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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

INFORMATION ON *EX SITU* COLLECTIONS MAINTAINED IN BOTANIC GARDENS

(with special emphasis on plant genetic resources for food and agriculture)

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This document was prepared at the request of the Secretariat of the FAO Commission on Genetic Resources for Food and Agriculture to provide information on germplasm of interest to food and agriculture held in *ex situ* conditions in botanical gardens. The information contained here could be of use in the process of revision of the International Undertaking. The views expressed are the responsibility of the author and do not represent the point of view of FAO or its staff.

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1. INTRODUCTION

1.1 The convention on biological diversity and role of FAO

The Convention on Biological Diversity recognizes the important role of *ex situ* conservation techniques in safeguarding the world's genetic resources. The impossibility of giving protected land status to all areas needing conservation and of managing the land accordingly, together with the risks that still exist in protected areas despite *in situ* methods and measures, make *ex situ* techniques important complementary actions that permit the conservation of extensive biological diversity in small areas and provide rapid access to the conserved resource.

The *ex situ* techniques used for plant genetic resources basically involve the conservation of collections of species and varieties in some form of germplasm bank (banks of cultivated germplasm or seed, pollen or tissue banks.).

The text of the Convention on Biological Diversity (June 1992) recognizes with regard to *ex situ* conservation that:

In the Preamble

"The Contracting Parties ... Noting further that *ex situ* measures, preferably in the country of origin, also have an important role to play";

In Article 9

"Each Contracting Party shall adopt measures for the *ex situ* conservation of components of biological diversity, preferably in the country of origin of such components ... Establish and maintain facilities for *ex situ* conservation of and research on plants ... Cooperate in providing financial and other support for *ex situ* conservation ... and in the establishment and maintenance of *ex situ* conservation facilities in developing countries."

In Article 15

"Recognizing the sovereign rights of States over their natural resources, the authority to determine access to genetic resources rests with the national governments and is subject to

national legislation. Each Contracting Party shall endeavour to create conditions to facilitate access to genetic resources ... by other Contracting Parties".

However, Resolution 3 of the Final Document of the Nairobi Conference for the Approval of an Agreed Text for the Convention on Biological Diversity (May 1992), among other matters:

- confirms the key importance of this Convention for the conservation and utilization of genetic resources for food and agriculture;

- takes note of the recommendations of the United Nations Conference on Environment and Development regarding the need to reinforce FAO's Global System on the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture, and also notes that priority policies and programmes for the conservation and sustainable use of these resources, which are to be approved before the year 2000, will include, among other measures, the establishment of networks of *ex situ* base collections; and

- recognizes the need to find solutions to unresolved issues associated with plant genetic resources within the framework of the Global System for Conservation and Sustainable Utilization, mentioning in particular access to *ex situ* collections not acquired in compliance with the Convention. This includes collections acquired prior to the entry into force of the Convention.

1.2 The international network of botanic gardens

Botanic gardens combine scientific research and conservation work with educational and cultural activities, interactively disseminating messages and knowledge with local societies and communities, while at the same time managing and conserving a multifaceted heritage that includes the documentary (libraries, herbaria, museological funds and collections), the genetic (collections of cultivated germplasm, seed banks, tissue banks) and even the historical, ethnological and artistic. The synergies from these multiple objectives provide unique potential for the conservation of plant genetic resources - not only those of wild origin but also those of interest to food and agriculture.

Besides cultivating plant species in an orderly and visually pleasing manner, botanic gardens can also maintain monographic collections, develop propagation techniques for endangered species, conserve plant germplasm in seed banks, research conservation and multiplication techniques and carry out studies on folk practices, cultivation systems, taxonomy, phytochemical components or phylogenetic origins and ecological needs of individual species.

This paper is a first step in analyzing and evaluating the potential role of the world's approximately 1 500 botanic gardens in the management and conservation of *ex situ* germplasm collections. It seeks to determine the significance of the collections that were maintained in these botanic gardens before the entry into force of the Convention. It also looks into the difficulties of assessing the collections and suggests a method of work to raise related information.

2. METHOD OF STUDY

2.1 Sources of reference

This preview has been based mainly on available documentation on collections in botanic gardens. It has not involved any form of survey, census or direct request for information. The main sources of reference have been:

- the directories of botanic gardens and arboreta of the world published by the International Association of Botanic Gardens (IABG) and Botanic Gardens Conservation International (BGCI), from HEYWOOD *et al., eds*. (1990).

- Occasional papers, information pamphlets or brochures and *Indices Seminum*, which are issued directly by many of the botanic gardens of the world, giving more or less precise information on their conserved collections.

- Consultation of specialist reviews on botanic gardens and conservation techniques including: *BGCI Newsletter, IABG - European Division Newsletter, IABG - Asian Division Newsletter, Threatened Plants Committee Newsletter, etc.*

- Consultation of various case studies on the above subjects, mainly from conferences and symposia organized by the BGCI, IABG and other regional associations of botanic gardens: BRAMWELL *et al.* Ed. (1987), STEPHEN *et al*. (1986), HERNANDEZ BERMEJO *et al*., eds. (1990), Van VLIET, ed. (1989), etc.

- And finally, information acquired directly by the author from personal visits to over 100 botanic gardens and arboreta in 30 countries of Europe, Asia, America and Australia.

The information has been compiled using DBASE IV in the format presented in Table 1.

A number of case studies are highlighted and detailed in corresponding boxes.

2.2. Difficulties encountered

Some of the main difficulties encountered in using the available information include:

- the absence of a standard register of collections at both international and national level, except in very rare cases (the Netherlands).

- The normal failure to differentiate between collections cultivated for straightforward educational or display purposes and collections of germplasm *stricto sensu* managed for conservation purposes, with sufficient individuals and genetic variability, methods of proven security and a detailed register of conserved accessions.

- The normal preference for holding collections of scientific, taxonomic or ornamental interest rather than for concrete practical purposes.

2.3 Types of collections

In spite of these difficulties, the different types of collections have been grouped under the following headings:

a) Cultivated species of agricultural, food or industrial interest - primary attention paid to collections involving species of nutritional or industrial interest (oil, fibres, etc.).

b) Cultivated species of forest, medicinal or aromatic interest - secondary attention paid to species of forest (timber or other forest resources) or medicinal interest (including aromas, spices and essences).

c) Uncultivated species of nutritional interest - species that are promising, extracted or of ethnobotanic interest, wild relatives, neglected or marginal crops.

d) Wild relatives of cultivated species - wild relatives understood not as the taxa closest to the cultivated species or varieties but as collections of taxa of the same genus as the cultivated species.

e) Species cultivated exclusively for ornamental purposes - perhaps the most common type of germplasm collection held, particularly in the more traditional botanic gardens.

f) Plants of ethnobotanic interest - uncultivated and of no nutritional interest (wild medicinals and dyes).

g) Indigenous threatened species - especially where covered by specific conservation programmes and where taxonomy suggests potential for the genetic enhancement of cultivated species or for the identification of new resources of economic interest.

The following have been excluded:

h) Collections of wild species without any apparent or immediate use to humankind, unless endangered.

The statistical data for these categories have been combined into three groups:

I. Collections of mainly agricultural interest (categories a + c)

II. Collections of mainly forest or medicinal interest (categories b + f)

III. Collections of mainly ornamental interest or comprising taxa of native flora often conserved because endangered (categories d + e + g).

Table 1 - Configuration of database used for registration of information

Field	Name	Type	Criteria
1	Name	Character	
2	Country	Character	
3	Development	Character	Scale 0-5 according to levels of per capita income
4	Continent	Character	
5	Age	Numerical	Years from foundation until 1995
6	Status	Character	St: Statal; Mu: Municipal; Pr: Private; UN; University; ?: Unknown; RS: Research Institute; Lo: Local Administration; MU: Combined Municipal-University
7	Area	Numerical	In ha.
8	Research	Numerical	Subjective scale 0-3
9	*In vitro* CU	Logic	Y/N: Yes/No
10	*Index Seminum*	Logical	Y/N: Yes/No
11	Register	Logical	Y/N: Yes/No
12	Computerized	Logical	Y/N: Yes/No
13	Taxa under cultivation	Numerical	
14	GB seeds	Logical	
15	Accessions	Numerical	
16	Glass cover	Logical	Y/N: Yes/No
17	Greenhouses	Numerical	En m^2
18	Collection 1	Character	
19	Collection 2	Character	
20	Collection 3	Character	
21	Collection 4	Character	
22	Collection 5	Character	
23	Collection 6	Character	

3. RESULTS

3.1 The International Network of Botanic Gardens

According to data compiled by the two more international botanic garden organizations, the IABG and BGCI, there are approximately 1 490 botanic gardens in the world. They are not uniformly distributed as 61% are in Europe, the former USSR and the United States, but they do cover 187 countries, which leaves only 44 (half in Africa) without a single botanic garden. Figure 1 shows the distribution of gardens according to large country or regional group of countries. Figures 2 and 3 indicate density of distribution by national land area and population.

