Chapter 3

The state of *ex situ* conservation

3.1 Introduction

Ex situ conservation continues to represent the most significant and widespread means of conserving PGRFA. Most conserved accessions are kept in specialized facilities known as genebanks maintained by public or private institutions acting either alone or networked with other institutions. PGRFA can be conserved as seed in specially designed cold stores or, in the case of vegetatively propagated crops and crops with recalcitrant seeds, as living plants grown in the open in field genebanks. In some cases, tissue samples are stored *in vitro* or cryogenically and a few species are also maintained as pollen or embryos. Increasingly, scientists are also looking at the conservation implications of storing DNA samples or electronic DNA sequence information (see Section 3.4.6).

Following a general overview of the status of genebanks around the world, this chapter addresses a number of facets of *ex situ* conservation: collecting, types of collection, security of conserved germplasm, regeneration, characterization and documentation, germplasm movement and botanical gardens. It ends with a brief overview of the changes that have taken place since the first SoW report was published and an assessment of gaps and needs for the future.

3.2 Overview of genebanks

There are now more than 1 750 individual genebanks worldwide, about 130 of which hold more than 10 000 accessions each. There are also substantial *ex situ* collections in botanical gardens of which there are over 2 500 around the world. Genebanks are located on all continents, but there are relatively fewer in Africa compared with the rest of the world. Among the largest collections are those that have been built up over more than 35 years by the CGIAR and are held in trust for the world community. In 1994, the CGIAR centres signed agreements with FAO, bringing their collections within the International Network of *Ex Situ* Collections. These were brought under the ITPGRFA (see Chapter 7).

Based on figures from the World Information and Early Warning System (WIEWS)[1] and country reports, it is estimated that about 7.4 million accessions are currently maintained globally, 1.4 million more than were reported in the first SoW report. Various analyses suggest that between 25 and 30 percent of the total holdings (or 1.9-2.2 million accessions) are distinct, with the remainder being duplicates held either in the same or, more frequently, a different collection.

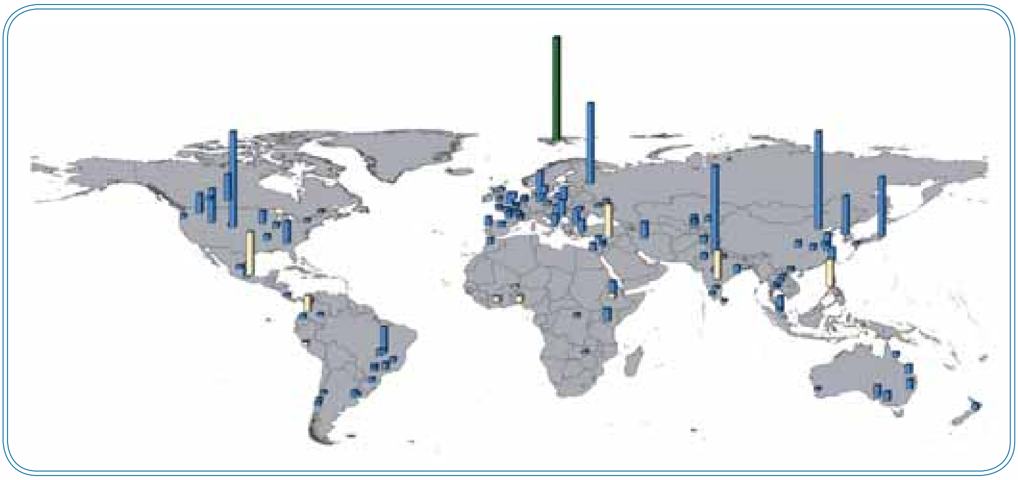
Germplasm of crops listed under Annex I of the ITPGRFA is conserved in more than 1 240 genebanks worldwide and adds up to a total of about 4.6 million samples. Of these, about 51 percent is conserved in more than 800 genebanks of the Contracting Parties of the ITPGRFA and 13 percent is stored in the collections of the CGIAR centres. Of the total 7.4 million accessions, national government genebanks conserve about 6.6 million, 45 percent of which held in only seven countries[2] down from 12 countries in 1996. This increasing concentration of *ex situ* germplasm in fewer countries and research centres highlights the importance of mechanisms to ensure facilitated access, such as that of the MLS under the ITPGRFA.

The geographic distribution of accessions stored in genebanks and as safety backup samples in the SGSV is summarized in Figure 3.1 and Table 3.1.

3.3 Collecting

According to the country reports, the trends reported in the first SoW report appear to have continued with respect to the decline in international germplasm collecting, an increase in national collecting and the greater importance now given to CWR. According to the country reports and on-line databases, more than 240 000 new accessions have been collected and added to *ex situ* genebanks over the period 1996-2007.[3] The large majority of missions collected germplasm of direct national interest, particularly obsolete cultivars, landraces and related wild species. Cereals, food legumes and forages were the main crop groups targeted. The number of accessions collected every year since 1920 and stored in selected genebanks,[4] including those of the CGIAR centres, is illustrated in Figure 3.2. There was a gradual increase in the annual collecting rate between 1920 and the

FIGURE 3.1
Geographic distribution of genebanks with holdings of >10 000 accessions (national and regional genebanks in blue; CGIAR centres genebanks in beige; SGSV in green)[5]



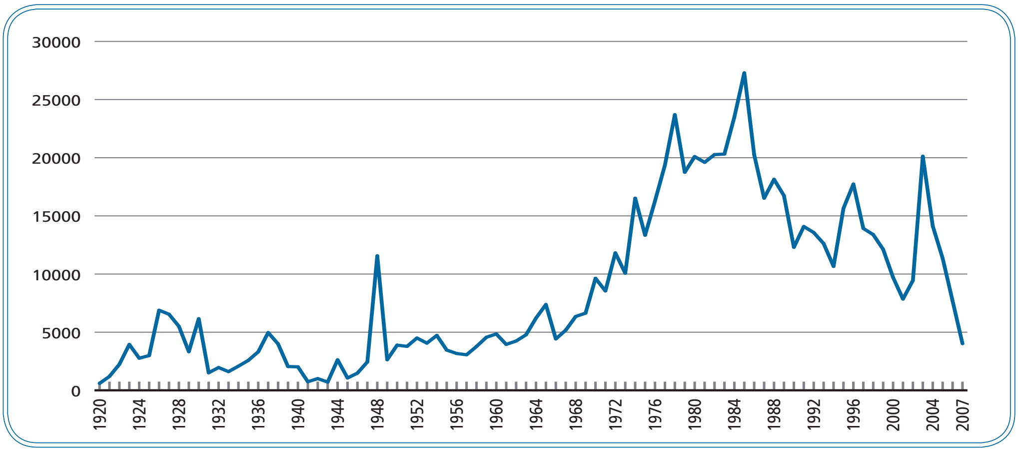
Source: WIEWS 2009; Country reports; USDA-GRIN 2009

TABLE 3.1
Regional and subregional distribution of accessions stored in national genebanks (international and regional genebanks are excluded)

Region [6]	Sub-region	Number of accessions
Africa	East Africa	145 644
Africa	Central Africa	20 277
Africa	West Africa	113 021
Africa	Southern Africa	70 650
Africa	Indian Ocean Islands	4 604
Americas	South America	687 012
Americas	Central America and Mexico	303 021
Americas	Caribbean	33 115
Americas	North America	708 107
Asia and the Pacific	East Asia	1 036 946
Asia and the Pacific	Pacific	252 455
Asia and the Pacific	South Asia	714 562
Asia and the Pacific	Southeast Asia	290 097
Europe	Europe	1 725 315
Near East	South/East Mediterranean	141 015
Near East	Central Asia	153 849
Near East	West Asia	165 930

Source: WIEWS 2009 and Country reports

FIGURE 3.2
Number of accessions collected each year since 1920 and stored in selected genebanks, including those of the CGIAR centres



Source: 31 genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/Departamento Nacional de Recursos Fitogenéticos y Biotecnología (DENAREF) (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info., 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI and WARDA (source: SINGER, 2008).

late 1960s and a rapid increase from then until the mid-1980s. Since then, collecting rates have gradually eased off with collecting by the CGIAR centres having levelled off since the early 2000s.[7]

An indication of the type of accessions collected by selected genebanks over two time periods, 1984-95 and 1996-2007 is shown in Figure 3.3 whereas Figure 3.4 shows the types of crop collected over the latter period, 1996-2007.

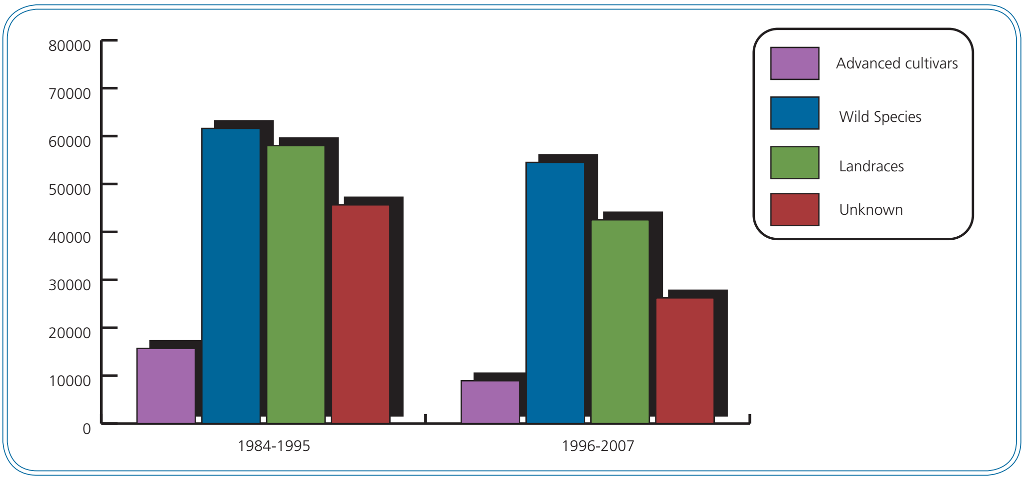
3.3.1 Situation in the regions

Most collecting missions during the last ten years have taken place in-country and have mostly aimed either to fill gaps in collections or to recollect germplasm lost during *ex situ* conservation. With changing patterns of land use and increasing environmental degradation in many parts of the world, there has been a perceived need to collect material for *ex situ* conservation that might otherwise have been conserved *in situ*. Concern about the effects of impending climate change has also steered some germplasm collecting in the direction of specific traits, such as drought and heat tolerance.[8]

Africa

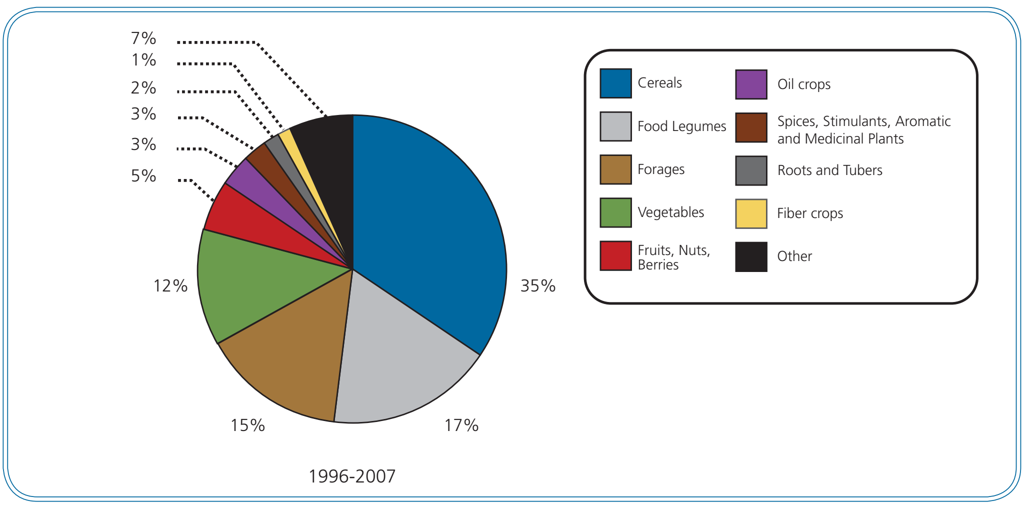
Many African nations have reported carrying out collecting missions over recent years, resulting in more than 35 000 new accessions. Since 1995, more than 4 000 accessions from some 650 genera have been collected and added to the collection in the National Genebank of Kenya. A wide range of species including cereals, oil plants, fruits and roots and tubers have been collected in Benin and the country reports of Angola, Cameroon, Madagascar, Togo, the United Republic of Tanzania and Zambia all reported the collecting of germplasm over recent years. Five missions were organized in Ghana yielding nearly 9 000 new accessions of legumes, maize, roots and tubers and fruits and nuts. The largest number of missions was carried out in Namibia; 73 between 1995 and 2008, to collect rice wild relatives and local vegetables and legumes.

