this diversity (Lorest and Jackson, 1996).

Box 1.1 Plant Genetic Resources

Landraces: Primitive forms developed in ancient times through natural selection, without the processes of modern breeding or selection. They are known by their local names and are genetically highly diverse.

Improved cultivars: The product of scientific plant breeding and the backbone of modern plant agriculture.

Wild/ weedy relatives: Wild species that constitute an important but scarcely exploited component of the genepool of domesticated species available to plant breeders. They are extensively used in resistance breeding. Weedy races are the close companions of cultivated plant species, and together form a genetically compatible complex.

Wild useful species: Plant species that are not yet domesticated but extensively used by human beings.

Wild species of potential uses: Plant species neither domesticated nor extensively used but possess great economic potential for future domestication.

Source: Hawkes (1983)

Indian region is a major centre of domestication and diversity of crop plants (Zeven and de Wet, 1982; Arora, 1991). About 33 per cent of the cultivated plant species have their origin in this region (Damania, 2002). This, being one of the twelve mega-centres of biodiversity, has more than 47,000 plant species including lower plants (bacteria, algae, fungi, bryophytes, pteridophytes, gymnosperms, etc.) (Nayar, 1997). The vascular plants, a dominant component of vegetation, represent over 17,000 species of higher plants, i.e. angiosperms (Table 1.1). These constitute about 7 per cent of the total flowering species of world. Out of 511 plant families, 315 are represented in this region (Brummit, 1992).

Table 1.1 Species richness and endemic species of higher plants in mega-biodiversity countries

Country	Plant species	Endemic plant species
Brazil	~50,000-56,000	~16,500-18,500
Colombia	45,000-51,000	15,000-17,000
Indonesia	~ 37,000	14,800-18,500
China	27,100-30,000	~10,000
South Africa	23,420	16,500
USA	18,956	4,036
Mexico	18,000-30,000	10,000-15,000
Peru	18,000-20,000	5,356
Ecuador	17,600-21,100	4,000-5,000
India	>17,000	7,025-7,875
Venezuela	15,000-21,070	5,000-8,000
Australia	15,638	14,458
Papua New Guinea	15,000-21,000	10,500-16,000
Malaysia	15,000	6,500-8,000
Philippines	8,000-12,000	3,800-6,000
Madagascar	11,000-12,000	8,800-9,600
Democratic Republic of Congo	11,000	3,200

Source: Mittermeier *et al.* (1997)

The Indian gene centre ranks first in the eastern Hemisphere and fourth in Asia having remarkably rich plant diversity (Zeven and de Wet, 1982; Groombridge, 1992). Endemism and intra-specific variation in Indian species are unparalleled to those found in any other part of the world (Seeni and Sabu, 1997). The three major phyto-geographical areas having endemic and floristic diversity are: the Himalaya (3,471 species), the peninsular India (2,015 species) and the Andaman and Nicobar Islands (239 species). Harbouring two of the world's major hot-spots, this region stands unique in several ways (Myers *et al.*, 2000).

The Indian sub-continent is a centre of domestication and diversification of several economically useful wild plant species comprising about 3,000 plants of edible value, 4,000 species having known reputed medicinal value, 700 plants of traditional and social significance, 500 fibre yielding species, 400 fodder plants, 40 plants having insectivorous uses, 300 gum and dye yielding plants and 100 aromatic and essential oil yielding species (Arora, 1991).

In early part of the 20th century, there was a speculation that hybridization may play a major role in adaptive evolution (Anderson, 1949; Stebbins, 1950). Artificial hybridization in recent times between crop plants and their wild progenitors, as well as wild relatives has led to variation in many crops. The wild relatives of crop plants have been the donors of many useful traits such as resistance/ tolerance to diseases, insect-pests and other stresses (Sharma *et al.,* 2003); some of which include wild annual rice (*Oryza nivara*), the only source of resistance to rice tungro virus, wild lady's finger (*Abelmoschus tuberculatus*) for yellow vein mosaic virus and wild mung (*Vigna radiata* var. *sublobata*) for resistance to yellow vein mosaic virus (Arora, 1996).

Wild related species constitute a part of the crop genepool. The WRCPs possess a big reservoir of untapped genes that have potential to be utilized in improvement of crops. The evaluation and direct utilization of wild relatives and related taxa is based on their classification. These can be classified into primary, secondary and tertiary genepools (Harlan, 1976).

The wild species in primary genepool include the wild progenitors of crops, wild and weedy forms and produce fertile hybrids with cultivated types (Harlan and de Wet, 1971). The species in secondary genepool can only result in some degree of fertility, in these, gene transfer being difficult. This includes the distantly but cross compatible wild related species, leading to partly fertile cross-progenies. In tertiary genepool, crossing is rather difficult. In terms of utilization of wild relatives, primary and secondary genepools are easy to exploit because they are wild progenitors/ closer/ relatively closer to their respective crop groups. The tertiary genepool is difficult to exploit and represents distantly related species or unrelated taxa of different genera/ species. This includes the genepool having little direct value. They can be used to trap valuable genes by application of gene transfer methodologies. For example, wild apricot (*Prunus armeniaca*, locally called chulli) growing wild in the high altitudes of western Himalaya is a source of gene to cold hardiness to the cultivated varieties of apricot (*P. armeniaca*). Thus, wild apricot constitutes the primary genepool for cultivated apricot. Other distantly related species *P. cerasus* and *P. napaulensis* belong to the tertiary genepool. Similarly for cultivated sesame (*Sesamum indicum*, til), wild sesame, *S. mulayanum* and *S. malabaricum* constitute the primary genepool and *S. laciniatum* and *S. prostratum*, the tertiary genepool.

In comparison to crop plants, less emphasis has been laid on collection/ augmentation, characterization, conservation and utilization of diversity in wild relatives of crop plants. Specific programmes on collection, conservation and utilization of wild relatives and related taxa need to be intensified in areas of species diversity (Arora and Nayar, 1984). Wild genepool occurring in biotically disturbed habitats is under the threat of genetic erosion and requires not only timely measures for its collection and conservation but also compilation

of all requisite information to make use of its wider adaptability/ tolerance/ resistance to diseases and insect-pests, yield, quality attributes and other biotic and abiotic characters.

Diversity in Wild Relatives of Crop Plants in India

The Indian gene centre harbours about 166 species of native cultivated plants. The crops with primary, secondary and regional centres of diversity represent a part of native and introduced species which account for over 480 species (Nayar *et al.*, 2003). Diverse agro-climate and agricultural practices have led to rich diversity of crop species in the form of landraces and cultivars. Besides, the centre has over 320 wild relatives (Arora and Nayar, 1984; Arora, 2000). The floristic diversity in wild relatives of cultivated/ weedy types and related taxa constitutes a useful genepool.

The crop species are accessible for collection in fields, orchards, gardens, markets and with farmers. On the contrary, the wild relatives are difficult to locate as they grow in their natural habitats with other wild plants. Except some weedy species, most of the wild relatives are confined to specific habitats (Arora and Chandel, 1972; Arora, 1993). Their identity requires a skill in systematic botany. This is perhaps the reason why wild relatives are meagrely represented in the germplasm collections.

The wild relatives of crop plants by and large, occur as component of disturbed habitats within the major vegetation types. The information on their occurrence is available from different herbaria/ floristic accounts/ floras, etc. This genetic wealth is largely distributed in the warm humid tropical, sub-tropical regions and in the western Himalaya with low representation in the drier North-western region (Arora and Nayar, 1984; Arora, 1993; 2000). Species of wild relatives are in abundance in Western Ghats, North-eastern region and in the high altitudes of the western Himalaya (Arora and Pandey, 1996). However, disturbed grasslands, scrub vegetation and open degraded forest areas on one hand and farmers' fields as weedy component on the other, represent suitable habitats for rich diversity.

Arora and Nayar (1984) classified the wild relatives of crop plants into different crop groups based on their agri-horticultural importance. These, based on the crop groups and number of species (given in parenthesis), have been grouped as: cereals and millets (51), legumes (31), oilseeds (12), fibres (24), vegetables (54), fruits (109), spices and condiments (27) and others (26).

The distributional pattern of the wild relatives in different botanical/ phyto-geographical regions and the areas of their concentration where rich diversity exists, are of special significance for undertaking programmes on collection as well as *in situ* conservation. The distributional pattern in different phyto-geographical regions reveal seven zones: Western Himalaya (125), Eastern Himalaya (82), North-eastern Region (132), Upper Gangetic Plains (66), Indus Plains (North-western Plains) (45), Malabar/ Western Peninsular Region/ Western Ghats (145), and Deccan/ Eastern Peninsular Region/ Eastern Ghats (91). More than 100 wild relatives and endemic/ rare/ endangered species, predominantly occurring in the hot-spots/ microcentres of India have been identified (Table 1.2) (Nayar, 1996; Pandey

Table 1.2 Wild relatives of crop plants and endemic/ rare/ endangered species in hot-spots/ microcentres of diversity in India

Hot-spots/ Microcentres	Prominent diversity
1. Andaman group of islands	*Amorphophallus carnosus, A. longistylus, A. oncophyllus, Ficus andamanica, Garcinia andamanica, G. candelliana, Jasminum andamanicum, J. unifoliatum, Mangifera andamanica, Mimusops andamanica, Oryza indandamanica, Syzygium andamanicum, S. kurzii, S. manii, S. viminalis* var. *fasciculatus, Vanilla andamanica*
2. Nicobar group of islands	*Amomum fenzlii, Jasminum multiflorum*
3. Agasthiyamala Hills (South Tranvancore and Thirunelveli Hills)	*Amorphophallus smithsonianus, Cinnamomum walaiwarense, Dioscorea wightii, Diospyros affinis, D. barberi, Eugenia mabaeoides, E. zeylanica* var. *lineare, Garcinia imbertii, G. rubroechinata, G. travancorica, Madhuca deplostemon, Piper hapnium, Rauvolfia hookeri, Syzygium beddomei, S. coutallense, S. gambleanum, S. parameswaranii, S. rama-varmae, Vitis gardneri, V. grandis*
4. Anamalai and high ranges	*Eugenia rottleriana, Garcinia wightii, Madhuca bourdillonii, Syzygium chandrsekharanii, Trichosanthes anamalaiensis*
5. Palni Hills	*Crotalaria kodaienses, Kaempferia evansii, Pimpinella pulneyensis*
6. Nilgiris, Silent Valley, Wyanad Kodagu/ Nilgiri Biosphere	*Cinnamomum heyneanum, C. malabatrum, Curcuma cannanorensis, C. escalcarata, C. haritha, C. kudagensis, C. malabarica, C. nilamburensis, C. raktakanta, C. thalakaveriensis, C. vamana, Piper meeboldii, P. nigrum* var. *hirtellosum, P. galeatum, P. pykarahense, P. silentvalleyensis, Syzygium utilis*
7. Shimoga-Kanara	*Amorphophallus mysorensis, Curcuma decepiens, Madhuca insignis, Syzygium kanarensis*
8. Mahabaleswar-Khandala ranges	*Amorphophallus commutatus, Curcuma purpurea*
9. Konkan-Raigad	*Chlorophytum borivilianum, Flemingia gracilis, Pimpinella rollae, Vigna khandalensis, Zingiber cernum*
10. Marathwada-Satpura ranges	*Crotalaria decaspermum, C. naikiana, Oryza nivara, Panicum deccanense, P. paianum* var. *minor, Sorghum deccanense, Vigna trilobata*

contd.

Hot-spots/ Microcentres	Prominent diversity
11. Tirupati-Cuddappah-Nallamalai Hills	*Crotalaria longipes*, *C. perfoliata*, *C. madurensis* var. *kurnoolica*, *Oryza granulata*, *O. officinalis* ssp. *malampuzhaensis*, *Shorea tumbuggaia*
12. Visakhapatnam-Ganjam-Jeypore Hills	*Amorphophallus sylvaticus*, *Dioscorea glabri*, *Cajanus cajanifolius*, *Oryza granulata*, *O. jeyporensis*, *O. sativa* var. *plena*, *Zingiber roseum*
13. Southern Deccan	*Crotalaria* spp., *Jasminum trichotomum*, *J. wightii*
14. Chhotanagpur Plateau	*Carum villosum*, *Mucuna minima*
15. Kathiawar-Kuchchh	*Solanum purpureilineatum*, *Ziziphus williamsii*
16. Rajasthan-Aravalli Hills	*Ziziphus truncatus*
17. Khasia-Jaintia Hills	*Citrus assamensis*, *C. ichangensis*, *C. indica*, *C. latipes*, *Coix lacryma-jobi* var. *ma-yuen*, *Eryobotrya angustissima*, *Hedychium aurantiacum*, *H. hookeri*, *H. burtii*, *H. calcaratum*, *H. ellipticum*, *Jasminum adenophyllum*, *Trichosanthes himalensis*
18. Patkoi-Manipur-Lushai Hills	*Trichosanthes tomentosa*
19. Assam Himalaya	*Camellia sinensis* var. *assamica*
20. Arunachal Pradesh Himalaya	*Camellia siangensis*, *Eurya arunachalensis*, *Hedychium gomezianum*
21. Sikkim Himalaya	*Allium sikkimense*, *Cajanus villosus*, *Neoluffa sikkimensis*, *Prunus himalaica*, *P. rufa* var. *imanishii*, *Rosa hirsuta*, *Saccharum sikkimense*, *Trichosanthes ovata*
22. Garhwal-Kumaon Himalaya	*Ferula wolffii*, *Pimpinella diversifolia* var. *serentifera*, *Trachyspermum amenthifolium*, *Viola jangiensis*
23. Lahul-Himachal Pradesh Himalaya	*Lactuca lahulensis*, *Jasminum parkeri*, *Rosa hookeriana*, *R. webbiana*, *Trigonella upendrae*
24. Kashmir-Ladakh Himalaya	*Cicer macranthum*, *Trigonella podperae*, *Vicia benthamiana*

Source: Nayar (1996, 1997); Gopalan and Henry (2000)

and Arora, 2004). The floristic strength of wild relatives and related species occurring in India, also includes many wild useful components (Arora and Nayar, 1984) (Box: 1.2).

Box 1.2 Wild Relatives of Crop Plants

- *Cultivated plants* have been derived from the wild relatives through the process of selection followed by hybridization for bringing desired improvement.
- *Wild related species* have contributed significantly towards improvement of crop plants such as paddy, wheat, potato, brinjal, tomato, sugarcane, etc.
- *Wild relatives* are economically important for edible, medicinal and other uses: *Allium*, *Cicer*, *Citrus*, *Coix*, *Crotalaria*, *Dioscorea*, *Piper*, *Prunus*, *Rubus*, *Saccharum*, etc.

There has been scattered information on the distribution, collection and conservation of wild relatives of crop plants from India, which obviously presents difficulties in identification of their potential and utilization. Some efforts have been made in past for collection, analysis and documentation of the diversity in wild relatives of crop plants of India. Negi *et al.* (1991); Singh and Pandey (1996); Pandey and Padhye (2000); Subudhi *et al.* (2000) and Pãtra *et al.* (2002) have studied distribution pattern and collected important diversity in wild relatives of crop plants from Himalaya, Rajasthan desert, Gujarat, Orissa and West Bengal regions of India, respectively.

Information on Wild Relatives of Crop Plants and Related Taxa

Over the years, *ex situ* collections of cultivated plants and their wild relatives have been augmented through active collaboration with various institutes under National Agricultural Research System (NARS), Indian Plant Genetic Resources Management System (IPGeRMS) and under National Agricultural Technology Project (NATP) sub-project on Sustainable Management of Plant Biodiversity during 1999-2004.

In the present synthesis, efforts have been made to compile the information on "Wild Relatives of Crop Plants in India" based on data on germplasm collections and conservation by the National Bureau of Plant Genetic Resources (NBPGR) during 1976-2004. The synthesis highlights an introduction to wild relatives of crop plants in India with the following objectives:

(i) Information on diversity in wild relatives in different phyto-geographical zones

(ii) Importance of wild relatives for desirable traits

(iii) Status of collection and conservation by the NBPGR

(iv) Priority species/ target areas for future collection and conservation

(v) Concerns and thrusts on management of wild relatives

The information was analyzed based on the passport data information available in exploration reports, annual reports and check-lists supplemented with data from the Agricultural Research Information System (ARIS), NBPGR, New Delhi. The distribution and taxonomy of the species were verified using floras, relevant literature and other published work. The current list of wild relatives and related taxa includes 389 species.

The list has been categorized as cereals and millets, legumes, oilseeds, fibres, vegetables, fruits, spices and condiments and other species. For consideration and analysis, wild/ weedy relatives, crop progenitors (as component of primary genepool; GP I) and distantly related taxa, having potential for crop improvement (secondary and tertiary genepools; GP II and GP III) have been considered. By and large, medicinal and aromatic plants and ornamental species have not been discussed. The areas of collection of genus/ species diversity have been plotted on the map in eight phyto-geographical zones (Chatterjee, 1939; Arora and Pandey, 1996). Photographic plates of important species are appended in the text. A priority list provided in chapter 4 has been prepared based on status and importance of wild relatives. This information can be effectively utilized for augmentation, utilization and conservation of wild relatives of crop plants at national level.

2

Wild Relatives: Source of Desirable Traits

The crop plants and their wild progenitors may spontaneously hybridize with each other when grown side by side (Govindaswami *et al.,* 1966). This may result in infiltration of wild genes to the cultivated germplasm and *vice-versa*. This process is called introgression or introgressive hybridization (Anderson, 1949). It is frequently observed in cross-pollinated crops than in the self-pollinated ones. Accomplishments of inter-specific crosses between crops and their related types have opened new dimensions in the utilization of wild relatives in various crop improvement programmes. The value of wild relatives was better recognized with findings of *Zea diploperennis*, a new teosinte from Mexico (Iltis, 1979) and *Oryza nivara* from India (Govindaswami *et al.*, 1966). Crossability of *Allium cepa* and *A. sativum* with *A. roylei* (a species of Indian origin) has opened a new avenue for utilization of Indian wild species. This species has been used for transferring resistance for powdery mildew and leaf blight in the cultivated taxa (de Vries *et al.*, 1992).

During 1970s, the great devastation caused by the grassy stunt virus in rice fields, from India to Indonesia, damaged the world's single most important food crop. After a critical screening of over 17,000 accessions of cultivated and wild rices, a sample of *O. nivara*, collected from Gonda, Uttar Pradesh was found to have gene for disease resistance. Presently rice containing gene for resistance to this virus is cultivated over a large part of Asia. Similarly, the muskmelon crop, threatened by a downy mildew outbreak was saved by a wild species of Indian muskmelon which provided the gene for resistance to downy mildew (Rana, 1993).

The wild relatives, semi-domesticated crops and distantly related taxa occurring in developing countries have contributed significantly towards improvement of major crop species (Witt, 1982). Identification and utilization of a single gene of importance has played a major role in crop improvement. For example, an accession of wild and weedy tomato from Peruvian Andes in 1962 has been the source of high sugar content in modern tomato (Rick, 1986; Khoshoo, 1988).

Important examples of wild relatives from India are: *Oryza nivara*, a wild relative of cultivated *Oryza* (paddy), having resistance to grassy stunt virus from Basti and Gonda, Uttar Pradesh; *Porteresia coarctata*, a weedy relative of paddy with hardiness trait for saline/ marshy habitats from Sunderban delta region in West Bengal; *Eleusine compressa*, a wild relative of *E. coracana* (finger millet) from North-western arid tracts, having traits for hardiness and drought tolerance; *Vigna mungo* var. *silvestris* and *V. radiata* var. *sublobata*, wild relatives of cultivated *V. mungo* (urd) and *V. radiata* (mung), respectively from Ghats and adjacent areas, exhibiting tolerance to yellow mosaic virus; *Cicer soongaricum* (*C. microphyllum*), a wild relative of *C. arietinum* (chickpea) having cold hardiness and more seeds/ pod from high altitudes of Himalaya; *Sesamum laciniatum* from coastal Andhra and Tamil Nadu, a wild relative of cultivated *Sesamum indicum* (sesame)

having potential for diseases and pests; *Linum perenne*, a wild relative of cultivated *Linum usitatissimum* (linseed) with cold hardy trait from Lahul and Spiti region, Himachal Pradesh and other parts of western Himalaya; *Citrus latipes*, a wild relative of cultivated *Citrus* species (lemon and limes) with cold resistance from the Shillong plateau, Khasi hills; *Abelmoschus tuberculatus* and *A. manihot,* wild relatives of *Abelmoschus esculentus* (lady's finger) having tolerance/ resistance to yellow vein mosaic virus and fruit borer from northern India.