Almost half of the higher plants of the planet are conserved in the world's 1 490 botanic gardens. One of these alone, Kew Gardens (England), holds some 70 000 different species, while others, such as St. Louis (Missouri) or Edinburgh (Scotland), conserve more than 30 000 species. Individual catalogues of collections exceed 10 000 species in many botanic gardens (about 10% of the total). These collections are not only outdoor but are also under climatized glass cover extending over half a million m^2. With the addition of species conserved in seed banks or *in vitro*, at least 125,000 different species are held, which represents 50% of documented vascular flora, and this despite the high level of duplication among botanic gardens.

This does not mean, of course, that such a conservation network, structure and technique are fully and effectively safeguarding the world's plant diversity. It is not enough, for example, to hold just one or a few exemplars. Germplasm collections that are sufficiently varied, effectively maintained, correctly characterized and adequately accessible to users are very few and in fact only account for a small proportion of the plant kingdom.

But the number of conserved or simply cultivated taxa does at least provide an indication of the potential of botanic gardens to act as a basic instrument of *ex situ* conservation of biodiversity.

Equally significant is the vast range of conservation facilities, resources and techniques employed. The over 500 000 m^2 of climatized greenhouses might conserve about 50 000 plant species. Over 150 also have germplasm banks with refrigerated stores for the conservation of endangered species and varieties, invariably as seeds. An estimated 35 botanic gardens engage in *in vitro* culture and have special laboratory facilities and dedicated chambers. They all use these techniques for the research and multiplication of endangered species and varieties. Some (perhaps no more than ten) conserve germplasm collections under tissue or slow growth culture, and a few use cryopreservation techniques. About 50% of the 1 490 botanic gardens are, include or depend on a botanic research institute, with millions of specimen-sheets in their herbaria and millions of volumes in their specialized libraries.

3.2 Location of collections

Provisional estimates show that 700 botanic gardens - 47% of the total - hold plant germplasm collections. Of these, 120 have collections of agricultural interest (mainly cultivated species of interest for food or industry, in addition to collections of wild stock of species used by humankind for nutrition or as a source of oils or fibres). Another 170 gardens have significant collections of medicinals or forest plants (timber, paper, pulp, cork). The remaining 410 are botanic gardens also involved in conservation but whose germplasm collections are either exclusively ornamental or else based essentially on endangered native flora.

The remaining 800 or so botanic gardens may hold a wide selection of plant biodiversity, in some cases exceeding 10 000 taxa under cultivation, but fail to maintain thematic collections with the minimal attention needed for cultivated germplasm (sufficient number of individuals, identification of geographic source). This assumption is based on the lack of precision in the gardens' reports on the taxonomic or biological nature of their collections, and more specifically on the absence of registration procedures, specific conservation objectives, infrastructure or interlinkage with scientific programmes and information on provenance.

Some 25% of botanic gardens with germplasm collections are located in the EU countries, which represent a very small proportion of total world area. Because many of these gardens are amongst the largest and the best equipped, their collections could in fact account for 40% of the world total. If we include the gardens of the other European countries (with those of the former USSR) and of the United States, we have a total of 65% of gardens with germplasm collections - more realistically probably 75%.

This information is portrayed in figures 4, 5 and 6 which indicate the number of botanic gardens that have acknowledged monographic germplasm collections. These have been grouped into three categories of increasing importance on the basis of type nature and combination of collections as in Section 3:

- the first group holds collections of categories C, D, E, F and G (see 3.1), basically ornamentals or endangered endemic plants, with sometimes plants of ethnobotanic interest.

- the second group also includes or basically hold collections of medicinals (including essences, spices and condiments) and species of forest interest.

- the third group is made up of gardens with collections that are clearly of interest to agriculture, plus in many cases the collections above.

The attention given and the management of collections of strict agricultural, medicinal, forest or ornamental interest or of endangered native species vary widely between gardens and sometimes between countries and continents.

Thus in the EU, 62% of gardens with specialized germplasm collections focus basically on ornamentals or on these and on the conservation of endangered native species, accounting for an estimated 30% of world collections of ornamentals and endangered native species. In addition, 24% of collections of medicinal or forest interest are found in the EU countries, although only some 40 gardens hold such collections. The number with collections of specific interest to agriculture only account for 9% of the world total. The botanic gardens of the United Kingdom, for example, maintain various national collections scrupulously and with acknowledged expertise but these basically involve ornamentals (*Nymphaea, Narcissus, Begonia, Iris, Mahonia*). Others are more strictly taxonomic such as the collections of *Euphorbia* (Oxford) or *Cistus* (Chelsea) and very few are of agricultural interest: *Phaseolus* in Southampton, *Citrus* in Birmingham or *Corylus* in Amfield.

The situation in the United States and its 240 botanic gardens is somewhat similar. Approximately 51% of the gardens have special germplasm collections (about 122). Of these 70% deal mainly with the conservation of ornamentals and endangered native plants. Many (about 40) are involved in specific programmes for the conservation of endangered native flora coordinated by the World Conservation Monitoring Centre (located in the Botanic Garden of St. Louis, Missouri). There is very limited interest in medicinal or agriculture collections, perhaps because there are other institutions specializing in these fields. Interest in forest and timber species is slightly greater as shown by the high number of arboreta in the United States.

Trends and objectives are different in the less developed countries where there is greater interest in collections for agricultural purposes. This is the case throughout Asia, particularly in India and China, although not in Japan whose botanic gardens and collections are essentially ornamental as in the more developed countries. A similar although less pronounced pattern is found in certain countries of Mesoamerica.

One interesting feature is the apparent greater interest shown in the former USSR for collections of interest to agriculture, as shown by the deviation from trend in Figures 4 and 5. However, the data supplied by these gardens show high duplication of collections which may be real or may be due to uniformity in presentation of data for the International Directory of Botanic Gardens.

3.3. Taxonomy of collections

3.3.1 *Collections of cultivated plants (food or industry)*

These collections are registered under the following headings in the Directory of Botanic Gardens:

Fruit crops	Mediterranean crops
Plants of economic interest	Oilseed crops
Horticultural crops	Cereal crops
Tropical crops	Pulse crops

Their taxonomy in the registers may refer to the genus of the accessions or the tribe, subfamily or family. The following taxa collections have been found in the registers:

Main known collections at family, subfamily or tribe level:

Annonaceae	*Fabaceae (sensu Leguminosae)*
Apiaceae	*Musaceae*
Araceae	*Oleaceae*
Arecaceae	*Phaseoleae*
Bambusoideae	*Rosaceae*
Brassicaceae	*Rutaceae*
Cactaceae	*Zingiberaceae*
Chenopodiaceae	

Main known collections at genus level:

Actinidia	*Diospyros*	*Passiflora*
Agave	*Eugenia (E. caryophylata)*	*Persea*
Aloe	*Ficus*	*Phaseolus*
Allium	*Fragaria*	*Phoenix*
Ananas	*Glycine*	*Prunus*
Annona	*Glycyrrhiza*	*Psidium*
Atriplex	*Gossypium*	*Pyrus*
Bambusa	*Hevea (H. brasiliensis)*	*Quercus*
Castanea	*Hibiscus*	*Ribes*
Cichorium	*Ilex*	*Rubus*
Cinnamomum	*Juglans*	*Simmondsia*
Citrus	*Lycopersicon*	*Solanum (S. tuberosum)*
Coffea	*Malus*	*Sorbus*
Corylus	*Mangifera*	*Theobroma*
Crataegus	*Michelia*	*Tilia*
Croccus	*Morus*	*Vitis*
Dioscorea	*Opuntia*	*Zingiber*