FIGURE 3.3
Type of accessions collected by selected genebanks over two time periods, 1984-95 and 1996-2007



Source: genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/DENAREF (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info, 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI and WARDA (source: SINGER, 2008)

FIGURE 3.4
Accessions collected by selected genebanks over the period 1996-2007 according to crop group



Source: 31 genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/DENAREF (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info., 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI and WARDA (source: SINGER, 2008)

Americas

Germplasm collection missions carried out in South America over the last decade included 13 by Argentina, yielding over 7 000 accessions of various crops including forages, ornamentals and forest species; 18 by the Plurinational State of Bolivia for crops of national interest including oxalis, quinoa, beans and maize; and 4 by Paraguay to collect maize, peppers and cotton. Chile carried out an unspecified number of missions that resulted in over 1 000 new accessions and Uruguay also reported collecting, mainly forages. In total about 10 000 accessions were reported to have been collected in South America. In North America, the United States Department of Agriculture (USDA) has collected samples of more than 4 240 species since 1996, from many different countries. In total, more than 22 150 accessions have been collected of which some 78 percent were wild materials. The genera yielding the largest number of accessions were: *Malus* (2 795), *Pisum* (1 405), *Poa* (832), *Cicer* (578), *Medicago* (527), *Glycine* (434), *Vicia* (426) and *Phaseolus* (413). Canada has collected accessions of wild relatives and native crop-related biodiversity. In Central America and the Caribbean, over the past decade, Cuba has carried out 37 national collecting missions, Dominica 3 and Saint Vincent and the Grenadines 2, mainly to collect fruits, vegetables and forages. The Dominican Republic, El Salvador and Trinidad and Tobago also reported having collected germplasm. In Guatemala, between 1998 and 2008, more than 2 300 accessions of a wide range of crops were collected including maize, beans, peppers and vegetables. Based on the country reports, about 2 600 accessions have been collected in Central America since 1996.

Asia and the Pacific

Many Asian country reports listed germplasm collecting missions undertaken since the publication of the first SoW report. Collectively, they resulted in more than 129 000 new accessions. India undertook 78 national missions, collecting about 86 500 new accessions of 671 species. Bangladesh added about 13 000 accessions to its national genebank through national collecting missions. Between 1999 and 2007 Japan organized 40 foreign collecting missions (rice and legumes) and 64 national ones (fruits, legumes, forages, spices and industrials). Several other Asian countries reported that they had undertaken collecting but did not provide details. In the Pacific, the Cook Islands, Fiji, Palau, Papua New Guinea and Samoa all indicated that regular germplasm collecting missions had been carried out for traditional crops including bananas, breadfruit, yams, taro and coconuts.

Europe

Many European countries reported collecting germplasm over the past ten years, the majority of which was collected nationally or from nearby countries. In total, more than 51 000 accessions were collected. Hungary reported having undertaken 50-100 national missions that gathered several thousand new accessions of cereals, pulses and vegetables; Finland reported four missions in the Nordic region resulting in 136 new accessions of bird cherry and reed canary grass; Romania reported undertaking 36 national missions to collect cereals and legumes; and Slovakia carried out 33 missions nationally and in neighbouring countries that resulted in over 6 500 landraces and CWR. Poland mounted 13 missions at home, in Eastern Europe and Central Asia that collected about 7 000 new accessions and more than 2 500 accessions were collected by Portugal in 42 separate missions.

Near East

In-country collecting was reported by Egypt, Jordan and Morocco, the latter targeting mainly fruit trees and cereals. Missions were undertaken in Oman, in collaboration with ICARDA and ICBA, to collect barley, forage and pasture species and by national institutions in the Islamic Republic of Iran, Pakistan, the Syrian Arab Republic, Tajikistan and Tunisia focusing mainly on cereals and legumes. Holdings of PGR in the national genebank of the Islamic Republic of Iran have doubled since 1996 due to extensive collecting missions conducted in the country. Both Afghanistan and Iraq, having lost considerable amounts of conserved germplasm during recent conflicts, carried out national collecting missions; Iraq mainly for cereal wild relatives and Afghanistan primarily for food staples as well as almond, pistachio and pomegranate. Collecting missions took place in Kazakhstan in 2000, 2003 and 2004, targeting cereals, fodder crops and medicinal plants and since 2000 the collecting of CWR has been conducted annually. Azerbaijan carried out 55 national missions between 1999 and 2006 that yielded more than 1 300 new accessions of a very large range of crops. According to the country reports, more than 14 000 accessions have been collected in the region over the past decade or so. However, this figure probably fails to fully reflect the total number of accessions collected in the almost 200 collecting missions carried out by countries of the region but for which, no figures were provided.

3.4 Types and status of collections

Both seed genebanks and field genebanks differ in their species coverage, the extent of the crop genepool that is covered, the types of accessions conserved (CWR, landraces, breeding lines, advanced cultivars, etc.) and the origin of the material. The large majority of genebanks, however, conserve germplasm of the major crop species, on which humans and livestock rely most for food and feed.

3.4.1 International and national genebanks

Eleven of the CGIAR centres manage germplasm collections on behalf of the world community: Bioversity International, CIAT, CIMMYT, CIP, ICARDA, the World Agroforestry Center (formerly ICRAF), ICRISAT, IITA, ILRI, INIBAP, IRRI and AfricaRice (formerly WARDA). The CIMMYT, ICARDA, ICRISAT and IRRI collections all comprise more than 100 000 accessions each. Collectively, the centres maintain a total of about 741 319 accessions of 3 446 species of 612 different genera (see Table 1.1 in Chapter 1).

In addition, many other international and regional institutions conserve important collections, for example:

- the AVRDC maintains about 56 500 accessions of vegetable germplasm;
- the Nordic Genetic Resource Center (NordGen) conserves about 28 000 accessions of a range of crops from 129 genera;
- the Center for Tropical Agricultural Research and Education (CATIE) has a total of more than 11 000 accessions of vegetables, fruits, coffee and cocoa;
- the Southern African Development Community (SADC) Plant Genetic Resources Centre (SPGRC) maintains more than 10 500 accessions of a range of crops important for African agriculture;
- the West Indies Central Sugarcane Breeding Station (WICSBS) in Barbados conserves about 3 500 accessions;
- the International Cocoa Genebank, Trinidad and Tobago (ICGT) at the University of the West Indies conserves about 2 300 accessions;
- the Centre for Pacific Crops and Trees (CePaCT) of the Secretariat of the Pacific Community holds collections of about 1 500 accessions from several crops, including taro, yam and sweet potato.

A highly significant development since the publication of the first SoW report has been the creation of the SGSV. While not a genebank in the strictest sense, the SGSV provides secure facilities for the storage of back-up samples of accessions from genebanks around the world (see Section 3.5).

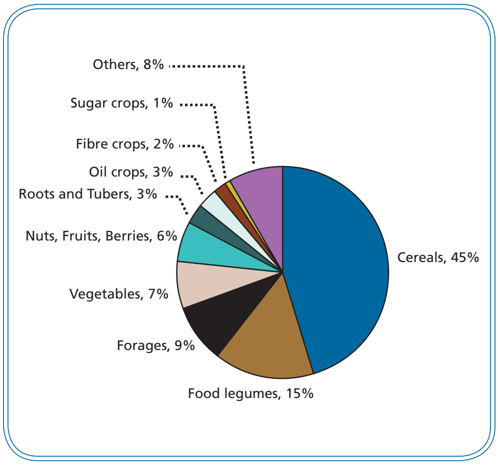
Around the globe, genetic resources are maintained in genebanks at the local and national level by governments, universities, botanical gardens, NGOs, companies, farmers and others in the private and public sectors. They house a wide range of different types of collection: national collections maintained for the long term, working collections maintained for the medium or short term, collections of genetic stocks or others. The four largest national genebanks are those housed at the Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences (ICGR-CAAS) in China, the National Center for Genetic Resources Preservation in the United States of America,[9] the National Bureau of Plant Genetic Resources (NBPGR) in India and the N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry (VIR) (see Table 1.2, Chapter 1). National genebanks housing more than 100 000 accessions are also found in Brazil, Canada, Germany, Japan and the Republic of Korea. The NPGS of USDA operates a system of germplasm conservation that networks 31 genebanks within the country and conserves more than 7 percent of the germplasm holdings representing more than 50 percent of the genera, conserved in genebanks worldwide. The Millennium Seed Bank is the world's largest seed genebank devoted to the conservation of wild species. It is run by the Royal Botanic Gardens at Kew, which also has sizeable living collections as well as herbarium and carpological collections.

3.4.2 Crop species coverage

Information in the WIEWS database indicates that about 45 percent of all the accessions in the world's genebanks are cereals. The country reports confirm this. Food legumes are the next largest group, accounting for about 15 percent of all accessions while vegetables, fruits and forage crops each account for 6-9 percent of the total number of accessions maintained *ex situ*. Roots and tubers, as well as oil and fibre crops each account for 2-3 percent of the total (see Figure 3.5). These percentages are very similar to those presented in the first SoW report.

Many countries have reported increases in the number of accessions held in their genebanks since 1996 and additional information on this is available in the WIEWS database. Angola, for example, added more than 1 800 local landraces of more than 33 species to its national genebank. Most countries in South America reported increases in their germplasm holdings, many of which, now house more than 50 percent more accessions than they did in 1996.[10] The only significant increase in holdings reported in Central America was in Mexico, where total holdings have increased by more than 160 percent since the first SoW report was published. In Asia, since 1996, the number of accessions stored at NBPGR in India grew by 137 percent and Bangladesh added more than 13 000 accessions to its national collection. During the same period, holdings in China's national genebank increased by nearly 33 000 accessions. Within the Pacific, only Australia's holdings appear to have increased, from 123 000 at the time the first SoW report was published, to 212 545 today. In Europe, Hungary added over 4 500 accessions in 1998 and

FIGURE 3.5
Contribution of major crop groups in total *ex situ* collections



Source: 31 genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/DENAREF (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info., 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI, WARDA (source: SINGER, 2008).

between 130 and over 700 new accessions annually thereafter. Spain reported adding more than 24 000 new accessions to its national collection over the last ten years. Yemen doubled the number of accessions conserved in its field genebanks and added over 4 000 accessions, mainly of cereals and legumes, to its national collection.

Although the overall growth in the number of accessions conserved over the past decade is impressive, it should be noted, however, that some or even much of this is probably due to an increase in the level of duplication, both planned safety duplication as well as the unplanned, redundant duplication of samples within and among collections. It may also reflect improved data management and reporting.

3.4.2.1 Major crops

Holders of the six largest *ex situ* collections of selected major crops are listed in Table 3.2. The largest total

TABLE 3.2
Holders of the six largest *ex situ* collections of selected crops

Genus (crop)	Total world accessions	Major holders rank			
		1	%	2	%
Triticum (wheat)	856 168	CIMMYT	13	NSGC (USA029)	7
Oryza (rice)	773 948	IRRI	14	NBPGR (IND001)	11
Hordeum (barley)	466 531	PGRC (CAN004)	9	NSGC (USA029)	6
Zea (mays)	327 932	CIMMYT	8	BPGV-DRAEDM (PRT001)	7
Phaseolus (bean)	261 963	CIAT	14	W6 (USA022)	6
Sorghum (sorghum)	235 688	ICRISAT	16	S9 (USA016)	15
Glycine (soybean)	229 944	ICGR-CAAS (CHN001)	14	SOY (USA033)	9
Avena (oat)	130 653	PGRC (CAN004)	21	NSGC (USA029)	16
Arachis (groundnut)	128 435	ICRISAT	12	NBPGR (IND001)	10
Gossypium (cotton)	104 780	UzRICBSP (UZB036)	11	COT (USA049)	9
Cicer (chickpea)	98 313	ICRISAT	20	NBPGR (IND001)	15
Solanum (potato)	98 285	INRA-RENNES (FRA179)	11	VIR (RUS001)	9
Pisum (pea)	94 001	ATFCC (AUS039)	8	VIR (RUS001)	7
Medicago (medicago)	91 922	AMGRC (AUS006)	30	UzRICBSP (UZB036)	11
Lycopersicon (tomato)	83 720	AVRDC	9	NE9 (USA003)	8
Trifolium (clover)	74 158	WARDA (AUS137)	15	AGRESEARCH (NZL001)	9
Hevea (rubber)	73 656	MRB (MYS111)	81	RRII (IND031)	6
Capsicum (capsicum)	73 518	AVRDC	11	S9 (USA016)	6
Prunus (prunus)	69 497	VIR (RUS001)	9	UNMIHT (USA276)	9
Pennisetum (pearl millet)	65 447	ICRISAT	33	CNPMS (BRA001)	11
Vigna (cowpea)	65 323	IITA	24	S9 (USA016)	12
Malus (apple)	59 922	GEN (USA167)	12	VIR (RUS001)	6
Vitis (grape)	59 607	INRA/ENSA-M (FRA139)	9	JKI (DEU098)	6
Lens (lentil)	58 405	ICARDA	19	NBPGR (IND001)	17
Vicia (faba bean)	43 695	ICARDA	21	ICGR-CAAS (CHN001)	10
Saccharum (sugar cane)	41 128	CTC (BRA189)	12	INICA (CUB041)	9
Aegilops (wheat)	40 926	ICCI-TELAVUN (ISR003)	22	ICARDA	9
Cucurbita (cucurbita)	39 583	VIR (RUS001)	15	CATIE	7
Helianthus (sunflower)	39 380	IFVCNS (SRB002)	14	NC7 (USA020)	9
x Triticosecale (wheat)	37 440	CIMMYT	46	VIR (RUS001)	5
Ipomoea (sweet potato)	35 478	CIP	18	NIAS (JPN003)	16
Festuca (fescue)	33 008	IHAR (POL003)	14	NIAS (JPN003)	13