Deliberate introduction of genes from wild progenitors is now being employed in all major crop improvement programmes (Stalker, 1980; Chang, 1985; Goodman *et al.*, 1987; Khush and Brar, 1988). Identification of wild relatives of many crop plants and establishing their close genetic affinities have made it possible to utilize them as potential source of genetic variation by the breeders (Jambhale, 1986; Kalloo and Chowdhary, 1992; Kalloo and Bergh, 1993; Sharma *et al.*, 2003).

Successful introgression of useful genes from distantly related wild species or cultivated species, though difficult, depends on cross-compatibility, production of hybrid seeds, normal development of F_1 hybrids, partial seed production (by natural or by back-crossing) and no hybrid breakdown in the segregating generations. The traits of economic value that have been successfully transferred include mainly those for biotic and abiotic stresses from distantly related species to cultivated types (Newell and Hymowitz, 1982; Kalloo and Chowdhary, 1992).

Wild relatives of crop plants are identified on the basis of evidences from morphology, biochemistry and breeding experiments followed by cytological investigation of the progenies (F_1 hybrids) (Ladizinsky, 1988;1998). Ancestry of crop plants has been proved through breeding experiments. For example crosses have been successful between *Zea mays* L. and *Z. mexicana* (Schrad.) Kunt. (Collins and Kempton, 1920); *Avena sativa* L., *A. sterilis* L. and *A. fatua* L. (Ladizinsky and Zohary, 1971).

The germplasm collections of major crop plants have been built-up and catalogued. For wild relatives of crop plants, some efforts have been made to evaluate them as source of desirable traits. The wild relatives have been identified as source of the following desirable traits in improvement of crop plants:

(i) Resistance to diseases and pests: paddy, chickpea, pigeon pea, sesame, brinjal, lady's finger and potato

(ii) Tolerance to adverse environmental stress (salt tolerance, heat/ frost, desiccation sensitivity, water flooding): chickpea, pigeon pea and soybean

(iii) High vegetative vigour: sugarcane and potato

(iv) Higher yield: chickpea, mung, urd and lady's finger

(v) Morphological traits: wheat, pigeon pea and lady's finger

(vi) Higher protein value: oat, pigeon pea and cassava

(vii) Higher oil content: coconut and oil palm

(viii) Greater fibre strength: cotton and jute

(ix) Cytoplasmic male sterility and restorer system: wheat, rye, mustard, cotton and tobacco

The wild relatives of crop plants with some important traits are given in the Table 2.1.

Table 2.1 Wild relatives of crop plants with important traits

Crop (s)	Wild relative (s)	Important trait (s)	Reference (s)
Resistance to diseases and insect-pests			
Allium cepa, *A. sativum*	*Allium roylei*, *A. vavilovii*	Resistance to powdery mildew and leaf blight	de Vries *et al.* (1992), Fritsch *et al.* (2001), Sharma and Gohil (2002)
Abelmoschus esculentus	*Abelmoschus manihot*, *A. tuberculatus*	Resistance to yellow vein mosaic virus and fruit borer	Pal *et al.* (1952), Arora and Singh (1973), Arumugam *et al.* (1975), Sharma and Sharma (1984)
Arachis hypogaea	*Arachis chacoense*, *A. correntina*, *A. villosa*, *A. cardenastii*	Immunity to rust diseases, insect and mites, resistance to leaf spot disease, peanut bud necrosis and peanut clump virus	Murty *et al.* (1982), Amin (1985), Singh and Nigam (1996)
Avena sativa	*Avena sterilis*, *A. strigosa*, *A. barbata*	Resistance to yellow dwarf virus, rust and mildew, crown rust disease	Zillinsky and Derick (1960), Aung *et al.* (1977), Landry *et al.* (1984)
Cajanus cajan	*Cajanus scarabaeoides*, *C. sericeus*, *C. acutifolius* and *Rhynchosia bracteata*	Resistance to pod fly damage, general resistance to diseases	Pundir and Singh (1985), Sharma *et al.* (2003)
Cicer arietinum	*Cicer reticulatum*, *C. echinospermum*, *C. bijugum*	Resistance to diseases and pests, cold and drought, ascochyta blight, fusarium wilt	Kabir and Singh (1991), Robertson *et al.* (1995), Singh and Robertson (1996)
Helianthus annuus	*Helianthus debilis*, *H. argophyllus*	Powdery mildew and drought resistance	Chandler and Beard (1983), Morizet *et al.* (1984), Jan and Chandler (1985)

contd.

Crop (s)	Wild relative (s)	Important trait (s)	Reference (s)
Hordeum vulgare	*Hordeum bulbosum*	Resistance to diseases and pests	Lange and Jochemsen (1976), Jie and Snape (1989)
Lycopersicon esculentum	*Lycopersicon pimpinellifolium*, *L. hirsutum* f. *glabratum*; *L. peruvianum*	Resistance to verticillium, fusarium and bacterial wilt, bacterial canker, grey leaf spot, leaf mould, septoria leaf spot, curly top virus, mosaic virus and spotted wilt virus, root-knot nematode, phytophthora fruit-rot; early blight, leaf curl virus, Tobacco Mosaic Virus (TMV)	Harlan (1976), Alexander (1963), Kerr and Bailey (1964), Kalloo and Banerjee (1990 a, b and c)
Nicotiana tabacum	*Nicotiana sylvestris*, *N. knightiana*, *N. debneyi*, *N. repanda*	Cytoplasmic streptomycin resistance, blue mould resistance	Clayton (1968), Stavely *et al.* (1973), Medgyesy *et al.* (1980)
Oryza sativa	*Oryza nivara*, *O. officinalis*, *O. rhizomatis*, *O. granulata*	Resistance to insects, grassy stunt virus, tropical strain of bacterial blight, brown plant hopper, green leaf hopper	Govindaswami *et al.* (1966), Chang *et al.* (1975), Khush (1977), Khush *et al.* (1977), Jena and Khush (1990), Lorest and Jackson (1996)
Pennisetum americanum	*Pennisetum squamulatum*	Resistance to floral disease	Dujardin and Hanna (1986)
Sesamum indicum	*Sesamum laciniatum*, *S. mulayanum*, *S. prostratum*	Resistance to phyllody and powdery mildew	Mehetre *et al.* (1994)
Solanum melongena	*Solanum incanum* and other wild relatives of brinjal	Resistance to diseases and borer	Dao and Mitra (1999)
Solanum tuberosum	*Solanum tarijense*, *S. berthaultii*, *S. demissum*, and other wild potatoes	Resistance to aphids, mites, thrips, cyst nematode, mosaic virus and late-blight diseases	Salaman (1949), Ross and Baerecke (1950), Chavez *et al.* (1988)
Triticum aestivum and other cultivated wheat	*Aegilops comosa*, *A. umbellulata*, other wild relatives of *Triticum*	Resistance to yellow and leaf rust and other diseases	Sears (1956), Sharma and Knott (1966), Riley *et al.* (1968)

contd.

Crop (s)	Wild relative (s)	Important trait (s)	Reference (s)
Zea mays	*Zea diploperennis*	Immunity to major diseases of maize	Iltis (1979)
Quality characters			
Camellia sinensis	Wild *Camellia* species	High flavour content	Bezbaruah (1974)
Gossypium spp. (upland cotton)	*Gossypium raimondi*, *G. thurberi*, *G. sturtianum*	Fibre strength, glanded plants and glandless seeds	Kerr (1951), Altman *et al.* (1987)
Lycopersicon esculentum	Wild tomato, *L. cheesmanii*, *L. peruvianum*, *L. pennellii*	High sugar content, salt tolerance	Tal and Shannon (1983), Rick (1986)
Nicotiana tabacum	*Nicotiana debneyi*	Lower nicotine content	Chari (1988)
Triticum aestivum	*Triticum turgidum*, *T. dicoccoides* (wild tetraploid wheat)	High protein content	Kushnir and Halloran (1984)
Yield characters			
Abelmoschus esculentus	*Abelmoschus tuberculatus*	Heavy bearing	Pal *et al.* (1952)
Avena sativa	*Avena sterilis*	Grain yield	Lawrence and Frey (1975)
Cajanus cajan	*Atylosia cajanifolia*	Higher pod and seed yield	Vavilov (1951)
Pennisetum americanum	Wild relatives of *Pennisetum*	Higher grain and fodder yield	Bramel-Cox *et al.* (1986)
Saccharum officinarum	Wild relatives of *Saccharum*	Higher culm yield	Daniels (1965)
Triticum aestivum	*Triticum turgidum*, *T. dicoccoides* (wild tetraploid wheat)	High kernel weight	Kushnir and Halloran (1984)
Cereals	Wild and weedy relatives of cereals	Yield character	Frey *et al.* (1984)
Vigna radiata, *V. mungo*	*Vigna radiata* var. *sublobata*	Higher yield	Jain and Mehra (1980)
Mode of reproduction			
Beta vulgaris	*Beta corolliflora*	Incorporation of apomixis	Jassem and Jassem (1971)
Brassica juncea, *B. campestris*	*Brassica oxyrrhina*, *Diplotaxis siifolia*, *D. catholica*, *Sinapis alba*	Cytoplasmic male sterile lines	Chopra and Prakash (1996)

contd.

Crop (s)	Wild relative (s)	Important trait (s)	Reference (s)
Gossypium spp. (cultivated)	Wild cotton	Cytoplasmic male sterile and restorer system	Narayanan *et al.* (1984)
Helianthus annuus	*Helianthus petiolans*	Cytoplasmic male sterile based traits	Khristov and Petrov (1988)
Nicotiana tabacum	*Nicotiana sylvestris*, *N. debneyi*	Cytoplasmic male sterile and restorer system	Aviv and Galun (1980), Asahi *et al.* (1988)
Pennisetum americanum	*Pennisetum schweinfurthii*	Cytoplasmic male sterile lines	Marchais and Pernes (1985), Hanna and Dujardin (1986)
Secale cereale	*Secale vavilovii*	Cytoplasmic male sterile and restorer system, cleistogamous and self-fertility	Kuvarin (1973)
Triticum spp. (cultivated)	Wild wheat; *Agropyron* spp.	Cytoplasmic male sterile and restorer system	Mann and Lucken (1972), Kuvarin (1973), Mann (1973)
Zea mays	*Tripsacum dactyloides*	Development of apomixis by distant hybridization	Belousova (1976)
General			
Glycine max	*Glycine soja*	Adaptability to colder regions and shorter-season	Carpenter and Fehr (1986)
Lycopersicon esculentum	*Lycopersicon hirsutum* and other wild tomatos	Salt tolerance, higher carotenoid content	Tal and Shanon (1983), Rick (1986)
Triticum spp. (cultivated)	*Agropyron* spp.	Winter hardiness	Kuvarin (1973), Mann (1973), Bothmer *et al.* (1992)
Vicia faba	*Vicia narbonensis*	Early pod and seedling growth	Roupakias (1986)

For utilization of wild relatives, there should be: (a) identification of wild genepool of the crop, (b) availability of sufficient material for screening and evaluation, and (c) appropriate method for gene transfer. In the Indian context, meagre information exists, that too pertaining to distribution, potential traits, crossability/ hybridization potential of some wild species with their crops. Emphasis needs to be laid on characterization/ evaluation for desirable traits and cataloguing for utilization. The knowledge on role of secondary genepool in crop evolution and potential/ desirable traits that wild species possess is insufficient. This area needs to be further investigated.

3

General Guidelines for Collection and Conservation

The basic objective of collection of crop genetic resources and their wild relatives is to conserve and utilize the variability in crop improvement programmes. They can be conserved *in situ*, in its natural habitats with protection of areas, rich in diversity or away from it, in genebanks, using an *ex situ* approach. Barriers to the gene flow from wild species to cultigens suggest secondary genepool having rich genetic diversity, not found in the cultigens (Ladizinsky, 1985).

The value for utilization of wild relatives would be more, if larger number of accessions from wider range of distributional habitats are collected, studied and conserved (Ladizinsky, 1989). The present collections of wild species maintained in genebanks worldwide lack adequate information or representation from the main habitats or the distributional range. This is the main reason why genebank holdings of wild relatives are under-utilized as compared to the cultivated germplasm.

Crop cultivar collections available with genebanks are likely to carry alleles already found in the existing collections and likely to be less important as compared to wild relatives which carry novel genepool for crop improvement programmes (Hawkes, 1977; Harlan, 1984; Brown and Marshall, 1986; Chapman, 1989). The importance of wild relatives in enhancing the genetic base has been discussed in the chapter 2.

Collection of Wild Relatives

Wild relatives have restricted eco-geographical and specific distribution and are difficult to collect. Many of the wild relatives are inconspicuous in nature, grow in smaller populations, and often found mixed with the wild species. This makes an inexperienced explorer rather confused while executing collection missions (Ladizinsky, 1989).

The explorations carried out for collection of plant genetic resources (PGR) differ from those for the floristic surveys which study the flora or vegetation of a region. The latter primarily help in listing the botanical richness of region alongwith taxonomic and eco-geographical aspects without dealing much with plant genetic diversity concept.

The field sampling procedure for collection of PGR captures the full range of genetic diversity of a region, in contrast to the exploration for floristic diversity where the true types are mainly aimed for collection. In view of deviation in the targets of exploration and collection for these two, different guidelines are followed to meet the objectives.

For collection of PGR, the spadework and background information is required, prior to proceeding for collection. Information on agro-ecological aspects of crops and their wild relatives, distribution, time of harvesting/ maturity, season of collection (for vegetative

propagules, the tubers, bud woods, etc.) and the areas to be surveyed, route maps, boarding facilities, mode of transport, equipments and other accessories, is required and needs to be worked out well in advance. The general sampling methodologies, logistics, and procedures for collection have already been published elaborately (Bennett, 1970; Hawkes, 1980; Arora, 1981b; Chang, 1985; Arora, 1991; Pareek *et al.*, 2000). General tips for the collection of wild relatives are given below (Box 3.1).

Modifications can be made as per the need of exploration missions (target areas/ species). General approach for collection of wild relatives is different from that of crop cultivars. Rescue collections of wild relatives are generally recommended in the natural habitats which are threatened due to their conversion into agricultural lands, urbanization, high pressure of grazing, commercial exploitation of the species, or proneness to natural calamities such as floods, drought, forest fires, etc. Some wild relatives also deserve collection on priority basis due to their confinement to specific locations (Arora and Nayar, 1984). Variation needs to be collected from the areas having large number of wild relatives rather than collecting the genepool in total. The representative sample should represent the breeders' and users' requirements.

Box 3.1 Collection and Conservation of Wild Relatives of Crop Plants: General Tips

- Identification of the targeted wild relatives using floristic records and other relevant information,
- Recording of distributional, ecological, morphological and phenological data from the literature,
- Collection of material from the cited location at proper time; preparation of herbarium from same or adjacent locations where species is recorded in flowering stage,
- Recording of significant observations such as depletion of population, migration from the site of occurrence (as per previous records or collection data) and causal factors, if apparent,
- Adopting suitable post-handling measures, depending on type of propagule (seed, corms, bulbs, rhizomes, etc.),
- Multiplication of seed/ propagating material, if received in insufficient quantity, using appropriate method (s),
- Identification of suitable regeneration site as per recommendations/ requirements, and
- Depositing sufficient quantity of properly processed material for long-term storage (the seed genebank, *in vitro* repository, cryobank, field genebank); herbarium and voucher seed samples in the national/ regional herbaria.

Collection and conservation of wild species are generally most effective when there is a specific requirement for research or for crop improvement programmes (Bothmer and Seberg, 1995). Passport data and the characterization data of available germplasm help in highlighting the priority for collection.

For example, there may be an urgent need to incorporate gene with desirable traits – source of resistance to abiotic stress (for example salinity, drought, frost, etc.) or biotic stress (diseases, pests, etc.). The desired traits may be systematically screened in genebank holdings of the targeted species, and related taxa in the primary and secondary genepool (Guarino *et al.,* 1995). The same may be screened in associated passport data accompanying the collected accessions. If the traits are not available in existing collections, missions are deliberately aimed to search for and collect the desired types in identified/ priority areas (Patra and Dhua, 2003). For collection of material, widely distributed areas having broader range of genetic diversity in wild relatives with the desired trait (s) or gene (s), should be explored. During collection trips, species occurring scanty or found depleted are given top priority.

For particular collections (or part of collection), the distribution of desired traits in the genepool is often poorly known. Field screening of germplasm with tolerance to abiotic stress in areas is based on species exposure to the stress factor for a considerable period. For example, possible sources of submergence tolerance in wild *Oryza* species can better be searched in germplasm collected from flood prone areas of India.

Strategies for collection of wild relatives differ from those of crop plants based on:

- Utilization or status (rare, endangered, high commercial value, etc.),
- Selection of target area (s)/ species distribution (s) or as per recommendations for special collection mission,
- Collection from geographically and ecologically diverse locations, and
- Emphasis on capturing variation among the species

For identification and locating wild relatives in the field, the following guidelines may be followed:

Determining wild relatives: The taxa under consideration include various forms of wild progenitors and members of secondary genepool. For establishing the relationship between crops and their related species, literature on botanical and genetical relationships and the monographs should be referred (Smart and Simmond, 1995). Collecting diversity of tertiary genepool is need-based. The non-traditional technologies such as genetic engineering and other biotechnological methods can be used to exploit the useful genes.

Recognising the morphology of target species: By using regional, local and national floras, the data from the herbarium specimens, the accounts on morphological details, diagnostic character (s) and range of variation can be obtained. The seed material is generally collected at the time of maturity of plant. Some of the identifiable characters such as leaf, floral characters, etc. are generally lost and difficult to detect at this stage. It is, therefore, recommended that the target species may also be examined at flowering or prior

to maturity before approaching for the field collection directly. On spot identification of target species and the off-types help adding variants or new species to the collection of valuable germplasm of wild species for genebank conservation.

Delimiting the eco-geographic distribution through survey: The wild relatives and related species are, by and large, distributed in specific habitats. Weedy species have wider distribution but some endemic types have narrow or restricted distribution (Arora and Nayar, 1984). The target species can be depicted for general/ specific distribution on maps. For location of a target species, the database, regional floristic records, monographs, herbarium material, plant collection reporters or recent publications can be consulted. In case, names of locality, village, district or state may change with time or the species may migrate or disappear from the mentioned locality, then broader areas may be considered.

Identification of ecological preferences: Linkages between the target species and the habitat preferences help in successful identification and collection of wild relatives in the field. Information about species co-associates, structure of community, habitat preference, migration/ disappearance from a locality, is also valuable clue for the collector.

Use of herbaria: Herbaria with large collections of plant genetic resources including wild relatives of crops assist the explorers in having an idea about the species diversity of a region. Herbarium field notes and associated data such as seed maturity of wild relatives from the locality of collection help in planning the duration of exploration. Since the herbarium specimens are generally collected during flowering, this information can be considered to be optimal for seed collection.

Documentation of passport information

Each germplasm accession is accompanied with a minimum set of information (the passport data) (Arora, 1991; Pareek *et al.*, 2000) which is useful for any future reference like place of collection, period/ time of collection, etc. For collection of wild material, passport data sheet, covering different fields has been standardized for reference to the users (Annexure I). The following details are included in passport data:

- Collector's name and affiliation, date of collection, collector's number
- Botanical information: name of the species, identity confirmed or requires confirmation
- The site of collection and exact geographical location (latitude and longitude)
- Ecological notes: topography, soil type, associated flora, habitat features (disturbed/ stable ecosystem)
- Population features: rare, endemic, common, uniformly distributed, patchy, contiguous, disjunct, etc.
- Information on diseases/ insect-pest resistance/ tolerance or other potential traits
- Type of material: seeds, vegetative propagules, leaf/ stem cuttings, bud wood, etc.

- Mode of propagation: seed, vegetative or others
- Seed maturity: synchronized, asynchronized
- Other material: economic products, ethnobotanically interesting material, etc.