3.3.2 Cultivated plants of forest, medicinal or aromatic interest

Timber and forest trees
Medicinal plants
Bee plants
Pasture plants
Aromatic plants
Essences and cosmetics
Conifers

Main known collections at family, subfamily or tribe level:

Annonaceae
Anthemideae
Apiaceae
Arecaceae
Bambusoideae
Betulaceae
Bromeliaceae
Chenopodiaceae
Commelinaceae
Cycadaceae
Cactaceae
Cupressaceae
Ericaceae
Fabaceae (Leguminosae)
Moraceae
Myrtaceae
Pinaceae
Rosaceae
Rutaceae
Salicaceae

Main known collections at genus level:

Abies
Acacia
Acer
Aloe
Allium
Araucaria
Artemisia
Atriplex
Bambusa
Begonia
Betula
Castanea
Casuarina
Cinchona
Cinnamomum
Citrus
Colchicum
Croccus
Cupressus
Diospyros
Eucalyptus
Fagus
Ficus
Gentiana
Glycyrrhiza
Grevillea
Ilex
Juglans
Mentha
Michelia
Morus
Myristica
Nicotiana
Notofagus
Opuntia
Papaver
Passiflora
Persea
Phoenix
Piceae
Pinus
Platanus
Populus
Pseudotsuga
Quercus
Ribes
Robinia
Salix
Sorbus
Syringa
Taxus
Thymus
Tilia
Zingiber

3.3.3 Plants of nutritional interest not presently cultivated

- Generic designations of collections:

Plants of ethnobotanic interest

Local varieties and marginal, neglected and traditional crops

Main known collections at genus level:

Allium
Ananas
Annona
Araucaria
Bambusa
Castanea
Cichorium
Crataegus
Diospyros
Ficus
Malus
Morus
Opuntia
Passiflora
Phaseolus
Persea
Persea
Prunus
Pyrus
Ribes
Rubus
Sassafras
Simmondsia
Sorbus

3.3.4 Wild relatives of cultivated crops

- Generic designations of collections:

Endangered plants of the native flora
Weeds
Plants of ethnobotanic interest

Main known collections at genus level:

Actinidia
Agave
Aloe
Allium
Ananas
Annona
Anthurium
Artemisia
Atriplex
Bambusa
Begonia
Camellia
Cichorium
Citrus
Coffea
Colchicum
Croccus
Crataegus
Dioscorea
Diospyros
Eucalyptus
Ficus
Fragaria
Gentiana
Glycine
Glycyrrhiza
Gossypium
Hibiscus
Hordeum
Hydrangea
Ilex
Iris
Lycopersicon
Magnolia
Malus
Mangifera
Medicago
Mentha
Narcissus
Nicotiana
Opuntia
Paeonia
Papaver
Passiflora
Phaseolus
Persea
Phoenix
Phylodendron
Pinus
Prunus
Psidium
Pyrus
Rhododendron
Ribes
Rosa
Rubus
Sorbus
Syringa
Theobroma
Thymus
Tilia
Trifolium
Vitis

3.3.5 Species cultivated mainly for ornamental purposes

- Generic designations of collections:

Ornamentals
Ferns
Plants for bonzai
Aquatic plants
Carnivorous plants
Conifers
Macaronesica distribution species

Main known collections at family, subfamily, or tribe level:

Araceae
Arecaceae
Betulaceae
Brassicaceae
Bromeliaceae
Commelinaceae
Cycadaceae
Cactaceae
Ericaceae
Fabaceae (Leguminosae)
Geraniaceae
Moraceae
Musaceae
Myoporaceae
Myrtaceae
Oleaceae
Orchidaceae
Pandanaceae
Rosaceae
Rutaceae
Salicaceae

Main known collections at genus level:

Abies
Acacia
Acer
Agave
Aloe
Allium
Ananas
Annona
Anthurium
Araucaria
Artemisia
Atriplex
Bambusa
Begonia
Betula
Camellia
Castanea
Casuarina
Cinchona
Citrus
Coffea
Corylus
Crataegus
Cupressus
Diospyros
Eucalyptus
Fagus
Festuca
Ficus
Glycyrrhiza
Grevillea
Hebe
Hibiscus
Hydrangea
Ilex
Iris
Juglans
Magnolia
Malus
Morus
Myristica
Narcissus
Notofagus
Opuntia
Poeonia
Papaver
Passiflora
Persea
Picea
Phoenix
Phylodendron
Pinus
Platanus
Populus
Prunus (sensu lato)
Pseudotsuga
Quercus
Rhododendron
Ribes
Robinia
Rosa
Rubus
Salix
Sassafras
Sorbus
Syringa
Taxus
Thymus
Tilia
Trifolium

3.3.6 Plants of ethnobotanic interest

- Generic designations of the collections:

Timber plants
Medicinals
Plants of ethnobotanic interest
Marginal crops
Wild relatives
Aromatics

Bee plants
Local varieties

Essences and cosmetics

Main known collections at genus level:

Agave	*Crataegus*	*Morus*
Aloe	*Cupressus*	*Opuntia*
Allium	*Eucalyptus*	*Papaver*
Araucaria	*Fagus*	*Phoenix*
Artemisia	*Gentiana*	*Pinus*
Atriplex	*Glycyrrhiza*	*Quercus*
Bambusa	*Hevea (H. brasiliensis)*	*Salix*
Castanea	*Ilex*	*Taxus*
Cichorium	*Juglans*	*Thymus*
Cinchona	*Mentha*	*Tilia*

3.3.7 Endangered native species

- Generic designations of collections:

Endangered species of native flora
Weeds

3.3.8 Other collections not included but frequently mentioned because present in many botanic gardens

Main known collections at family, subfamily or tribe level:

Aizozaceae	*Crassulaceae*
Combretaceae	*Proteaceae*

Main known collections at genus level:

Arctostaphylos	*Dracaena*	*Nymphaea*
Anemone	*Encephalartos*	*Pandanus*
Begonia	*Erica*	*Peperomia*
Berberis	*Erytrina*	*Primula*
Buxus	*Euphorbia*	*Protea*
Campanula	*Fraxinus*	*Pyracantha*
Carduus	*Ginkgo*	*Rheun*
Carpinus	*Gladiolus*	*Rhododendron*
Cedrus	*Heliconia*	*Rhus*
Centaurea	*Hemerocallis*	*Sanseveria*
Cercis	*Hosta*	*Sempervivum*
Chrytsanthemum	*Hydrangea*	*Spirea*
Cistus	*Hypericum*	*Styrax*
Clematis	*Jasminun*	*Tagetes*

Codiaeum
Colchicum
Commiphora
Cornus
Cortaderia
Cotoneaster
Dahlia
Dianthus
Kalanchoe
Larix
Ligustrum
Lilium
Liriodendron
Lonicera
Mahonia
Nepenthes
Thuja
Tulipa
Ulmus
Viburnum
Victoria
Vinca
Viola
Welwitschia

SUMMARY TABLE OF UTILIZATION OR ECONOMIC INTEREST OF GERMPLASM COLLECTIONS IN BOTANIC GARDENS

TAXA	AG	IN	FO	ME	OR	ET	WR	ot
Abies			+		+			
Acacia			+		+			
Acer		+	+		+	+		
Actinidia								
Agave	+	+			+	+	+	
Aizoaceae					+			
Aloe				+	+	+		
Allium	+			+		+	+	
Ananas		+				+		
Anemone					+			
Annona		+				+		+
Annonaceae	+				+		+	
Anthemideae				+		+		
Anthurium					+			
Apiaceae	+			+	+	+	+	
Araceae		+			+	+	+	+
Araucaria		+	+		+	+		
Arctostaphylos					+	+	+	
Areca					+	+		
Arecaceae					+	+		
Artemisia				+	+	+		
Atriplex		+				+	+	
Bambusa	+	+	+		+	+		
Bambusoideae	+	+	+		+	+		
Begonia						+		
Berberis					+			+
Betula	+	+	+	+	+	+	+	+
Betulaceae	+	+	+	+	+	+	+	+
Brassicaceae	+	+		+	+	+	+	
Bromeliaceae	+			+	+	+		
Buxus			+		+	+		
Cactaceae	+	+		+	+	+	+	+
Camellia					+			
Campanula				+	+			
Carduus					+	+		
Carpinus			+		+	+		
Castanea	+	+	+		+	+		
Casuarina			+		+			
Cedrus		+	+		+	+		
Centaurea				+	+			
Cercis					+			
Chenopodiaceae		+	+		+	+	+	+
Chrysanthemum					+	+		
Cichorium	+			+		+		
Cinchona			+	+	+	+		
Cinnamomum	+		+	+				
Cistus				+	+	+		