TABLE 3.2 (continued)
Holders of the six largest *ex situ* collections of selected crops

Major holders rank							
3	**%**	**4**	**%**	**5**	**%**	**6**	**%**
ICGR-CAAS (CHN001)	5	NBPGR (IND001)	4	ICARDA	4	(several)	4
CNRRI (CHN121)	9	NIAS (JPN003)	6	RDAGB-GRD (KOR011)	3	DB NRRC (USA970)	3
CENARGEN (BRA003)	6	ICARDA	6	NIAS (JPN003)	5	IPK (DEU146)	5
NC7 (USA020)	6	ICGR-CAAS (CHN001)	6	INIFAP (MEX008)	4	VIR (RUS001)	3
CNPAF (BRA008)	6	INIFAP (MEX008)	5	IPK (DEU146)	3	ICGR-CAAS (CHN001)	3
ICGR-CAAS (CHN001)	8	NBPGR (IND001)	7	IBC (ETH085)	4	CNPMS (BRA001)	3
RDAGB-GRD (KOR011)	8	AVRDC	7	CNPSO (BRA014)	5	NIAS (JPN003)	5
VIR (RUS001)	9	IPK (DEU146)	4	KARI-NGBK (KEN015)	3	TAMAWC (AUS003)	3
S9 (USA016)	8	UNSE-INSIMA (ARG1342)	6	ICRISAT (NER047)	6	ICGR-CAAS (CHN001)	5
CICR (IND512)	9	ICGR-CAAS (CHN001)	7	VIR (RUS001)	6	IRCT-Cirad (FRA002)	4
ICARDA	13	ATFCC (AUS039)	9	W6 (USA022)	6	NPGBI-SPII (IRN029)	6
CIP	8	IPK (DEU159)	5	NR6 (USA004)	5	NIAS (JPN003)	3
ICARDA	7	IPK (DEU146)	6	W6 (USA022)	6	IGV (ITA004)	4
ICARDA	10	W6 (USA022)	9	INRA CRRAS (MAR088)	4	VIR (RUS001)	3
IPB-UPLB (PHL130)	6	IPK (DEU146)	5	VIR (RUS001)	3	NIAS (JPN003)	3
ICARDA	6	WPBS-GRU-IGER (GBR016)	6	SIAEX (ESP010)	5	W6 (USA022)	5
IDEFOR-DPL (CIV061)	3	FPC (LBR004)	2	IAC (BRA006)	1	RRI (VNM009)	1
INIFAP (MEX008)	6	NBPGR (IND001)	5	IAC (BRA006)	3	NIAS (JPN003)	3
CRA-FRU (ITA378)	3	EFOPP (HUN021)	3	AARI (TUR001)	3	(several)	2
NBPGR (IND064)	9	ORSTOM-MONTP (FRA202)	7	PGRC (CAN004)	6	ICRISAT (NER047)	4
CENARGEN (BRA003)	8	LBN (IDN002)	6	NBPGR (IND001)	5	ICGR-CAAS (CHN001)	4
NIAS (JPN003)	4	NFC (GBR030)	4	PSR (CHE063)	3	(several)	3
RAC (CHE019)	5	DAV (USA028)	5	IVM (UKR050)	4	CRA-VIT (ITA388)	4
ATFCC (AUS039)	9	NPGBI-SPII (IRN029)	5	W6 (USA022)	5	VIR (RUS001)	4
ATFCC (AUS039)	6	IPK (DEU146)	4	INRA-RENNES (FRA010)	4	UC-ICN (ECU003)	4
WICSBS	8	NIAS (JPN003)	7	MIA (USA047)	6	GSC (GUY016)	5
NPGBI-SPII (IRN029)	6	NIAS (JPN003)	6	VIR (RUS001)	5	NSGC (USA029)	5
CENARGEN (BRA003)	5	ICGR-CAAS (CHN001)	4	INIFAP (MEX008)	4	NIAS (JPN003)	3
ICGR-CAAS (CHN001)	7	INRA-CLERMON (FRA040)	6	CNPSO (BRA014)	6	VIR (RUS001)	4
NSGC (USA029)	5	SCRDC-AAFC (CAN091)	5	LUBLIN (POL025)	5	IR (UKR001)	5
S9 (USA016)	3	MHRP (PNG039)	3	CNPH (BRA012)	3	BAAFS (CHN146)	2
W6 (USA022)	7	IPK (DEU271)	7	WPBS-GRU-IGER (GBR016)	5	AGRESEARCH (NZL001)	3

TABLE 3.2 (continued)
Holders of the six largest *ex situ* collections of selected crops

Genus (crop)	Total world accessions	Major holders rank			
		1	%	2	%
Manihot (cassava)	32 442	CIAT	17	CNPMF (BRA004)	9
Dactylis (grasses)	31 394	BYDG (POL022)	19	NIAS (JPN019)	9
Coffea (coffee)	30 307	IRCC/Cirad (CIV011)	22	IAC (BRA006)	14
Mangifera (mango)	25 659	Ayr DPI (AUS088)	73	CISH (IND045)	3
Beta (sugarbeet)	22 346	W6 (USA022)	11	IPK (DEU146)	10
Elaeis (oil-palm)	21 103	INERA (COD003)	84	MPOB (MYS104)	7
Panicum (millet)	17 633	NIAS (JPN003)	33	KARI-NGBK (KEN015)	13
Chenopodium (chenopodium)	16 263	BNGGA-PROINPA (BOL138)	27	INIA-EEA.ILL (PER014)	9
Dioscorea (yam)	15 903	IITA	21	UNCI (CIV006)	10
Musa (banana)	13 486	INIBAP	9	Cirad (FRA014)	4
Theobroma (cocoa)	12 373	ICGT	19	CRIG (GHA005)	8
Eragrostis (millet)	8 820	IBC (ETH085)	54	W6 (USA022)	15
Colocasia (taro)	7 302	WLMP (PNG006)	12	RGC (FJI049)	12
Psophocarpus (bean)	4 217	DOA (PNG005)	11	DGCB-UM (MYS009)	10
Corylus (nut)	2 998	COR (USA026)	28	AARI (TUR001)	14
Olea (olive)	2 629	CRA-OLI (ITA401)	17	CIFACOR (ESP046)	12
Bactris (peach palm)	2 593	UCR-BIO (CRI016)	31	CATIE	24
Pistacia (pistachio)	1 168	NPGBI-SPII (IRN029)	29	DAV (USA028)	26

TABLE 3.2 (continued)
Holders of the six largest *ex situ* collections of selected crops

Major holders rank							
3	**%**	**4**	**%**	**5**	**%**	**6**	**%**
IITA	8	ICAR (IND007)	4	NRCRI (NGA002)	4	SAARI (UGA001)	4
IPK (DEU271)	6	W6 (USA022)	5	WPBS-GRU-IGER (GBR016)	3	AGRESEARCH (NZL001)	2
Cirad (FRA014)	13	CATIE	6	ECICC (CUB035)	5	JARC (ETH075)	4
HRI-DA/THA (THA056)	1	MIA (USA047)	1	ILETRI (IDN177)	1	NUC (SLE015)	1
IFVCNS (SRB002)	10	INRA-DIJON (FRA043)	7	ICGR-CAAS (CHN001)	6	VIR (RUS001)	6
CPAA (BRA027)	3	ICA/REGION 5 (COL096)	1	IOPRI (IDN193)	1	NUC (SLE015)	1
S9 (USA016)	4	CN (CIV010)	3	CIAT	3	ORSTOM-MONTP (FRA202)	3
IPK (DEU146)	6	DENAREF (ECU023)	4	UBA-FA (ARG1191)	3	U.NACIONAL (COL006)	2
UAC (BEN030)	7	PGRRI (GHA091)	5	DCRS (SLB001)	3	PU (LKA002)	3
DTRUFC (HND003)	4	QDPI (AUS035)	3	CNPMF (BRA004)	3	CARBAP (CMR052)	3
CEPEC (BRA074)	6	CORPOICA (COL029)	6	CATIE	6	(several)	6
KARI-NGBK (KEN015)	12	NIAS (JPN003)	4	NBPGR (IND001)	3	CIFAP-CAL (MEX035)	3
MARDI (MYS003)	9	NBPGR (IND024)	6	HRI-DA/THA (THA056)	6	PRC (VNM049)	5
TROPIC (CZE075)	10	IDI (LKA005)	9	LBN (IDN002)	9	(several)	6
KPS (UKR046)	6	HSCRI (AZE009)	6	IRTAMB (ESP014)	4	UzRIHVWM (UZB031)	4
NPGBI-SPII (IRN029)	9	DAV (USA028)	5	HSCRI (AZE009)	5	AARI (TUR001)	5
IAC (BRA006)	13	CORPOICA (COL029)	10	EENP (ECU022)	6	INRENARE (PAN002)	3
IRTAMB (ESP014)	9	GRI (AZE015)	5	ACSAD (SYR008)	4	CSIRO (AUS034)	4

number of *ex situ* accessions are of wheat, rice, barley and maize accounting for 77 percent of the total cereal and pseudo-cereal holdings. Other large cereal holdings include sorghum (about 235 000 accessions) and pearl millet (more than 65 000 accessions). In some tropical countries, roots and tubers, including cassava, potato, yam, sweet potato and aroids, are more important as staple foods than cereals, but being more difficult to conserve, collection sizes tend to be smaller. CIP holds the world's largest sweet potato collection (more than 6 400 accessions) as well as the third largest potato collection (representing about 8 percent of total world holdings of about 98 000 accessions) after those of the Institut national de la recherche agronomique (INRA)-Rennes (France) and VIR (the Russian Federation). Other important collections of *Solanum* are found at the External Branch North of the Department Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research, Oil Plants and Fodder Crops in Malchow, Germany (IPK) and USDA (Sturgeon Bay, United States of America). The largest cassava collection (more than 5 400 accessions) is held by CIAT in Colombia, followed by the collections of the Brazilian Agricultural Research Corporation (Embrapa), in Brazil and IITA in Nigeria.

The genebanks of the CGIAR centres generally represent the major repositories for germplasm of their mandate crops. For example: the world's major wheat (13 percent of the total) and maize (8 percent of the total) collections are held at CIMMYT, that of rice (14 percent of total) is at IRRI. ICRISAT maintains the world's largest collections of sorghum (16 percent), pearl millet (33 percent), chickpea (20 percent) and groundnut (12 percent). ICARDA houses the world's largest collections of lentil (19 percent), faba bean (21 percent) and vetches (16 percent). CIAT is responsible for the world's largest collections of beans (14 percent) and cassava (17 percent).

China holds the largest collection of soybean germplasm (14 percent of the world's accessions). Among fruits, *Prunus* species are represented by more than 69 000 accessions, including breeding and research materials, with the VIR in the Russian Federation holding 9 percent and the Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Centro di Ricerca per la Frutticoltura (CRA-FRU) in Italy 3 percent of the total. *Malus* and *Vitis* species are represented by the second and third largest number of accessions, the largest collections of *Malus* being held by USDA in Geneva, Cornell University (12 percent), while for *Vitis* these are held at INRA/Centre régional de la recherche agronimique, Station de recherches viticoles (ENSA-M) in France (9 percent) and the Julius Kühn-Institut - Federal Research Centre for Cultivated Plants (JKI) in Germany (6 percent). After Bioversity International's *Musa* collection maintained at the International Transit Centre in Leuven, the most important banana germplasm holdings are at the Centre de coopération internationale en recherche agronomique pour le développement (Cirad) in Guadeloupe, Laloki Dry-lowlands Research Programme (DLP) Laloki in Papua New Guinea and the Honduran Agricultural Research Foundation (FHIA) in Honduras. Among vegetables, most accessions are of tomatoes followed by peppers (*Capsicum* spp.). The largest collections are at AVRDC, which accounts for about 10 percent of the total for both crops. Other important collections of tomato are held at USDA in Geneva and IPK in Germany and of *Capsicum* at USDA in Griffin and the Istituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) in Mexico.