Collection of herbarium specimens

Each germplasm sample should be supplemented with herbarium specimen (s) (Arora, 1981a). They serve as a source of confirming the identity of material raised from seeds and help in correct field identification and avoid manual/ mechanical mixing of the collected germplasm. Often good herbarium specimen cannot be prepared at the time of germplasm collection for which prior visits are necessary. The site of collection should be labeled to mark the target populations (Annexure II). The landmark showing location of herbarium collection must be recorded (Pandey and Venkateswaran, 1994).

Conservation of Wild Relatives

Cultivated plants and their wild relatives are important component of plant diversity and their conservation has been emphasized at various international fora. The wild relatives are less threatened with genetic erosion, provided their environment is protected (Jackson, 1995). This fast eroding plant diversity needs to be conserved using suitable conservation strategies. The wild relatives of crop plants can be conserved using two broader approaches namely, *in situ* and *ex situ* conservation. Wild species are maintained in their ecosystems within a natural or properly managed ecological continuum and evolve in the habitat to which they are adapted. This necessitates the formation of nature's reserve in appropriate climatic, altitudinal and latitudinal zones. However, for widely distributed species and those that occur in scattered pockets, *in situ* conservation strategies are insufficient and difficult. On one hand the *ex situ* conservation methods curtail the evolutionary process which is continuing in nature, on the other hand, the *in situ* conservation approach seems to be the only way to maintain diversity through evolutionary process. This method of conservation is ideal for wild relatives of crop plants, agro-forestry species, endangered and nearly extinct species, where there are limitations on the effectiveness of *ex situ* methods.

Conservation of wild relatives using *in situ*/ on-farm can be successfully achieved by providing special incentives to farmers/ local people for growing difficult or uneconomical material on private land or domestic gardens. The village communities may get the benefits through watershed management, wild life habitats and environmental stabilization. Conservation of diversity of cultivated plants on private land using on-farm approach and their wild relatives in the landscape has been strongly recommended (Gadgil *et al.*, 1996).

The biosphere reserves (an approach for maintaining the integrity and biological support for man and nature represent means for maintaining the genepool of microorganisms, plant species and animals) can be used to conserve the wild species of a region. The species diversity may be identified for conservation in the biosphere reserves, located in different regions (Table 3.1).

Table 3.1 Established biosphere reserves in India

Site (Area in sq km)	Date of notification	Location (State)
1. Nilgiri (5,520)	01.08.1986	Parts of Wynad, Nagarhole, Bandipur and Madhumalai, Nilambur, Silent Valley and Siruvani Hills (Tamil Nadu, Kerala and Karnataka): Western Ghats
2. Nanda Devi (5,860.69)	18.01.1988	Parts of Chamoli, Pithoragarh and Almora districts (Uttaranchal)
3. Nokrek (820)	01.09.1988	Parts of Garo Hills (Meghalaya): Eastern Himalaya
4. Manas (2,837)	14.03.1989	Parts of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup and Darang districts (Assam): Eastern Himalaya
5. Sundarbans (9,630)	29.03.1989	Parts of delta of Ganges and Brahmaputra river system (West Bengal): Gangetic Delta
6. Gulf of Mannar (10,500)	18.02.1989	Indian part of Gulf of Mannar between India and Sri Lanka (Tamil Nadu): Coastal regions
7. Great Nicobar (885)	06.01.1989	Southern most Islands of Andaman and Nicobar Islands (A & N)
8. Simlipal (4,374)	21.06.1994	Parts of Mayurbhanj district (Orissa): Deccan Peninsula
9. Dibru-Saikhowa (765)	28.07.1997	Parts of Dibrugarh and Tinsukia districts (Assam): Eastern Himalaya
10. Dehang-Debang (5,112)	02.09.1998	Parts of Siang and Debang Valley (Arunachal Pradesh): Eastern Himalaya
11. Pachmarhi (4,926)	03.03.1999	Parts of Betul, Hosangabad and Chindwara districts (Madhya Pradesh): Semi-arid regions
12. Kanchanjanga (2,619)	07.02.2000	Parts of Kanchanjanga Hills (Sikkim): Eastern Himalaya
13. Agasthiyamala (1,701)	12.11.2001	Neyyar, Peppara and Shenduruny Wildlife Sanctuaries and their adjoining areas (Kerala)

Source: Das (2000); MoEF (2003)

Gadgil *et al.* (1996) have cited following guiding principles for *in situ* conservation of wild relatives of crop plants:

- Management of the entire landscape using ecosystem approach.
- Establishment of priorities for conservation at the habitat level. For any region, these may be arrived at through: (a) Inventorisation; (b) Mapping the distribution of habitat types in the region as types of landscape elements (LSEs) with the help of satellite imagery alongwith field survey data; (c) Association of groups of wild relatives with different types of LSEs on the basis of field surveys; (d) Assessment of rates of transformations of LSE types with the help of satellite imagery of earlier years, official records and oral history; (e) Assessment of threats; (f) Assignment of conservation priorities on the basis of likely threats to their populations, rarity, endemicity, economic use and taxonomic distinctiveness; and (g) Assignment of conservation priorities to different types of habitats or landscape elements on the basis of richness and conservation significance.
- Assessment of protected area systems in terms of diversity in WRCPs and conservation of habitats using appropriate methods.
- Management of habitats important from the perspective of WRCPs conservation outside the protected area systems by providing appropriate inputs to the process of development planning.
- Regular monitoring of conservation efforts with respect to ongoing ecological changes and appropriate adjustment of the regime of management of habitats of WRCPs both within and outside the protected area systems.
- Involvement of local communities as active partners in conservation of WRCPs both within and outside the protected areas by awarding positive incentives.

The *ex situ* conservation broadly includes, conserving seed or vegetative material in genebanks, the botanic gardens and field genebanks (where clonal materials are maintained as living collections in a field/ orchard or plantation). The germplasm maintained in field genebanks is at the potential risk of being lost due to diseases, stress or disaster and requires more space and labour to maintain a small proportion of diversity. Germplasm conserved in cryogenebanks serves as complementary holdings for base collections.

In the seed genebank, under ideal storage conditions the mean viability is greatly extended by reducing the life processes to a low level. Successful seed storage depends on effective control of several factors including temperature, seed moisture content, storage atmosphere, etc. in response to storage conditions. If there are large number of collections represented from an area, genebank holdings may be reduced to manageable proportions (Frankel and Brown, 1984; Schoen and Brown, 1995).

The choice of *in situ* and *ex situ* conservation necessarily requires an assessment to alternate strategies to ensure long-term conservation of the species. The conservation strategy depends on the life cycle, mode of reproduction, need for conservation and distribution/ ecological status. Despite specific habitat requirements and problems associated

with maintenance, *in situ* conservation methods are proposed to be the ideal (Singh, 2002). However, the germplasm of wild relatives maintained in *ex situ* collection in genebank can serve as an alternative for conservation and is ideal for utilization.

Species in danger of severe genetic erosion or extinction need highest priority for collection and conservation (Patra and Dhua, 1998; 2003). Efforts invested towards finding out information on existing collections of wild relatives in the genebanks are helpful in deciding priority of the species to be conserved. The material conserved in long-term storage in a genebank should be representative of the genetic variation within each species of the target genepool. The poor ecological coverage of wild relative collections demands re-collection of material for conservation in the genebanks.

Material collected through explorations is generally insufficient or does not qualify the genebank germination standards. In view of the potential importance of the material, a standard of 85 per cent germination may be relaxed for wild relatives (Khanna and Singh, 1991, Khanna *et al.,* 1989). For conserving germplasm as base collection, if material is insufficient, it needs to be multiplied in fields or under natural conditions. A comparative assessment may be sought for adopting suitable strategy (Table 3.2).

Table 3.2 Comparative advantages and disadvantages of germplasm collections augmented through explorations and multiplied under field conditions

Parameter (s)	Collections from explorations	Collections from field multiplication/ seed increase
1. Botanical identity	Needs identification/ confirmation before conservation	Identity is confirmed after study
2. Seed quantity	Generally insufficient	Enough quantity is obtained for storage in genebank
3. Seed quality	Generally a heterogeneous mixture of mature and immature seeds	Comparatively better seed quality is obtained
4. Type of material	Good for seed propagated species; difficult for vegetatively propagated material	All types of genetic resources can be taken care of
5. Seed harvesting	Not controlled; difficult due to asynchronized seed maturity	Managed by field operations such as gathering, bagging, etc.
6. Disease/ pests occurrence	As in nature; hidden infestation may occur	May be protected through field management practices

contd.

Parameter (s)	Collections from explorations	Collections from field multiplication/ seed increase
7. Influence of other factors/ disturbance/ genetic erosion	Species may get influenced due to various natural factors	Mostly under control
8. Cost effective	Seed collection along with other explorations is rather difficult; collecting large quantity of material requires additional funds and manpower	After setting up of germination/ multiplication protocols, enough seed is produced for conservation

Phytogeographical regions with large number of wild relatives (centres of diversity), qualify for top priority for collection. Higher priority may be given to the species within the genepool that are most easily used and those that are trait-specific, endemic, vulnerable, rare and endangered or having high commercial value. Intensive explorations should be made to collect material from populations in marginal areas, unusual, distinctive or isolated habitats, having greater possibility of representing distinct taxa with unique traits.

Major concern in conservation of plant genetic wealth of wild relatives is that distributional area for many of them is shrinking fast due to various bio-edaphic/ ecological and socio-economic reasons. Rehabilitation of such wealth by adopting *ex situ* measures or through protection of habitats using *in situ* measures is desirable for *Saccharum, Citrus* and *Musa* spp. and others in the north-eastern region; *Lathyrus, Crotalaria, Linum, Prunus, Pyrus* and *Allium* in the western Himalaya and *Vigna, Crotalaria, Garcinia, Artocarpus, Zingiber* and *Piper* species in Ghats, in peninsular region and *Mangifera, Zingiber* and *Piper* spp. in Andaman & Nicobar Islands.

***Annexure* I**

National Bureau of Plant Genetic Resources
New Delhi 110 012, India
Passport Data Sheet

Mission code:_____ Date of start:_____ Date of completion:_____
Cooperating/ collaborating institute (s):_____
Name and address of cooperator (s)/ collaborator (s):_____
Phyto-geographical Zone:_____

Date:_____ Collector's No.:_____ Accession No.:_____
Botanical name:_____ Common name (English):_____ Vernacular name:_____
Cultivar name:_____ Region explored:_____ Village:_____
Block:_____ District:_____ State:_____
Latitude :_____°N Longitude :_____°E Altitude :_____m
Temperature (°C):_____ Total rainfall (mm):_____

Biological status : 1. Landrace 2.Wild 3.Primitive cultivar 4. Weedy type 5. Natural hybrid 6.Mutant 7.Chimera 8. Others (specify)

Season : 1. Kharif 2. Rabi 3. Spring 4. Summer

Collection site : 1.Field 2.Wild 3.Forest 4. Market 5. Farm store 6.Threshing floor 7.Plantation 8.Farmer's store 9.Institute 10.Others (specify)

Frequency : 1. Abundant 2. Frequent 3. Occasional 4. Rare/ Endangered

Sample type : 1. Population 2. Pure line 3. Individual type

Sampling method : 1. Bulk 2. Random 3. Selective (non-random)

Habitat : 1. Cultivated 2. Disturbed 3. Partly disturbed 4. Rangeland 5.Others (specify)

Disease symptoms : 1. Susceptible 2. Mildly susceptible 3. Tolerant 4. Resistant 5. Immune

Associated crops/ flora : 1. Sole 2. Mixed with_____

Cultural practices : 1. Irrigated 2. Rainfed 3. Arid 4. Wet 5.Others (specify)

Soil : 1. Colour_____ 2. Texture_____ 3. Soil fertility: a. poor b. medium c. high

Topography : 1. Swamp 2. Floodplain 3. Level 4. Undulating 5. Hilly dissected 6. Valley 7. Others (specify)

Type of germplasm collected : 1. Seed 2. Fruit 3.Vegetative propagule (Root, tuber, rhizome, suckers) 4. Live plant 5. Others (specify)

Seed characters : Size: 1. Small..... 2. Medium..... 3. Large.....
Seed shape: .....; Seed coat type: 1. Smooth 2. Rough;
Seed colour.....;
Maturity: 1. Synchronized 2. Partly synchronized 3. Asynchronized
Shattering: Yes/ No

Characters of vegetative propagule (tuber, bud wood, etc.) : Shape_____ Size (L x B)_____ Av. weight (g)_____ TSS_____ Flesh colour_____ Aroma _____ Stage of ripeness and proposed time for collection_____

Obvious reasons for genetic erosion : 1. Nil 2. Due to less population 3. Commercial exploitation 4. Plant succession 5. Grazing 6. Biotic/ abiotic factors (specify) 7. Any other

Economic value of germplasm (if any) : 1. Domestic use 2. Commercial use 3. Potential use 4. Use not known

Additional material (if collected) : 1. Herbarium specimen 2. Economic product 3. Others

Specific traits/ characteristics of plant (if known):

Ethnobotanical uses and associated indigenous knowledge:

Farmer's/ Donor's name:_____ Community/ Ethnic group:_____
Address:_____

***Annexure* II**

National Bureau of Plant Genetic Resources
New Delhi 110 012, India
Herbarium Record

Botanical name	:	
Family	:	
Common/ English name	:	
Local name	:	
Locality (place, town, distt., state)	:	
Date of collection	:	
Collector's name and IC number	:	
Herbarium collected alongwith germplasm of wild relatives	:	Yes/ No
Field collection/ grown in experimental conditions	:	
Identified by	:	Self/ others
Number of specimens	:	
Additional material collected	:	Seed/ fruit/ economic product
Uses, if any, in locality of collection	:	
Notes	:	
Herbarium specimen number	:	

Source: Arora (1981a)

4

Collection and Conservation of Wild Relatives

In the present international scenario, global climatic changes, unsustainability of high input agriculture, search for novel genes for food and nutrition, biotic and abiotic stresses have increased the focus on collection, conservation and utilization of potential diversity in the years to come. More and more plant species have to be tested against the threat of nature and to meet with the challenges. There is, thus, an urgent need to initiate targeted collection and conservation of plant genetic resources including wild relatives of crop plants, and their characterization/ evaluation, thereafter, for future use.

Collection of Wild Relatives

The collection missions are primarily aimed at tapping germplasm variability in plant genetic resources of different agri-horticultural crops and their wild relatives in the entire genepool. The germplasm is collected on the basis of priority for collection from targeted regions, and (or) of species. The information on ecological distribution with precise location of species helps in collection of targeted genepool. Detailed guidelines for collection of germplasm of wild relatives are given in chapter 3.

The systematic plant germplasm exploration and collection work started with the establishment of the Division of Botany, Imperial Agricultural Research Institute (now Indian Agricultural Research Institute, New Delhi) in 1946. Collections of crop specific germplasm and their wild relatives were made during mid nineteen fifties to seventies. The exploration activities were further systematized with the creation of NBPGR in 1976. During the period 1976-1999, valuable genetic resources were augmented from diverse habitats through region specific/ multi-crop exploration activities involving Regional Stations and the Base Centres. The decade (1987-97) witnessed with collaborative activities, both nationally and globally.

Wild relatives were collected during crop exploration missions, undertaken with foreign collaborators under Memorandum of Understandings. The major collections were made in wild/ weedy relatives of *Brassica* under PL-480 Scheme and Indo-Canadian Mission from different parts of North India; herbaceous grasses and legumes under Indo-Australian Mission from central India, Deccan Plateau and Peninsular region; rices under Indo-Japanese Mission from Madhya Pradesh, peninsular region and with IRRI from north Orissa, North and South Bihar, West Bengal, coastal and mountainous regions of Tamil Nadu, Kerala, Cuttack, Chhotanagpur, Chhattisgarh, Madhya Pradesh, eastern Uttar Pradesh and foothills of Himalaya; *Cucumis* with Indo-United States Agency for International Development from Rajasthan, Madhya Pradesh and Uttaranchal; and under Indo-Japanese Mission from Madhya Pradesh and peninsular region; *Sesamum* from South Asia and southern India; *Abelmoschus* and *Solanum* with IPGRI from Orissa, Eastern Ghats, Rajasthan and adjoining areas; and *Pennisetum* and *Atylosia* with ICRISAT from different parts of Tripura and Uttaranchal.

Under foreign collaborations, wild relatives of *Abelmoschus* and *Solanum* were collected from Sri Lanka and sunflower from USA.

Since August 1976 to March 2004, a total of 2,10,698 accessions of economically important agri-horticultural crops and their wild relatives (representing 1,87,580 accessions of cultivated and 23,118 accessions of wild species) have been assembled through 2,352 explorations, undertaken in different agro-ecological regions of the country (Table 4.1).

Table 4.1 Explorations undertaken and germplasm collected (1976-2004)

Years	Exploration	Germplasm (no. of accessions)		
	(number)	Cultivated	Wild*	Total
1976-79	28	12280	227	12507
1979-83	41	17165	293	17458
1983-87	122	27039	330	27369
1987-91	217	32125	2983	35108
1991-95	125	11043	1249	12292
1995-99	101	7302	1324	8626
Total	**634**	**106954**	**6406**	**113360**
1999-2000	207	10199	2993	13192
2000-01	419	21857	3982	25839
2001-02	387	19714	4068	23782
2002-03	509	15147	3789	18936
2003-04	196	13709	1880	15589
Total	**1718**	**80626**	**16712**	**97338**
Grand Total	**2352**	**187580**	**23118**	**210698**

Source: NATP (1999); NATP (1999-2004)
* Includes wild relatives of crop plants

The diversity in wild relatives collected during 1976-2004 was represented by 51 families, 124 genera and 389 species. The major diversity under different genera in wild relatives collected from different phyto-geographical regions has been depicted in Fig. 4.1. The diversity was classified crop group-wise (species given in parenthesis) as cereals and millets (18), legumes (27), oilseeds (16), fibres (21), vegetables (59), tubers (26), fruits (114), spices and condiments (74), medicinal and aromatic plants (26) and others (20). In the present analysis, wild relatives of crop plants broadly include wild/ weedy relatives and distantly related taxa of the crop genepool. By and large wild relatives of medicinal and aromatic plants, ornamentals and other lesser-known species have not been included.