TAXA	AG	IN	FO	ME	OR	ET	WR	ot
Citrus	+	+		+	+			
Clematis				+	+			
Codiaeum					+			
Coffea	+			+	+			
Colchicum		+		+				
Combretaceae	+	+	+					
Commelinaceae						+		
Commiphora				+				+
Cornus					+			
Cortaderia					+			
Corylus		+				+		
Cotoneaster					+			
Crassulaceae					+			
Crataegus	+		+	+	+	+		
Croccus		+				+		
Cupressaceae		+	+		+			+
Cupressus		+	+		+			+
Cycadaceae	+	+			+	+		+
Dahlia					+			
Dianthus					+			
Dioscorea				+	+			
Diospyros	+		+		+			
Dracaena	+			+	+	+		
Encephalartos					+			
Erica		+	+		+	+		
Ericaceae		+	+	+	+	+		+
Erythrina					+			
Eucalyptus		+	+	+	+	+		+
Eugenia	+			+	+	+		
Euphorbia		+		+	+	+		+
Fabaceae	+		+	+	+	+	+	+
Fagus			+		+	+		+
Ficus	+		+	+	+	+	+	+
Fragaria		+				+		+
Fraxinus			+	+	+	+		
Gentiana				+	+	+		
Geraniaceae					+			
Ginkgo						+		
Gladiolus					+			
Glycine		+	+					
Glycyrrhiza	+			+		+		
Gossypium		+						
Grevillea			+		+			
Hebe					+			
Heliconia					+			
Hemerocallis					+			
Hevea (H. brasiliensis)		+						
Hibiscus	+			+	+			
Hordeum	+	+						
Hosta					+			
Hydrangea					+			

TAXA	AG	IN	FO	ME	OR	ET	WR	ot
Hypericum				+	+			
Ilex	+		+		+			+
Iris					+			
Jasminum		+		+	+			
Juglans		+		+		+		
Kalanchoe					+			
Larix		+	+		+			
Ligustrum			+		+			
Lilium					+			
Liriodendron			+		+			
Lonicera					+			
Lycopersicum	+				+			
Magnolia			+		+			
Mahonia					+			
Malus	+	+			+			
Mangifera	+				+			
Medicago	+							
Mentha		+	+		+	+		
Michelia		+						
Moraceae	+	+	+		+	+		
Morus	+	+	+		+	+		
Musaceae	+				+			
Myoporaceae					+			
Myristica	+							
Myrtaceae	+		+	+	+	+	+	
Narcissus					+			
Nepenthes					+			
Nicotiana		+		+				
Notofagus			+		+			
Nymphaea					+			
Oleaceae	+	+		+	+	+		
Opuntia		+	+			+	+	
Orchidaceae					+			
Paeonia						+		
Pandanus					+			
Papaver			+		+	+		
Passiflora	+				+			
Peperomia					+			
Persea	+		+		+			
Phaseoleae	+						+	
Phaseolus	+						+	
Phylodendron					+			
Phoenix		+				+		
Picea			+		+			
Pinaceae		+	+		+			
Pinus		+	+		+			
Platanus			+	+		+		
Populus			+	+		+		
Primula						+		
Protea					+			
Proteaceae					+			

TAXA	AG	IN	FO	ME	OR	ET	WR	ot
Prunus	+						+	
Pseudotsuga			+		+			
Psidium		+				+		
Pyrus	+						+	
Pyracantha					+			
Quercus	+	+	+		+	+		+
Rheum	+			+				
Rhododendron			+		+			
Rhus		+						
Ribes	+				+			
Robinia				+		+		
Rosa		+			+		+	
Rosaceae	+	+	+	+	+	+	+	+
Rubus	+				+			
Rutaceae	+	+		+	+			
Salicaceae		+	+		+			
Salix		+	+		+			
Sanseveria					+			
Sassafras	+							
Sempervivum					+			
Simmondsia		+						
Solanum	+	+		+	+	+	+	
Sorbus	+		+	+	+			
Spiraea						+		
Syringa						+		
Styrax		+			+			
Tagetes					+	+		
Taxus			+	+	+			+
Theobroma	+							
Thuja			+		+			
Tulipa					+			
Thymus		+	+			+	+	
Tilia				+	+			
Trifolium					+			+
Ulmus			+		+			
Viburnum				+	+			
Victoria						+		
Vinca				+	+			
Viola					+			
Vitis	+	+			+		+	
Welwitschia					+			
Zingiber	+			+				
Zingiberaceae	+			+	+			

This catalogue summarizes all taxa at genus, tribe, subfamily or family level as listed in the Directory of Botanic Gardens (HEYWOOD & HEYWOOD, eds.) of the BGCI & IABG.

Categories of taxa use or application:

AG:	Agricultural	ME: Medicinal	ET: ethnobotanic
IN:	Industrial	OR: Ornamental	ot: other
FO:	Forest	WR: Wild relatives	

3.4 Duplication of collections

There is clear duplication in the conservation of certain germplasm collections.

Among the collections of **interest to agriculture,** most comprise fruit species of the *Rosaceae* family, in particular the genera *Malus, Pyrus, Prunus* and *Sorbus*. Among the *Graminae* there are numerous collections of *Bambusoideae* and some *Triticum, Hordeum* and *Festuca spp*. There are also regional specializations: the botanic gardens of the United States with their various collections of *Citrus*; those of the former USSR with their relatively large number of *Vitis, Fragaria, Malus, Pyrus, Juglans, Ribes* and also *Citrus;* those of the Asian countries and their focus on *Bambusoideae, Musaceae, Zingiber, Manfigera, etc.*). However, there are few collections of other genera and species of great relevance to agriculture, such as *Gossypium, Coffea, Solanum tuberosum, Theobroma* and *Hevea brasiliensis*. It goes without saying that there are no targeted collections of many species, genera and families of high relevance to food and agriculture.

As regards collections of plants of **forest interest**, there are many collections of *Coniferae (Cupressus, Pinus, Abies), Fagaceae (Quercus, Fagus), Salicaceae (Populus, Salix*) and *Myrtaceae (Eucalyptus).* With respect to **medicinal** and **aromatic** plants there is a narrow concentration on, for example, *Taxus, Thymus* and *Artemisia*. Again hundreds of specimens of other relevant genera and species seem to be systematically neglected by the botanic gardens.

Duplication is all the more in evidence in the case of **ornamental collections** which always focus on a narrow band of families *(Cactaceae, Bromeliaceae, Orchidaceae, Cycadaceae, Arecaceae, Araceae, Ericaceae*). Some biotypes are conserved especially (bulbous plants). There are also clear preferences at genus level (*Camellia, Rhododendron, Begonia, Iris, Rosa, Erica, Paeonia, Narcissus*). These are often determined by regional or national popularity and have nothing to do with point of origin. For example, the botanic gardens of the United States are particularly keen on genera such as *Rhododendron, Camellia, Ilex* and *Magnolia,* while European gardens prefer *Cactaceae, Orchidaceae* and *Bromeliaceae* (*Tillandsia* for example*).* The former USSR countries are also partial to collections of selected *Rosaceae (Sorbus, Malus, Pyrus), Betulaceae (Betula, Corylus), Aceraceae (Acer), Salicaceae (Salix)* and *Coniferae (Pinus).* There is on the other hand very little duplication in collections of certain important ornamentals such as *Dianthus, Ginkgo, Viola, Chrysanthemum, Jasminum* and *Pelargonium.*

3.5 Size of collections

The literature distributed by botanic gardens usually fails to mention the size of their collections. This information is only occasionally available in the directories of gardens, brochures or *Indices Seminum.*

One of the most useful publications in this regard is perhaps that of van VLIET (ed., 1989) on the *ex situ* collections of the Dutch botanic gardens. It provides information on the number of genera, species, accessions and cultivars in each of the ten national gardens that operate a system whereby the data on their *ex situ* collections are centralized.