Australia is the predominant holder of forage legume germplasm, with 30 percent of the world holdings of *Medicago* at the Australian Medicago Genetic Resource Centre (AMGRC) and 15 percent of the world's clover holdings at the Western Australian Department of Agriculture (WADA). The most important temperate forage grasses include *Festuca*, *Dactylis* and *Lolium* (approximately 92 000 accessions among them). Some of the largest collections of these are held in Germany, Japan and Poland. Among the tropical forage grasses, Kenya Agricultural Research Institute's National Genebank of Kenya (KARI-NGBK) holds the largest collection of *Cenchrus*, while CIAT and ILRI together hold the largest collection of *Brachiaria*. Among oilseed crops, sesame accounts for more than 50 000 accessions globally and sunflower almost 40 000. The largest single collections of these are held by India (17 percent) and Serbia (14 percent), respectively.

Cotton is the most important fibre crop in terms of the total number of accessions held, with almost 105 000 accessions being maintained worldwide. Of these, 11 percent are held in Uzbekistan at the

Uzbek Research Institute of Cotton Breeding and Seed Production (UzRICBSP). About 80 percent of the over 70 000 accessions of rubber are conserved in Malaysia at the Malaysia Rubber Board (MRB). Among the major beverages, the largest collection of coffee is held in Côte d'Ivoire (22 percent) and that of cacao is held by ICGT at the University of the West Indies in Trinidad and Tobago (19 percent).

3.4.2.2 Minor crops and wild relatives

According to the country reports, since 1995, there has been a growing interest in collecting and conserving minor, neglected and underutilized crops. In the case of yam, for example, the number of conserved accessions has increased from 11 500 in 1995 to 15 900 in 2008, and in the case of bambara groundnut from 3 500 in 1995 to 6 100 in 2008. This increased interest in minor crops reflects, in part, the growing realization that many of them are under threat due to replacement by major crops or the disappearance of the agricultural environments in which they are grown. Similarly, concerns exist for CWR whose natural habitats are under threat, compounded by concerns over climate change and the realization that many CWR could possess traits such as biotic and abiotic stress resistance or tolerance that could be useful in adapting crops to changing conditions.

3.4.3 Types of material stored

The nature of the accessions (for example whether they comprise advanced cultivars, breeding lines, landraces, wild relatives, etc.) is known for about half of the material conserved *ex situ*. Of these, about 17 percent are advanced cultivars, 22 percent breeding lines, 44 percent landraces and 17 percent wild or weedy species.[11] As Figure 3.6 shows, the number of accessions of landraces, breeding material and wild species conserved worldwide has increased since the first SoW report was published, possibly reflecting a growing interest in securing such material before it is lost, as well as for use in genetic improvement programmes.

Table 3.3 provides a breakdown of type of accession by crop group. Forages and industrial crops show a relatively high percentage of accessions that are wild relatives. The reverse is true for sugar crops, the majority of which are represented by advanced cultivars.

3.4.4 Source of material in genebanks

About 55 percent of all accessions held in genebanks globally for which the country of origin is known, are indigenous, i.e. they originated in the country where the collection is maintained. Table 3.4 shows the total number of accessions and the proportion of indigenous germplasm on a subregional basis.

The percentage of indigenous accessions is greatest for Southern Africa, West Asia and South Asia and is lowest for Central Africa, North America and the Pacific. In general, the distribution of accessions held in genebanks between native and exotic germplasm appears little changed from that reported in the first SoW report and overall, large national genebanks tend to maintain a greater proportion of non-indigenous materials than smaller ones.

For Africa, indigenous germplasm predominates in the collections of the SADC countries, Ethiopia and Kenya. Country reports from the Asia and the Pacific region indicate that accessions are predominantly indigenous in Papua New Guinea, Samoa, Sri Lanka and Viet Nam while in the Cook Islands, Fiji and Palau they are exclusively so. In China, 82 percent of materials in seed collections are reportedly indigenous, while at NIAS in Japan, native accessions are about 39 percent of the total conserved.

In the Americas, the majority of accessions in the Caribbean and in Central and South American national genebanks were of native origin, with the exception of Brazil and Uruguay that reported more than five times and more than once respectively, the number of foreign accessions compared with native ones. According to the USDA's GRIN database, native accessions comprise about 16 percent of the total germplasm conserved in the NPGS of USDA.

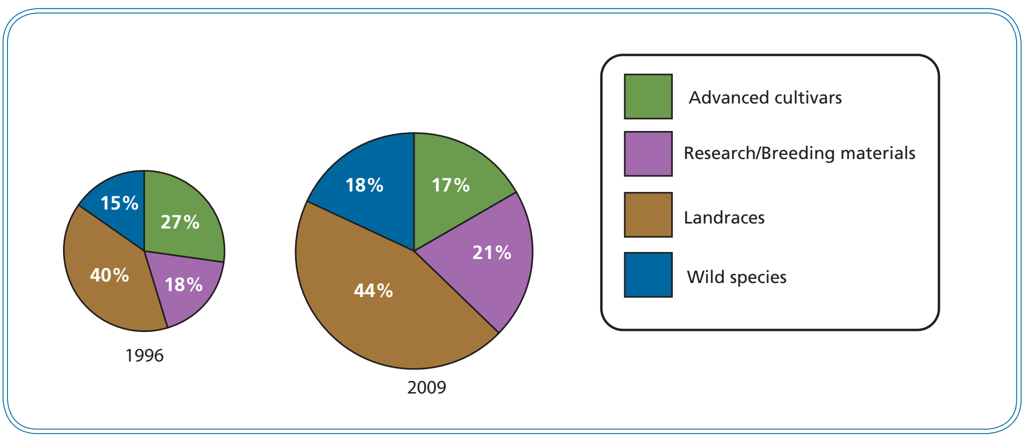
A wide range in origins of germplasm is reported in European genebanks. More than 75 percent of germplasm holdings stored in Greece, Romania, Portugal and Spain, are indigenous, as are those conserved at NordGen, originating in the five

TABLE 3.3
Global germplasm holdings in terms of type of accession (mean percentage) for groups of crops included in Appendix 2

Commodity group	No. of accessions	% Wild species	% Landraces	% Breeding materials	% Advanced cultivars	% Others
Cereals	3 157 578	5	29	15	8	43
Food legumes	1 069 897	4	32	7	9	49
Roots and tubers	204 408	10	30	13	10	37
Vegetables	502 889	5	22	8	14	51
Nuts, fruits and berries	423 401	7	13	14	21	45
Oil crops	181 752	7	22	14	11	47
Forages	651 024	35	13	3	4	45
Sugar crops	63 474	7	7	11	25	50
Fibre crops	169 969	4	18	10	10	57
Medicinal, aromatic, spice and stimulant crops	160 050	13	24	7	9	47
Industrial and ornamental plants	152 325	46	1	2	4	47
Other	262 993	29	4	2	2	64
Total/overall mean	**6 998 760**	**10**	**24**	**11**	**9**	**46**

Source: WIEWS 2009

FIGURE 3.6
Types of accessions in *ex situ* germplasm collections in 1996 and 2009 (the size difference in the charts represents the growth in total numbers of accessions held *ex situ* between 1996 and 2009)



Source: WIEWS 1996 and 2009

TABLE 3.4
Number and percentage of accessions of local origin in *ex situ* genebanks, excluding collections held in international and regional genebanks

Region	Subregion	Number of indigenous accesions	Total number of accessions ([a])	% of indigenous accessions
Africa	West Africa	32 733	40 677	80
Africa	Central Africa	934	18 829	5
Africa	Eastern Africa	100 125	119 676	84
Africa	Sourthern Africa	40 853	41 171	99
Africa	Indian Ocean Islands	131	273	48
America	South America	145 242	180 604	80
America	Central America and Mexico	41 370	51 513	80
America	Caribbean	13 746	23 671	58
America	North America	114 334	521 698	22
Asia and the Pacific	East Asia	179 055	255 673	70
Asia and the Pacific	South Asia	420 019	443 573	95
Asia and the Pacific	Southeast Asia	74 466	137 763	54
Asia and the Pacific	Pacific	42 649	188 988	23
Europe	Europe	354 015	939 620	38
Near East	South/East Mediterranean	66 363	73 428	90
Near East	West Asia	54 735	55 255	99
Near East	Central Asia	20 375	25 283	81
World		**1 701 145**	**3 117 695**	**55**

[a] Total number of accessions whose country of origin is reported.
Source: WIEWS 2009

countries served by the genebank. However, the percentage of indigenous accessions in the national genebanks of Bulgaria, the Czech Republic, Germany, the Netherlands and the Russian Federation varies between 14 and 20 percent. Austria, France, Hungary, Italy, Poland and Ukraine conserve more foreign germplasm than native.

In the Near East region, either all or the majority of accessions in the national genebanks are of native origin; exclusively so for Jordan, Kyrgyzstan and Lebanon and predominantly so for Pakistan, Tajikistan and Yemen.

3.4.5 Gaps in collection coverage

The extent of coverage of the total diversity of different crops in *ex situ* collections is difficult if not impossible to estimate with any real precision as it varies considerably according to crop and according to the perceptions of different stakeholder groups. Over recent years, the GCDT has supported the development of a number of crop and regional conservation strategies.[12] These have brought together information from different countries and organizations and, *inter alia*, have attempted to identify major gaps in *ex situ* collections as estimated by different stakeholders. Thus, for wheat, according to the opinion of collection managers, the major gaps in collections are of landraces and cultivars. Key users of wheat genetic resources, however, indicated the need for more mapping populations, mutants, genetic stocks and a wider range of wild relatives. For maize, the situation is slightly different as there are relatively few areas where no comprehensive collection has been made. Major gaps identified in existing *ex situ* maize collections thus include hybrids and tropical inbred lines, in addition to gaps resulting from the loss of accessions from collections; for example, the entire collection of Dominica was lost as was much of the maize collected by the International Board for Plant Genetic Resources (IBPGR) in the 1970s. For barley there are gaps in collections of wild relatives and many species and populations are endangered as a result of the loss of their natural habitats.

For potatoes, the most useful genetic material has already been collected and there are currently few significant gaps. However, several Latin American collections are threatened by lack of funding and, if lost, would result in critical gaps in the overall coverage of the genepool. The situation for sweet potato is somewhat different, as important geographic as well as trait gaps have been identified. Among the best estimates of genepool coverage are those for banana and plantain. About 300-400 key cultivars are known to be missing from the International Transit Collection including 20 plantains from Africa, 50 *Callimusa* from Borneo, 20-30 *Musa balbisiana* and 20 other types from China and India, 10 accessions from Myanmar, 40 wild types from Indonesia and Thailand and up to 100 wild types from the Pacific.

The situation for legumes differs from those described above. For lentils, landraces from China and Morocco and wild species, particularly from southeast Turkey, are not well represented in collections. There are gaps in chickpea collections from Central Asia and Ethiopia and there are relatively few accessions of wild relatives collected, particularly from the secondary genepool. For faba beans, various geographic gaps have been identified including local varieties and landraces from North Africa, the Egyptian oases, South America and China. The small-seeded subspecies, *paucijuga*, is also under-represented in collections and there are trait gaps, especially for heat tolerance. An important consideration for many legume collections is also the need to collect and maintain samples of *Rhizobium*. This is especially the case for wild legume species, for which *Rhizobium* collections are rare.

While there are still sizeable gaps in the *ex situ* collections of many major crops, these tend to be small in comparison with those in the collections of the numerous minor crops. Indeed, many useful plant species only occur in the wild or as landraces in farmers' fields. In many cases these species are threatened by the vagaries of climate and changes in land use.

A problem common to many crops is the difficulty in conserving their wild relatives, especially perennials. As a result, they are often missing from collections and are generally best conserved *in situ* as they can be difficult to collect and maintain *ex situ*, or can become serious weeds.

While today there is a better understanding of the extent and nature of gaps in *ex situ* collections than at the time of the first SoW report, the picture is still far from complete. The use of molecular data to improve understanding on the nature, extent and distribution of genetic diversity, more detailed field surveys and better georeferencing of accessions would all be helpful in efforts to more accurately identify gaps and redundancy within and among individual collections and in genepools as a whole.

3.4.6 Conservation of deoxyribonucleic acid samples and nucleotide sequence information

In addition to storage of seeds, whole plants and tissues, isolated DNA can be maintained at low temperatures or electronically as sequence data on computers, *in silico*. The latter is becoming increasingly possible as data storage costs fall and the power of analytical tools increases. While current technology does not permit the regeneration of the original plant from isolated DNA or electronic information sources, these can be used in many ways, e.g. in genetic diversity and taxonomic studies. In 2004, Bioversity International surveyed international and national conservation programmes, botanic gardens, universities and private companies involved in PGRFA conservation in 134 countries.