The collected diversity revealed the species richness in genera *Piper* (18 species), *Dioscorea* and *Vigna* (16 species each), *Curcuma* (14 species), *Solanum* (12 species), *Citrus*, *Syzygium* and *Zingiber* (11 species each), *Cinnamomum* (10 species), *Allium* (9 species),

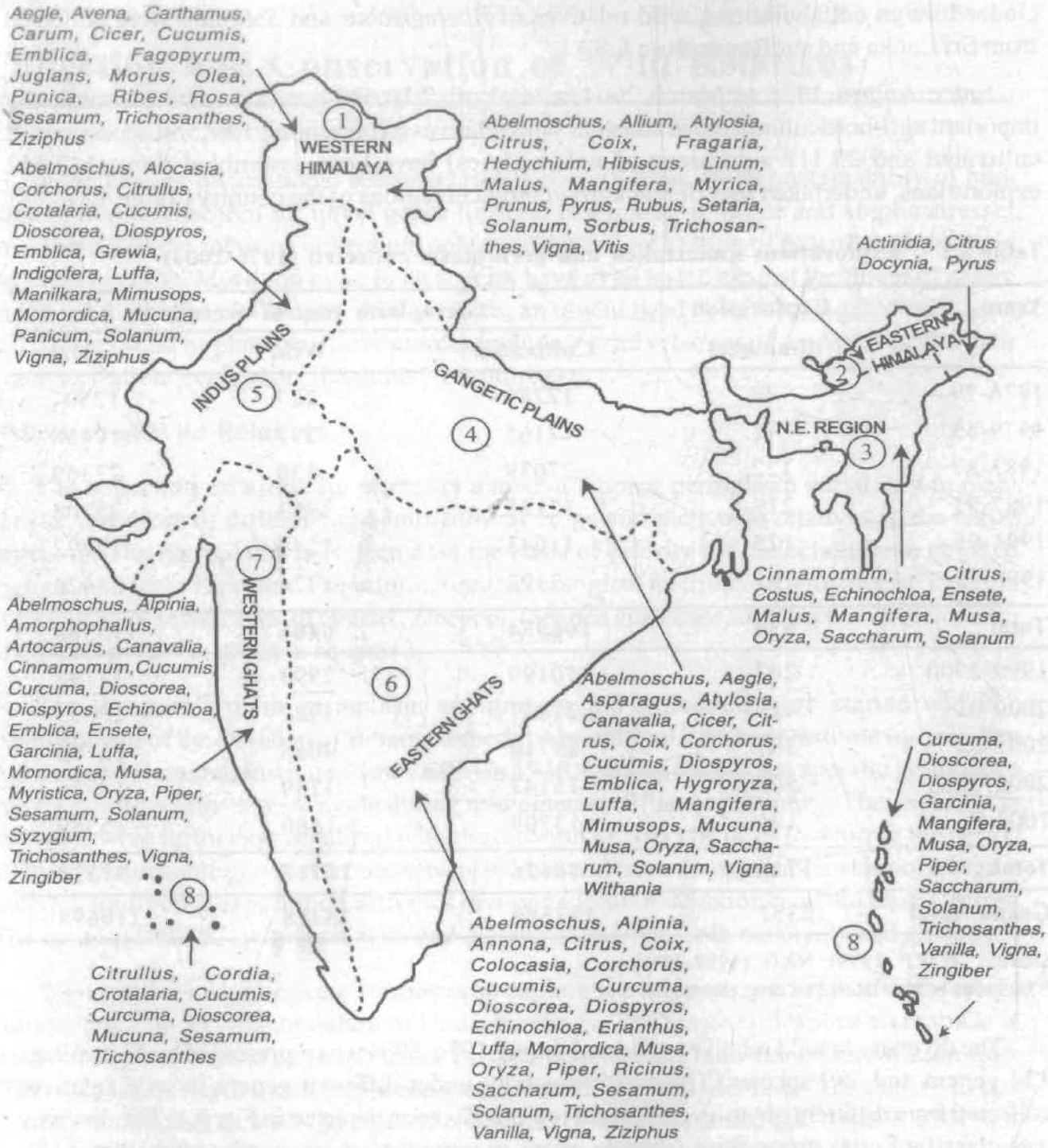

Fig. 4.1 Collection of wild relatives of crop plants from different phyto-geographical regions of India (1999-2004)

Momordica, Oryza and related genera, *Trichosanthes* and *Sesamum* (6-7 species each). Total species diversity was represented by Fabaceae (41), Zingiberaceae (37), Rosaceae (29), Cucurbitaceae (25), Poaceae (22), Piperaceae (18), Dioscoreaceae and Malvaceae (16 each), Solanaceae (15), Rutaceae (13) and Myrtaceae (11) as major families (Fig. 4.2).

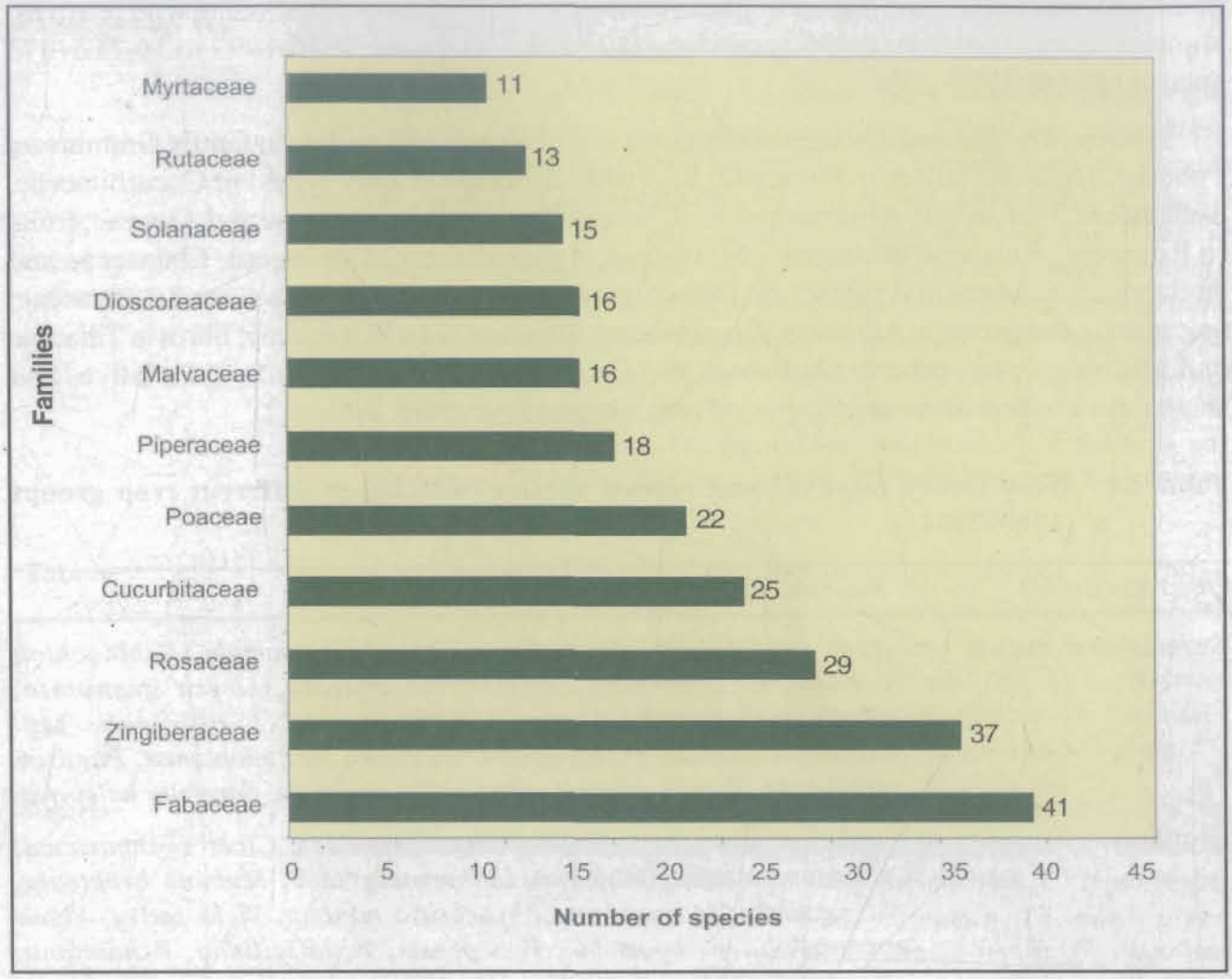

Fig. 4.2 Collections of wild relatives (1976-2004) representing major families and species (number)

Collections made under National Agricultural Technology Project

Under National Agricultural Technology Project (NATP) on Sustainable Management of Plant Biodiversity under Jai Vigyan National Science and Technology Mission, germplasm of wild/ weedy relatives of crop plants was collected from different phyto-geographical regions of the country. Besides, significant diversity in trait specific germplasm, landraces, primitive cultivars, under-utilized/ less-known cultivated plants, wild economic types and rare, threatened/ vulnerable, endangered species was also assembled.

During the period 1999-2004, a total of 16,712 accessions of a large number of wild species including wild/ weedy relatives of crop plants (3,030 accessions) were, collected through 1,718 explorations from different phyto-geographical regions of India. The collected germplasm of wild and weedy types belong to 48 families representing 120 genera and 373 species. The diversity collected during 1999-2004 was classified crop group-wise (species given in parenthesis) as cereals and millets (17), legumes (26), oilseeds (16), fibres (19), vegetables (59), tubers (24), fruits (111), spices and condiments (71), medicinal and aromatic

plants (26) and others (16). The germplasm collections of wild species (including wild relatives) showed an increase from 6,406 accessions (125 species) during 1976-1999 to 16,712 (373 species) during 1999-2004.

Botanically, this assemblage mainly consisted of cereals and millets in family Gramineae/ Poaceae; legumes/ pulses in Fabaceae; vegetables (including leafy types) in Cucurbitaceae, Solanaceae, Malvaceae, Amaranthaceae, Chenopodiaceae, Polygonaceae and Araceae; fruits in Rosaceae, Rutaceae, Musaceae, Myrtaceae, Anacardiaceae, Clusiaceae, Ebenaceae and Juglandaceae; tubers in Araceae and Dioscoreaceae; oilseeds in Pedaliaceae and Asteraceae; spices and condiments in Alliaceae, Zingiberaceae, Piperaceae and Lauraceae; fibres in Tiliaceae and Malvaceae; and others in Liliaceae and Orchidaceae. An account of wild relatives and related taxa collected during the period under report is given in Table 4.2.

Table 4.2 Wild/ weedy relatives and related species collected in different crop groups (1999-2004)

Crop group (s)	Species diversity
Cereals and millets	: *Aegilops tauschii*, *Avena fatua*, *Coix lacryma-jobi*, *Echinochloa colona*, *E. crus-galli*, *Hygroryza aristata*, *Oryza granulata*, *O. meyeriana*, *O. nivara*, *O. officinalis*, *O. officinalis* ssp. *malampuzhaensis*, *O. rufipogon*, *O. sativa* var. *spontanea*, *Panicum antidotale*, *P. pedicellatum*, *Porteresia coarctata*, *Sorghum halepense*
Legumes	: *Atylosia cajanifolia*, *Cajanus scarabaeoides*, *Cicer soongaricum*, *Cyamopsis tetragonolobus*, *Lathyrus aphaca*, *Mucuna bracteata*, *M. capitata*, *M. pruriens*, *Rhynchosia minima*, *Vicia sativa*, *Vigna aconitifolia*, *V. bourneae*, *V. capensis*, *V. dalzelliana*, *V. hainiana*, *V. khandalensis*, *V. marina*, *V. mungo* var. *silvestris*, *V. pilosa*, *V. radiata* var. *setulosa*, *V. radiata* var. *sublobata*, *V. trilobata* var. *pusilla*, *V. trilobata* var. *trilobata*, *V. umbellata*, *V. vexillata*, *V. wightii*
Oilseeds	: *Brassica quadrivalvis*, *B. tournefortii*, *Carthamus lanatus*, *C. oxyacanthus*, *Lepidium capitatum*, *Madhuca longifolia*, *Olea ferruginea*, *O. glandulifera*, *Ricinus communis*, *Sesamum alatum*, *S. indicum* ssp. *anamalayensis*, *S. laciniatum*, *S. malabaricum*, *S. mulayanum*, *S. prostratum*, *S. radiatum*
Fibres	: *Corchorus aestuans*, *C. capsularis*, *C. depressus*, *C. pseudo-olitorius*, *C. tridens*, *C. trilocularis*, *Crotalaria alata*, *C. burhia*, *C. medicaginea*, *C. pallida*, *C. retusa*, *C. tetragona*, *Gossypium arboreum*, *Hibiscus cannabinus*, *H. radiatus*, *H. tiliaceus*, *Linum perenne* ssp. *perenne*, *Urena lobata* var. *lobata*, *Urena lobata* var. *sinuata*
Vegetables	: *Abelmoschus angulosus*, *A. crinitus*, *A. ficulneus*, *A. moschatus* ssp. *manihot*, *A. moschatus* ssp. *moschatus*, *A. tetraphyllus* var. *pungens*, *A. tetraphyllus* var. *tetraphyllus*, *A. tuberculatus*, *Amaranthus blitum*, *A. caudatus*, *A. cruentus*, *A. gangeticus*, *A. spinosus*, *A. viridis*,

contd.

Crop group (s)	Species diversity
	Artocarpus heterophyllus, *A. lakoocha*, *Canavalia ensiformis*, *Carissa congesta*, *Chenopodium album*, *Citrullus colocynthis*, *Coccinia cordifolia*, *Cordia myxa*, *C. rothii*, *Cucumis callosus*, *C. melo* var. *agrestis*, *C. prophetarum*, *C. sativus* var. *hardwickii*, *C. sativus* var. *hardwickii* x *C. melo* (hybrid), *Fagopyrum cymosum*, *Hibiscus radiatus*, *Luffa acutangula* var. *amara*, *L. echinata*, *L. hermaphrodita*, *Malva rotundifolia*, *Momordica balsamina*, *M. charantia* var. *muricata*, *M. cochinchinensis*, *M. denudata*, *M. dioica*, *M. tuberosa*, *Solanum ferox*, *S. giganteum*, *S. incanum*, *S. indicum*, *S. khasianum*, *S. mammosum*, *S. nigrum*, *S. spirale*, *S. surattense*, *S. sisymbrifolium*, *S. torvum*, *S. viarum*, *Trichosanthes bracteata*, *T. bracteata* var. *tomentosa*, *T. cucumerina* var. *anguina*, *T. cucumerina* var. *cucumerina*, *T. dioica*, *T. nervifolia*
Tubers	: *Alocasia macrorrhiza*, *Amorphophallus bulbifer*, *A. dubius*, *A. hohenackeri*, *A. paeoniifolius* var. *campanulatus*, *A. sylvaticus*, *Colocasia esculenta*, *C. fallax*, *Dioscorea alata*, *D. bulbifera*, *D. deltoidea*, *D. esculenta*, *D. glabra*, *D. hispida*, *D. intermedia*, *D. oppositifolia*, *D. pentaphylla*, *D. puber*, *D. spicata*, *D. tomentosa*, *D. wallichii*, *D. wightii*, *Moghania vestita*, *Xanthosoma nigrum*
Fruits	: *Actinidia callosa*, *Aegle marmelos*, *Annona muricata*, *A. reticulata*, *Artocarpus gomesianus*, *A. heterophyllus*, *A. hirsutus*, *A. lakoocha*, *Carissa congesta*, *C. spinarum*, *Citrus assamensis*, *C. ichangensis*, *C. indica*, *C. jambhiri*, *C. latipes*, *C. limon*, *C. macroptera*, *C. madurensis*, *C. megaloxycarpa*, *C. pseudolimon*, *C. rugulosa*, *Cordia dichotoma*, *C. myxa*, *C. rothii*, *Democarpus longan*, *Diospyros blancoi*, *D. buxifolia*, *D. chloroxylon*, *D. kaki*, *D. lotus*, *D. marmorata*, *D. melanoxylon*, *D. montana*, *D. peregrina*, *Docynia indica*, *Duchesnea indica*, *Elaeocarpus serratus*, *Emblica officinalis*, *Ensete glaucum*, *E. superbum*, *Ficus palmata*, *Fragaria daltoniana*, *F. nilgerrensis*, *Garcinia cowa*, *G. gummi-gutta*, *G. imbertii*, *G. indica*, *G. morella*, *G. xanthochymus*, *Grewia subinaequalis*, *G. hirsuta*, *G. tenax*, *Juglans nigra*, *J. regia*, *Madhuca longifolia*, *Malus baccata* var. *himalaica*, *M. baccata* var. *baccata*, *M. sikkimensis*, *Mangifera andamanica*, *M. camptosperma*, *M. indica*, *M. sylvatica*, *Manilkara hexandra*, *M. littoralis*, *Mimusops elengi*, *Morus alba*, *M. serrata*, *Musa acuminata* x *M. balbisiana*, *M. acuminata*, *M. balbisiana*, *M. ornata*, *M. velutina*, *Myrica esculenta*, *Phoenix rupicola*, *P. sylvestris*, *P. zeylanica*, *Physalis minima*, *Prunus armeniaca*, *P. cerasoides*, *P. cornuta*, *P. jacquemontii*, *P. napaulensis*, *Punica granatum*, *Pyrus pashia*, *P. pyrifolia* var. *pyrifolia*, *Ribes glaciale*, *R. grossularia*, *R. nigrum*, *Rubus ellipticus*, *R. fruticosus*, *R. niveus*, *R. rosaefolius*, *Sorbus foliolosa*, *S. lanata*, *Spondias pinnata*, *Syzygium bourdillonii*, *S. caryophyllatum*, *S. cordifolium*,

contd.

Crop group (s)	Species diversity
	S. cumini, S. gardneri, S. hemisphericum, S. laetum, S. mundagum, S. samarangense, S. travancoricum, Vitis parvifolia, Ziziphus mauritiana, Z. nummularia, Z. oenoplia, Z. rugosa, Z. xylopyrus
Spices and condiments:	*Allium auriculatum, A. carolinianum, A. govanianum, A. hookerii, A. rubellum, A. stracheyi, A. tuberosum, A. victorialis, A. wallichii, Alpinia calcarata, A. galanga, A. malaccensis, Amomum aculeatum, A. acuminatum, A. cannicarpum, Carum carvi, Cinnamomum cassia, C. filipedicillatum, C. macrocarpum, C. multiflorum, C. nitidum, C. sulphuratum, C. tamala, C. wightii, C. zeylanicum, Curcuma amada, C. angustifolia, C. aromatica, C. caesia, C. longa, C. lutea, C. malabarica, C. montana, C. neilgherrensis, C. nilamburensis, C. oligantha, C. pseudomontana, C. zedoaria, Globba bulbifera, G. pauciflora, Hedychium spicatum, Murraya koenigii, Myristica malabarica, Piper argyrophyllum, P. bababudani, P. bantamense, P. barberi, P. betle, P. colubrinum, P. galeatum, P. hapnium, P. hymenophyllum, P. longum, P. mullesus, P. nigrum, P. thomsoni, P. trichostachyon, Zingiber cernuum, Z. neesanum, Z. nimmonii, Z. odoriferum, Z. officinale, Z. pseudomontana, Z. purpureum, Z. roseum, Z. rubens, Z. spectabile, Z. wightianum, Z. zerumbet*
Medicinal and aromatic plants	*Achyranthes aspera, Aconitum ferox, A. heterophyllum, Acorus calamus, Asparagus adscendens, A. dumosus, A. racemosus, Cannabis sativa, Carthamus lanatus, C. oxyacanthus, Chlorophytum borivilianum, C. breviscapum, C. laxum, C. orchidastrum, C. tuberosum, Cichorium endivia, C. intybus, Citrullus colocynthis, Costus speciosus, Diplocyclos palmatus, Mentha longifolia, Rauvolfia serpentina, R. tetraphylla, Tagetes minuta, Vanilla wightii, Withania somnifera*
Others	*Cichorium endivia, C. intybus, Erianthus arundinaceus, E. munja, Fagopyrum cymosum, Indigofera tinctoria, Rosa brunonii, R. macrophylla, R. sericea, Saccharum arundinaceum, S. spontaneum, Sapindus mukorossi, S. trifoliatus, S. trifoliatus* var. *emarginatus, Trifolium pratense, T. repens*

Source: NATP (1999-2004)

Through intensive surveys and explorations carried out in different phyto-geographical regions all over the country, wide diversity was assembled in wild relatives and related species belonging to genera: *Coix, Oryza, Panicum, Atylosia, Lathyrus Crotalaria, Corchorus, Hibiscus, Linum, Abelmoschus, Amaranthus, Artocarpus, Citrullus, Cucumis, Luffa, Momordica, Solanum, Trichosanthes, Amorphophallus, Dioscorea, Citrus, Diospyros, Fragaria, Garcinia, Malus, Mangifera, Musa/ Ensete, Prunus, Pyrus, Ribes, Syzygium, Ziziphus, Allium, Cinnamomum, Curcuma, Piper, Zingiber, Cichorium, Erianthus, Rosa*

and *Saccharum*. Significant collections made from diverse habitats in different phyto-geographical regions (in crop groups) are given below (Table 4.3).

Table 4.3. Significant collections of wild relatives of crop plants (1999-2004)

Species	Area (s) of collection
Cereals and millets	
Aegilops tauschii	Himachal Pradesh
Avena fatua	Chamoli (Uttaranchal)
Oryza nivara; *O. meyeriana* ssp. *granulata*, *O. officinalis*; *O. rufipogon*	Eastern Uttar Pradesh; Western Ghats (Kerala and Tamil Nadu), Bihar and Orissa; Eastern Uttar Pradesh, southern and central regions of Kerala
Porteresia coarctata	Sunderban region (West Bengal)
Legumes	
Atylosia cajanifolia	Mahendragiri, Gajapatti (Orissa)
Cajanus scarabaeoides	Jharkhand, Chhattisgarh and Dehra Dun (Uttaranchal)
Lathyrus aphaca	Kashmir (J & K)
Vigna dalzelliana, *V. hainiana*; *V. khandalensis*; *V. radiata* var. *sublobata*, *V. trilobata*, *V. umbellata*	Rajasthan, Maharashtra, Andhra Pradesh, North-western Himalaya, Madhya Pradesh and Orissa; Western Ghats, Pune (Maharashtra); southern parts of Western Ghats, Himachal Pradesh, Madhya Pradesh and coastal region of Kanyakumari (Tamil Nadu)
Vigna mungo var. *silvestris*	Western Ghats and parts of Rajasthan, Maharashtra, Madhya Pradesh
Oilseeds	
Sesamum alatum, *S. laciniatum*, *S. prostratum*; *S. mulayanum*	Kerala, Tamil Nadu and Andhra Pradesh; Kerala, Tamil Nadu, Madhya Pradesh, Maharashtra, Orissa, Maharashtra and Uttaranchal
Fibres	
Corchorus pseudo-olitorius; *C. capsularis*; *C. trilocularis*	North West Rajasthan, Tamil Nadu; Runn of Kuchchh, Sunderban region (West Bengal); North Gujarat
Crotalaria tetragona	Uttaranchal
Linum perenne	Cold desert of Lahul and Spiti (Himachal Pradesh)

contd.