These collections are essentially of ornamentals, and the information indicates an average of two accessions per species, though the ratio can sometimes be much higher. The data refer to a total of 5 000 accessions that are for the most part held in four gardens (Leiden, Utrecht, Wageningen and Amsterdam). Thus the Botanic Garden of Utrecht has a collection of *Coniferae* comprising 34 genera and 260 species, with a total of 1 277 accessions. The Botanic Garden of Wageningen has a collection of *Orchidaceae* with 1 273 accessions for 789 species of 70 genera. The Botanic Garden of Utrecht also has a collection of *Betulaceae* comprising 246 accessions of 75 species (Case Study No. 1).

Other examples include:

The Botanic Garden of Homestead (Florida, US) has a collection of orchids with about 20 000 accessions representing some 2 000 species, making for an average of ten accessions per species.

The Botanic Garden of Nanjing (China) has collections of medicinal plants of about 600 taxa, a classified collection of over 300 species, an arboretum with over 400 woody species, collections of native flora of China, tropical and sub-tropical collections and a collection of Mediterranean taxa where Olea Europaea alone has more than 450 cultivars (Case Study No. 2).

The National Botanic Garden of Cuba uses some of its 600 hectares to conserve tropical tree species in small plantations, with each species represented by hundreds of specimens planted over several thousand square metres of land. Its collections of *Palmaceae* and native trees of Cuba are of special interest (Case Study No. 3).

Mexico's botanic gardens have a wide selection of collections of mainly endemic species of economic and ornamental interest. They have begun to develop "national collections" assigning individual gardens specific responsibilities for taxonomic groups or plants of economic interest. For example, the national collection of *Zamiaceae* is held in the Botanic Garden of Xalapa, Veracruz, while the Botanic Garden of the UNAM, Mexico D.F., is responsible for *Agavaceae* (Case Study No. 4).

The Botanic Garden of Meise (Belgium) has a collection of *Phaseoleae* (under long-term conservation in seed bank) with 1 277 accessions, mainly of *Phaseolus* and *Vigna* (Case Study No. 5).

It would appear therefore that the catalogues and registers of botanic gardens specify the number of cultivated taxa in their collections but rarely mention the number of accessions, which is estimated range from one to ten but is more usually two or three. There is hardly ever any information on size of accession, particularly in reference to collections under cultivation.

CASE STUDY NO. 1

EX SITU COLLECTIONS OF BOTANIC GARDENS OF THE NETHERLANDS*

There are ten botanic gardens in the Netherlands and a further 42 sister institutions that include arboreta, ecological gardens, pine forests and collections of succulent, herbacious and other plants. The computerizeration of collection data began in the 1980s as encouraged at a number of conferences (Kew 1978, Durham 1986). Botanic garden thematic specialization is recognized as being the most effective way of conserving plant resources, especially endangered species, and of promoting related education.

The botanic gardens of the Netherlands hold mainly ornamentals. Available information refers principally to family level though certain genera are also comprehensively documented (*Iris, Petunia, Rosa, Magnolia, Tillandsia* and *Betula*).

The main collections are conserved in the Botanic Gardens of:

	Acronym
Amsterdam ("De Plantage")	AMD
Amsterdam (University)	AMV
Rotterdam	BLI
Delft	DEL
Harem	GRO
Leiden	LEI
Utrecht	UTR
Wageningen	WAG
Biddinghuizen	BID
Nijmegen	NIJ

Biodiversity conservation for selected collections according to taxonomic group:

		Genera	Species	Cultivars	Accessions
Coniferae	AMD	53	214	275	561
	GRO	28	124	65	255
	UTR	34	263	769	1277
Annonaceae	UTR	22	41	-	68
Betulaceae	UTR	5	75	25	246
	WAG	6	97	38	160
Rosaceae	WAG	64	831	770	1333
Orchidaceae	LEI	142	730	26	960
	UTR	163	899	59	1409
	WAG	70	789	-	1273

*Information from VAN VLIET (1989)

CASE STUDY NO. 2

COLLECTIONS OF THE BOTANIC GARDEN OF NANJING (CHINA)

The Botanic Garden of Nanjing (China), which is located south of the Yangtze River, was established in 1929 and is one of the oldest botanic gardens in the country. Its 186 hectares comprise natural and landscaped areas with collections of ornamentals, medicinals, Mediterranean plants, plants native to China, endangered plants, an arboretum, a pinetum and experimental plots for introduction and cultivation trials.

One of its main collections is of medicinals of which there are some 600 taxa (429 genera and 131 families). Some germplasm collections are remarkable such as that of *Dioscorea* which includes over 20 species native to China. Their function, apart from conservation and display, is pharmacological research.

The classified collection has over 300 species (204 genera). The arboretum has approximately 400 woody species which are mainly endemic to China and include important collections of *Fagaceae, Lauraceae, Theaceae, Magnoliaceae, Aquifoliaceae.* The pinetum has over 90 species of *Pinaceae, Taxodiaceae* and above all *Cupresaceae.* The Mediterranean collections include one of *Olea europaea* with more than 450 cultivars of olive. The ornamentals section has over 600 taxa and numerous cultivars of *Rosa, Viburnum, Pyracantha* and *Acer*. A total of 845 tropical and sub-tropical species are conserved under glass cover (347 genera and 105 families). The area given over to experimentation, genetic enhancement and the introduction of new cultivated varieties includes the conservation of collections such as Z*izyphus jujuba* (26 cultivars) and *Castanea mollissima* (59 cultivars).

*Information from SHAN-AN (1988).

CASE STUDY NO. 3

COLLECTIONS OF THE NATIONAL BOTANIC GARDEN OF CUBA*

The National Botanic Garden of Cuba is situated 25km from Havana City. It was begun 1967 and inaugurated in 1984. Its 600 hectares include a variety of facilities and documentary resources including tropical pavilions, a laboratory and *in vitro* culture rooms, a herbarium (with over 70 000 specimen sheets of Cuban flora), a library, etc. Its main objectives are education and the conservation of endemic flora.

Its field collections are mainly tropical tree species. Cuban florae are well represented with about 800 taxa representing 12% of the total. Its collections of *Palmaceae* are perticularly noteworthy (over 150 taxa). The most salient feature, however, is the high number of specimens and the area given over to their cultivation and/or conservation. There is a small plantation for each tree species with several thousand m^2 given over to trees of the same taxon.

*Information from LIEVA (1988).

CASE STUDY NO. 4

COLLECTIONS OF THE NATIONAL NETWORK OF BOTANIC GARDENS: MEXICO*

Mexico is one of the many countries with an officially established national Association of Botanic Gardens grouping about 35 gardens (13 established and 22 under consolidation). While there is no preset allocation of collections under cultivation, this is nevertheless to some degree taking place and is gradually converting Mexico's network of botanic gardens into the custodian not only of Mexican flora but also of many plant species and varieties of economic interest.

For example, the Botanic Garden of UNAM has sizeable collections of *Cactaceae, Agavaceae* and other families, and more specifically of *Opuntia, Agave, Dasylirion, Yucca and Chamaedorea*. Other botanic gardens hold collections of medicinal plants ("Maximino Martinez" Botanic Garden in Chapingo) or of ethnobotanic interest (Botanic Garden of Morelos in Cuernavaca).

The Botanic Garden of Puyacatengo, in Tabasco, was set up in 1984 with the primary aim of establishing a collection of plants of direct use to local indigenous communities. Its arboretum includes 135 native tree species of economic interest, in addition to collections of exotic tropical cultivars such a *Theobroma cacao* (37 clones), *Coffea* spp. (13 varieties) and *Citrus* (6 species and 28 varieties).

The Botanic Garden of the Scientific Research Centre of Yucatan (CICY) in Merida was set up in 1983. Its field collections include *Agavaceae* (340 accessions with 32 taxa), *Orchidaceae* (200 accessions of 25 species), *Palmaceae* (55 specimens of 12 species) and *Cactaceae* (78 accessions of 16 species). Its collection of native species of the region with more than 280 different taxa is also worthy of note.