The results provide useful baseline information on the use of plant DNA storage. Only 21 percent of the 243 respondents stored plant DNA, with about as many in developing as in developed countries. Lack of funds, equipment, personnel and training were cited as the main reasons by the remainder for not employing DNA storage. Nearly half of the institutions that conserve DNA, supply it to others for research, despite that many considered it to be a somewhat unclear legal situation. Bioversity International published the results of the survey in 2006[13] in a publication that also discusses options and strategies for integrating DNA and sequence information with other conservation approaches. There is still considerable debate within the PGRFA community about the current and potential future role of DNA and sequence information storage for conservation purposes.

3.5 Storage facilities

Since the publication of the first SoW report there has been an increase in storage capacity as new genebanks have been established and existing ones expanded. However, this says little about storage conditions and whether there has been a general improvement. There remains an enormous range in types and conditions of storage facilities worldwide. The problems associated with storage facilities in the developed world are magnified in the developing world, where utilities are less reliable and funding more constrained.

Technical requirements for conserving seeds have been widely published[14,15] and broad recommendations can generally be made. The same is not true for conserving plants in field genebanks, *in vitro* storage or cryopreservation, where requirements can be highly crop specific and techniques demanding of management and facilities. While some countries in the developed and developing world are able to meet such demands, many are not, and consequently some collections are degenerating.

One of the major developments that has occurred since the publication of the first SoW report is the establishment of the SGSV, as a safety net for *ex situ* seed collections of the world's crops. This is the first and only truly global germplasm conservation facility in the world. Located in the permafrost, 130 metres into a mountainside on an island just 800 km from the North Pole, SGSV provides unprecedented levels of physical security. The Government of Norway built the facility as a service to humanity and maintains and operates it with support from the GCDT and the NordGen. The seed vault opened in early 2008 and as of June 2009 has housed more than 412 000 accessions, all of which are safety duplicate copies of material already held in *ex situ* collections elsewhere. All materials in SGSV remain under the ownership and control of the depositor, who is responsible for the periodic monitoring of viability and regeneration of accessions deposited at SGSV. Details of the collections deposited in SGSV are provided in Table 3.5.

The following sections describe the status of facilities for conserving PGRFA in various regions and in International Agricultural Research Centres (IARCs).

Africa

Based on the country reports, data on storage facilities in Africa are less complete than for other regions. Most countries reported having seed and field genebanks, but only Benin, Cameroon, the Congo, Ghana, Kenya, Mali, Nigeria and Uganda reported having *in vitro* storage facilities. No country specified having the ability to conserve germplasm cryogenically. Seed genebanks are generally much more important and widespread than field genebanks in the continent. Ethiopia, for example, reported having 60 000 accessions in its national seed genebank and 9 000 in its field genebank. Burkina Faso, the Niger and Zambia all reported having many more accessions in their seed genebanks than in their field genebanks. Although most countries reported having long-, medium- and/or short-term storage facilities, they also mentioned numerous problems in their use, including reliability of electricity supplies, pests and disease related problems as well as lack of staff, equipment, or funds. Guinea reported the loss of its entire *ex situ* collection as a result of a failure in the electricity supply.

TABLE 3.5
Germplasm holdings at SGSV as of 18 June 2009

Depositor	Number of			
	Genera	Species	Accessions	Countries of origin
Centre for Genetic Resources (Netherlands)	31	224	18 212	143
Department of Agriculture, Food and Rural Development (Ireland)	3	4	100	4
Institute of Plant Production n.a. V.Y. Yurjev of UaaS (Ukraine)	5	7	885	31
Leibniz Institute of Plant Genetics and Crop Plant Research (Germany)	408	1 272	17 671	110
N.I. Vavilov all-Russian Scientific Research Institute of Plant Industry (Russian Federation)	12	40	945	68
National Agrobiodiversity Center (Republic of Korea)	26	32	13 185	1
National Genebank of Kenya (Kenya)	3	4	558	1
National Plant Genetic Resources Laboratory (Philippines)	3	4	500	16
National Plant Germplasm System (United States of America)	223	827	30 868	150
Nordic Genetic Resource Center	84	226	12 698	73
Oak Park Research Centre (Ireland)	6	7	577	1
Plant Gene Resources of Canada, Saskatoon Research Centre (Canada)	50	154	9 233	83
Plant Genetic Resources Institute, National Agricultural Research Centre (Pakistan)	5	8	480	1
Seed Savers Exchange (United States of America)	19	39	1 421	66
Station fédérale de recherches en production végétale de Changins (Switzerland)	3	3	3 845	21
Taiwan Agricultural Research Institute	1	1	4 018	1
AVRDC	12	55	7 350	89
CIAT	88	502	34 111	125
CIMMYT	4	6	80 492	57
CIP	2	173	5 847	23
ICARDA	29	249	62 834	117
ICRAF	63	120	508	27
ICRISAT	7	7	20 003	84
IITA	3	30	6 513	85
ILRI	112	506	4 008	91
IRRI	6	45	70 180	121
WARDA	1	4	5 404	64
Total [a]	**664**	**3 286**	**412 446**	**204**

[a] Distinct for genera, species and countries of origin (former country denominations e.g. Soviet Union are also counted); undetermined genera and species are not counted. (Elaborated from http://www.nordgen.org/sgsv)

Asia and the Pacific

Virtually all Asian countries that submitted country reports indicated that they maintained both seed genebanks and field genebanks, but less than half stored germplasm *in vitro*, and only India, Indonesia, Japan, Nepal, Pakistan and the Philippines used cryopreservation. China reported having 53 separate storage facilities, India 74 and the Philippines 45. Several other Asian countries reported having up to ten storage facilities. Long-, medium- and short-term facilities are available in most countries, although the numbers of each differed markedly among countries. While Japan and Pakistan reported meeting international standards for germplasm storage, according to the country reports, many other countries were unable to meet such standards indicating that there was room for improvement. The reasons stated for failure to meet international standards included lack of funds, insufficient and inadequately trained staff, lack of space, poor equipment and unreliable electricity supplies. Field genebanks predominate in the Pacific Islands countries, reflecting the regional importance of crops such as taro, coconut and banana that cannot be stored as seed. Fiji and Papua New Guinea were the only countries in the subregion to report having *in vitro* storage. No information was supplied on the existence of long-, medium- or short-term seed storage facilities, although numerous problems were reported with regards to the vulnerability of germplasm stored under field conditions.

Americas

All nine South American countries that submitted country reports, reported that they maintained both seed and field genebanks and stored germplasm *in vitro*. Only Ecuador reported using cryopreservation, although the Bolivarian Republic of Venezuela was preparing for it. Long-, medium- and short-term storage facilities were available in all countries. Brazil reported having 383 separate conservation facilities, Argentina 33 and the Bolivarian Republic of Venezuela 26. Most other countries reported fewer than ten. Uruguay and the Bolivarian Republic of Venezuela reported that they had built new long-term facilities in the last ten years. Several countries met internationally agreed standards for genebank operations, but widespread problems of funding and staffing were reported.

The majority of countries in Central America and the Caribbean maintain long-, medium- and short-term seed stores, field genebanks and *in vitro* genebanks. In the subregion, only Cuba reported activities on germplasm cryopreservation. As elsewhere, fewer accessions tend to be stored in field than seed genebanks: Cuba, for example reported having 4 000 accessions in the field compared with more than 12 000 seed accessions, and Mexico has approximately 61 000 field accessions and 107 000 seed accessions, although only half of these are in cold storage. However, roughly equal proportions of field and seed accessions are maintained in Costa Rica and El Salvador, while the Dominican Republic conserves about four times more material in the field than in its seed genebank. Most countries reported having ten or fewer genebanks, while Mexico reported having about 150 genebanks, 22 of these having cold storage facilities but only three meeting international standards for long-term conservation. As elsewhere in the developing world, many countries reported difficulties in maintaining international genebank standards for the same reasons, indicated by others. However, Cuba and Dominica also reported problems created by extreme weather events. In North America, both Canada and the United States of America operate long- and medium-term conservation genebanks, including cryopreservation facilities.

Europe

According to country reports, most European states have long-, medium- and short-term seed storage facilities as well as field genebanks. Belgium, Germany, Poland and the Russian Federation maintain cryopreservation facilities and virtually all countries conserve some germplasm *in vitro*. Hungary and Italy both reported having more than 60 separate storage facilities, but most countries have fewer than 20. However, the relative importance of the different types of storage varies considerably. Italy, for example, conserves more germplasm in the field than in seed genebanks and Germany reported having more than 155 000 accessions in genebanks (seed and field collections), of which 3 200 *in vitro*. Belgium too, reported substantial numbers of *in vitro* accessions (more than 1 500), largely as a result of the international collection of banana germplasm maintained in Leuven. In all cases, international standards were met and few problems were encountered, e.g. Albania reported a limitation of financial resources and skilled staff and The former Yugoslav Republic of Macedonia was hampered by the lack of a national strategy.

Near East

In 2004, the National Genebank of Egypt became operational with a storage capacity for 200 000 accessions (15 percent of capacity was being used by the end of 2006) as well as facilities for *in vitro* conservation and cryopreservation. New long-term storage facilities have also been established in Morocco (2002) and Tunisia (2007). Tajikistan stated its reliance on donor funds to maintain storage facilities in good order and Uzbekistan indicated that it is modernizing its facilities. Most of the remaining countries conserve their genetic resources under ambient or medium-term conservation conditions (5-10°C with no relative humidity control). While several countries in this region have no genebank some, including Kuwait, Saudi Arabia and the United Arab Emirates have made plans for the establishment of long-term storage facilities to serve national and regional needs. A number of countries reported problems relating to funding, staffing and reliability of utilities.

International Agricultural Research Centre Genebanks

Since the publication of the first SoW report there has been considerable upgrading of storage facilities among the IARCs. In 1996, the Government of Japan funded a new genebank at CIMMYT. More recently, the World Bank supported two projects to upgrade the standards of all the CGIAR genebanks. Through these projects, CIAT received a grant to convert cold rooms into a low temperature seed vault; ILRI has recently installed new humidifiers and a new irrigation system for its field genebank and in 2007, IRRI built a new long-term seed store and enlarged its screenhouse complex. The projects also funded the renovation of IITA's facilities, where there are now improved cold storage chambers, drying rooms, *in vitro* laboratories and a store for yams. WARDA built a new cold room, screenhouses, a drying room and laboratories in Cotonou, Benin.

3.6 Security of stored material

Many of the world's collections of PGR are maintained under suboptimal conditions that have a negative impact on the viability of the collections. Two main areas of concern are the extent of safety duplication and backlogs with respect to regeneration. Both were also identified as significant constraints in the first SoW report.

Although a substantial number of the world's collections are partly or entirely duplicated in more than one genebank, current data and information often do not allow identification of the same accession in different genebanks and the clear distinction between safety and redundant duplicates. In this respect, there has been little change since the publication of the first SoW report. Analyses based on country of origin suggest that only about 25-30 percent of the total number of accessions worldwide are distinct, in line with the first SoW report, but there are large differences according to species. A preliminary estimate of the duplication for selected crops based on WIEWS data indicates that for barley about 120 000 distinct accessions are stored worldwide compared with a total of 467 000 accessions. This figure is in line with a separate study undertaken by the GCDT on the process of developing the Barley Crop Strategy.[16] Considerable safety duplication exists among the four largest barley collections; those of PGRC, USDA, Embrapa and ICARDA. There is a large overlap between the Canadian and USDA collections following safety duplication of the USDA collection of oats and barley in Canada in 1989 and the Brazilian collection is mostly integrated into that of USDA. The ICARDA collection is to be duplicated in the SGSV as a second level of safety, as are many other CGIAR collections; 33 percent of this collection is already duplicated at CIMMYT and 65 percent is duplicated elsewhere. Many other barley collections are partly or wholly safety duplicated, but those of Bulgaria, Ecuador, France, Hungary and Italy, for example, are not. The duplication of accessions among collections, whether planned or unplanned, may result in large numbers of common accessions among different genebanks which, in turn, may be duplicated again as part of the planned safety duplication of entire collections. Whether duplication tends to occur primarily through a small number of samples being duplicated many times, or through a larger number of samples being duplicated only a few times, has yet to be determined for any crop.