Species	Area (s) of collection
Vegetables	
Abelmoschus crinitus; *A. tetraphyllus*; *A. tuberculatus*; *A. ficulneus*	Cold arid tracts of Chamoli district (Uttaranchal), Vidarbha (Maharashtra); Madhya Pradesh, Orissa, Goa, Chhattisgarh and Rajasthan; Madhya Pradesh, Maharashtra and Rajasthan; Vidarbha (Maharashtra)
Cucumis melo var. *agrestis*, *C. melo* var. *momordica*; *C. sativus* var. *hardwickii*	Rajasthan, western Uttar Pradesh, Punjab; Madhya Pradesh, Uttaranchal, Himachal Pradesh, Orissa, Chhattisgarh, Maharashtra, Goa
Solanum incanum; *S. indicum*; *S. khasianum*; *S. torvum*	Tamil Nadu, Gujarat; Madhya Pradesh, Gujarat; Madhya Pradesh, Meghalaya and Orissa; Kerala and Tamil Nadu (Western Ghats), Andhra Pradesh and Orissa
Trichosanthes cucumerina var. *anguina*, *T. bracteata*; *T. dioica*	Tamil Nadu; Uttaranchal, Western Ghats and coastal regions of Kerala
Dioscorea alata, *D. bulbifera*; *D. oppositifolia*, *D. tomentosa*, *D. wallichii*	Andhra Pradesh, Gujarat; extreme southern Western Ghats (Kerala)
Fruits	
Citrus assamensis, *C. ichangensis*, *C. indica*, *C. latipes*, *C. macroptera*, *C. megaloxycarpa*; *C. madurensis*	Himalaya and North-eastern region; East Godavari (Andhra Pradesh)
Ensete glaucum; *Musa acuminata*, *M. ornata*	Deep forsts of Mizoram; Western Ghats and coastal regions of Kerala
Garcinia indica, *G. morella*, *G. xanthochymus*	Western Ghats
Mangifera andamanica; *M. indica*; *M. sylvatica*	Andaman and Nicobar Islands; Western Ghats (Sirsi Forests, Karnataka); North Eastern Hill
Syzygium caryophyllatum, *S. cumini*, *S. hemisphericum*, *S. travancoricum*	Southern Western Ghats (Kerala)
Spices and condiments	
Allium humile, *A. stracheyi*, *A. wallichii*	Uttaranchal, Himachal Pradesh and J & K
Curcuma pseudomontana	Kerala and Western Ghats (Tamil Nadu)
Piper argyrophyllum; *P. bantamense*, *P. galeatum*, *P. nigrum* (wild), *P. hapnium*; *P. hymenophyllum*	Kerala; southern Western Ghats (Kerala); South Andaman & Nicobar Islands; Karnataka, Andhra Pradesh, Tamil Nadu
Zingiber purpureum, *Z. roseum*, *Z. zerumbet*	Western and Eastern Ghats

contd.

Species	Area (s) of collection
Medicinal and aromatic plants	
Asparagus adscendens, *A. racemosus*; *Carthamus lanatus*	Gujarat (Western Ghats), Himalaya; Kashmir
Vanilla wightii	East Godavari (Andhra Pradesh)
Others	
Erianthus arundinaceus; *Saccharum spontaneum*	North-western parts of Bihar and adjoining areas; Andhra Pradesh, Tamil Nadu, North-western Bihar and adjoining region

In wild relatives of cereals and millets, *Oryza nivara* from Uttar Pradesh (Sultanpur), *O. rufipogon*, a weedy type from South-central Kerala and *Porteresia coarctata* from Sunderbans were collected.

In legumes, wild relatives of *Vigna bourneae* and *V. hainiana* from Western Ghats, Tamil Nadu and extreme southern parts of Kerala; *V. radiata* var. *sublobata* and *V. trilobata* from saline areas of Western Ghats (southern part), Kerala, Tamil Nadu, Orissa, Chhattisgarh and Madhya Pradesh; *V. vexillata* from hill tracts of Himachal Pradesh and Maharashtra; *V. umbellata* from diverse pockets of Uttaranchal, Tamil Nadu and Kerala; *V. khandalensis* and *V. mungo* var. *silvestris* from Maharashtra and Madhya Pradesh; *Cajanus scarabaeoides* from Chhattisgarh, Jharkhand and Uttaranchal; *Lathyrus aphaca* from Kashmir; *Cicer soongaricum* from the high elevation zones/ cold tracts of Lahul, Spiti and Pangi regions of Himachal Pradesh and Ladakh were among the significant collections.

In oilseeds, diversity in wild relatives was assembled for *Sesamum mulayanum* from diverse parts of Kerala, Tamil Nadu, Orissa, Madhya Pradesh, hilly tracts of Uttaranchal, Maharashtra and Goa; *S. prostratum, S. laciniatum* from sandy/ hilly tracts of Tamil Nadu and Kerala; *S. malabaricum* from Maharashtra and Goa; *Brassica quadrivalvis* from northern parts of Punjab and adjacent region.

In jute and allied fibres, the diversity was mainly assembled in *Linum perenne* from Himachal Pradesh (Lahul and Spiti). Diversity in wild relatives was collected in *Gossypium* from eastern Himalaya and NEH region; *Corchorus trilocularis* and *C. depressus* from arid zone of Rajasthan and Gujarat; *C. urticifolius* and *C. olitorius* (wild) from Runn of Kachchh and *C. pseudo-olitorius* from Tirunelvelli district, Tamil Nadu. *Corchorus pseudo-olitorius,* a close wild relative of cultivated jute and a new record for India reported for resistance to stem, root and soft rot diseases, *C. tridens* for finer fibre, *C. urticifolius* for rot diseases, *C. olitorius* (wild) for salt tolerance, and *Linum perenne,* a source of cold hardiness were among the significant collections.

In vegetables, the wild relatives of lady's finger, *Abelmoschus tuberculatus* from Madhya Pradesh, Rajasthan, Maharashtra; *A. pungens* and *A. tetraphyllus* from Madhya Pradesh, Maharashtra, Orissa, Chhattisgarh, Rajasthan and coastal region of Goa; *A. ficulneus* and *A. crinitus* from areas of Gujarat, Madhya Pradesh and Uttaranchal were collected. Among the

cucurbitaceous vegetables, diversity was collected in *Cucumis callosus* from plains of North India; *C. prophetarum* from tropical parts of Kerala and dry regions of Rajasthan; diverse collections in *Cucumis sativus* var. *hardwickii* from temperate region of western Himalaya, Orissa, Chhattisgarh, coastal region of Goa, southern peninsular region and parts of Rajasthan; *Momordica dioica* from plains of North India, *M. denuda* from eastern peninsular region and *M. balsamina* from Gujarat and South Andaman and Nicobar Islands.

In tubers, *Dioscorea tomentosa*, an endemic species to Western Ghats, Kerala, *D. wallichii* from Thiruvananthapuram district, Kerala and *D. oppositifolia* from Western Ghats, Kerala and Andhra Pradesh; and *Amorphophallus paeonifolius* from West Coastal region and Western Ghats of Goa, Karnataka and Kerala were collected.

Species diversity in wild relatives of fruits in *Citrus assamensis*, *C. ichangensis*, and *C. indica* (endemic) from North-eastern region was among the significant collections. In tropical fruits, *Musa balbisiana* from Andaman and Nicobar Islands, Tripura, Assam and Myanmar; *M. acuminata* from Western Ghats and coastal region of Kerala; *Ensete glaucum* from deep forest of Mizoram and *E. superbum* from Uttar Kannada in Karnataka (Western Ghats) were collected. The germplasm of *Mangifera andamanica* from Andamans, *M. sylvestris* from North Eastern Hill region, diverse variability in wild type of cultivated mango, *M. indica* from Uttaranchal and eastern Himalaya was collected. In *M. indica*, a pickling type (Apimeddi) was collected from Sirsi, Karnataka (Western Ghats). *Pyrus jacquemontii* and *P. pashia*, closely related wild species of cultivated pear, having larger fruits and hardiness were amongst the important species collected from high altitude regions of western Himalaya besides other temperate wild species.

In wild relatives of spices and condiments, *Piper bababudani*, having bold sized fleshy berries, *P. bantamense* from Western Ghats, *P. beddomei* from South Andaman and Nicobar Islands, *P. hapnium* (new records from Kerala, India), *P. nigrum* with bisexual flowers from Nelliambrathy forests of Kerala were significant collections assembled during this period. High altitude regions of western Himalaya were explored for collection of diversity in wild relatives of *Allium*: *A. carolinianum* from cold desert of Spiti and Leh region, *A. humile*, *A. tuberosum* and *A. wallichii* from Himachal Pradesh and Uttaranchal regions of western Himalaya and *A. hookerii* from the eastern Himalaya.

Wild relatives of sugarcane, *Erianthus munja* and *E. arundinaceus*, *Saccharum spontaneum* were collected from coastal Andhra Pradesh, Tamil Nadu and North-west, North Bihar and North-eastern region.

The endemic diversity in wild relatives was collected in *Oryza nivara* from eastern Uttar Pradesh; *Vigna khandalensis* from Pune, Maharashtra; *Atylosia cajanifolia* from Khandala region of Western Ghats; *Abelmoschus tuberculatus* from northern plains; *Citrus* species from NEH region; *Carthamus lanatus* from Kashmir; *Garcinia imbertii* from Agasthiyamala range, Chemuga Hill, Kerala and *Solanum giganteum*, *Luffa hermaphrodita* and *Cucumis prophetarum* (rare species) from Aravali ranges, Rajasthan. Besides, rare and endangered diversity was collected in *Aegilops tauschii* (an endangered species) from stony alpine habitats

in Lahul and Spiti, Kinnaur and Pangi regions in Himachal Pradesh and *Syzygium bourdillonii* (species rediscovered after 100 years) from Thiruvananthapuram, Kerala.

Conservation of Wild Relatives

In situ conservation of wild relatives through protection of habitats and ecosystems is being implemented by the Department of Environment and Forests, Government of India. On the basis of survey data, fourteen biosphere reserves have been identified and out of which thirteen have been made operational. *Ex situ* conservation of PGR including wild relatives is the sole responsibility of National Bureau of Plant Genetic Resources that operates under ICAR/ DARE to support various national and international crop improvement programmes. Botanical Survey of India and several other organizations such as National Botanical Research Institute, Lucknow, Central Institute for Medicinal and Aromatic Plants, Lucknow, Tropical Botanical Gardens and Research Institute, Thiruvananthapuram and state departments maintain the botanical gardens to help in *ex situ* conservation of rare, endangered, threatened species and wild relatives of crop plants.

The National Genebank (base collection), National Facility of Plant Tissue Culture Repository, Cryopreservation Facility and a chain of clonal repositories (Field Genebanks) are under operation by the Bureau to maintain the *ex situ* collections of seed and vegetatively propagated plant species. The National Genebank (NGB) is the largest *ex situ* seed repository in India and third largest in the World (after USA and China) having base collection of landraces, traditional and rare cultivars, released varieties, breeding lines, genetic stocks and wild/ weedy relatives of crop plants. Over the years, the *ex situ* germplasm in base collection has been raised to 2,67,417 belonging to 521 species in various crop groups and wild/ weedy relatives. A total of 186 species (7,381 accessions) of wild relatives including 63 species (2,364 accessions) from indigenous source have been conserved in base collection (Table

Table 4.4 Number of species and accessions of wild relatives conserved in National Genebank (as on 31 March 2004)

Crop group (s)	Exotic		Indigenous		Total	
	Species	Accessions	Species	Accessions	Species	Accessions
Cereals	80	3822	4	47	84	3869
Pseudocereals	7	28	3	18	10	46
Millets and forages	3	976	1	1586	4	2562
Legumes	22	117	16	93	38	210
Oilseeds	1	2	5	259	6	261
Fibres	-	-	8	87	8	87
Vegetables	6	23	21	256	27	279
Fruits	-	-	-	-	-	-
Medicinal and aromatic plants	3	7	5	18	8	25
Others	1	42	-	-	1	42
Total	**123**	**5017**	**63**	**2364**	**186**	**7381**

4.4). Besides, germplasm accessions of wild relatives have also been conserved in cryogenebank (59 species; 231 accessions) and *in vitro* repository (15 species; 46 accessions) as complementary collections.

Germplasm collected under NATP was smoothly handled by a multidisciplinary unit (Germplasm Handling Unit) with representatives from all divisions of NBPGR. Material received through defined channels has been processed and the qualified accessions as per the guidelines of IRST (1996) have been conserved in the long-term storage. A total of 3,030 accessions have been conserved in medium-term storage (MTS) facility as reference material (voucher samples) and in field genebanks while they are in the process of multiplication for long-term storage (Table 4.5) (Annexure I).

Table 4.5 Number of species and accessions of wild relatives conserved in medium-term storage and field genebanks (1999-2004)

Crop group (s)	Species	Accessions
Cereals	11	201
Legumes	16	76
Oilseeds	9	106
Fibres	14	146
Vegetables	42	480
Tubers	22	262
Fruits	70	655
Spices and condiments	52	741
Medicinal and aromatic plants	15	202
Others	10	198
Total	**261**	**3030**

The Bureau, through its network of 11 Regional Stations, located in different agro-climatic zones of the country, supports the active conservation of wild relatives in field repositories. National Active Germplasm Sites (NAGS), an integral component of the network are entrusted with the responsibility of multiplication, evaluation, conservation of active collections and their distribution to users both at national and international levels. Fifty seven NAGS (based at the crop-based institutes for specific crops or crop groups) have been further strengthened to handle diverse germplasm.

Utilization of germplasm depends on the availability of correct passport information of individual accession. The data received from different sources have been updated for passport information on germplasm collections stored in the NGB. Besides, conserving the material in long-term and medium-term storage facilities, efforts for *in situ*/ on-farm conservation of selected species are being initiated in different areas.

The genebank holdings for wild relatives did not increase considerably due to difficulties associated with their conservation, maintenance and rejuvenation/ seed multiplication. However,

the material collected through various explorations would be multiplied and subsequently conserved in genebank.

Priority Areas for Collection and Conservation

Based on the efforts made in the past and now under the NATP project, priorities have been set up for future collections and conservation of wild relatives. Priorities for the species have been defined on the basis of conservation status (endemic, rare, vulnerable, threatened, endangered, etc.) and those having high demand in crop improvement programmes (Arora and Nayar, 1984; Nayar, 1996, 1997; Malik *et al.,* 2001). List of species (crop group-wise) and priority areas are given in Table 4.6.

Table 4.6 Priority areas for collection of diversity in wild relatives of crop plants in India

Species	Priority areas
Cereals and millets	
Chionachne koenigii; *C. semiteres*	Tarai region, Dehra Dun Valley (Uttaranchal), Western Ghats, Maharashtra and southwards; Tamil Nadu
Coix gigantea and *C. aquatica*	Central peninsular region, Western Ghats
Coix lacryma-jobi var. *ma-yuen*	North Eastern Hills
Digitaria cruciata var. *esculenta*, *D. purpureus* (wild lignosus forms)	Eastern Himalaya, Khasi region (North Eastern Hills)
Digitaria sanguinalis subsp. *aegyptiaca* var. *frumentacea*	Western Himalaya (Kashmir)
Elymus dahuricus	North-western Himalaya
Eremopyrum spp.	Alpine regions, western Himalaya
Hordeum agrocrithon (ancestral form of cultivated barley)	Sikkim, eastern Himalaya
Oryza officinalis ssp. *malampuzhaensis*	Peninsular region
Oryza nivara, O. rufipogon; *Hygroryza aristata*	Simlipal and Jeypore Hill Forest (Orissa), Gulf of Mannar; Sunderban region (West Bengal)
Panicum hippothrix	Deccan peninsular region
Porteresia coarctata	Sunderban region (West Bengal)
Polytoca digitata; *P. wallichiana*	Eastern India; North-eastern region
Trilobachne cookie	Konkan region (Western Ghats)
Legumes	
Atylosia cajanifolia	Mahendragiri (Orissa) and Belladilla ranges, Bastar (Chhattisgarh)

contd.

Species	Priority areas
Cajanus lineatus	Western Ghats (Tamil Nadu) and Silent Valley (Kerala)
Canavalia stocksii; *C. virosa*, *C. ensiformis*	Deccan peninsular region; Western Ghats, Nilgiris (Tamil Nadu)
Dolichos bracteatus	Konkan Hills
Glycine javanica	Western Ghats, Khandala region to Mysore (Karnataka), Nilgiris and Palni Hills (Tamil Nadu)
Lathyrus altaicus; *L. aphaca*	Baltal and Chenab Valley, western Himalaya; northern and Upper Gangetic plains, temperate Himalaya
Macrotyloma sar-garhwalensis	Garhwal Himalaya (Uttaranchal), peninsular region
Mucuna bracteata; *M. pruriens*	Western Himalaya; Eastern Ghats
Vigna aconitifolia; *V. capensis*, *V. grandis*, *V. mungo* var. *silvestris*	Rajasthan and adjoining areas; Khandala Ghats, Western Ghats
Vigna adenantha; *V. bourneae*, *V. wightii*	Tamil Nadu; South Western Ghats
Vigna khandalensis	Western Ghats, Pune (Maharashtra)
Vigna lutea	Gulf of Mannar, Sunderban region (West Bengal)
Vigna marina	Andman and Nicobar Islands
Vigna minima; *V. pilosa*	Parts of Western Ghats; Parts of Kerala and Tamil Nadu (Western Ghats)
Vigna radiata var. *setosa*; *V. radiata* var. *sublobata*	Konkan region, Tarai areas of Siwalik, Kumaon; Khandala Ghats and Western Ghats in Konkan extending southwards
Vigna umbellata (wild form)	Western Ghats, Eastern Ghats, sub-Himalayan tracts, North-eastern Hills (NEH region)
Oilseeds	
Brassica quadrivalvis; *B. tournefortii*	Upper Gangetic plains; western India, Himalayan region
Carthamus oxyacanthus	Northern plains
Linum mysorensis; *L. perenne*	Mount Abu hills and Aravali ranges (Rajasthan), western Peninsular region; Lahul in North-western Himalaya
Sesamum laciniatum, *S. malabaricum*, *S. prostratum*	Coastal Andhra Pradesh to Tamil Nadu

contd.