Finally, the "Francisco Xavier Clavijero" Botanic Garden of Xalapa (Veracruz), which was established in 1977, has large collections *Coniferae* (*Pinus* and *Cupressus* mainly), succulent plants (*Agave, Yucca, Cactaceae*), *Orchidaceae* (national collection of *Bletia*), *Palmaceae*, commonly-used plants (with collections of *Bixa, Persea* and *Zea*), *Bromeliaceae* and *Aristoloquiaceae*. Of particular note is its national collection of *Cicadeae* (*Zamiaceae*, especially *Dioon edule*) On the basis of this germplasm, the garden has introduced programmes of education, propagation and domestication which have led to successful cultivation, thereby averting the illegal extraction of plants from the natural populations of Mexican *Zamiaceae*.

*Information from COLUNGA *et al*. (1990), DELGADEO MONTOYA *et al*. (1988), GONZALO ORTIZ (1996), HERNANDEZ ZACARIAS *et al*. (1990), HERRERA (1983), VOVIDES *et al*. (1995).

3.6 Characterization, evaluation and documentation

This is without doubt a neglected element. The botanic gardens are rarely involved with or linked to agricultural or forest research programmes and only a few germplasm banks belong to the network of the International Plant Genetic Institute (IPGRI). Most in fact conserve the bulk of their collections without going further in terms of evaluation or characterization than taxonomic description, collection details and geographic origin. There is no agronomic evaluation which is an area clearly requiring further work. Whether this should be the remit of botanic gardens is open to debate, but they should at least adopt a method of registration of accessions that includes the passport data.

3.7 Conservation regime

3.7.1 Collections under cultivation

The botanic gardens are basically using traditional field or greenhouse cultivation techniques to maintain their germplasm collections. Some 80% of collections and accessions are probably maintained in this manner. Most of the collections are *ex situ*, as the gardens use *in situ* methods almost exclusively for wild species. There are numerous satellite, alpine and highland gardens and genuine *in situ* gardens, but very few closely involve local farmers in the coordinated or collaborative conservation of germplasm collections - where they do, there are deficiencies in resources and techniques hampering continuity. A rare exception might be the Botanic Garden of Puyacatengo in Tabasco, Mexico (Case Study No. 4).

3.7.2 Seed Banks

There are approximatly 150 botanic gardens with seed banks, which suggests that between 15 and 20 percent of taxa and accessions are conserved with this method. The technique employed by the germplasm bank of the Botanic Garden of Meise (Case Study No. 5) may be very representative.

3.7.3 In vitro collections

The 35 or so botanic gardens with *in vitro* culture facilities use this method mainly to research new and more effective propagation techniques or else to obtain disease-free plant material. Only a minority use this technique for conservation by handling genuine tissue banks. The number of species, varieties and accessions under strict *in vitro* conservation is probably only symbolic, although it does include certain bulbous plants, orchids and bromeliads (in slow culture medium) and collections of fungi to innoculate higher plants.

3.7.4 Other methods

Other methods of conservation such as cryopreservation and pollen conservation are even rarer. There are probably no genetic libraries.

CASE STUDY NO. 5

COLLECTION OF PHASEOLAE OF THE BOTANIC GARDEN OF MEISE*

The *Phaseolae* collection started in 1965 by Professors G. Le Marchand and R. Marechas of the Faculty of Agricultural Sciences of Gembloux was absorbed in 1988 by the National Botanic Garden of Belgium (Meise) after the Ministry of Agriculture had accepted responsibility for its conservation and management. The collection is recognized by the IPGRI as a "base collection" for wild species of the *Phaseolus* and *Vigna* genera.

As a base collection, it has a very wide genetic diversity among wild and agrestal species. Its main objective is to ensure long-term conservation as seeds. It currently comprises 1 277 accessions of 185 different taxa, mainly of the *Phaseolinae* subtribe. The two predominant genera are *Phaseolus* and *Vigna.*

Number of species and accessions of the most important genera in the collection

Genus	No. species	No. taxa	No. accessions
Phaseolus	20	40	635
Vigna	53	75	454
Macroptilium	11	13	73
Macrotyloma	7	9	28
Centrosema	9	9	17
Dolichos	3	5	6
Other	32	34	64
Total	144	185	1277

The collection is maintained in plastic-foil pouches stored at -20°C after reducing humidity to 5-6% in silica-gel drying chambers. Periodic germination and multiplication tests are conducted in greenhouse environments to check viability and obtain material for research work on intraspecies variability and phylogenetic relations, compatibility with cultivated species and other domestication activities.

*Information from VANDERBORGHT (1995)

3.8 Type and origin of germplasm

Although many botanic gardens (40%) do not keep an actual register of the plant collections they cultivate, most of those with monographic germplasm collections have some sort of record (60%) - some 25% on computer.

The origin of the conserved germplasm depends on taxonomy. Collections of native species and plants of medicinal or ethnobotanic interest (e.g. crafts or dyes) are usually from wild stock. The opposite holds for ornamentals. Collections solely of interest to agriculture vary in origin but most gardens work with local varieties. The fifth edition of the International Directory of Botanic Gardens frequently employs terms such as **old varieties**, **land races**, **lost crops** and **related wild taxa**.

While many botanic gardens tend to use commercial species and varieties under extensive cultivation, others are firmly committed to collecting and conserving local varieties. A case in point is the Botanic Garden of Puyacatengo (state of Tabasco, Mexico) where species and varieties of local origin and interest to agriculture are conserved, cultivated and distributed to local farmers. Some gardens are considered partially or totally ethnobotanic as they focus essentially on conserving locally-used species and are duly equipped for this purpose. Examples include two botanic gardens in Hawaii (US) and the Botanic Garden of Cordoba (Spain).

Endangered conifers are a good example of the extent to which figures and methods of operation can differ between gardens. LEADLEY (1992) has compiled information on 183 botanic gardens that maintain these species, representing only 26% of gardens with germplasm collections. They hold 179 endangered taxa which is 68% of conifers in danger of extinction (according BGCI data). Between 15 and 20% of the accessions of these species are of wild origin but one institution alone, the Botanic Garden of Amsterdam, holds 135 of these taxa and 90% of its accessions are wild in origin (Case Study No. 6).

It is extremely difficult to determine accurately where the botanic gardens procure the specimens, wildlife species, cultivars and accessions for their seed banks. Potential sources include:

a) **exchange through the *Index Seminum***. This is still a very useful channel despite the risks involved: lack of information on geographic provenance of the germplasm; collections grown in the garden itself from specimens of dubious provenance; identification errors and so forth. About 25% of germplasm accessions of botanic gardens are likely to come from this source. This system, whose shortcomings are examined below (Case Study No. 7), works as a more or less direct transfer from country of origin of resource to country of recipient garden. It offers free access to germplasm without requiring anything specific in return apart from the tradition of international co-operation among botanic gardens.

b) More explicit and efficient exchange between gardens through **Cooperation Agreements and Protocols** concerning complete collections or donations of a certain number of specimens. This exchange mechanism is more common in helping newly established gardens or between institutions also collaborating in other areas such as research or education. This method of exchange has been gaining popularity in recent years with the development of international botanic garden associations and meetings.

c) from **direct on-site collection,** almost always in the country of origin. The botanic gardens organize expeditions to other countries for taxonomic studies and/or the specific collection and removal of specimens and propagules. HEPPER (ed. 1989) illustrates the importance of this traditional means of acquiring germplasm in his historical study of the many expeditions fielded by Kew Gardens throughout the world.

d) through the **commercial acquisition** of specimens from public or private nurseries. Surprisingly, this is a very common source and in many gardens probably accounts for up to 50% of accessions. Under this method, the problem of identification of provenance is transferred to the registration of germplasm by nurseries and commercial producers of agricultural, forest and ornamental plants.

e) **donation and seizure**. Donations of collections of plants from private individuals are especially frequent in the gardens of the more developed countries. Enforcement of international agreements (notably CITES) leads to material being seized at borders and sent temporarily or permanently to botanic gardens serving as official depositories.

CASE STUDY NO. 6

INVENTORY OF COLLECTIONS HELD IN BOTANIC GARDENS: A BGCI STUDY OF COLLECTIONS OF CONIFEROUS PLANTS*.