Many wheat and maize germplasm collections are partially or wholly safety duplicated. According to a preliminary analysis, the lowest level of duplication is associated with vegetatively propagated and recalcitrant seeded plants, including cassava, yam and taro, cashew and rubber. Inadequate duplication also occurs for *Chenopodium*, *Eragrostis*, *Psophocarpus* and bambara groundnut, all of which are of high importance in local areas. CWR, neglected and underused crops and newly domesticated crops also appear more vulnerable in terms of lack of safety duplication. Banana germplasm is largely safety duplicated *in vitro*, but the situation for potato remains uncertain. For other crops, including lentil and chickpea, the degree of safety duplication is not well documented.

The CGRFA invited countries to report on risks and threats to *ex situ* genetic resources in their national collections, as part of an international Early Warning System. In the late 1990s, the Russian Federation alerted the CGRFA about the difficulties the Vavilov Institute was facing at that time.

Since the publication of the first SoW report, a major step forward in ensuring the safety of collections has been the establishment of the GCDT,[17] described elsewhere in this report (see Section 6.5). The GCDT funds operations at the SGSV and supports long-term storage in a small but growing number of genebanks.

The following sections summarize the germplasm security status of collections in the different regions.

Africa

Burkina Faso, Cameroon, Ethiopia, Mali and the Niger reported the safety duplication of some of their germplasm in genebanks of the CGIAR countries. Ghana and Namibia both indicated that the majority of their germplasm was duplicated within the country. The regional SADC genebank provides safety duplication for all member country collections under long-term storage conditions. Uganda had not yet embarked on a programme of safety duplication, but Kenya reported having deposited safety duplicates of some of its germplasm in the Millennium Seed Bank, Kew.

Americas

In South America, Argentina reported safety duplicating its germplasm at CIP, CIMMYT, CIAT, IITA and the NCGRP of USDA. Chile reported similarly, but other countries provided no information. Very little information was provided in most of the country reports from Central America and the Caribbean, but Cuba and Mexico have undertaken a small amount of safety duplication.

Asia and the Pacific

As with Africa and the Americas, most of the Asia and the Pacific country reports provided little information on duplication, but major germplasm holding nations, including China and India, reported safety duplicating all accessions in-country. Rice growing nations such as Indonesia, the Lao People's Democratic Republic and Malaysia, all reported that IRRI maintains safety duplicates of their rice collections. Other IARCs hold safety duplicates of crops from other countries. For example, Indonesia has deposited safety duplicates of banana germplasm at the International Transit Centre in Leuven, Belgium. The CePaCT maintains safety duplicates of the national vegetatively propagated crop collections from the Pacific islands.

Europe

Most European countries indicated that their germplasm collections were safety duplicated to some extent, usually within their own national systems. The Nordic countries, Denmark, Finland, Iceland, Norway and Sweden, all reported having secured their accessions through depositing duplicate samples in Denmark as well as SGSV. Other countries, including Romania, reported not having safety duplicated their collections and the Russian Federation offered to make available facilities for safety duplication to other countries.

Near East

Kazakhstan reported storing safety duplicates at VIR and IRRI and other countries in the region, including the Islamic Republic of Iran, Turkey and Uzbekistan, reported having safety duplicated at least some germplasm in-country. Most of the cereal, legume and range species collected from the region are duplicated at ICARDA. Pakistan reported having safety duplicates of crop germplasm collections at ICARDA, IRRI and AVRDC.

3.7 Regeneration

As aging of conserved accessions occurs even under optimal *ex situ* storage conditions, periodical monitoring of the viability and timely regeneration of materials are an essential, though often neglected, part of *ex situ* conservation. Limited financial resources, infrastructure and human capacity still represent the main constraints to regeneration, as was reported in the first SoW report. The need for skilled staff is especially great in the case of difficult and poorly researched species, such as many of the CWR. The crop and regional conservation strategies supported by the GCDT have highlighted the fact that regeneration backlogs occur in all types of conserved germplasm and in all regions.[18] According to information from NISM databases,[19] since 1996, capacity has worsened in 20 percent of the surveyed genebanks, regeneration backlogs have persisted in 37 percent of them and in 18 percent they have increased. Recently, regeneration and documentation updating efforts have been supported by the GCDT in over 70 countries for about 90 000 accessions in collections identified by crop experts as being of highest priority.

Africa

Regular viability testing was carried out in Madagascar, Nigeria, Uganda and Zambia, but generally not elsewhere. The systematic regeneration of stored material appears sporadic, although Ethiopia reported regular regeneration of germplasm when viability fell below 85 percent. Funding, staffing and facilities were frequently reported to be inadequate to allow the necessary germplasm regeneration to be undertaken. Ongoing regeneration backlogs have been reported for the fonio and sorghum national collections in Mali, as well as for cereal and vegetable collections held at the Institut sénégalais de recherche agricole – Unité de recherche comune en culture *in vitro* (ISRA-URCI) in Senegal and at the Institute of Biodiversity Conservation (IBC) in Ethiopia. The national genebank of the United Republic of Tanzania also warned about a decreasing capacity to manage regeneration that has resulted in growing backlogs for both cross- and self-pollinated crop collections.

Americas

Viability testing in Argentina has not been carried out as regularly as desired, but a considerable amount of regeneration has been done since the first SoW report was published. The Plurinational State of Bolivia, Cuba, Ecuador, Peru, Uruguay and the Bolivarian Republic of Venezuela also reported having carried out viability testing and regeneration, but many problems were reported including lack of finance, staff and equipment. Ongoing backlogs were reported for vegetatively propagated species *inter alia* by INIA Carillanca (Chile), INIAP/Departamento Nacional de Recursos Fitogenéticos y Biotecnología Instituto Nacional Autonomo de Investigaciones Agropecuarias (DENAREF, Ecuador), INIA-Maracay the Bolivarian Republic of Venezuela, Instituto de Investigaciones Fundamentales en Agricultura Tropical "Alejandro de Humboldt" (INIFAT) and the Centro de Bioplantas (Cuba). Important field collections such as the coffee collection held at CATIE are also in need of regeneration and in Brazil, regular seed regeneration is still recognized as a bottleneck for many active collections especially of cross-pollinated species.

Asia and the Pacific

Many of the Asian country reports provided little information on regeneration. While many countries practiced regeneration, they frequently faced difficulties due to lack of funds and facilities. Viet Nam reported the loss of entire collections. Some countries, including Sri Lanka and the Philippines, were able to carry out regular viability testing of stored germplasm, but this was not always possible in other countries. Regeneration backlogs for vegetatively propagated crops were reported *inter alia* by PGRC (Sri Lanka), Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, SKUAST (India) and the Central Institute of Temperate Horticulture (CITH, India), the Field Crops Research Institute - Department of Agriculture (FCRI-DA, Thailand) and the Lam Dong Agricultural Research and Experiment Centre (LAREC, Viet Nam). Regarding cross-pollinated species regeneration backlogs were reported by the Directorate of Oilseeds Research (DOR, India) and the Philippine Coconut Authority-Zamboanga Research Center (PCA-ZRC) (the Philippines). China reported regeneration activities that addressed more than 286 000 accessions and New Zealand reported the systematic regeneration of all crop germplasm, including fruits.

Europe

While viability testing was carried out regularly in most countries, the country reports contained few details on this. There were differences among countries regarding the level to which viability was allowed to fall before regeneration was considered necessary. Iceland, Norway and Sweden specified 60 percent, while the Russian Federation used a value of 50 percent and Poland a value between 80 and 85 percent. In general, there were no major problems reported by European countries regarding regeneration, although Finland indicated that in some cases small amounts of seeds made regeneration difficult. Notwithstanding an overall increase in capacity to perform regeneration, Armenia reported urgent regeneration needs and growing backlogs for its cereal and vegetatively propagated collections.

Near East

Uzbekistan reported some loss of accessions arising from reduced viability. Many countries have faced difficulties in ensuring that the genetic integrity of cross-pollinated species is maintained during regeneration. Cyprus, Egypt, the Islamic Republic of Iran and Pakistan reported having regenerated more than 50 percent of the accessions stored in their national genebanks. The main genebanks in Kazakhstan, Morocco and Uzbekistan have undertaken substantial regeneration while the other genebanks in these countries have only carried out regeneration to a more limited extent. There is a need to regenerate the entire wheat collections held in the national genebanks of Azerbaijan, Tajikistan and Turkmenistan.[20]

3.8 Documentation and characterization

3.8.1 Documentation

The first SoW report highlighted the poor documentation available on much of the world's *ex situ* PGR. This problem continues to be a substantial obstacle to the increased use of PGRFA in crop improvement and research. Where documentation and characterization data do exist, there are frequent problems in standardization and accessibility, even for basic passport information.

Nonetheless, there has been an overall improvement in the accessibility of information. A number of national genebanks have published collection data on the web or are in the process of doing so, often with the facility of being able to order materials on-line. However, a significant imbalance exists among regions and countries within regions. The large majority of countries still do not maintain an integrated national information system on germplasm holdings. According to the country reports and NISM data, important *ex situ* holdings in at least 38 countries are still, at least partly, documented only on paper (16 countries) and/or in spreadsheets (32 countries).[21] Dedicated information management systems are used to manage passport and characterization data on *ex situ* collections in only 60 percent of the countries that provided information on this topic, while generic database software is used in about 34 percent of countries.

The lack of a freely available, flexible, up-to-date, user-friendly, multilanguage system has constrained documentation improvement in many countries, although in some cases, regional and/or bilateral collaboration has helped to meet information management needs through the sharing of experiences and tools.

Almost all the CGIAR centres have developed their own documentation systems that, in most cases, include characterization data as well as an on-line ordering system. They contribute data to the SINGER, which holds passport, collecting mission and distribution data on CGIAR and AVRDC collections.[22]

The crop strategies sponsored by the GCDT contain information which is relevant to the state of documentation and characterization on a crop basis. For wheat, most developed and developing countries have computerized management systems and many provide web-based access to passport information as well as characterization data. However, the major problem is the lack of standardization among systems. A similar problem exists for maize, in that there are passport data for most accessions in most collections, but there is little uniformity in its management. Tracing materials through donor collection identifiers is generally quite difficult in web-accessible information systems. For barley, some characterization information is available on the web, but there is a lack of electronically available evaluation data.

Electronic documentation of potato accessions world-wide is only partially complete and few genebanks are able to provide characterization and evaluation data through their own web sites. For sweet potato a similar situation exists and inadequate documentation and characterization information is available, particularly in Africa. For banana, however, the research community is well served regarding information and there is an effective information network managed through INIBAP. The *Musa* Information System contains information on more than 5 000 accessions managed in 18 of the approximately 60 collections. A similar information system has been put in place for rice by IRRI. For pulses, a considerable amount of evaluation and documentation still remains to be recorded and standardized; electronic global information systems are needed for most collections.

The following sections describe the status of documentation in the various regions, based mainly on information contained in the country reports.

Africa

Most African nations reported having characterization and evaluation data on their collections, but with some exceptions (e.g. most SADC countries, Ethiopia, Kenya and Mali), it was generally incomplete and not standardized. Togo indicated that its documentation was in a rudimentary state and several other countries reported serious weaknesses. Kenya reported its intention to develop national documentation systems that are in line with the SADC Documentation and Information System (SDIS) system in use in all SADC countries. While three countries reported that they still maintained some records on paper and eight use spreadsheets, at least eight others have dedicated electronic systems.[23] Ghana, Kenya and Togo reported using generic databases to manage information on *ex situ* collections.

Americas

A significant amount of information is publicly available on the *ex situ* holdings in North America. Passport information is freely accessible through the web-based GRIN[24] on more than half a million accessions of about 13 000 species stored in 31 NPGS genebanks belonging to the USDA. In addition, more than 6.5 million observations are available on various morphological and agronomic traits for 380 000 accessions. The Canadian GRIN-CA has also adopted this information system.[25]

Country reports from South America indicate that documentation and characterization systems are working relatively well and that electronic databases containing comprehensive data on germplasm accessions are commonly used. Chile, Paraguay and Peru, however, reported that paper systems are still in use for some collections and no data from national programmes in the region are accessible via the web. Passport data were generally reported to be available for large numbers of accessions. The Sistema para la Documentación de Recursos Genéticos Vegetales (DBGERMO), developed by INTA, Argentina, is a dedicated germplasm data management system that is popular in the region and is being used in Argentina, Chile, Ecuador, Paraguay, Uruguay and by CATIE in Costa Rica. Paraguay expressed the need for DBGERMO to be adopted at a regional level in order to harmonize data collection and retrieval. The Sistema brasileiro de informação de recursos genéticos (SIBRAGEN) is the documentation and dissemination system in use by Embrapa in Brazil. GIS are reportedly used in Argentina and Ecuador for the geographical analysis of collected materials.

In their country reports, most countries in Central America and the Caribbean indicated that while documentation of germplasm holdings existed, it was often not standardized. Little information on the availability of passport data was provided in the country reports. The use of dedicated genebank documentation systems and databases are relatively rare in this region. They are reportedly in use only in Cuba, Mexico and Trinidad and Tobago and by the genebank at CATIE in Costa Rica. Some genebanks in Mexico still use paper records in addition to electronic filing and in more than 40 percent of the reporting countries spreadsheets are the most common tool for data management.