Species	Priority areas
Fibres	
Boehmeria platyphylla	Deccan peninsular region
Corchorus pseudo-olitorius	Peninsular India, Rajasthan and adjoining regions
Crotalaria tetragona and other *Crotalaria* spp.	Western Himalaya including the foothill region, Palni Hills, Nilgiris (Tamil Nadu)
Vegetables	
Abelmoschus tuberculatus	North and North-western plains, Saharanpur and adjoining areas (Uttar Pradesh), Vidarbha (Maharashtra) and adjoining areas
Allium roylei, A. rubellum, A. stracheyi, A. wallichii	High altitude regions of western Himalaya and Mussoorie Hills (Uttaranchal)
Artocarpus chama	Namdapha Biosphere Reserve (NEH region)
Chenopodium foliosum	North-western Himalaya
Cucumis callosus	Karnataka and Kerala
Cucumis hystrix	Eastern plains to NEH region, Tura range in Meghalaya and Mishmi Hills
Cucumis prophetarum	Sirohi and Abu areas (Rajasthan); Karnataka and Kerala
Cucumis sativus var. *hardwickii*	Western Himalaya, Dehra Dun/ Mussoorie (Uttaranchal) and adjoining areas in foothills of Himalaya, Western and Eastern Ghats, Orissa
Cucumis melo var. *momordica*	Khasi Hills, West Bengal
Cucumis setosus	Upper Gangetic plains, eastern India, Karnataka and Maharashtra
Curcuma amarissima and other *Curcuma* spp.	Peninsular region (Western Ghats)
Luffa acutangula var. *amara, L. echinata, L. hermaphrodita, L. umbellata*	Kerala and Tamil Nadu, plains of northern India and adjoining parts and Karnataka
Momordica charantia var. *muricata, M. cochinchinensis, M. dioica, M. subangulata, M. tuberosa*	Tamil Nadu, Kerala, Karnataka, eastern Bihar, West Bengal, central peninsular tracts and Western Ghats, Silent Valley (Kerala)
Neoluffa sikkimensis	Sikkim, North-eastern region
Solanum melongena var. *insanum, S. melongena* var. *potangi* (primitive type)	Eastern peninsular tract, Simlipal forest area (Orissa)
Solanum incanum	Siwalik ranges, lower hills of western Himalaya and peninsular India

contd.

Species	Priority areas
Solanum erianthum, *S. nigrum*, *S. torvum*, *S. viarum*	Southern Western Ghats
Trichosanthes khasiana; *T. ovata*, *T. bracteata* var. *tomentosa*	Khasi Hills, North-eastern region; southern Western Ghats
Tubers	
Amorphophallus bulbifera, *A. campanulatus*	Khasi Hills (Meghalaya) and eastern Himalaya (Sikkim) and Deccan Plateau
Amorphophallus mysorensis, *A. nicolsonianus*, *A. smithsonianus* and other *Amorphophallus* spp.	Southern Western Ghats and Silent Valley (Kerala)
Dioscorea alata	Western and North-eastern Himalaya
Dioscorea belophylla, *D. daemona*, *D. glabra*, *D. intermedia*, *D. wallichi*, *D. wightii*	Kerala and Karnataka
Dioscorea pentaphylla, *D. pentaphylla* var. *communis*	Andaman Islands, Tamil Nadu and Karnataka
Moghania vestita	Himalayan region
Fruits	
Actinidia callosa	Eastern and western Himalaya
Artocarpus heterophyllus, *A. gomezianus*	Southern Western Ghats and Silent Valley (Kerala)
Citrus assamensis, *C. ichangensis*, *C. indica*, *C. macroptera*, *C. megaloxycarpa*, *C. rugulosa* and wild types of sweet orange	Western Himalaya and North-eastern Himalayan region
Docynia hookeriana	North-eastern Himalayan region
Euphoria longan	Peninsular region and Western Ghats
Garcinia gummi-gutta var. *gummi-gutta*, *G. gummi-gutta* var. *conicarpa*, *G. rubro-echinata*, *G. indica*, *G. imbertii*	South Maharashtra to Tamil Nadu; Southern Western Ghats in Kerala and Tamil Nadu; Agasthiyamala range and Chemugi Hill, Kerala
Malus baccata var. *himalaica*, *M. flaviflora* and other *Malus* spp.	Western and eastern Himalaya
Malus nagensium; *M. sikkimensis*	Nagaland, eastern Himalaya; central and eastern Himalaya
Mangifera andamanica, *M. camptosperma*	Mount Harriet, Jhirkatang and Andaman Islands (A&N)
Mangifera khasiana; *M. sylvatica*	Assam, West Bengal and Tripura; Arunachal Pradesh
Musa cheesmanii; *M. flaviflora* (*Musa thompsonii*)	Assam; Manipur and Meghalaya

contd.

Species	Priority areas
Prunus acuminata; *P. jenkinsii*	Central and eastern Himalaya; Upper Assam and Arunachal Pradesh
Prunus tomentosa	Kashmir and Ladakh
Pyrus kumaoni	Kashmir to Kumaon
Rubus burkillii; *R. lanatus*, *R. lineatus*	Namdapha Biosphere Reserve (NEH Region); Kumaon to Sikkim Himalaya
Syzygium bourdillonii; *S. heyneanum*; *S. samaragense*	Thiruvananthapuram (Kerala); Peninsular region; Andaman and Nicobar Islands
Spices and condiments	
Amomum microstephanum, *A. muricatum*	Southern Western Ghats, hills of Karnataka and the Anamalai (Tamil Nadu)
Carum balbocastanum	North-western Himalaya
Cinnamomum filipedicellatum, *C. heyneanum*, *C. travancoricum*, *C. walaiwarense*; *C. zeylanicum*	Southern Western Ghats
Curcuma amada, *C. aromatica*, *C. cannanorensis*, *C. decipiens*, *C. malabarica*, *C. neilgherrensis*, *C. pseudomontana*, *C. thalakaveriensis* and other *Curcuma* spp.	Southern Western Ghats
Piper clarkia; *P. hapnium*; *P. barberi*, *P. wightii*	Namdapha Biosphere Reserve (NEH region); Agasthiyamala Hills; Western Ghats
Zingiber cernuum, *Z. purpureum*, *Z. roseum*, *Z. wightianum*; *Z. zerumbet*	Kerala, Tamil Nadu; Karnataka
Others	
Camelia caudata; *C. kissi*, *C. drupifera*, *C. lutescens*	Namdapha Biosphere Reserve (NEH region); North-eastern India
Coffea bengalensis; *C. jenkinsii*; *C. khasiana*	Humid tropical belt in eastern region; Namdapha Biosphere Reserve (NEH region)
Eurya acuminata, *E. japonica*	North-western Himalaya, Eastern Ghats and Western Ghats from Konkan southwards
Eurya runachalensis, *Gordonia excelsa*, *Schima wallichi*	North-eastern India
Saccharum sikkimensis; *S. benghalensis*, *S. ravennae*	Sikkim Himalaya; NEH region

Source: Arora and Nayar (1984); Hajra and Mudgal (1997); Nayar (1997); Das (2000); Malik *et al.* (2001); Dhillon *et al.* (2004) and authors' observations

The relative advantages and disadvantages of conserving wild relatives, using *ex situ* or *in situ* conservation strategies may be critically examined. One or both approaches together may be followed. Important diversity may be conserved in NAGS identified for conserving the crop species. In collaboration with other organizations/ agencies such as Botanical Survey of India (BSI), Calcutta; Ministry of Environment and Forests, Government of India and NAGS located at different institutes, the task of collection and conservation of wild species can be accomplished successfully. The integrated approach through network linkages will accelerate the efforts towards managing the diversity in wild species for current and future needs.

***Annexure* I**

Wild/ Weedy Relatives and Related Species Conserved in Medium-Term Storage and Field Genebanks (1999-2004)

Crop group (s)		Species (accession no.)
Cereals and millets	:	*Avena fatua* (1), *Coix lacryma-jobi* (16), *Echinochloa colona* (1), *E. crus-galli* (5), *Oryza meyeriana* ssp. *granulata* (4), *O. nivara* (75), *O. officinalis* (2), *O. officinalis* ssp. *malampuzhaensis* (2), *O. rufipogon* (92), *O. sativa* var. *spontanea* (2), *Sorghum halepense* (1)
Legumes	:	*Atylosia cajanifolia* (1), *Cajanus scarabaeoides* (4), *Cicer soongaricum* (6), *Rhynchosia minima* (6), *Rhynchosia* sp. (3), *Vigna bourneae* (11), *V. capensis* (1), *V. dalzelliana* (3), *V. hainiana* (3), *V. khandalensis* (1), *V. pilosa* (4), *V. radiata* var. *setulosa* (1), *V. radiata* var. *sublobata* (7), *V. trilobata* (4), *V. umbellata* (16), *V. vexillata* (2), *V. wightii* (3)
Oilseeds	:	*Carthamus oxyacanthus* (1), *Carthamus* sp. (1), *Olea ferruginea* (5), *O. glandulifera* (1), *Ricinus communis* (72), *Sesamum alatum* (2), *S. indicum* ssp. *anamalayensis* (1), *S. laciniatum* (2), *S. malabaricum* (9), *S. mulayanum* (11), *Sesamum* sp. (1)
Fibres	:	*Corchorus aestuans* (23), *C. capsularis* (5), *C. depressus* (5), *C. fascicularis* (5), *C. pseudo-olitorius* (13), *C. tridens* (13), *C. trilocularis* (18), *Corchorus* sp. (10), *Crotalaria alata* (5), *C. medicaginea* (5), *C. pallida* (20), *C. retusa* (3), *Crotalaria* sp. (17), *Urena lobata* var. *lobata* (5), *U. lobata* var. *sinuata* (1)
Vegetables	:	*Abelmoschus angulosus* (5), *A. crinitus* (1), *A. ficulneus* (4), *A. moschatus* (16), *A. tetraphyllus* var. *pungens* (4), *A. tetraphyllus* var. *tetraphyllus* (7), *A. tuberculatus* (1), *Amaranthus blitum* (1), *A. caudatus* (2), *A. cruentus* (1), *A. spinosus* (2), *A. viridis* (1), *Artocarpus gomesianus* (2), *A. heterophyllus* (6), *A. hirsutus* (4), *Artocarpus* sp. (1), *Chenopodium album* (4), *Chenopodium* sp. (4), *Citrullus colocynthis* (94), *Cucumis callosus* (22), *C. melo* var. *agrestis* (3), *C. prophetarum* (5), *C. sativus* var. *hardwickii* (32), *Luffa acutangula* var. *amara* (3), *L. echinata* (3), *Malva verticillata* (1), *Momordica balsamina* (1), *M. charantia* var. *muricata* (5), *M. cochinchinensis* (1), *M. dioica* (77), *M. tuberosa* (*Luffa tuberosa*) (2), *Solanum ferox* (1), *S. giganteum* (1), *S. incanum* (35), *S. indicum* (11), *S. khasianum* (5), *S. nigrum* (18),

contd.

Crop group (s)	Species (accession no.)
	S. surattense (39), *S. sisymbrifolium* (1), *S. torvum* (9), *S. viarum* (15), *Solanum* sp. (3), *Trichosanthes bracteata* (10), *T. cucumerina* var. *anguina* (8), *T. nerviflia* (8), *Trichosanthes* sp. (1)
Tubers	*Alocasia macrorrhiza* (9), *Alocasia* sp. (5), *Amorphophallus bulbifer* (2), *A. dubius* (4), *A. hohenackeri* (1), *A. paeoniifolius* var. *campanulatus* (27), *A. sylvaticus* (1), *Amorphophallus* sp. (10), *Colocasia esculenta* (47), *C. fallax* (1), *Colocasia* sp. (18), *Dioscorea alata* (4), *D. bulbifera* (25), *D. deltoidea* (2), *D. esculenta* (2), *D. glabra* (1), *D. hispida* (6), *D. intermedia* (3), *D. oppositifolia* (32), *D. pentaphylla* (22), *D. puber* (4), *D. spicata* (5), *D. tomentosa* (11), *D. wallichii* (10), *D. wightii* (1), *Dioscorea* sp. (9)
Fruits	*Aegle marmelos* (35), *Annona muricata* (2), *A. reticulata* (2), *Carissa congesta* (3), *C. spinarum* (3), *Carissa* sp. (3), *Citrus indica* (17), *C. jambhiri* (6), *C. macroptera* (1), *Cordia dichotoma* (1), *C. myxa* (2), *C. rothii* (1), *Diospyros buxifolia* (1), *D. chloroxylon* (2), *D. lotus* (8), *D. marmorata* (1), *D. melanoxylon* (12), *D. peregrina* (3), *Diospyros* sp. (25), *Emblica officinalis* (13), *Ensete superbum* (2), *Ficus glomerata* (4), *F. palmata* (6), *Ficus.* sp. (6), *Fragaria* sp. (4), *Garcinia cowa* (22), *G. gummi-gutta* (48), *G. imbertii* (2), *G. indica* (5), *G. morella* (7), *G. xanthochymus* (10), *Garcinia* sp. (23), *Grewia subinaequalis* (2), *G. hirsuta* (2), *Grewia* sp. (6), *Juglans nigra* (1), *J. regia* (30), *Juglans* sp. (57), *Madhuca indica* (*M. longifolia*) (19), *Malus baccata* (3), *Mangifera andamanica* (5), *M. camptosperma* (4), *M. sylvatica* (1), *Manilkara hexandra* (4), *M. littoralis* (1), *Manilkara* sp. (1), *Mimusops elengi* (6), *Musa acuminata* (3), *Musa acuminata* x *M. balbisiana* (13), *Musa balbisiana* (19), *Musa* sp. (2), *Myrica esculenta* (1), *Phoenix rupicola* (1), *P. zeylanica* (2), *Phoenix* sp. (2), *Physalis minima* (5), *Prunus cerasoides* (1), *P. cornuta* (1), *P. napaulensis* (1), *Punica granatum* (3), *Pyrus pashia* (1), *Ribes glaciale* (1), *R. grossularia* (1), *Rubus ellipticus* (1), *Rubus* sp. (18), *Spondias pinnata* (8), *Syzygium caryophyllatum* (4), *S. cordifolia* (1), *S. cumini* (14), *S. gardneri* (1), *S. hemisphericum* (2), *S. laetum* (2), *S. samarangense* (4), *S. travancoricum* (11), *Syzygium* sp. (8), *Vitis parvifolia* (1), *Ziziphus mauritiana* (16), *Z. nummularia* (17), *Z. oenoplia* (5), *Z. rugosa* (4), *Z. xylopyrus* (3), *Ziziphus* sp. (19)
Spices and condiments	*Allium auriculatum* (1), *A. wallichii* (1), *Amomum acuminatum* (1), *A. aculeatum* (2), *A. cannicarpum* (2), *A. subulatum* (1), *Carum carvi* (3), *Cinnamomum cassia* (3), *C. sulphuratum* (3), *C. wightii* (2), *C. zeylanicum* (2), *Cinnamomum* sp. (11), *Curcuma amada* (6), *C. angustifolia* (6), *C. aromatica* (14), *C. caesia* (3),

contd.

Crop group (s)	Species (accession no.)
	C. nilamburensis (1), *C. longa* (7), *C. lutea* (1), *C. malabarica* (5), *C. montana* (1), *C. neilgherrensis* (5), *C. oligantha* (1), *C. pseudomontana* (4), *C. zedoaria* (8), *Curcuma* sp. (116), *Globba bulbifera* (3), *G. pauciflora* (1), *Globba* sp. (4), *Murraya koenigii* (11), *Piper bantamense* (100), *P. argyrophyllum* (82), *P. bababudani* (7), *P. barberi* (5), *P. betle* (30), *P. colubrinum* (male) (2), *P. galeatum* (63), *P. hapnium* (10), *P. hookeri* (1), *P. hymenophyllum* (62), *P. longum* (79), *P. magnificum* (1), *P. mullesus* (*P. brachystachyum*) (12), *P. thomsoni* (4), *P. trichostachyon* (21), *Piper* sp. (9), *Zingiber purpureum* (3), *Z. cernuum* (1), *Z. neesanum* (7), *Z. nimmonii* (2), *Z. odoriferum* (1), *Z. pseudomontana* (1), *Z. roseum* (6), *Z. rubens* (1), *Z. spectabile* (1), *Z. wightianum* (1)
Medicinal and aromatic plants	*Achyranthes aspera* (24), *Acorus calamus* (37), *Cannabis sativa* (6), *Chlorophytum borivilianum* (10), *C. breviscapum* (1), *C. laxum* (1), *C. orchidastrum* (1), *C. tuberosum* (16), *Chlorophytum* sp. (1), *Cichorium intybus* (1), *Diplocyclos palmatus* (10), *Mentha longifolia* (4), *Rauvolfia serpentina* (27), *R. tetraphylla* (15), *Tagetes minuta* (1), *Withania somnifera* (47)
Others	*Erianthus arundinaceus* (9), *Erianthus* sp. (4), *Rosa brunonii* (1), *R. macrophylla* (3), *R. sericea* (4), *Rosa* sp. (1), *Saccharum spontaneum* (105), *Sapindus mukorossi* (2), *S. trifoliatus* var. *emarginatus* (2), *S. trifoliatus* (4), *Sapindus* sp. (5), *Trifolium pratense* (2), *T. repens* (56)

5

Concerns and Future Thrusts

The present status of diversity in wild relatives is rather a major concern due to degradation of natural habitats and changed environmental conditions. Loss of genetic material can be attributed to various factors such as large-scale deforestation, encroachment of forest lands for diverse uses, over-exploitation, etc. Commercial exploitation of wild relatives for useful products in the form of tubers, rhizomes, bulbs, rootstocks, causes the depletion of species from nature. Indiscriminate land use is the other major factor responsible for loss of these species.

The present collections of wild species maintained in the national genebank, meagrely represent the germplasm from Indian region. Accessions from widely distributed habitats are required to be augmented and conserved. Special missions are needed to be launched in the areas of occurrence of rich diversity to collect and conserve the germplasm of wild relatives using *ex situ* and *in situ* approaches. The areas where these types tolerate adversity of biotic or abiotic stress may be thoroughly surveyed and collections may be made. Germplasm may be multiplied and characterized/ evaluated in at least two to three geographical locations for conservation and future utilization.

Difficulties in Management

The wild relatives of crop plants for all their proven value and obvious potential have not been fully utilized. Lack of awareness about the potential of wild material, pattern of variability, reproductive biology, the knowledge and aptitude for identification, etc. are the major difficulties associated with different breeding programmes while using germplasm of wild relatives. The problem of taxonomic delineation is more serious than is generally realized, in case of cultivated plants in general, and wild relatives, in particular. Conventional botanical treatments have been inappropriate to accommodate the range of morphological variations found in wild relatives, thereby resulting in confusion.

While collecting the germplasm of wild relatives from natural populations, several problems are encountered due to asynchronized seed maturity, non-availability of sufficient material due to poor density of plant population, dormancy in the bud woods, particularly in trees and vegetatively propagated species.

The germplasm of wild relatives is often represented by a few accessions available with the institutions and are considered inadequate to represent the status of wild germplasm. When working within primary genepool, sterility is rarely a problem. However, backcrossing attempted over a number of generations, often eliminates the problems linked with deleterious genes. In actual practice, the deleterious genes introduced from wild relatives are less of a problem than thought. Sterility barriers are a major cause of concern in utilization of secondary or tertiary genepool.

Due to the problems associated with seed germination and lack of required agro-climatic conditions necessary for multiplication, they are often lost during the process of seed multiplication. For example, the wild relatives of onion and garlic (*Allium* spp.) having photoperiodic sensitivity, should be multiplied for seed or bulb in temperate climate. In absence of suitable conditions, it may be difficult to carry out successful seed multiplication.

The multiplication of germplasm of wild relatives in newer habitats (to which it is poorly adapted) is in itself a major cause of loss. For example wild relatives of *Vigna* collected from Western Ghats may be very poorly adapted to conditions of North India and thus are difficult to maintain and multiply under normal field conditions.

The asynchronized seed maturity and shattering habit are problematic traits associated with wild species in the natural habitats, collection sites and during characterization and evaluation. In order to collect seeds, they are to be bagged before maturity. Seed dormancy problem may be overcome by using standard seed treatment protocols, which require expertise, financial inputs and manpower.

During maintenance of wild relatives, weedy races often can replace wild accessions in a collection and cause seed loss or poor seed quality. The seed shattering while collecting or during field operations causes appearance of unwanted plants in subsequent season. Hand rouging of volunteer plants during maintenance and other field management problems are often time and labour consuming.

Management of Wild Relatives: An Integrated Approach

Emphasis needs to be given on targeted collection, conservation and sustainable management of wild relatives. Using *ex situ* and *in situ* measures, the valuable germplasm of rare/ endangered wild relatives should be conserved. Collaborative/ networking approaches through inter-institutional linkages can help in periodic monitoring of the status of wild genepool. For this, Botanical Survey of India, Ministry of Environment and Forests, Government of India and Non-Governmental Organizations (NGOs) may actively collaborate to perform the task effectively.