In September 1989, the BGCI conducted a survey among botanic gardens to determine the taxonomy of their collections of *Coniferae* under cultivation. LEADLEY (1992) then supplemented the information given in an early publication (WYSE JACKSON 1989) with data supplied by 183 botanic gardens. The main objective of the study was to determine how many and which of the 264 taxa of endangered Coniferales were maintained in botanic gardens.

The study revealed that 179 taxa (68% of the endangered total) were maintained in at least one garden; 41 in one garden only, 18 in two gardens and the remainder in three or more gardens, which is an acceptable level of duplication and therefore security.

The number of accessions per taxon varies considerably as does the number of sources:

	No. Accessions total	**No. Of sources**
Picea omorika	71	5
Abies pinsapo	54	9
Araucaria heterophylla	44	5
Microbiota decussata	41	9

N.B. This study does not provide specific information on provenance of germplasm, number of specimens per accession or characterization of variability under cultivation. There is even less information on regeneration, genetic integrity of stock and exchange of germplasm.

*Information from LEADLEY (1992) and WYSE JACKSON (1989).

3.9 Administration and ownership of germplasm

There is generally no clearcut definition of ownership of the germplasm collections held in the botanic gardens. A legal study is needed to finalize the question of ownership.

An idea can be obtained by equating the administrative regime of collections with that of the garden. A preliminary analysis of information from 30% of the 700 gardens with germplasm collections indicates the following administrative breakdown:

Categories	%
State and regional administration	37.5
Local (municipal) administration	9.0
Municipality/university consortium	1.0
Universities and research institutes	31.0
Private bodies	11.0
Others (or no data available)	10.5

At least 79% of the collections are therefore under public administration, a proportion probably rising to 85% once discrepancies and omissions have been dealt with, which leaves only 11 to 15 % under private ownership.

Such data are not however conclusive. A garden under local (municipality) administration or a research institute may in fact be holding collections under regional, national or state ownership - this from the legal perspective prior to the entry into force and ratification of the International Agreement on Biological Diversity, after which matters become even more complicated with the need for an agreement on ownership of germplasm between collector and country of origin.

One element of concern in the relationship between the public and private sectors is the growing dependence of botanic gardens on the private sector. This sometimes even extends to the stipulation of rights and work programmes regarding the utilization and research of germplasm collected or conserved in the gardens.

3.10 Security of collections

We need to estimate the level of security of the collections held by the botanic gardens. It would be worrying to imagine these collections being irreversibly lost. We do not know whether and to what extent mechanisms exist for their automatic regeneration.

It would also be useful to identify the level of expertise of the gardens in the effective propagation of conserved species and varieties. Care needs to be taken to safeguard the genetic integrity of these collections which might or might not - we do not know - multiply under natural selection.

Possible indicators of security and integrity include:

- Legal status of the garden (the answering body). In principle, the most stable would appear to be those under national, federal or regional administration and those belonging to universities and research centres (about 70%).

- Facilities for research and conservation (existence of an affiliated research institute, total greenhouse area, seed banks, *in vitro* culture units, library, conservatory, herbarium, laboratories, total area).

- Age since foundation. Some are over 450 years old but there are also well-resourced gardens no more than 20 to 30 years of age.

- Annual budget of garden.

- Number of staff, especially university graduates and technical personnel.

It is too early to answer these questions, but the database and second phase of the ongoing study will shed greater light on these matters.

3.11 Availability and exchange

Botanic gardens have a traditional method of exchange which is based on requests and dispatch through *Indices Seminum*. The early seed lists published for the purpose of free exchange among botanic gardens reputedly date back to the mutual assistance of the Botanic Gardens of Chelsea and Leiden in 1682. An estimated 65% of gardens with germplasm collections still use this system of exchange.

However, the method has recently been scrutinized by commentators and found wanting in effectiveness, ethics and returns. For example, CLEMENTE MUÑOZ and HERNANDEZ BERMEJO (1990) conducted a statistical survey of the aggregate experience of the Botanic Garden of Cordoba over five consecutive years (1982-86) during which 16 000 samples were sent to 300 different botanic gardens in 47 countries. The survey revealed that: many requests were highly frivolous; little attention was paid to provenance; requests were repeated each year for the same species; the basic data requested as part of the exchange process were not supplied; most requests were for taxa listed on the first pages of the *Index*, among the first species of the family or the first of the localities of the taxon in question.

There was also seen to be a marked geographical distortion in demand for species and accessions, with most requests coming from botanic gardens in a few specific countries.

Another problem was that the more discriminating requests were for the rarer and endangered taxa. The sourcing of accessions from the natural environment - the more sensible option- would after a few years gradually deplete the stock of wild relatives of these taxa. Though the system is based on exchange among supposedly scientific institutions, there is seldom any

acknowledgement of the donor in reports on scientific progress, genetic enhancement or synthesis of active ingredients or any other benefit beyond that of exchanging material at no cost.

This system of exchange may be free of charge but it is also virtually anonymous, indiscriminate, prone to genetic erosion and devoid of ethical integrity. It is also unaffected by international law and agreements, not very efficient, wasteful of germplasm and even a touch naive and obsolete. On the plus side, its traditional generosity provides easy access for the applicant who receives the requested goods by return of post. It has also been very effective for gardens working on joint conservation programmes and has in fact saved several species from extinction, a well-known case being *Lysimachia minoricensisI*, a species endemic to the island of Menorca.

These criticisms have been fuelling pressure for change. It was with this in mind that, in 1991, the Ibero-Macaronesica Association of Botanic Gardens (gardens of Spain and Portugal) adopted a model of *Indices Seminum* publication and exchange that has served as an example for other botanic gardens of the world. It produces a joint catalogue - thus avoiding duplication, cutting economic and genetic costs, centralizing information for rapid access - and adopts a strict policy of not supplying endangered taxa without good reason. This system has been successfully employed for the last five years and is beginning to be imitated by other groups and associations of botanic gardens (including Holland, Mexico and Cuba). Perhaps the future will see a single comprehensive *Index Seminum* released electronically, on diskette or on CD Rom (Case Study No. 7).

CASE STUDY NO. 7

A COORDINATED SYSTEM OF GERMPLASM EXCHANGE: THE EXPERIENCE OF THE IBERO-MACARONESICA ASSOCIATION OF BOTANIC GARDENS*

The traditional system of exchange of germplasm among botanic gardens has been in operation for more than three hundred years through the publication and distribution of seed catalogues (*Index Seminum*). Supply, which is often from specimens and collections maintained in the garden and less often from natural stock, is carried out generously and operates through *Desiderata* and the subsequent remittance of the samples requested (always in small quantities) at no charge. Despite its tradition and the high altruism this system of exchange represents, the *Index Seminum* concept and model has been in crisis in recent decades. Numerous authors have drawn attention to its problems, shortcomings and drawbacks (JURY, 1984; CLEMENTE MUÑOZ and HERNANDEZ BERMEJO, 1989-90); CLEMENTE MUÑOZ and CONTRERAS, 1990; WIJNADS, 1989).

Problems include:

The absence of a standard format for publication of the *Index seminum*, with frequent absences of information on origin of the material, identification mistakes, taxonomy errors etc.;
High costs of collecting and cleaning of the seeds;
Difficulties in dispatch because of phytosanitary inspection and CITES restrictions;
High costs of mailing;
Unreasonable, frivolous or indiscriminate requests;
Uncertainty about final use of the seeds, with the frequent omission of acknowledgement of the donor institution in scientific works, enhancement programmes or other uses of the donated germplasm;
Excessive consumption of germplasm in the case of rare or endangered species drawn from wild stock.

As a result, many gardens and regional associations have begun to change the format of *Index Seminum* publication and distribution and have introduced changes in the listed material and conditions of supply. The most significant experience in this connection might perhaps be that of the Ibero-Macaranesic Association of Botanic Gardens (AIMJB) and its coordinated *Indices Seminum*. Full details are provided by CLEMENTE MUÑOZ, 1994.

The joint AIMJB catalogue was designed and published for the first time in 1991 by the Botanic Garden of Cordoba on behalf of the eleven participating institutions. It has subsequently been published annually under rotating responsibility (in 1992 the Botanic Garden of Blanes; in 1993 “Viera y Clavijo” of Gran Canaria; in 1994 Barcelona and in 1995 Madrid).