Asia and the Pacific

In their country reports, all Asian countries indicated that at least some documentation existed on their germplasm holdings. Passport data were generally available across the region, for the large majority of accessions. About 75 percent of the reporting countries make use of a dedicated information system for the management of *ex situ* germplasm, although in four countries some data have not been put in electronic format yet. China reported having a web-based database, but only in Chinese. Sri Lanka reported the use of GIS and together with Bangladesh, Thailand and Viet Nam recognized the need for a nationwide *ex situ* germplasm information system. Significant advances in making information on *ex situ* holdings publicly available were reported by Japan and the Republic of Korea, including passport and characterization data on more than 87 000 accessions held at the National Institute of Aerobiological Sciences in Japan[26] and passport data on about 20 000 accessions at the National Agrobiodiversity Centre in the Republic of Korea.[27]

Country reports from the Pacific suggested that relatively little comprehensive documentation work has been done in this region. Fiji, New Zealand, Palau, Papua New Guinea and Samoa all reported that documentation existed, but did not generally follow standard formats. Some information was available in electronic databases, and the Cook Islands, for example, stated that the development of a database was a national priority. Efforts to increase the availability of data on *ex situ* collections have been undertaken by Australia and New Zealand through web-based systems. The Australian Plant Genetic Resource Information Service (AusPGRIS)[28] at present includes passport data on about 40 000 accessions from 229 genera stored at Biloela of the Queensland Department of Primary Industries (QUPI), the web sites of the Margot Forde Forage Germplasm Centre[29] and the Arable crop genebank and online database.[30]

Europe

The state of documentation is generally good across Europe, according to the country reports. A variety of tools are used for data storage and management, among which spreadsheets and generic databases are the most common. Standardized passport data from 38 countries have been published by the European Internet Search Catalogue (EURISCO),[31] a centralized web-based catalogue that has been managed by Bioversity International since 2003 under the ECPGR. The network has also supported the establishment and maintenance of European Central Crop Databases that compile and disseminate characterization and evaluation data on several crops. The Nordic countries have standardized their approach to documentation and characterization and provide information through NordGen using the Sesto system.[32] The former Yugoslav Republic of Macedonia reported that it was ready to adopt the same information system. Croatia reported that it still had not compiled characterization data, although passport data were recorded for most accessions.

Near East

Good progress has been made since 1996 on documenting accessions held in the main genebanks. Egypt, Jordan, Morocco, Pakistan, the Syrian Arab Republic and Turkey all reported that their germplasm information is now fully maintained in a dedicated system supported technically by ICARDA and Bioversity International. Significant progress has also been made in Azerbaijan with the inclusion of passport data from the national genebank in EURISCO and the recording of characterization and evaluation data electronically for more than 60 percent of the *ex situ* cereal accessions and 50 percent of the fruit and fibre accessions.[33] Passport data for some accessions from Cyprus are also recorded in EURISCO. Other countries, including Kazakhstan and Lebanon, reported that documentation was not systematic or standardized, although Lebanon reported that evaluation data for vegetables are available via the Horticulture Cultivars Performance Database (HORTIVAR).[34] Iraq and Kazakhstan reported using crop registers in paper format and Tajikistan reported that a joint computerized system was being developed with Kyrgyzstan. Egypt maintains documentation on all germplasm accessions and has substantial amounts of data on morphological and molecular characteristics as well as on agronomically important traits.

3.8.2 Characterization

In 1996 the GPA highlighted the importance of characterization both as a way to help link the conservation of PGRFA with its use, and to facilitate the identification of gaps in collections and the development of core collections. Since then, in spite of the considerable work on characterization reported by many genebanks and associated programmes, often involving regional and international collaboration (see Chapter 6), overall, the information produced has been underused due largely to a lack of standardization and to accessibility constraints. Many country reports indicated that the lack of readily available characterization and evaluation data is a major limitation to the greater use of PGRFA in breeding programmes.

An indication of the level of characterization of the collections held by international centres is reported in Table 3.6

TABLE 3.6
Extent of characterization for some of the collections held by CGIAR centres and AVRDC

Crop groups	% of accessions characterized	Total number of accessions	Reporting centres
Cereals[35]	88	292 990	6
Food legumes	78	142 730	4
Vegetables	17	54 277	1
Fruits (banana)	44	883	2
Forages	45	69 788	3
Roots and tubers	68	25 515	3
Total	**73**	**586 193**	**11**

Source: CGIAR System-wide genetic resources programme (SGRP) 2008

TABLE 3.7
Average extent of characterization and evaluation of national collections in 40 countries[36]

Crop groups	Percentage of germplasm holdings						
	Characterized	Evaluated				Total number of	
	Morphologically	*Agronomically*	*Biochemically*	*For abiotic factors*	*For biotic factors*	*Accessions*	*Reporting countries*
Cereals	63	44	10	13	23	410 261	34
Food legumes	67	56	14	13	20	139 711	33
Vegetables	65	44	12	7	14	48 235	27
Oil crops	63	42	52	11	17	40 700	18
Fiber crops	89	84	9	19	18	37 879	15
Fruits, nuts and berries	66	54	12	24	30	31 838	26
Forages	43	50	15	13	15	27 120	20
Roots and tubers	66	54	13	17	24	22 834	27
Spices	82	81	39	7	22	17 755	10
Stimulants	53	64	20	22	35	10 413	15
Sugar crops	46	80	22	36	57	6 413	14
Medicinal plants	65	64	24	11	43	3 744	7
Ornamental plants	74	23	0	48	47	2 622	8
Others	34	85	3	8	22	20 189	11
Total	**64**	**51**	**14**	**14**	**22**	**319 528**	**40**

Sources: NISM on PGRFA, 2004, 2006, 2007, 2008

The extent to which selected national germplasm collections have been characterized and evaluated is provided in Table 3.7, based on data from 40 countries and 262 stakeholders. It is evident that while most crop commodity groups have been substantially characterized morphologically, relatively little biochemical evaluation has been done. Among the crop commodity groups, fibre crops and spices have been the most extensively characterized and evaluated, while biochemical evaluation has been chiefly carried out in oil crops and spices.

Africa

In most African nations there has been an increase in the morphological characterization of materials in *ex situ* collections since the publication of the first SoW report. The work has mostly been carried out by national PGRFA centres and programmes, sometimes in collaboration with research institutes and universities. The level of morphological characterization is high for Ethiopia's collections of cereals, pulse and oil crops (97 percent), Mali's collections of cereals and vegetables (99 percent)[37] and Senegal's collection of groundnut (100 percent). Ninety percent of Ghana's important cocoa collection is characterized for morphological traits, 10 percent using molecular makers and 80 percent has been evaluated agronomically and for biotic stresses.[38] Several countries including Kenya, Malawi and Namibia reported having generated morphological characterization data, but agronomic and particularly, molecular characterization data were scarce across Africa. Generally, it was apparent from the country reports that a considerable amount of work is still needed in most countries and capacity, particularly for new molecular techniques, is still far from adequate.

Americas

In South America many countries reported having recorded characterization data on a range of morphological, agronomic, molecular and biochemical traits. In Argentina, the Plurinational State of Bolivia, Ecuador and Peru, a large proportion of total *ex situ* holdings has been morphologically characterized and almost half evaluated for agronomically important traits including tolerance to environmental and other stresses. Cuba reported that it had characterized its germplasm holdings using morphological, agronomic, molecular and biochemical traits for 51, 80, 7 and 6 percent of accessions, respectively.[39] Mexico reported morphological and agronomic characterization for 46 percent of accessions and Nicaragua for 100 percent. Within the Caribbean, Saint Vincent and the Grenadines stated that characterization and evaluation were rarely carried out, but Trinidad and Tobago reported considerable progress in this area.

Asia and the Pacific

In their country reports, all Asian countries indicated that morphological characterization and agronomic evaluation data were widely available; for example Japan has compiled a full complement of characterization data and in India, characterization and evaluation data are available on 74 and 73 percent respectively of the national germplasm collections. The equivalent figures for the Philippines are 40 and 60 percent, respectively. While India reported that it has molecular characterization data on 21 percent of its accessions, only 3 percent of the total holdings of Malaysia, the Philippines, Sri Lanka, Thailand and Viet Nam have any molecular characterization data on them and these are mainly of food legume and cereal crops. A number of countries including Malaysia, the Philippines and Thailand also reported using biochemical markers. In the Pacific, characterization based on morphological, agronomic and molecular traits was reported for taro by Fiji, Palau and Samoa.

Europe

According to the country reports, the state of characterization has generally improved across Europe since the first SoW report was published. For example, at the Institute for Agrobotany (ABI) in Hungary, approximately 90 percent of the accessions of cereals and legumes, 50 percent of the root and tubers, 75 percent of the vegetables, 80 percent of the forages and 30 percent of the underused crops have now been characterized and evaluated. The

Czech Republic reported relatively comprehensive data on morphological and agronomically important traits including abiotic and biotic stresses, on its collections of fruit trees, wheat, barley, peas and soybean. In Romania, about 20 percent of the total holdings in the national genebank have been phenotypically characterized and biochemically evaluated. Albania reported on its extensive use of morphological and agronomic descriptors but indicated that, with few exceptions, the characterization data are not readily accessible.

Near East

The characterization and evaluation of genetic resources using standard descriptors have advanced in almost all countries of the region since the publication of the first SoW report. Characterization has been carried out on a wide range of species for morphological traits of agronomic importance, quality attributes and for tolerance and resistance to biotic and abiotic stresses. Several countries, for example, Egypt, the Islamic Republic of Iran, Jordan, Morocco, Pakistan, the Syrian Arab Republic, Tunisia and Turkey also reported that they had undertaken molecular characterization, largely through academic studies. Molecular characterization of date palm has been carried out in Kuwait, Qatar, Saudi Arabia and the United Arab Emirates.

3.9 Germplasm movement

Information on germplasm movement provides a valuable indicator of the use of PGR (see Chapter 4). However, such information is often not recorded and only limited data were provided in the country reports. However, there is now more information available on this issue than was the case at the time when the first SoW report was published.

Genebanks play a central role in the movement of germplasm within and among countries. Germplasm movement includes exchange among genebanks, sometimes as part of repatriation agreements, material collected in field collecting missions, acquisitions by genebanks from research and breeding programmes and distribution to plant breeders, researchers and directly to farmers.

While some information on total numbers of samples moved is available, this is often not broken down into the different crops or types of germplasm concerned, or the nature of the recipient or providing institution. More detailed information on these factors would enable better understanding of patterns of use. Figure 4.1 in Chapter 4 provides an indirect estimate of one aspect of germplasm exchange; sources of germplasm for use in plant breeding programmes.

The ability of a potential recipient to access a particular accession is often limited by the size of a stored sample and its phytosanitary status (see Chapter 7). Furthermore, inadequate information systems often make it difficult to access the same accession from an alternative source.

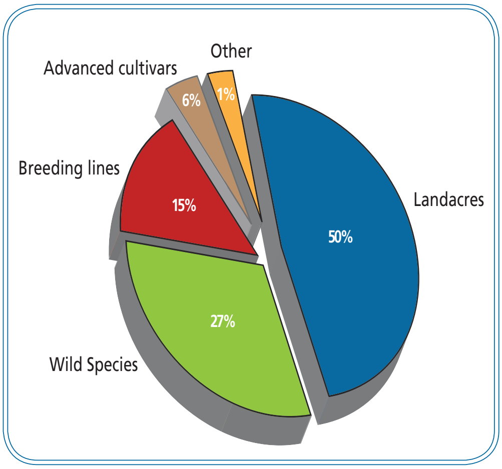
Comprehensive data on germplasm acquisition and distribution are readily available only for the genebanks of the IARCs. Over the past 12 years, the CGIAR centres and AVRDC have distributed more than 1.1 million samples, 615 000 of which, (about 50 000 per year), went to external recipients. In general, total distribution has remained steady over the period from 1996 to 2007 at about 100 000 accessions each year, although it peaked in 2004. These figures are similar to those reported in the first SOW report for the period 1993 to 1995.

In terms of the types of germplasm distributed by the IARCs, Figure 3.7 shows that the largest proportion are landraces, followed by wild species and breeding lines.

Figure 3.8 shows the distribution of germplasm by the IARCs to different types of recipient organizations. Nearly half the germplasm was distributed within or between the centres themselves and 30 percent went to developing country NARS. Developed country NARS received 15 percent and the private sector 3 percent. Breeding materials and advanced cultivars went mainly to NARS in developing countries, whereas developed country NARS requested mainly landraces. Wild species were requested equally by most types of organizations.