Wild genetic resources including wild relatives of crop plants deserve due attention for their sustainable management on the following:

Collection and conservation

***Habitat protection*:** For effective habitat protection, practices such as guided land use plan, ecozoning of an area/ buffer zoning should be adopted. Hot-spots and critical habitats should be the conservation areas for protection of wild species. Role models for *in situ*/ on-farm conservation may be developed on regional basis. For this, community involvement and less dependence of local people on the natural stock (wild genetic resources) may be emphasized.

***Harvesting tips*:** There should be dissemination of information on sustainable harvesting tips to ensure public support, to maximize economic benefits and minimize negative impacts on habitats and species diversity from use of wild genetic resources. Over-exploitation of commercially important species (such as wild *Allium*, *Asparagus*, *Dioscorea*, *Rauvolfia*,

etc.) from reserve areas, adopting precautionary measures for controlled grazing, fixing date for harvesting, organizing environmental education programmes and by harvesting only after maturation/ shedding of seeds, by retaining some part for perpetuation and by practicing scientific methods of storage can help to protect rich diversity in wild relatives (Chaudhary and Singh, 1998).

Enforcement of plans and programmes: Enforcement of all existing national (governmental and non-governmental) plans/ acts, strategies, programmes/ regulations including forthcoming National Biodiversity Action Plan in an effective way can gear rescue operations to conserve genetic diversity and restore degraded habitats.

Compilation of passport information: Based on passport information generated through explorations and also through literature, compiled data on time of flowering, fruiting (in case of seed bearing species) and the time of maturity (of seed, tuber, rhizome, bulb or other underground parts) can be prepared to help in timely collection of the wild relatives. This will help in planning and execution of collection programmes.

Promote research and development: Gaps identified in the management of wild relatives should be bridged through appropriate research and development (R&D). Different organizations/ institutes engaged in the R&D work should come together and work jointly to conserve the diversity.

Networking linkages: Communication links among relevant national/ international institutions and rapport between scientists and journalists on one hand, and administrators, Non-Governmental Organizations (NGOs) and local communities on the other hand, can facilitate the networking in terms of exchange of news and views and maintain flow of information.

Documentation

Systematic documentation and updating of scientific database will be of critical importance if Trade Related International Patenting System (TRIPS) comes into effect. In this, scientific database of any species is must for sovereign rights over a species. This warrants adequate research work and compilation of comprehensive updated database on plant genetic diversity of India, especially of wild relatives of crop plants. Forthcoming publications on "Wild relatives of crop plants of India" with data on ecological, morphological, cytological, potential traits, etc., would be desirable in this context.

Awareness generation

Education: Through formal and informal education curricula, emphasis can be laid on environmental education to conserve the biodiversity. Special papers and training courses should include issues such as diversity and management strategies, potentials of wild relatives, etc. Teachers should be oriented towards access to reference materials, logistic facilities and incentives to promote this task effectively.

***Public awareness generation*:** Greater momentum can be generated through awareness programmes on wild relatives of crop plants. Urban and rural populations should be informed about importance of wild relatives such as of wild rice (*Oryza nivara*) as a genetic source of resistance to the cultivated rice, to broaden the genetic base of wild species and ensure potential security and reduced risk of diseases and pests. Representative species of wild relatives may be displayed in the botanical gardens.

***Mass publicity*:** Effective public environmental awareness can be imparted by addressing key issues on wild genetic resources, such as diversity, economic values, threats, IPR related issues and ways of conservation and utilization of wild relatives. Help through exhibitions, posters, pamphlets, audio-visual aids, advertisements, popular/ investigative articles in media/ newspapers, magazines, television channels and journals can be sought to promote awareness among the public.

***Emphasizing bioprospecting*:** Emphasis on sustainable management of genetic resources through "cashing" bioprospect, value of commercially important wild genetic resources in terms of their possible value added products could be enhanced.

Box: 5.1 Wild Relatives: Conservation Involving Local Communities

The modern agricultural practices strongly favour reduction of diversity by providing crop subsidies for replacement of landraces of crops by uniform stands of high yielding varieties and use of herbicides to eliminate weedy relatives of crop plants. For effective implementation of biodiversity conservation programmes, positive incentives to local communities may be awarded to maintain minimal levels of biological diversity in general and maintain wild relatives in particular. This can be achieved through: (1) greater community control over common property resources of the locality, and (2) special grants or awards for communities or individuals those who maintain high levels of biological diversity on private land.

Keeping in view the importance of wild relatives, the following thrust areas have been identified:

- Identifying gaps in collection
- Survey and collection of wild relatives through special exploration missions in priority areas
- Documentation of information on diversity, distribution, traits, phenology, reproductive biology, etc.
- Collection of priority species to meet with threat or demand
- Characterization and evaluation of wild relatives for specific traits
- Studies on multiplication and seed increase under *in situ*/ and field conditions
- Intensification of conservation work to develop protocols for long-term and *in situ*/ on-farm conservation

- Establishing linkages among organizations dealing with *in situ* and *ex situ* conservation and developing national database
- Awareness generation at various levels and linking with management of wild relatives

Due to advancement in gene transfer using biotechnological means, the diversity in wild species has become more accessible for use in plant breeding (Witt, 1982; Chopra and Prakash, 1996). By utilizing modern techniques such as DNA fingerprinting and molecular techniques to identify the genepool and tissue culture technique (through embryo rescue), the desired traits of wild species can be exploited. Previously, it was difficult to trap valuable germplasm through conventional breeding and sexual hybridization. Through the modern methodology applications, utilization of secondary and tertiary genepools has now become approachable. However, our knowledge of the wild/ weedy relatives and related species of most crop plants is still fragmentary. Basic information on species delimitation, distribution and diversity of desirable traits and genetic variation, chromosome numbers, crossability aspects, etc. in many species is either incomplete or totally lacking.

The genetic erosion has increased alarmingly in many parts of the world. The national and international concern for systematic management of wild and weedy relatives of crop plants has necessitated collection and conservation for immediate and future use in breeding programmes. In response to the recent developments on Intellectual Property Rights (IPR) under the provisions of World Trade Organization (WTO), there has been a need to assess the potential of wild wealth available with us. In view of these provisions, wild relatives of crop plants, with valuable traits and potential need to be collected, conserved, characterized and documented on priority basis. Studies pertaining to taxonomy, cytology and phylogenetic relationship among the wild species are required for their utilization.

Thus, this publication on wild relatives of crop plant species and related taxa would provide a baseline for planning and execution of exploration programmes, sorting out the priority areas/ species for collection, multiplication, evaluation, utilization, *vis-à-vis* effective management and adopting suitable conservation strategies in national perspective.

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Oryza officinalis spp. *malampuzhaensis*

Oryza rufipogon

Vigna hainiana

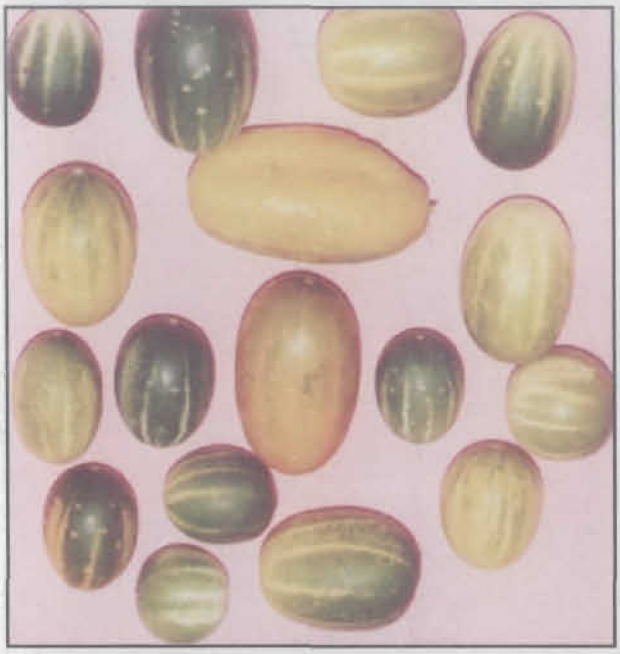
Vigna khandalensis

Vigna mungo var. *silvestris*

Vigna radiata var. *setulosa*

Corchorus pseudo-olitorius

Moghania vestita



Cucumis sativus var. *hardwickii*

Citrus indica

Ensete glaucum

Musa velutina

***Appendix* I**

Wild/ Weedy Relatives of Crop Plants and Related Species Collected in different Crop Group (s) (1976-2004)

Cereals and millets (Poaceae)

Aegilops tauschii Coss.

Avena fatua L.*

Coix lacryma-jobi L. *

Digitaria setigera Roem & Schult.

Echinochloa colona (L.) Link

Echinochloa crus-galli (L.) P. Beauv.

Hygroryza aristata (Retz.) Nees ex Wight & Arn*

Oryza meyeriana (Zollin. & Mor. ex Steud.) Baill. ssp. *granulata* Tateoka

Oryza nivara Sharma et Shastry*

Oryza officinalis Wall. ex G. Watt

Oryza officinalis Wall. ex Watt. ssp. *malampuzhaensis* (Krish. & Chandr) Tateoka

Oryza rufipogon Griff. *

Oryza sativa var. *spontanea* L.

Panicum antidotale Retz.

Panicum pedicellatum Trin.

Porteresia coarctata (Roxb.) Tateoka*

Setaria glauca (L.) Beauv. (*Penisetum glaucum* (L.) R. Br.*

Sorghum halepense (L.) Pers.

Legumes (Fabaceae)

Atylosia cajanifolia Haines*

Cajanus scarabaeoides (L.) Thou. (*Atylosia scarabaeoides*)*

Cicer soongaricum Stepf. (*Cicer microphyllum* Royle)*

Cyamopsis tetragonolobus (L.) Taub.

Lablab niger var. *lignosus* (L.) Prain*

Lathyrus aphaca L.*

Mucuna bracteata DC.

Mucuna capitata Wight & Arn.*

Mucuna pruriens (L.) DC. *

Rhynchosia minima (L.) DC.

Vicia sativa L.

Vigna aconitifolia (Jacq.) Marechal

Vigna bourneae Gamble

Vigna capensis (Thunb.) Burtt-Davy*

Vigna dalzelliana (Kuntze) Verdc. *

Vigna hainiana Sharma, Babu and Gopinathan*

Vigna khandalensis (Santapau) Raghavan and Wadhwa

Vigna marina (Burm.) Merr.

Vigna mungo var. *silvestris* Lukoki, Marechal & Otoul*

Vigna pilosa (Willd.) Baker

Vigna radiata var. *setulosa* (Dalzell) Ohwi & H. Ohashi

Vigna radiata var. *sublobata* (Roxb.) Verd.*

Vigna trilobata var. *pusilla* (L.) Verdc.*

Vigna trilobata var. *trilobata* (L.) Verdc. *

Vigna umbellata (Thunb.) Ohwi & Ohashi*

Vigna vexillata (L.) A. Rich var. *vexillata*

Vigna wightii Benth. ex Bedd.

Oilseeds

Brassica quadrivalvis Hk. f. & Thom. (Brassicaceae)*

Brassica tournefortii Gouan (Brassicaceae)*

contd.

*Species reported by Arora and Nayar (1984)

Carthamus lanatus L. (Asteraceae)*

Carthamus oxyacanthus M. Bieb. (Asteraceae)*

Lepidium capitatum Hk. f. & Thomson (Brassicaceae)*

Madhuca longifolia (L.) J. f. Macbr. (Sapotaceae)

Olea ferruginea Royle (Oleaceae)

Olea glandulifera Wall. ex G. Don (Oleaceae)

Ricinus communis L. (Euphorbiaceae)

Sesamum alatum L. (Pedaliaceae)

Sesamum indicum ssp. *anamalayensis* (Pedaliaceae) *

Sesamum laciniatum Klein ex Willd. (Pedaliaceae)*

Sesamum malabaricum Burm. (Pedaliaceae)

Sesamum mulayanum L. (Pedaliaceae)

Sesamum prostratum Retz. (Pedaliaceae)*

Sesamum radiatum Schumach. (Pedaliaceae)

Fibres

Corchorus aestuans L. (Tiliaceae)

Corchorus capsularis L. (Tiliaceae)*

Corchorus depressus (L.) C. Christense (*C. antichorus* Raeuh.) (Tiliaceae)*

Corchorus fascicularis Lam. (Tiliaceae)

Corchorus pseudo-olitorius Islam & Zaid (Tiliaceae)

Corchorus tridens L. (Tiliaceae)*

Corchorus trilocularis L. (Tiliaceae)*

Corchorus urticifolius Wight & Arn. (Tiliaceae)*

Crotalaria alata Buch.-Ham. (Fabaceae)

Crotalaria burhia Buch.-Ham. ex D. Don (Fabaceae)

Crotalaria medicaginea Lam. (Fabaceae)

Crotalaria pallida Aiton (*Crotalaria striata* DC.) (Fabaceae)*

Crotalaria retusa L. (Fabaceae)*

Crotalaria tetragona Roxb. (Fabaceae)

Gossypium arboreum L. (Malvaceae)*

Hibiscus cannabinus L. (Malvaceae)*

Hibiscus radiatus Cav. (Malvaceae)*

Hibiscus tiliaceus L. (Malvaceae)*

Linum perenne ssp. *perenne* L. (Linaceae)*

Urena lobata var. *lobata* L. (Malvaceae)*

Urena lobata var. *sinuata* King (Malvaceae)

Vegetables

Abelmoschus angulosus Mast. (Malvaceae)*

Abelmoschus crinitus Wall. (Malvaceae)

Abelmoschus ficulneus (L.) Wight & Arn. (Malvaceae)*

Abelmoschus moschatus (L.) Medic. ssp. *manihot* (Malvaceae)

Abelmoschus moschatus Medic. ssp. *moschatus* (Malvaceae)

Abelmoschus tetraphyllus Medic. var. *pungens* (Roxb.) Hochr. (Malvaceae)

Abelmoschus tetraphyllus var. *tetraphyllus* (Roxb. ex Hornem) Boiss. (Malvaceae)

Abelmoschus tuberculatus Pal & Singh (Malvaceae)*

Amaranthus blitum L. (Amaranthaceae)*

Amaranthus caudatus L. (Amaranthaceae)*

Amaranthus cruentus L. (Amaranthaceae)*

Amaranthus gangeticus L. (Amaranthaceae)*

Amaranthus spinosus L. (Amaranthaceae)*

Amaranthus viridis L. (Amaranthaceae)

Artocarpus heterophyllus Lam. (Moraceae)

Artocarpus lakoocha Roxb. (*A. lacucha* Buch.-Ham.) (Moraceae)

contd.

*Species reported by Arora and Nayar (1984)

Canavalia ensiformis (L.) DC. (Fabaceae)

Carissa congesta Wight (*C. carandas* L.) (Apocynaceae)*

Chenopodium album L. (Chenopodiaceae)*

Citrullus colocynthis (L.) Schrad. (Cucurbitaceae)*

Coccinia cordifolia (L.) Cogn. (*C. indica* Wight & Arn.) (Cucurbitaceae)

Cordia myxa L. (Boraginaceae/ Ehretiaceae)*

Cordia rothii Roem. & Schult. (Boraginaceae/ Ehretiaceae)*

Cucumis callosus (Rottl.) Cogn.* (Cucurbitaceae)

Cucumis melo (L.) var. *agrestis* (Naud.) Pangalo (Cucurbitaceae)*

Cucumis melo (L.) var. *momordica* (Roxb.) Duthie & J. B. Fuller (Cucurbitaceae)*

Cucumis prophetarum L. (Cucurbitaceae)*

Cucumis sativus var. *hardwickii* (Royle) Gabaev (Cucurbitaceae)*

Fagopyrum cymosum Meissn. (Polygonaceae)*

Hibiscus radiatus Cav. (Malvaceae)*

Luffa acutangula var. *amara* (Roxb.) Clarke (Cucurbitaceae)*

Luffa echinata Roxb. (Cucurbitaceae)*

Luffa hermaphrodita Singh & Bhandari (Cucurbitaceae)

Malva rotundifolia L. (Malvaceae)*

Malva sylvestris L. var. *mauritiana* Boiss (Malvaceae)*

Momordica balsamina L. (Cucurbitaceae)*

Momordica charantia var. *muricata* L. (Cucurbitaceae)

Momordica cochinchinensis (Lour.) Spreng. (Cucurbitaceae)*

Momordica denudata Thw. (Cucurbitaceae)*

Momordica dioica Roxb. ex Willd. (Cucurbitaceae)*

Momordica tuberosa (Roxb.) Cogn. (*Luffa tuberosa* Roxb.) (Cucurbitaceae)

Solanum ferox L. (Solanaceae)

Solanum giganteum Jabq. (Solanaceae)

Solanum incanum L. (Solanaceae)*

Solanum indicum L. (Solanaceae)*

Solanum khasianum Cl. (*S. aculeatissimum* Jacq.) (Solanaceae)

Solanum mammosum L. (Solanaceae)

Solanum nigrum L. (Solanaceae)

Solanum sisymbrifolium Lam. (Solanaceae)

Solanum spirale Roxb. (Solanaceae)

Solanum surattense Burm. f. (*S. virginianum* L.) (Solanaceae)*

Solanum torvum Sw. (Solanaceae)*

Solanum viarum Dunal (Solanaceae)

Trichosanthes bracteata L. (Cucurbitaceae)*

Trichosanthes bracteata var. *tomentosa* L. (Cucurbitaceae)*

Trichosanthes cucumerina L. subsp. *anguina* (L.) Haines (*T. anguina*) (Cucurbitaceae)*

Trichosanthes cucumerina subsp. *cucumerina* L. (Cucurbitaceae)

Trichosanthes dioica Roxb. (Cucurbitaceae)*

Trichosanthes nervifolia L. (Cucurbitaceae)

Tubers

Alocasia macrorrhiza (L.) G. Don (Araceae)*

Amorphophallus bulbifer L. (Araceae)*

Amorphophallus dubius Bl. (Araceae)

Amorphophallus hohenackeri (Schott.) Engl. & Gehrm. (Araceae)

Amorphophallus paeoniifolius (Dennst.) Nicolson var. *campanulatus* (Decne) Sivad. (*A. campanulatus* Decne) (Araceae)*

contd.

*Species reported by Arora and Nayar (1984)

Amorphophallus sylvaticus (Roxb.) Kunth (Araceae)

Colocasia esculenta (L.) Schott. (Araceae)*

Colocasia fallax Schott. (Araceae)

Dioscorea alata L. (Dioscoreaceae)*

Dioscorea bellophylla Voigt. ex Haines (Dioscoreaceae)

Dioscorea bulbifera L. (Dioscoreaceae)*

Dioscorea deltoidea Wall. (Dioscoreaceae)

Dioscorea esculenta (Lour.) Burkill (Dioscoreaceae)*

Dioscorea glabra Roxb. (Dioscoreaceae)

Dioscorea hamiltonii Hk. f. (Dioscoreaceae)*

Dioscorea hispida Dennst. (Dioscoreaceae)*

Dioscorea intermedia Thw. (Dioscoreaceae)

Dioscorea oppositifolia L. (Dioscoreaceae)

Dioscorea pentaphylla L. (Dioscoreaceae)*

Dioscorea puber Bl. (*D. anguina* Roxb.) (Dioscoreaceae)

Dioscorea spicata Roth (Dioscoreaceae)

Dioscorea tomentosa Koenig ex Spreng. (Dioscoreaceae)

Dioscorea wallichii Hk. f. (Dioscoreaceae)

Dioscorea wightii Hk. f. (Dioscoreaceae)

Moghania vestita (L.) O. Kuntze (Fabaceae)*

Xanthosoma nigrum (Vell.) Mansfeld (*X. violaceum* Schott.) (Araceae)

Fruits

Actinidia callosa Lindl. (Actinidiaceae)

Aegle marmelos (L.) Correa (Rutaceae)*

Annona muricata L. (Annonaceae)

Annona reticulata L. (Annonaceae)

Artocarpus gomesianus Wall. (Moraceae)

Artocarpus heterophyllus Lam. (Moraceae)*

Artocarpus hirsutus Lam. (Moraceae)

Artocarpus lakoocha Roxb. (*A. lacucha* Buch.-Ham.) (Moraceae)

Carissa congesta Wight (*C. carandas*) (Apocynaceae)*

Carissa spinarum L. (Apocynaceae)

Citrus assamensis Dutta & Bhattacharya (Rutaceae)*

Citrus ichangensis Swingle (Rutaceae)*

Citrus indica Tanaka (Rutaceae)*

Citrus jambhiri Lush. (Rutaceae)*

Citrus latipes (Swingle) Tanaka (Rutaceae)*

Citrus limon (L.) Burm. f. (Rutaceae)*

Citrus macroptera Montr. (Rutacee)*

Citrus madurensis Lour. (Rutaceae)

Citrus megaloxycarpa Lush. (Rutaceae)

Citrus pseudolimon Tanaka (Rutaceae)

Citrus rugulosa Hort. ex Tanaka (Rutaceae)

Cordia dichotoma G. Forst. (Boraginaceae/ Ehretiaceae)

Cordia myxa L. (Boraginaceae/ Ehretiaceae)*

Cordia rothii Roem. & Schult. (Boraginaceae/ Ehretiaceae)*

Democarpus longan Lour. (*Euphoria longan* (Lour.) Steud.) (Sapindaceae)*

Diospyros blancoi A. DC. (Ebenaceae)

Diospyros buxifolia (Bl.) Hiern (Ebenaceae)

Diospyros chloroxylon Roxb. (Ebenaceae)

Diospyros kaki Thunb. (Ebenaceae)

Diospyros lotus L. (Ebenaceae)*

Diospyros marmorata Parker (Ebenaceae)

Diospyros melanoxylon Roxb. (Ebenaceae)*

Diospyros montana Roxb. (Ebenaceae)

Diospyros peregrina (Gaertn.) Gurke (Ebenaceae)*

Docynia indica Decne (Rosaceae)*

Duchesnea indica (Andrews) Focke (Rosaceae)*

contd.