The main characteristics of this joint catalogue are:

a) A common cover and binding, with individual inserts for each botanic garden and an introduction and rules of exchange that apply to the whole catalogue;
b) Each insert or individual *Index* is presented in standard format. The characteristics of each garden are included in each of these subcatalogues.
c) Seeds for supply are listed in alphabetical order of families, genera and species. Supply is limited to a maximum of 100 taxa;

d) Voluntary membership of the system;
e) Publication under a common logo;
f) Publication under the rotating responsibility of the affiliated botanic gardens;
g) Common distribution with one directory;
h) One *Desiderata* for each botanic garden which deals directly with requests received.

The purpose of the catalogue is to reduce the publication and distribution costs, the consultation effort and the depletion of natural resources and to optimize quality and efficiency in the exchange of germplasm.

*Information from CLEMENTE MUÑOZ (1994)

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 The International Network of Botanic Gardens

Conclusions

The almost 1500 botanic gardens of the world constitute the greatest concentration of the planet's biodiversity. They hold almost 50% of the world's vascular flora species. They have vast conservation facilities and equipment, with over 1 million^2 of climatized greenhouses, millions of volumes in their libraries, millions of specimen-sheets in their herbaria, hundreds of thousands of accessions in their seed banks, scores of *in vitro* culture laboratories, specialised museums, pollen and sperm banks etc..

The botanic gardens hold special collections - sometimes called 'national' - that approximate the concept of collections of germplasm under cultivation as each taxon is represented by a number of specimens and they hold sufficient taxa at one level to constitute a higher level. It is estimated

that 47% of the botanic gardens (about 700) maintain collections of plant germplasm in this way. Of these, 120 have collections of agricultural interest, 170 have medicinal and forest plants while the remaining 410 gardens tend to have collections of ornamental plants or of species endemic to their region or country.

Recommendations

In view of this and despite the shortcomings noted, it would seem appropriate to increase the involvement of the international network of botanic gardens in the conservation and efficient management of collections of germplasm of interest to food and agriculture. In this connection, we need to recognize the potential of some of the most important botanic gardens in the world, with their extensive facilities and resources, but more specifically, we also need to acknowledge the role of the other, often smaller, botanic gardens located in the less developed countries or regions. These have closer contact with local populations, indigenous peoples and folklore; are more strongly committed to conserving local flora and plant genetic resources; and have proven their skill in the management and conservation of plant germplasm.

The role of botanic gardens should be reinforced and their respective governments should be urged to accord greater recognition of and attention to their function in the conservation of plant genetic resources.

In spite of the many limitations mentioned, the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture should both include all the collections of germplasm currently held in botanic gardens when assessing capacity and know-how and should continuously involve these institutions in the pursuit of its objectives.

More specifically and also possibly under the Global Plan of Action, a Directive or Specific Programme on Germplasm Collections in Botanic Gardens could be formulated with the participation of all botanic gardens that have sufficiently documented germplasm collections, that offer suitable conditions for conservation and that provide accessibility to germplasm and to information on its cultivation and use. The Plan of Action and the international organizations of botanic gardens could then work out the criteria for recognition of eligible gardens. Official recognition of this nature could help the gardens secure funding and support from their governments or from any organization for the conservation and management of their collections.

Another possible objective, once these criteria have been established, would be to set up an Index or Directory of Germplasm Collections Maintained in the Botanic Gardens of the World.

4.2 Concept and existence of germplasm collections in botanic gardens

Conclusions

There is no world catalogue of plant collections in botanic gardens. Only a small percentage of gardens have published details of their collections under cultivation (about 10%) and over half do not even know how many or which species they hold. There are also very few cases of a composite national catalogue of collections under cultivation.

It is unusual for botanic gardens to operate under the concept of germplasm collection, understood as a collection of a wild or cultivated taxon with a sufficiently high number of specimens or propagules to ensure genetic variability and maintained under conditions conducive to long-term conservation. Gardens tend to talk of special collections when referring to those most resembling the concept of germplasm collection.

A number of countries have developed the concept of national collection whereby a determinate taxon (family, tribe, genus or species, as applicable) is conserved in a specific botanic garden.

The depository gardens conserve and manage such collections more for scientific, ornamental or public display purposes than for their applied or economic interest or out of any firm commitment to their conservation as germplasm collections.

4.3 System of registration

Conclusion

Despite the increased computerization of registration of collections and specimens maintained in botanic gardens and proposals for standardized computer registration and exchange (ITF: International Transfer Format) there is still no unified comprehensive format for identification of type, status or location - in general or even less so for germplasm collections.

Recommendation

A passport or standard registration system needs to be developed to improve the documentation process.

4.4 Size and variability of the collections

Conclusion

Botanic gardens do not generally pay sufficient attention to holding collections with sufficient specimens and variability of each taxon for purposes of conservation or research. Nor do they mention these aspects in their catalogues. Unfortunately, there is a broad tendency to concentrate on acquiring a larger number of taxa even though their representation might be minimal (often one or very few individuals of the same origin).

Recommendation

Acceptable minimum criteria need to be determined on number of specimens and genetic variation of the conserved taxon, in accordance with holding capacity of the garden and the conservation objectives.

4.5 Security and rigour of conservation methods

Conclusion

Although botanic gardens may have existed for a long time, be solidly established, and possess extensive facilities in the form of libraries, herbaria, propagation greenhouses, climatization systems, large cultivation areas and resources, the security of their collections needs to be upgraded by concentrating more on conservation, characterization, evaluation, study and management.

Recommendation

Botanic gardens need to accept and operate under the concept of germplasm collection more clearly and tightly. This will mean more stringent control over cultivation procedures: avoiding hybridization with closely-related taxa, refining propagation methods, determining and controlling fertilization systems, mastering the biology and ecological needs, monitoring response to cultivation, checking possible variations relative to wild stock, evaluating variability, safeguarding information on provenance of specimens and populations under cultivation, and organizing the parallel monitoring of wild stock of the same taxon, where this exists.

4.6 Characterization and evaluation of collections

Conclusion

Very few botanic have conducted an agronomic evaluation of their germplasm collections. Characterization is slightly more frequent. A computerized system of registration is gradually being introduced, with a move even towards standardization and networking (ITF International Transfer Format, BGCI Recorder).

Recommendation

Even though it should not necessarily be the remit of botanic gardens to carry out agronomic evaluations of their collections, they should at least see to these are characterized. As a minimum, all the accessions should have passport data with complete information on origin and type of material collected or acquired.

4.7 System of germplasm exchange

Conclusion

The botanic gardens operate an intensive traditional system of germplasm exchange through the publication of *Index Seminum*. However, this system has criticized as inefficient and unviable. There is no guarantee that the dispatched material will be used appropriately and there are many errors in the taxonomic classification of material which is of unspecified or dubious origin. All this points to the need for urgent revision. Some gardens and national associations are already testing more viable systems that are easier to control and that comply with local legislation and international agreements on the transfer of germplasm.

Recommendation

The system of exchange needs to be refined and tailored not only to traditional cooperation through *Index Seminum* but also to international agreements, such as the International Agreement on Biological Diversity and the Agreement of Washington (CITES), and to international and national plant protection regulations. The transfer process should also be extended to include germplasm and relevant technical know-how on cultivation, use and management.

4.8 Administration and ownership of collections

Conclusion

The status of ownership of germplasm collections in botanic gardens is not clear. The fact that 80% of the gardens belong to the public sector facilitates but does not resolve the future definition of ownership under the International Convention on Biological Diversity. In general terms and more specifically with regard to germplasm, the botanic gardens have not yet tackled the ownership implications of the entry into force of the Convention.

Recommendation

A legal study is needed on the pre-Convention ownership of botanic garden collections.

4.9 Sharing responsibilities and the equitable distribution and location of collections

Conclusion

The higher concentration of botanic gardens in developed countries, the bias in their collections and the duplicated conservation of certain taxa or thematic collections reveal a strong imbalance and an inefficient use of facilities and resources.

Recommendations

A global strategy is needed to ensure that responsibility for the conservation of germplasm collections is shared more equitably.

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Other Reference Material

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