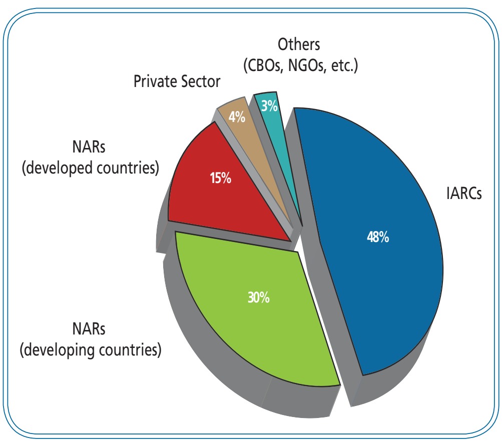
The following sections describe the status of germplasm movement on a regional basis, based on information contained in the country reports.

FIGURE 3.7
Distribution of germplasm held by the IARCs by type of germplasm (1996-2007)



Source: CGIAR, SGRP 2008

FIGURE 3.8
Distribution of germplasm from the IARCs to different types of recipient organization between 1996 and 2007



Source: CGIAR, SGRP 2008

Africa

Little data on germplasm movement was provided in the country reports from Africa. Uganda indicated that there was no national monitoring system for germplasm movement in place and Mali reported that germplasm movement was poorly documented. Both Ghana and Guinea stated that there was considerable movement, but no figures were available. A significant increase in germplasm movement since 1996 was reported by Malawi, which distributed more than 1 000 accessions and Kenya which distributed 3 189 accessions over a five year period. In its country report, Ethiopia estimated that an average of 5 000 samples were distributed annually to national programmes.

Asia and the Pacific

Little detailed information on germplasm movement was also reported from Asia, however, China has distributed 212 000 accessions since 1998, 95 percent of which, were within the country. India has distributed more than 164 000 accessions over the past ten years, while Pakistan has supplied some 13 000 samples to national institutions and more than 5 000 to international organizations since 1996. Japan distributed more than 36 000 samples in-country and about 1 300 abroad over the period 2003-2007.

Europe

The extent of germplasm movement in Europe and the availability of associated data varied considerably among countries. While Romania reported little movement of germplasm, Germany reported that since 1952, IPK had distributed about 710 000 samples to various users with, for example, more than 13 000 samples being distributed in 2006 alone. Between 1985 and 2003, 140 000 samples were requested from the Federal Centre of Breeding Research on Cultivated Plants (Braunschweig, Germany) (BAZ) genebank in Braunschweig. Poland distributed between 5 000 and 10 000 samples annually between 1996 and 2007 and Switzerland distributed an annual average of 270 samples nationally and internationally.

Near East

Jordan reported that most germplasm movement occurred among farmers, a situation that is also likely to occur in many other countries of this region and elsewhere. However, it is difficult to assess the importance of farmer-farmer exchanges in relation to the overall distribution of genetic diversity nationally, regionally and internationally. Cyprus indicated that there was little public awareness of the existence of its genebank and hence few requests for germplasm – a problem that likely has occured in other countries too. There was otherwise little information from this region.

3.10 Botanical gardens

There are over 2 500 botanical gardens worldwide that together grow over 80 000 plant species (approximately one-third of all known plant species).[40] As well as their living collections, botanical gardens often have herbaria and carpological collections and an increasing number have seed banks and *in vitro* collections. In general, botanical gardens focus on conserving the interspecific diversity of flora and thus, tend to maintain a large number of species with relatively few accessions for each species.

Over the last ten years, the number of botanical gardens recorded in Botanic Gardens Conservation International's global database increased from 1 500 to more than 2 500,[41] at least partly reflecting the current interest in establishing new botanical gardens in many parts of the world. In its country report, China indicated that it had 170 botanical gardens and India reported 150. The Russian Federation reported that it had about 75 botanical gardens, Germany 95, Italy 102, Mexico 30 and Indonesia 12. Most other countries, however, reported having less than ten. Botanical gardens often maintain very substantial germplasm holdings although only a percentage of these are important for food and agriculture. The German botanical gardens together conserve about 300 000 accessions of 50 000 taxa.

Botanical gardens are diverse institutions; many are associated with universities and focus on research and teaching (as mentioned in 19 country reports), while others may be governmental, municipal or private. Throughout their history, botanical gardens have been concerned with cultivating plants of importance to humankind for medicinal, economic and ornamental purposes. In recent years, the focus of many gardens is turning to the conservation of species found in the native wild flora (as mentioned in 19 country reports), especially those under threat of extinction. Many of these species are either of direct socio-economic or cultural importance to local communities or in some cases are CWR; both are groups that tend to be less well represented in traditional collections of PGRFA.

The GSPC,[42] adopted by the CBD in 2002, includes some measurable targets for conserving plants. Botanical gardens played a key role in developing the strategy and are expected to be important contributors to its implementation. Other international organizations, including Bioversity International, FAO and IUCN, have also been identified as lead international partners for specific targets, with a role in supporting country implementation of the Strategy. In some countries, stakeholder consultations held to develop national responses to GSPC have been successful in bringing the botanical garden and environmental sectors together with the agricultural sector, forging closer linkages on the conservation of PGRFA. However, in many countries cross-sectoral linkages remain poorly developed and botanical gardens are not generally included in national PGR programmes or networks. Despite this, botanical gardens are mentioned as being involved in plant conservation by 98 countries and the country reports of Kenya, Uganda and Zambia specifically note that botanical gardens are included in their national PGR networks.

3.10.1 Conservation facilities, statistics and examples

The majority of botanical gardens are located in Europe (36 percent) and the Americas (34 percent) with 23.5 percent in Asia and the Pacific and only 5.5 percent in Africa. Worldwide, over 800 botanical gardens specifically focus on conservation and their *ex situ* collections include a wide range of socio-economically important species. CWR are well

TABLE 3.8
Botanical garden collections of selected crops listed in Annex 1 of the ITPGRFA[44]

Crop	Genus	Number of species recorded in plant search
Breadfruit	*Artocarpus*	107
Asparagus	*Asparagus*	86
Brassica	13 genera	122
Chickpea	*Cicer*	16
Citrus	*Citrus*	18
Yams	*Dioscorea*	60
Strawberry	*Fragaria*	16
Sunflower	*Helianthus*	36
Sweet potato	*Ipomoea*	85
Grass pea	*Lathyrus*	82
Apple	*Malus*	62
Pearl millet	*Pennisetum*	23
Potato	*Solanum tuberosum*	190
Sorghum	*Sorghum*	15
Wheat	*Triticum aestivum* *Agropyron* *Elymus*	36
Faba bean/vetch	*Vicia*	77
Cowpea *et al.*	*Vigna*	12

represented in botanical garden collections with, for example, over 2 000 CWR taxa in botanical gardens in Europe. Further details on CWR in botanical garden collections are provided in Table 3.8. Similarly, some 1 800 medicinal plant taxa are represented in botanical garden collections globally.[43]

Ex situ conservation in botanical gardens tends to focus on living collections and in this regard they can play a useful role in the conservation of vegetatively propagated species, those with recalcitrant seeds and tree species. In Poland's country report, for example, specific mention is made of the conservation of apple germplasm by a botanical garden. However, seed conservation is important for some botanical gardens and at least 160 gardens around the world have seed banks. The Millennium Seed Bank Project (MBSP) of the Royal Botanical Gardens, Kew, is the largest and together with its partners around the world, aims to conserve seed of 24 200 species by 2010, with particular focus on dryland species. China's largest seed bank, the Germplasm Bank of Wild Species (GBWS), is located at the Botanical Garden of the Kunming Institute of Botany. In Europe, the European Native Seed Conservation Network (ENSCONET) brings together the seed conservation activities of over twenty European botanical gardens and other institutes. Through this network, seeds of nearly 40 000 accessions of more than 9 000 native European plant taxa are conserved.[45]

3.10.2 Documentation and germplasm exchange

The global PlantSearch database maintained by BGCI includes some 575 000 records on around 180 000 taxa[46] which are in cultivation in about 700 botanical gardens worldwide. However, this information consists of species names only and does not include descriptive information or the country of origin of accessions. At the national level, some countries have developed national databases of plants in cultivation in botanical gardens that provide more detailed accession-level information. These include PlantCol in Belgium,[47] SysTax in Germany,[48] and the Dutch National Plants Collection.[49] In the United States of America, the Plant Collections Consortium aims to bring together information on collections in 16 United States of America institutions and 4 international institutions.[50] In the the United Kingdom and Northern Ireland, the Electronic Plant Information Centre (ePIC) developed by the Royal Botanical Gardens, Kew, provides a single point of search across all Kew's major specimen, bibliographic and taxonomic databases. Kew's Seed Information Database is included in ePIC, which is an ongoing compilation of species' seed characteristics and traits, both from the MSBP's own collections and from the published and unpublished data of many seed biologists worldwide.[51]

One of the main international mechanisms for the exchange of germplasm between botanical gardens is the germplasm catalogue, the *Index seminum*. While still popular in Europe, concerns over the potential spread of invasive species have limited the use of the *Index seminum* in the United States of America. In Europe, the International Plant Exchange Network (IPEN) was developed as a response to the ABS provisions of the CBD, to facilitate the exchange of germplasm for non-commercial use.[52]

3.11 Changes since the first State of the World report was published

While significant advances have been made over the period since the first SoW report was published, in almost all areas further work is needed. Major changes include:

- more than 1.4 million germplasm accessions have been added to *ex situ* collections, bringing the total number now conserved worldwide to about 7.4 million. The majority of these are maintained in seed genebanks;
- more than 240 000 new accessions have been collected and are now being conserved *ex situ*. This number, however, is believed to be a considerable underestimate in that many countries did not provide figures on the number of accessions collected;
- fewer countries account for 45 percent of the total world *ex situ* germplasm holdings than was the case in 1996;
- interest in collecting and maintaining collections of CWR is growing as land-use systems change, concerns about the effects of climate change grow and techniques for using the material become more powerful and more readily available;
- interest is also growing in neglected and underutilized crops in recognition of their potential to produce high-value niche products and as novel crops for the new environmental conditions that are expected to result from climate change;
- significant advances have been made in regeneration: at the international level, largely as a result of funding provided to the CGIAR centres for the 'Global Public Goods' project, and at the national level, in part as a result of funding by the GCDT. However, much more remains to be done;
- documentation and characterization data on collections have progressed somewhat, although there are still large data gaps and much of the existing data is not accessible electronically;
- the number of botanical gardens around the world now exceeds 2 500, maintaining samples of some 80 000 plant species, including CWR. Botanical gardens took the lead in developing the GSPC adopted by the CBD in 2002;
- the GCDT, founded in 2004, represents a major step forward in underpinning the world's ability to secure PGRFA in the long term;
- with the establishment of the highly innovative SGSV, a last resort safety back-up repository is now freely available to the world community for the long-term storage of duplicate seed samples.

3.12 Gaps and needs

The overall needs of *ex situ* conservation remain largely the same as those listed in the first SoW report. This does not suggest that good progress has not been made, but that progress has not been complete and that many of the most important constraints can only be addressed through long-term commitments and action. Continuing gaps and needs include:

- many countries, although aware of the importance of collecting, conserving, regenerating, characterizing, documenting and distributing PGR, do not have adequate human capacity, funds or facilities to carry out the necessary work to the required standards. Many valuable collections are in jeopardy as their storage and management are suboptimal;
- greater efforts are needed to build a truly rational global system of *ex situ* collections. This requires, in particular, strengthened regional and international trust and cooperation;
- while there are still high levels of duplication globally for a number of crops, especially major crops, much of this is unintended and many crops and important collections remain inadequately safety duplicated. The situation is most serious for

vegetatively propagated species and species with recalcitrant seeds;

- in spite of significant advances in the regeneration of collections, many countries still lack the resources needed to maintain adequate levels of viability;
- for several major crops, such as wheat and rice, a large part of the genetic diversity is now represented in collections. However, for many other crops, especially many neglected and underutilized species and CWR, comprehensive collections still do not exist and considerable gaps remain to be filled;
- in order to improve the management of collections and encourage an increased use of germplasm, documentation, characterization and evaluation, need to be strengthened and harmonized and the data need to be made more accessible. Greater standardization of data and information management systems is needed;
- *in situ* and *ex situ* conservation strategies need to be better linked to ensure that a maximum amount of genetic diversity is conserved in the most appropriate way and that biological and cultural information is not lost inadvertently;
- greater efforts are needed to promote the use of the genetic resources maintained in collections. Stronger links are needed between the managers of collections and those whose primary interest lies in using the resources, especially for plant breeding;
- in the effort to mobilize additional resources for *ex situ* conservation, greater efforts are needed to raise awareness among policy-makers and the general public, of the importance of PGRFA and the need to safeguard it.

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[4] Collecting of duplicate samples derived from joint missions are included.

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