*Species reported by Arora and Nayar (1984)

Elaeocarpus serratus L. (Elaeocarpaceae)

Emblica officinalis Gaertn (*Phyllanthus emblica* L.) (Euphorbiaceae)*

Ensete glaucum (Roxb.) Cheesman (Musaceae)

Ensete superbum (Roxb.) Cheesman (Musaceae)

Ficus glomerata Roxb. (Moraceae)

Ficus palmata Forsk. (Moraceae)*

Fragaria daltoniana J. Gay (Rosaceae)

Fragaria nilgerrensis Schlecht. (Rosaceae)*

Fragaria vesca L. (Rosaceae)

Garcinia cowa Roxb. ex DC. (Clusiaceae/ Guttiferae)*

Garcinia gummi-gutta (L.) Robson (Clusiaceae/ Guttiferae)

Garcinia imbertii Bourd. (Clusiaceae/ Guttiferae)*

Garcinia indica (Thouars) Choisy (Clusiaceae/ Guttiferae)*

Garcinia morella (Gaertn.) Desr. (Clusiaceae/ Guttiferae)

Garcinia xanthochymus Hk f. ex T. Anderson (Clusiaceae/ Guttiferea)

Grewia hirsuta Vahl (Tiliaceae)

Grewia subinaequalis DC. (Tiliaceae)*

Grewia tenax (Forsk.) Aschers. & Schwf. (Tiliaceae)*

Juglans nigra L. (Juglandaceae)

Juglans regia L. (Juglandaceae)

Madhuca longifolia (L.) J. F. Macbr. (Sapotaceae)

Malus baccata (L.) Borkh. var. *himalaica* (Maxim.) C. K. Schneid. (Rosaceae)*

Malus baccata var. *baccata* (L.) Borkh. (Rosaceae)

Malus sikkimensis (Wenz.) Koehne ex C. K. Schneid. (Rosaceae)

Mangifera andamanica King (Anacardiaceae)

Mangifera camptosperma (Anacardiaceae)

Mangifera indica L. (Anacardiaceae)*

Mangifera sylvatica Roxb. (Anacardiaceae)*

Manilkara hexandra (Roxb.) Dubard (Sapotaceae)*

Manilkara littoralis (Kurz) Dubard (Sapotaceae)

Mimusops elengi L. (Sapotaceae)*

Morus alba L. (Moraceae)*

Morus serrata Roxb. (Moraceae)*

Musa acuminata Colla (Musaceae)*

Musa acuminata x Musa balbisiana (Musaceae)

Musa balbisiana Colla (Musaceae)*

Musa ornata Roxb. (Musaceae)

Musa velutina H. Wendl. & Drude (Musaceae)*

Myrica esculenta Buch.-Ham. (Myricaceae)*

Phoenix rupicola T. Anders. (Arecaceae)

Phoenix sylvestris (L.) Roxb. (Arecaceae)*

Phoenix zeylanica Trimen (Arecaceae)

Physalis minima L. (Solanaceae)

Prunus armeniaca L. (Rosaceae)

Prunus cerasoides D. Don. (Rosaceae)*

Prunus cornuta (Wall. ex Royle) Steud. (Rosaceae)*

Prunus jacquemontii Hk. f. (Rosaceae)

Prunus napaulensis (Ser.) Steud. (Rosaceae)*

Punica granatum L. (Punicaceae)*

Pyrus pashia Buch.-Ham. ex D. Don (Rosaceae)*

Pyrus pyrifolia (Burm. f.) Nakai var. *pyrifolia* (Rosaceae) *

Ribes glaciale Wall. (Grossulariaceae)*

Ribes grossularia L. (Grossulariaceae)

contd.

*Species reported by Arora and Nayar (1984)

Ribes nigrum L. (Grossulariaceae)*

Rubus ellipticus Sm. (Rosaceae)*

Rubus fruticosus L. (Rosaceae)*

Rubus niveus Thunb. (Rosaceae)*

Rubus paniculatus Sm. (Rosaceae)*

Rubus rosaefolius Sm. (Rosaceae)

Sorbus foliolosa (Wall.) Spach (Rosaceae)

Sorbus lanata (D. Don) S. Sehauer (Rosaceae)

Spondias pinnata (L. f.) Kurz. (Anacardiaceae)*

Syzygium bourdillonii (Gamble) Rathakr. & Nair (Myrtaceae)

Syzygium caryophyllatum (L.) Alston (Myrtaceae)

Syzygium cordifolium Klotz (Myrtaceae)

Syzygium cumini (L.) Skeels (Myrtaceae)*

Syzygium gardneri Thw. (Myrtaceae)

Syzygium hemisphericum (Walp.) Alston (Myrtaceae)

Syzygium laetum (Büch.-Ham.) Gandhi (Myrtaceae)

Syzygium malaccense (L.) Merril & Perry (Myrtaceae)

Syzygium mundagam (Bourd.) Chithra (Myrtaceae)

Syzygium samarangense (Bl.) Merrill & Perry (Myrtaceae)*

Syzygium travancoricum Gamble (Myrtaceae)

Vitis jacquemontii Parker (Vitaceae)

Vitis parvifolia Roxb. (Vitaceae)*

Ziziphus mauritiana Lam. (Rhamnaceae)*

Ziziphus nummularia (Burm. f.) Wight & Arn. (Rhamnaceae)*

Ziziphus oenoplia Mill. (Rhamnaceae)*

Ziziphus rugosa Lam. (Rhamnaceae)*

Ziziphus xylopyrus Willd. (Rhamnaceae)

Spices and condiments

Allium auriculatum Kunth. (Alliaceae)

Allium carolinianum DC. (Alliaceae)

Allium humile Kunth *(A. govanianum* Wall.) (Alliaceae)

Allium hookerii Thw. (Alliaceae)

Allium rubellum M. Bieb. (Alliaceae)

Allium stracheyi Baker (Alliaceae)

Allium tuberosum Rottler ex Spreng (Alliaceae)*

Allium victorialis L. (Alliaceae)

Allium wallichii Kunth (Alliaceae)

Alpinia calcarata Rosc. (Zingiberaceae)

Alpinia galanga (L.) Sw. (Zingiberaceae)*

Alpinia malaccensis Rosc. (Zingiberaceae)

Amomum aculeatum Roxb. (Zingiberaceae)

Amomum acuminatum Thw. (Zingiberaceae)

Amomum cannicarpum (Wight) Benth. (Zingiberaceae)

Carum carvi L. (Apiaceae)*

Cinnamomum cassia Bl. (Lauraceae)

Cinnamomum filipedicillatum (Lauraceae)

Cinnamomum riparium Gamble (Lauraceae)

Cinnamomum macrocarpum Hk. f. (Lauraceae)

Cinnamomum multiflorum Wight (Lauraceae)

Cinnamomum nitidum Bl. (Lauraceae)

Cinnamomum sulphuratum Nees (Lauraceae)

Cinnamomum tamala (Buch.-Ham.) Nees & Eberm. (Lauraceae)

Cinnamomum wightii Meissn. (Lauraceae)

Cinnamomum zeylanicum Breyn. (Lauraceae)*

Curcuma amada Roxb. (Zingiberaceae)*

contd.

*Species reported by Arora and Nayar (1984)

Curcuma angustifolia Roxb. (Zingiberaceae)*
Curcuma aromatica Salisb. (Zingiberaceae)
Curcuma aurantiaca (Zingiberaceae)
Curcuma caesia Roxb. (Zingiberaceae)
Curcuma longa L. (Zingiberaceae)*
Curcuma lutea (Zingiberaceae)
Curcuma malabarica (Zingiberaceae)
Curcuma montana Rosc. (Zingiberaceae)*
Curcuma neilgherrensis Wight (Zingiberaceae)
Curcuma nilamburensis (Zingiberaceae)
Curcuma oligantha Trim. (Zingiberaceae)
Curcuma pseudomontana J. Graham (Zingiberaceae)
Curcuma zedoaria (Christm.) Rosc. (Zingiberaceae)*
Globba bulbifera Roxb. (Zingiberaceae)
Globba pauciflora King (Zingiberaceae)
Hedychium spicatum Buch.-Ham. (Zingiberaceae)
Murraya koenigii (L.) Spreng. (Rutaceae)
Myristica malabarica Lam. (Myristicaceae)*
Piper argyrophyllum Miq. (Piperaceae)
Piper bababudani (Piperaceae)
Piper bantamense Bl. (*P. attenuatum* Ham.) (Piperaceae)
Piper barberi Gamble (Piperaceae)
Piper betle L. (Piperaceae)
Piper colubrinum Link (Piperaceae)
Piper galeatum C. DC. (Piperaceae)
Piper hapnium Buch.-Ham. (Piperaceae)
Piper hookeri Miq. (Piperaceae)
Piper hymenophyllum Miq. (Piperaceae)
Piper longum L. (Piperaceae)*
Piper magnificum (Piperaceae)
Piper mullesus Buch.-Ham ex D. Don (*P. brachystachyum* Wall. ex Hk. f.) (Piperaceae)
Piper nigrum L. (Piperaceae)*
Piper schmidtii Hk. f. (Piperaceae)*
Piper thomsoni Hk. f. (Piperaceae)
Piper trichostachyon DC. (Piperaceae)
Trachyspermum stictocarpum (Clarke) Wolff. (*Carum stictocarpum* Clarke) (Apiaceae)
Zingiber cernuum Dalz. (Zingiberaceae)
Zingiber neesanum (Grah.) Ramamorthy (*Z. macrostachyum* Dalz.) (Zingiberaceae)
Zingiber nimmonii Dalz. (Zingiberaceae)
Zingiber odoriferum Bl. (Zingiberaceae)
Zingiber officinale Rosc. (Zingiberaceae)*
Zingiber pseudomontana (Zingiberaceae)
Zingiber purpureum Rosc. (*Z. cassumunar* Roxb.) (Zingiberaceae)*
Zingiber roseum Rosc. (Zingiberaceae)
Zingiber rubens Roxb. (Zingiberaceae)
Zingiber spectabile Griff. (Zingiberaceae)
Zingiber wightianum Thw. (Zingiberaceae)
Zingiber zerumbet (L.) Sm. (Zingiberaceae)*

Medicinal and aromatic plants

Achyranthes aspera L. (Amaranthaceae)*
Aconitum ferox Wall. ex Ser. (Ranunculaceae)*
Aconitum heterophyllum Wall. (Ranunculaceae)
Acorus calamus L. (Araceae)
Asparagus adscendens Roxb. (Liliaceae)
Asparagus dumosus Baker (Liliaceae)
Asparagus racemosus Willd. (Liliaceae)
Cannabis sativa L. (Cannabinaceae)
Carthamus lanatus L. (Asteraceae)

contd.

*Species reported by Arora and Nayar (1984)

Carthamus oxyacanthus M. Bieb. (Asteraceae)*

Chlorophytum borivilianum Sant. & Fernadez (Liliaceae)

Chlorophytum breviscapum Dalz. (Liliaceae)

Chlorophytum laxum Br. (Liliaceae)

Chlorophytum orchidastrum Lindl. (Liliaceae)

Chlorophytum tuberosum Baker (Liliaceae)

Cichorium endivia L. (Asteraceae)*

Cichorium intybus L. (Asteraceae)*

Citrullus colocynthis (L.) Schrad. (Cucurbitaceae)*

Costus speciosus (Koen.) Sm. (Zingiberaceae)

Diplocyclos palmatus (L.) Jeffrey (*Bryonopsis laciniosa* L.) (Cucurbitaceae)

Mentha longifolia (L.) Nathh. (Lamiaceae)

Rauvolfia serpentina (L.) Benth. ex Kurz (Apocynaceae)*

Rauvolfia tetraphylla L. (Apocynaceae)

Tagetes minuta L. (Asteraceae)

Vanilla wightii Lindl. ex Wight (Orchidaceae)

Withania somnifera (L.) Dunal (Solanaceae)*

Others

Cichorium endivia L. (Asteraceae)*

Cichorium intybus L. (Asteraceae)*

Erianthus arundinaceus (Retz.) Jesw. ex Heyne (*Saccharum arundinaceum* Retz.) (Poaceae)*

Erianthus munja Jesw. (Poaceae)

Fagopyrum cymosum Meissn. (Polygonaceae)*

Indigofera tinctoria L. (Fabaceae)

Medicago hispida Gartn. (Fabaceae)

Medicago sativa L. spp. *falcata* (L.) Arcang. (Fabaceae)

Miscanthus nepalensis (Trin.) Hack. (Poaceae)*

Rosa brunonii Lindl. (Rosaceae)

Rosa macrophylla Lindl. (Rosaceae)

Rosa moschata Herrm. (Rosaceae)

Rosa sericea Lindl. (Rosaceae)

Rosa webbiana Royle (Rosaceae)

Saccharum spontaneum L. (Poaceae)*

Sapindus mukorossi Gaertn. (Sapindaceae)

Sapindus trifoliatus L. (Sapindaceae)

Sapindus trifoliatus var. *emarginatus* (Vahl) Radlk. (Sapindaceae)

Trifolium pratense L. (Fabaceae)

Trifolium repens L. (Fabaceae)

*Species reported by Arora and Nayar (1984)

***Appendix* II**

Hot-spots of Indian Flora

1. Andaman group of Islands
2. Nicobar group of Islands
3. Agasthiyamala Hills
4. Anamalai and High Ranges (Cardamom Hills)
5. Palni and Highway Mountains
6. Nilgiris, Silent Valley-Wynaad-Kodagu
7. Shimoga-Kanara
8. Mahabaleshwar-Khandala Ranges
9. Konkan-Raigadh
10. Marathwada-Satpura Ranges
11. Tirupati-Cuddappa-Nallamalai Hills
12. Vizagapatnam Ganjam-Jeypore Hills
13. Southern Deecan (Leeward side)
14. Chhotanagpur Plateau
15. Kathiawar-Kuchchh
16. Rajasthan-Aravalli Hills
17. Khasia-Jaintia Hills
18. Patkoi-Manipur-Lushai Hills
19. Assam
20. Arunachal Pradesh Himalaya
21. Sikkim Himalaya
22. Garhwal-Kumaon Himalaya
23. Lahul-Himachal Pradesh Himalaya
24. Kashmir-Ladakh Himalaya
25. Nepal (interface of eastern Himalaya and western Himalaya)
26. Eastern Himalaya
27. Khasi-Jaintia-Lushai
28. Central India
29. Eastern Ghats
30. Southern Western Ghats
31. Northern Western Ghats
32. Western Himalaya
33. Sandstone flora of Dun and Mussoorie
34. Myristica swamps of Kerala
35. Sea grasses of Coromandel coast
36. Mangroves of Sunderbans
37. Mangroves and coral reefs of Andamans
38. Wetland flora of Chilka Lake
39. Cold desert flora of Ladakh
40. Lakshadeep coral reefs and algal flora

Source: Nayar (1996)

Appendix III

Proposed Areas for *In situ*/ Home Garden Conservation of Landraces, Wild and Semi-wild *Citrus* Species in India

Species	Name of the cultivar/ landrace/ wild species	Proposed area (s) for on-farm conservation
Citrus indica	Memon Narang	Garo Hills in their natural haitat
Citrus latipes	Soh Shyrkhoit	Upper Shillong area, Meghalaya
Citrus macroptera	Satkara	Shella area, Meghalaya, Manipur and Mizoram in their natural habitats
Citrus limettioides	Sweet Lime	Jaintia Hills, Meghalaya and Uttaranchal
Citrus aurantium	Karanjamir	Ribhoi district, Meghalaya
Citrus assamensis	Ada Jamir	Dawki area, Meghalaya
Citrus magaloxycarpa	Sour Pummelo	Jaintia Hills, Meghalaya
Citrus medica	Citron	Basar area, Arunachal Pradesh and Meghalaya
Citrus pseudolimon	Hill Lemon	Paonta Valley, Himachal Pradesh and Doon Valley, Uttaranchal
Citrus sinensis	Tasi	Basar area, Arunachal Pradesh
	Sohbitara	Shillong area, Meghalaya
	Soh Nairiang	Shillong area, Meghalaya
Citrus grandis	Pummelo	Paonta Valley, Himachal Pradesh; Doon Valley, Uttaranchal; lower Assam and Tura and Dawki areas, Meghalaya
Citrus jambhiri	Rough Lemon (Jambhiri)	Nagpur and Aurangabad area, Maharashtra
	Soh Myndong	Assam and Meghalaya
Citrus limonia	Rangpur Lime	Nagpur area, Maharashtra and Andhra Pradesh
Citrus pennivesiculata	Gajnimma	Gudur area, Nellore, Andhra Pradesh
Citrus rugulosa	Athanni	Bhowali, Nainital, Uttaranchal

Source: Singh and Singh (2003)

***Appendix* IV**

Primary and Secondary Genepools of the Major Cereals

Crop	Primary genepool (GP I)			Secondary genepool (GP II)
	Cultivated species	Spontaneous subspecies		
		Wild races	Weed races	
Wheat				
Einkorn	*Triticum monococcum*	*T. boeoticum*	*T. boeoticum*	*Triticum* ssp., *Secale* ssp., *Aegilops* spp.
Emmer	*T. dicoccum*	*T. dicoccoides*	-	*Triticum* ssp., *Secale* spp., *Aegilops* spp.
Timopheevi	*T. timopheevi*	*T. araraticum*	*T. timopheevi*	*Triticum* spp., *Secale* spp., *Aegilops* spp.
Bread	*T. aestivum*	-	-	*Triticum* spp., *Secale* spp., *Aegilops* spp.
Rye	*Secale cereale*	*S. cereale*	*S. cereale*	*Triticum* spp., *Secale* spp., *Aegilops* spp.
Barley	*Hordeum vulgare*	*H. spontaneum*	*H. spontaneum*	-
Oats				
Sand	*Avena strigosa*	*A. hirtula*, *A. wiestii*	*A. strigosa*	*Avena* spp.
Ethiopian	*A. abyssinica* *A. vaviloviana*	*A. barbata*	*A. barbata*	*Avena* spp.
Cereal	*A. sativa*	*A. sterilis*	*A. sterilis*, *A. fatua*	*Avena* spp.
Rices				
Asian	*Oryza sativa*	*O. rufipogon*	*O. rufipogon*	*Oryza* spp.
African	*O. glaberrima*	*O. barthii*	*O. stapfii*	*Oryza* spp.
Sorghum	*Sorghum bicolor*	*S. bicolor*	*S. bicolor*	*S. halepense*
Pearl millet	*Pennisetum americanum*	*P. violaceum*	*P. violaceum*	*P. purpureum*
Maize	*Zea mays*	*Z. mexicana*	*Z. mexicana*	*Tripsacum* spp., *Z. perennis*

Source: Harlan (1975)